3.

ICHTHYOFAUNA

3.1 Introduction

Estuaries are typically shallow systems, sheltered from major wave action; they have variable temperatures, salinities, turbidities and oxygen content and are among the most productive of ecosystems on earth (Odum, 1983). By providing abundant food and shelter, estuaries are utilised by a variety of fish species, which typically are composed of a mixture of euryhaline freshwater species, species restricted to estuaries and euryhaline marine species (Wallace, 1975; Blaber, 1985). A stenohaline marine component usually occurs in the mouth area of most permanently open estuaries where the salinity does not fall below that of sea water, but these are not generally considered part of the estuarine fauna (Wallace, 1975). The most important function of estuaries with regard to fish is the provision of nursery areas for species of marine origin. Of a total of 155 fish species that are commonly associated with estuaries in southern Africa, 40% are marine species which utilise estuarine systems as nurseries and/or foraging areas (Whitfield, 1998). Species that live and breed in estuaries account for 27% of the total estuarine ichthyofauna. Marine species which occur in estuaries in small numbers but are not dependent on these systems comprise 25% of the total estuarine-associated fish taxa. Freshwater species including obligate catadromous eels (*Anguilla*) which utilise estuaries as transit routes between the marine and freshwater environments comprise only 8% of the total (Whitfield, 1998). The occurrence of both freshwater and marine vagrants in estuaries is largely determined by the salinity tolerance of the various species.

The 3 000 km South African coastline has some 300 rivers entering the coastal zone ranging from small estuaries which are only occasionally open to the sea to large, permanently open systems (Heydorn, 1991). Despite the great variety and number of estuaries along our coastline, a review of the available scientific information on individual systems revealed that very little information exists on the vast majority of South Africa's estuaries (Whitfield, 1995). During the period 1993 to 1999 basic ichthyofaunal surveys were conducted on some 250 estuaries along the South African coast. The aim of these surveys was to improve our state of knowledge on these systems and provide an assessment of the status of their fish communities.

3.2 Ichchtyofaunal surveys

The ichthyofauna of South African estuaries between the Gariep (Orange River) estuary and Kosi Bay was sampled over the period 1993 to 1999. Using information contained in Heydorn & Tinley (1980), Whitfield (1995) and aerial photographs, the coastline was divided into arbitrary sections, each containing approximately 40 estuaries. The estuaries in each section of coast were sampled during the spring/summer period and a new section was sampled each year until the entire coastline was covered. Due to logistics, only selected estuaries were identified on the Transkei and KwaZulu-Natal coasts. Sampling began in 1993 starting at the Gariep estuary on the west coast and the final KwaZulu-Natal section of coast was completed in 1998/9.

The ichthyofauna of the estuaries were sampled using a 30 m x 1.7 m x 15 mm bar mesh seine net fitted with a 5 mm bar mesh purse and, where possible, a fleet of gill nets. Each gill net had a range of mesh sizes and comprised three 45 mm, 75 mm and 100 mm stretch mesh monofilament panels and were either 10 m or 20 m in length and 1.7 m deep. Seine netting was carried out during daylight hours and was limited to shallow (<1.5 m deep), unobstructed areas with gently sloping banks. Gill netting was generally carried out in deep (>1 m) open, mid-channel waters with the nets being deployed in the evening and lifted the following morning. In most cases only the larger, deeper systems could be sampled using gill nets. The sampling effort undertaken in each estuary varied depending on the size of the system, and usually took one to three days to complete. Sampling was generally carried out until no new species were collected or until all representative habitats within each estuary were sampled.

Specimens collected by seine netting were, where possible, identified in the field, measured to the nearest mm standard length (SL) in the field, using a measuring board, and returned alive to the system. A minimum of 25 specimens of the abundant species as well as those specimens that could not be identified in the field were placed in labelled plastic bags and preserved in 10% formalin for transport to the laboratory. Specimens collected in the gill nets were identified, measured to the nearest mm SL and weighed in the field. During the 1993 surveys the fishes captured in each estuary were batch weighed to the nearest 100 g using a Super Samson spring balance while from 1994 specimens were weighed to the nearest 1.0 g using a Bonso model 323 balance. Specimens that could not be identified in the field were preserved in 10% formalin in labelled plastic bags for transport to the laboratory.

In the laboratory, specimens collected during the surveys were identified by reference to Smith & Heemstra (1991) and Skelton (1993). A minimum of 25 specimens of the abundant species were measured to the nearest mm SL and weighed to the nearest 0.01g using a Mettler PJ 3000 balance. The remaining specimens were counted and batch weighed. Voucher specimens were also sent to the J.L.B. Smith Institute of Ichthyology for verification.

A total of 257 estuaries were visited, however, a number of systems particularly on the arid west coast comprised nothing more than dry riverbeds. These included the Holgat, Bitter, Brak, Dwars (Noord), Jacobsbaai, Lêerbaai, Fresh Water Poort, Blue Krans and Shwele-Shwele. Furthermore, a number of systems, due to their small size, were not considered to be estuaries and were excluded from this study. These were the Buffels, Swartlintjies, Spoeg, Groen, Sout (Noord), Jakkals, Wadrif, Papkuils (west coast), Dwars (Suid), Modder, Bok, Silwerstroom, Sout (Suid), Bokramspruit, Booiskraal, Buffels (Wes), Elsies, Mossel, Rooi, Meul, Grooteiland, Kranshoek, Crooks, Brak (south coast), Helpmekaars, Klip, Witels, Geelhoutbos, Kleinbos, Bruglaagte, Langbos, Sanddrif, Eerste (south coast), Klipdrif (Wes), Boskloof, and Kaapsedrif. A number of systems such as the Soutrivier, Seekoe (south-west coast), Bakens, Papkuils (south-west coast), and Koega (Ngcura) were also severely altered due to human activities. Fishes were not captured in some systems (Mvubukazi, Ngqenga and Uvuzana) and these were also excluded from further analyses.

3.3 Biogeography

3.3.1 *Introduction*

The occurrence and diversity of fishes in South African estuaries varies according to (a) latitude (biogeography) and (b) the individual characteristics of each estuary (estuary type) (Blaber, 1985). Marine species inhabiting southern African estuaries include tropical and subtropical Indo-Pacific species, temperate endemic south coast species, temperate eastern-Atlantic species and cosmopolitan species (Wallace, 1975; Wallace & van der Elst, 1975). As one moves from KwaZulu-Natal around the coast to the Western Cape, estuarine fish diversity declines (Wallace & van der Elst, 1975, Day *et al*., 1981; Whitfield *et al*., 1989). This is linked to the attenuation in the distribution of tropical species where the fauna of estuaries in Transkei, KwaZulu-Natal and Moçambique are dominated by subtropical and tropical Indo-Pacific species (Day *et al*., 1981). South of Transkei there is a marked change and the percentage of tropical species decreases while that of endemic species increases. Most of the species from the southern Cape are either endemic or cold water forms from the south (Wallace, 1975; Wallace & van der Elst, 1975; Blaber 1981; Day *et al*., 1981; Whitfield, 1983). Before attempting to characterise and assess the fish community structure of South Africa's estuaries, it is important that their biogeography be taken into account. The aim here is to investigate the biogeography of the fish communities of South Africa's estuaries.

3.3.2 *Methods*

Since the individual characteristics of each estuary (estuary type) plays an important role in determining the fish community structure in estuaries (Blaber, 1985), the estuaries from this study were first grouped according to their geomorphological characteristics as outlined in the previous chapter. The assumption here is that estuaries in which similar physical/geomorphological processes operate ought to produce similar habitats and thus contain similar fish communities. Any differences in the fish communities of estuaries of a particular type therefore ought to be due to biogeography.

Six basic estuary types were identified. Estuary types A, B and C are normally closed systems ranging from small (Type A), medium (Type B) and large (Type C) estuaries based on their surface areas. The remaining systems (Types D, E and F) were classified as predominantly open estuaries and were divided into non-barred (Type D) and barred (Types E and F) systems. The barred estuaries were further divided into small (Type E) estuaries and medium to large (Type F) systems based on their MAR. Two estuary types (Type C and D) were restricted in their geographical range and as a result were excluded from this analysis. Only two estuaries, the Bot and Klein, belonged to type C and these were located on the south-west coast. Type D estuaries were mainly restricted to the south coast region.

The ichthyofaunal data for the remaining estuary types was analysed using multivariate statistical procedures outlined by Field *et al*. (1982). A combination of hierarchical agglomerative clustering and non-metric multi-dimentional scaling (MDS) was performed using PRIMER, the Plymouth Routines in Multivariate Ecological Research package developed at the Plymouth Marine Laboratory in the United Kingdom (Clark & Warwick, 1994). Multivariate methods compare two (or more) samples on the extent to which they share particular species, at comparable levels of abundance. Multivariate techniques are founded on similarity coefficients calculated between every pair of samples which then facilitates a classification or clustering of samples into groups which are similar, or an ordination plot in which the samples are 'mapped' (in two or more dimensions) in such a way that the distances between pairs of samples reflect their relative similarity of species composition (Clark & Warwick, 1994). The similarity coefficient used in this analysis is the Bray-Curtis (IS_{BC}) measure:

$$IS_{BC} = 2c/A + B$$

Where c is the sum of the smaller (abundance/biomass) values of the species common to two samples; A is the sum of the (abundance/biomass) values of all the species in the one sample, and B is the sum of the (abundance/biomass) values of all the species in the other sample. The reason why only the smaller values of the common species are used is because only the smaller value is contained in or is common to both samples (Mueller-Dombois & Ellenberg, 1974). The Bray-Curtis measure takes all the species in a sample into consideration but has the advantage in that it is not affected by joint absences of species (Field *et al.*, 1982).

Hierarchical agglomerative clustering is a classification method which results in the production of a dendogram in which samples are clustered into distinct groups based on their similarities, although the cut-off levels are arbitrary and depend upon convenience (Field *et al.*, 1982). Dendograms, however, have a number of disadvantages and in view of this, it is advisable to employ an additional method of presentation to show individual relationships. If the two complimentary methods agree, then discontinuities can be accepted as real (Field *et al.*, 1982).

Non-metric multi-dimensional scaling (MDS) produces a two-dimensional graphical representation or 'map' of the similarity relationships between samples. The distance between two samples on the ordination plot is a reflection of the similarity between those two samples (Field *et al.*, 1982). The 'goodness-of-fit' of the resultant scatter plot is measured by the stress formula. If stress is large, the 'map' tallies poorly with the observed dissimilarities while a low stress indicates that the sample relationship is well represented by the 'map' (Field *et al.*, 1982). Clarke & Warwick (1994) suggest that a stress of approximately 0.1 or less allows for fairly confident interpretation of the ordination plot. Although a stress of less that 0.2 still gives a potentially useful two-dimensional picture, a cross-check of any conclusions should be made against those from an alternative technique (Clarke & Warwick, 1994).

Before calculating the Bray-Curtis similarity coefficient, the data was first standardised by computing the relative (%) abundance of each species within each estuary. Such standardisation is essential if sampling effort in each estuary was different as was the case during this study. The Bray-Curtis coefficient will reflect differences between two samples due both to differing community composition and/or differing total abundance. Standardisation removes any effect of the latter (Clark & Warwick, 1994). After standardisation, the data was then 4th root transformed which has the effect of scaling down the importance of abundant species so that they do not swamp the other data (Field *et al.*, 1982). The data for each group of estuary types was then analysed using a combination of hierarchical agglomerative clustering and non-metric multi-dimentional scaling (MDS).

For ease of interpretation the estuaries were labelled according to their geographic position following Heydorn & Tinley (1980) where: W = west coast from, and including the Gariep estuary to Cape Columbine; SW = south-west coast from Cape Columbine to Cape Agulhas; S = south coast from Cape Agulhas to Cape Padrone; SE = south-east coast from Cape Padrone to, and including the Great Kei estuary; T = Transkei coast between the Great Kei and Mtamvuna estuaries; KZ = KwaZulu-Natal coast from, and including the Mtamvuna estuary to, and including Kosi Bay (Figure 3.1).

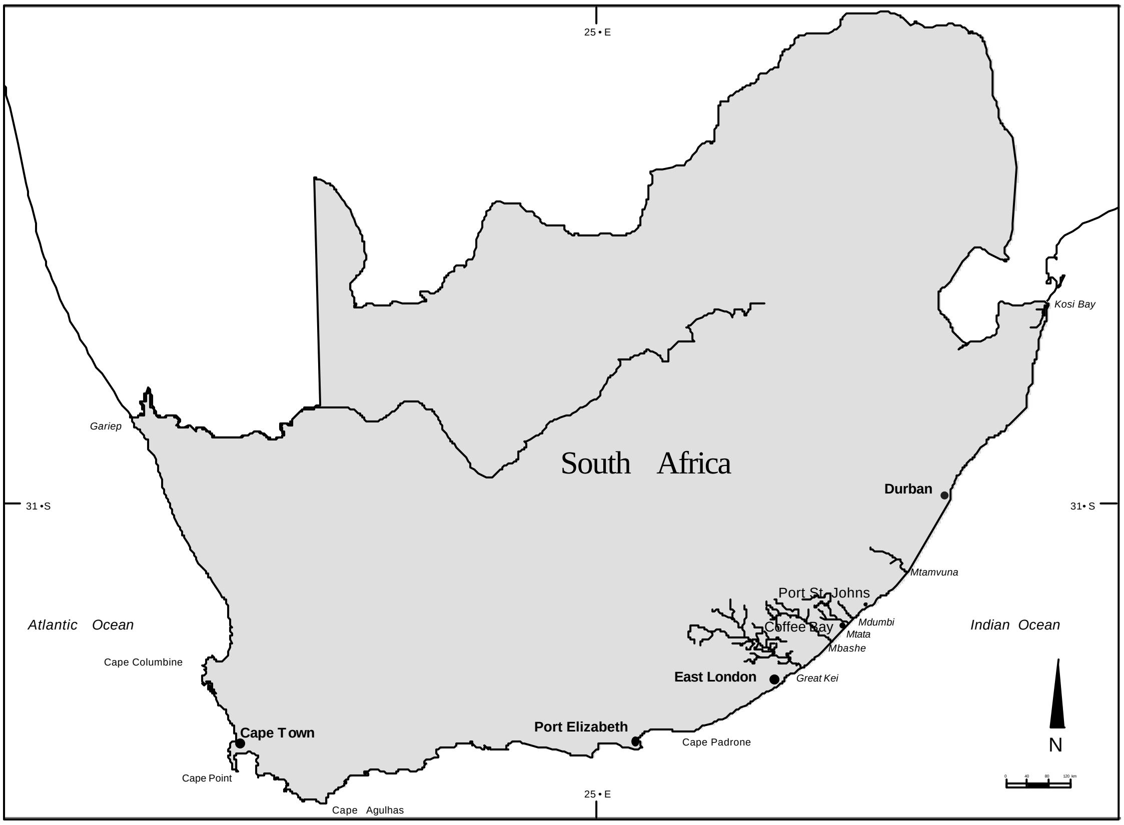

Figure 3.1. Map of South Africa indicating place names and estuaries mentioned in the text.

3.3.3 *Results & discussion*

Type A estuaries

The results of the cluster analysis for type A estuaries are presented in Figure 3.2. A distinct group separated from the remainder at approximately 18% similarity and these mostly comprised estuaries which occurred along the south-west and south coasts. At approximately 35% similarity a group comprising estuaries from the south and south-east coast was formed. The remaining systems separated into two groups at approximately 48% similarity. One group comprised mostly systems from the south-east coast while the remaining group mostly comprised systems from the Transkei and KwaZulu-Natal coasts. The latter could be further sub-divided (at about 50% similarity) into systems from KwaZulu-Natal and systems mostly from the Transkei (Figure 3.2).

The results of the ordination produced a 'map' with a moderate stress (S = 0.13) and the pattern somewhat reflected the geographical distribution of these estuaries. The estuaries on the south-west and south coast were situated to the left of the ordination plot. Systems on the south-east coast were largely situated in the centre of the ordination while those from Transkei and KwaZulu-Natal lay to the right of the plot (Figure 3.2).

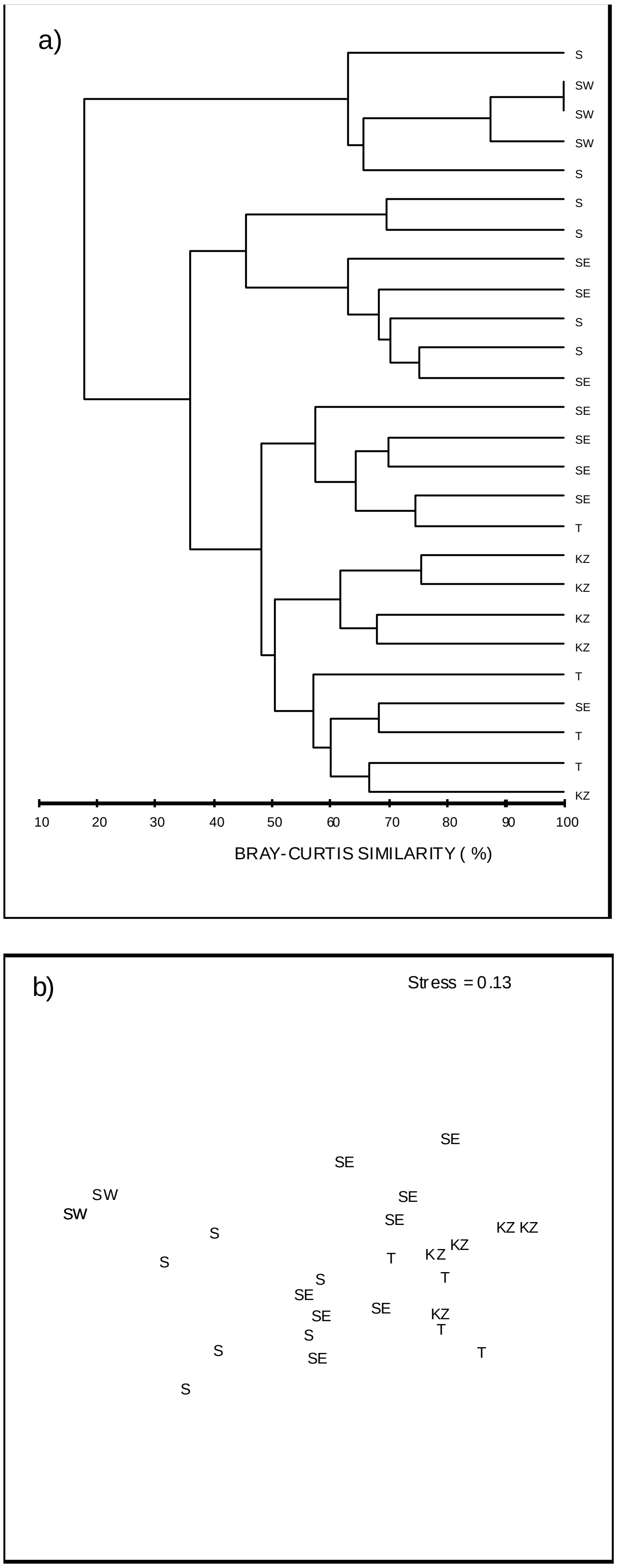

Figure 3.2. Dendogram (a) and MDS ordination (b) of type A estuaries on the South African coast.

Type B estuaries

For type B estuaries a distinct group of systems separated from the remainder at approximately 15% similarity. This group comprised systems mostly from the west and south-west coasts. The remaining estuaries separated into two groups at approximately 40% similarity. One group comprised estuaries mostly from the south and south-east coasts while the remaining group comprised systems mostly from the KwaZulu-Natal coast (Figure 3.3).

The results of the ordination revealed the presence of three possible groups. Systems on the subtropical KwaZulu-Natal coast formed a grouping to the right of the ordination plot. Estuaries on the south, south-east and Transkei coasts formed a group situated in the centre of the plot while estuaries mostly from the south-west and west coast produced a wide spread to the left of the plot. The ordination had a moderate stress value (S = 0.14) and the pattern generally corresponded with the geographical position of the estuaries (Figure 3.3).

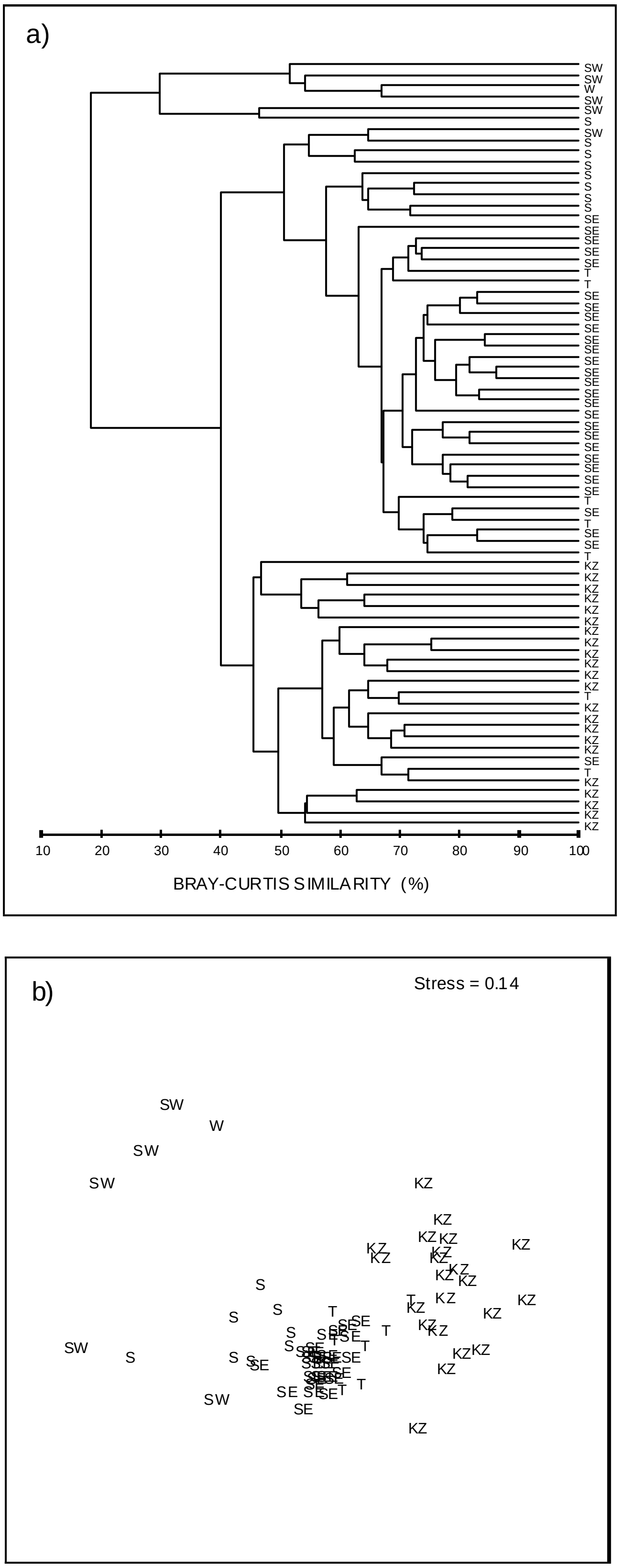

Figure 3.3. Dendogram (a) and MDS ordination (b) of type B estuaries on the South African coast.

Type E estuaries

For type E estuaries, a distinct group separated from the remaining systems at approximately 15% similarity. All these systems were estuaries which lie on the south-west coast. At approximately 30% similarity one estuary on the KwaZulu-Natal coast (Mgobezeleni) separated as an outlier. The remaining systems formed two groups at approximately 50% similarity. One group comprised estuaries from the south-east and Transkei coasts while the other group comprised systems from the Transkei and KwaZulu-Natal coasts (Figure 3.4).

The ordination plot of type E systems resulted in two groupings. Estuaries on the south-west coast were grouped to the left of the ordination while the remaining systems from the south, south-east, Transkei and KwaZulu-Natal coasts formed a cluster to the right. This grouping appeared to grade from estuaries on the south and south-east coast through to systems on the Transkei and KwaZulu-Natal coasts. Overall, the ordination had a relatively low stress (S = 0.11) and the relative positions of the estuaries corresponded with their geographic location (Figure 3.4).

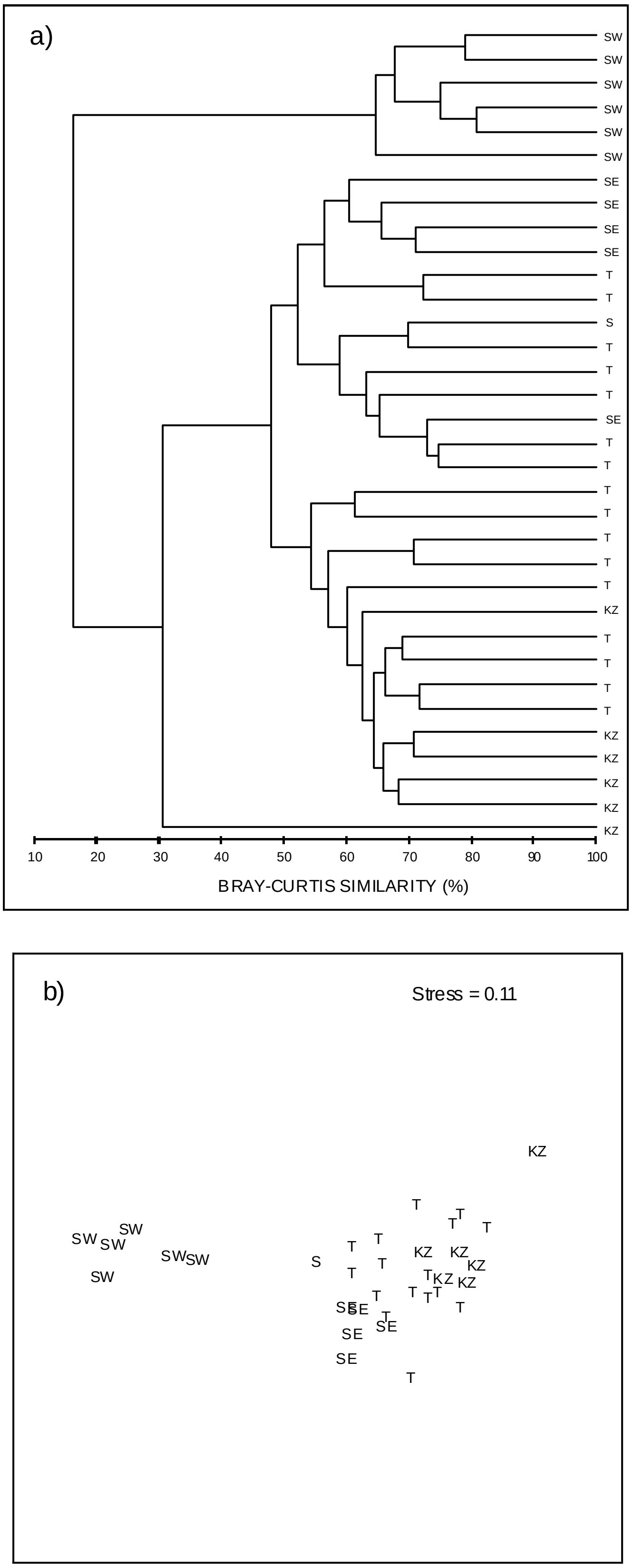

Figure 3.4. Dendogram (a) and MDS ordination (b) of type E estuaries on the South African coast.

Type F estuaries

The results of the cluster analysis for type F estuaries is presented in Figure 3.5. The estuaries on the west and south-west coast separated from the remainder of the systems at approximately 18% similarity. Three systems in KwaZulu-Natal (Kosi Bay, Thukela and Mvoti) separated out at approximately 22% similarity. The remaining estuaries formed two groups at approximately 40% similarity. The one group comprised estuaries on the KwaZulu-Natal and Transkei coasts, while the other group consisted of estuaries mainly from the south and south-east coast as well as a few from the Transkei region (Figure 3.5)

The ordination of type F estuaries produced a 'map' with a relatively low stress value (S = 0.10) and the pattern produced broadly corresponded with their geographic position. Estuaries on the west and south-west coast formed a cluster to the left of the ordination. The remaining systems appeared to form a gradation from those on the south and south-east coast to the Transkei and KwaZulu-Natal (Figure 3.5).

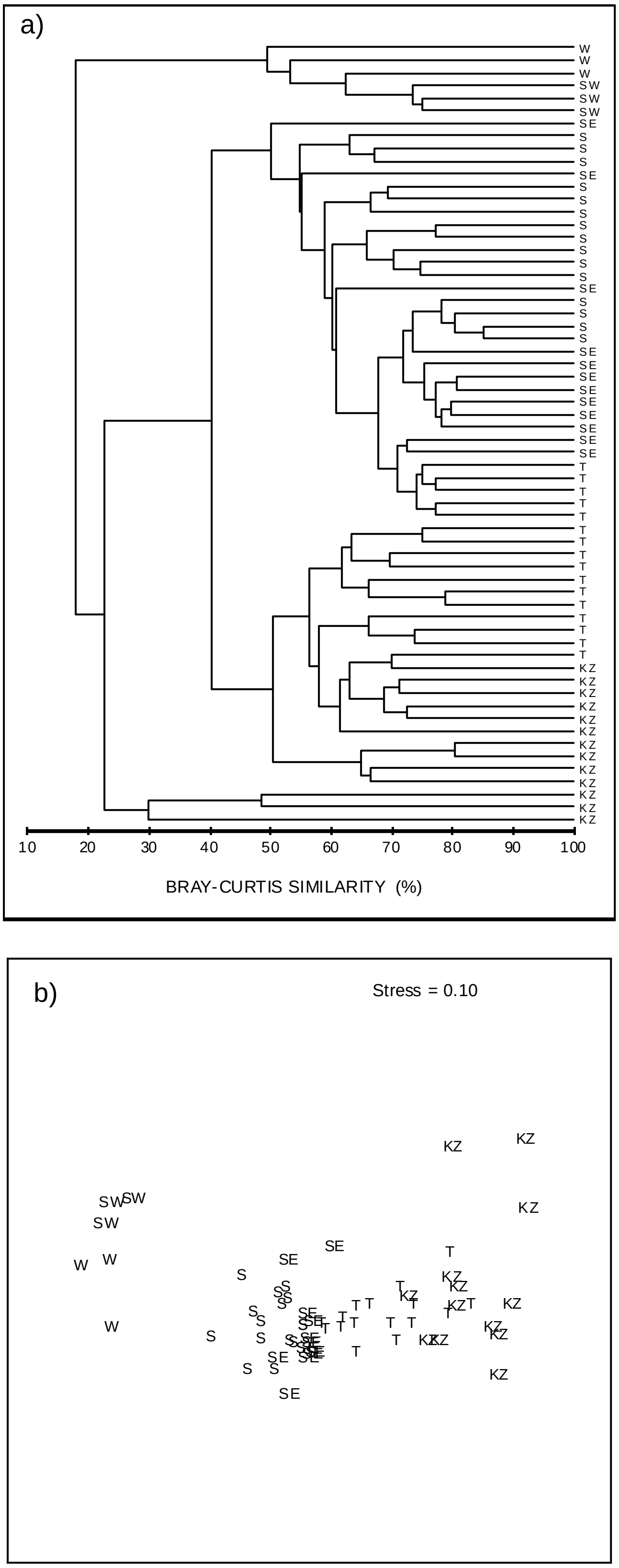

Figure 3.5. Dendogram (a) and MDS ordination (b) of type F estuaries on the South African coast.

Day (1981b) grouped southern African estuaries into three main biotic provinces based mainly on water temperature but also rainfall and river flow. The estuaries of southern Moçambique from the Morrumbene (23°44'S; 35°24'E) to the Great Kei (32°40'S; 28°23'E) at the southern Transkei border were classified as subtropical. These systems are characterised by warm waters (>16 °C), and a good summer rainfall and river discharge. Estuaries from the Great Kei to Cape Point (34°22'S; 18°30'E) were characterised as warm-temperate. These systems have minimum winter temperatures of between 12 and 14 °C and experience variable rainfall. The cold-temperate estuaries are those on the west (Atlantic) coast between Cape Point and the Gariep estuary (28°38'S; 16°28'E) and this area is characterised by very low rainfall and high evaporation (Day, 1981b). Whitfield (1994) suggested that the region between Cape Point and the Gariep be referred to as 'cool-temperate' since estuarine water temperatures in this region are always above 10 °C. He also suggested that the division between the subtropical and warm-temperate regions be changed to the Mbashe estuary (32°17'S; 28°54'E). The transitional nature of the Mbashe was highlighted by the presence of both mangroves which favour subtropical conditions, and saltmarshes which are normally associated with temperate systems (Whitfield, 1994).

From the results of this study it appears that, based on their fish communities, the estuaries within each geomorphological type formed groupings which were related to their geographical position or biogeography. Furthermore, it appears that estuaries on the west and south-west coast were more distinct than the remaining systems. This suggests that the cool-temperate region lies between the Gariep estuary and Cape Agulhas (34°50'S; 20°00'E). The region between Coffee Bay (31°59'S; 29°09'E) and Port St Johns (31°38'S; 29°33'E) in the Transkei appears to be a transition zone between the warm-temperate and subtropical regions.

To test if estuaries in different biogeographic regions have distinctive fish communities, each group of estuary types was divided into the biogeographic regions proposed by Whitfield (1994) and an analysis of similarities (ANOSIM) performed on the data. The ANOSIM test utilises the (rank) similarity matrix underlying the clustering or ordination procedure and tests for differences between and within *a priori* groupings (Clark & Warwick, 1994). A test statistic (R) is computed which reflects the observed differences between groupings, contrasted with differences within groupings. The R statistic falls within the range -1 to 1 but usually falls between 0 and 1. If R = 1 then all sites within a group are more similar to each other than any sites from different groups; if R is approximately zero then the similarities between and within groups are the same on average. The global R statistic reflects the similarities between all groupings (Clark & Warwick, 1994).

The results of the ANOSIM test are presented in Table 3.1. Apart from type A estuaries, the global R statistic for each estuary type were above 0.5 indicating that the fish communities of the estuaries within each biogeographic region are significantly different ($p<0.001$) to those recorded in the other biogeographic provinces.

Table 3.1. Test statistic (R) and significance (p) of the ANOSIM test applied to estuaries grouped according to the biogeographic zones suggested by Whitfield (1994). (GR = Global R statistic).

Type A estuaries	GR = 0.380 (p = 0.000)	
	Gariep - Cape Point	Cape Point - Mbashe
Cape Point - Mbashe	0.461 (p = 0.007)	
Mbashe - Kosi Bay	1.000 (p = 0.022)	0.272 (p = 0.010)
Type B estuaries	GR = 0.806 (p = 0.000)	
	Gariep - Cape Point	Cape Point - Mbashe
Cape Point - Mbashe	0.971 (p = 0.000)	
Mbashe - Kosi Bay	1.000 (p = 0.000)	0.759 (p = 0.000)
Type E estuaries	GR = 0.510 (p = 0.000)	
	Gariep - Cape Point	Cape Point - Mbashe
Cape Point - Mbashe		
Mbashe - Kosi Bay		0.510 (p = 0.000)
Type F estuaries	R = 0.659 (p = 0.000)	
	Gariep - Cape Point	Cape Point - Mbashe
Cape Point - Mbashe	0.777 (p = 0.001)	
Mbashe - Kosi Bay	0.998 (p = 0.000)	0.613 (p=0.000)

This analysis was repeated using Cape Agulhas and the Mdumbi estuary (31°56'S; 29°13'E) as the boundaries between the cool- and warm-temperate and warm-temperate and subtropical regions respectively. The ANOSIM test resulted in higher global R values (0.415 - 0.863) and generally higher R statistics for each estuary type (Table 3.2) than those recorded in Table 3.1.

Table 3.2. Test statistic (R) and significance (p) of the ANOSIM test applied to estuaries grouped according to the modified biogeographic zones (GR = Global R statistic).

Type A estuaries	GR = 0.415 (p = 0.000)	
	Gariep - Cape Agulhas	Cape Agulhas - Mdumbi
Cape Agulhas - Mdumbi	0.646 (p = 0.001)	
Mdumbi - Kosi Bay	1.000 (p = 0.012)	0.175 (p = 0.057)
Type B estuaries	GR = 0.846 (p = 0.000)	
	Gariep - Cape Agulhas	Cape Agulhas - Mdumbi
Cape Agulhas - Mdumbi	0.940 (p = 0.000)	
Mdumbi - Kosi Bay	0.994 (p = 0.000)	0.813 (p = 0.000)
Type E estuaries	GR = 0.753 (p = 0.000)	
	Gariep - Cape Agulhas	Cape Agulhas - Mdumbi
Cape Agulhas - Mdumbi	0.989 (p = 0.000)	
Mdumbi - Kosi Bay	0.999 (p = 0.001)	0.517 (p = 0.000)
Type F estuaries	R = 0.863 (p = 0.000)	
	Gariep - Cape Agulhas	Cape Agulhas - Mdumbi
Cape Agulhas - Mdumbi	0.997 (p = 0.000)	
Mdumbi - Kosi Bay	1.000 (p = 0.000)	0.808 (p=0.000)

The precise boundaries between biogeographic regions are clearly not distinct and zones of overlap (transition zones) exist. The area between Cape Point and Cape Agulhas is generally regarded as the transition zone between the cool-temperate and warm-temperate biogeographic regions while the transition zone between the subtropical and warm-temperate biogeographic regions lies somewhere in the Transkei between the Great Kei and Port St Johns (Hockey & Buxton, 1991). It is often convenient, however, to provide some firm boundary between the various regions and the results of this analysis suggests that, based on their fish communities, the subtropical biogeographic zone extends from Kosi Bay to the Mdumbi estuary, the warm-temperate region stretches from the Mdumbi estuary to Cape Agulhas, and the cool-temperate region continues from Cape Agulhas to the Gariep estuary.

3.4 Classification

3.4.1 *Introduction*

Having determined the biogeographic boundaries for estuaries along the South African coast, one can now investigate the fish community structure in relation to estuary type. This also serves to test the earlier assumption that estuaries with similar physical characteristics ought to have similar fish communities.

3.4.2 *Methods*

The estuaries sampled were divided into the biogeographic regions outlined above and the data analysed using a combination of hierarchical agglomerative clustering and non-metric multi-dimentional scaling (MDS) using PRIMER (Clark & Warwick, 1994). Before analysis the data was first standardised and then 4th root transformed. To assess whether the various physical/geomorphological estuary types within each biogeographic region contain distinctive fish assemblages, the ANOSIM test was applied to each grouping of estuary types within each biogeographic region. For ease of interpretation the estuaries are denoted by their physical/geomorphological type (A-F) as outlined in the previous chapter.

3.4.3 *Results & discussion*

Cool-temperate estuaries

For estuaries in the cool-temperate region, a group comprising a mixture of estuary types B, C and F separated from the remaining systems at approximately 40% similarity. At approximately 45% similarity two outliers, the Gariep (Type F) and Steenbras (Type D) separated out. The next grouping (at approximately 50% similarity) comprised type B systems. The remaining estuaries in the region formed two groups at approximately 58% similarity. The one group comprised systems mostly belonging to type A while the remaining estuaries were further subdivided (at just over 60% similarity) into predominantly type E systems and a combination of type B, E and F systems (Figure 3.6).

The results of the ordination revealed a fairly wide spread (stress = 0.16). Type C systems were situated to the left of the ordination. The centre of the plot comprised type E and F estuaries while type A systems formed a group to the right of the ordination. Type B systems were widely scattered but most were situated to the right of the plot. Only one type D system (Steenbras) was identified in this region and it was situated near the top of the ordination (Figure 3.6).

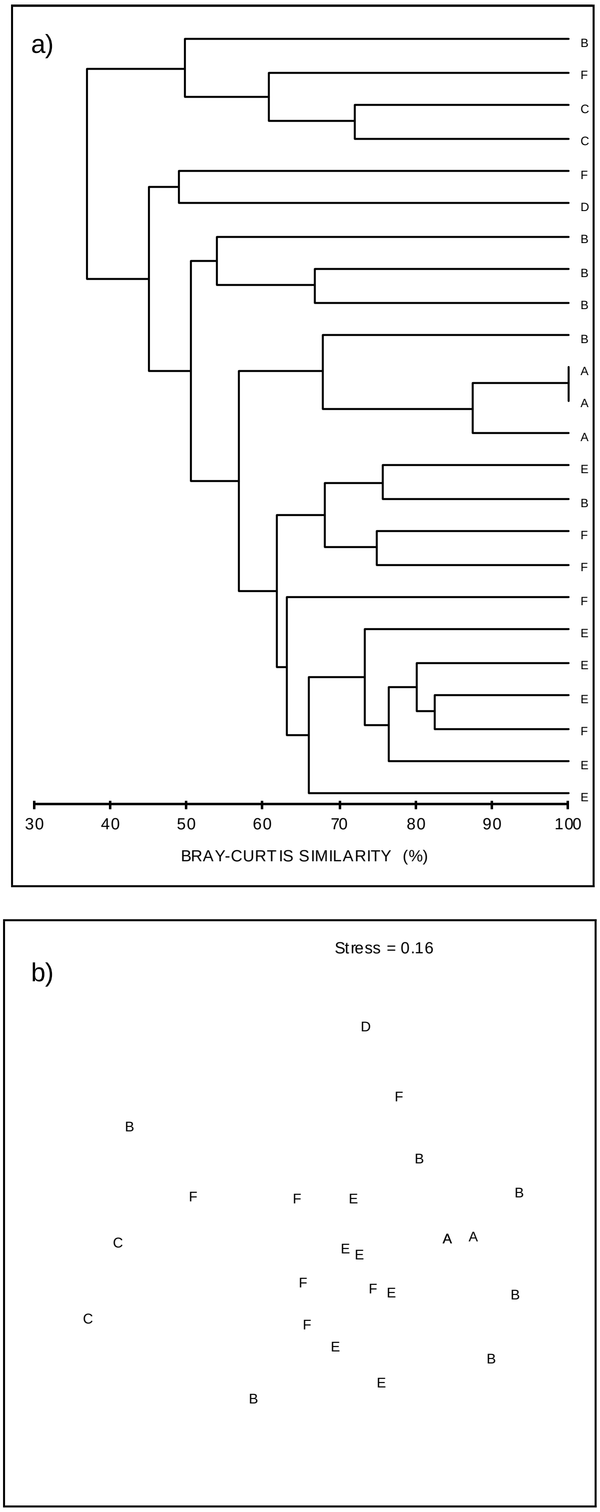

Figure 3.6. Dendogram (a) and MDS ordination (b) of cool-temperate estuaries on the South African coast.

Cool-temperate estuaries had a Global R value of 0.332 ($p = 0.001$). Relatively high significance levels were recorded ($p = 0.762 - 0.028$) and this is partially due to the small number of systems in each group of estuary types. Type B systems were highly variable and did not appear to be significantly different to the vast majority of the other estuary types in the region. The most distinctive groups were estuary types C, D and A. Estuary types E and F exhibited substantial overlap in the MDS plot and this is also reflected in the ANOSIM results (Table 3.3).

Table 3.3. Test statistic (R) and significance (p) of the ANOSIM test applied to estuaries in the cool-temperate zone (Global R = 0.332, p = 0.001).

Estuary Type	A	B	C	D	E	F
A		-0.142 (p = 0.762)	1.000 (p = 0.100)	1.000 (p = 0.250)	0.512 (p = 0.036)	0.290 (p = 0.107)
B	-0.142 (p = 0.762)		0.406 (p = 0.036)	0.289 (p = 0.429)	0.254 (p = 0.028)	0.059 (p = 0.277)
C	1.000 (p = 0.100)	0.406 (p = 0.036)		1.000 (p = 0.333)	1.000 (p = 0.360)	0.510 (p = 0.360)
D	1.000 (p = 0.250)	0.289 (p = 0.429)	1.000 (p = 0.333)		0.978 (p = 0.143)	0.778 (p = 0.143)
E	0.512 (p = 0.036)	0.254 (p = 0.028)	1.000 (p = 0.360)	0.978 (p = 0.143)		0.161 (p = 0.061)
F	0.290 (p = 0.107)	0.059 (p = 0.277)	0.510 (p = 0.360)	0.778 (p = 0.143)	0.161 (p = 0.061)	

Warm-temperate estuaries

The dendogram of warm-temperate estuaries is presented in Figure 3.7. Two systems, the Lottering and Storms (Type D), separated out as an outliers at approximately 20 and 25% similarity respectively. At approximately 35% similarity two groups were formed. One group comprised predominantly type D estuaries while the other were mainly type A systems. Another group of predominantly type A systems separated out at approximately 45% similarity. Three systems separated out from the remainder of the estuaries at between 45 and 48% similarity and these included the Great Kei (Type F), Mapuzi (Type E) and Mtendwe (Type A). At approximately 48% similarity a group of predominantly type B systems was formed. The remaining estuaries formed three groups at approximately 55% similarity. Two groups comprised predominantly type F estuaries while the remainder comprised mostly type B estuaries.

Although the ordination of warm-temperate estuaries had a relatively high stress (S = 0.18), some pattern was discernible (Figure 3.7). Type F estuaries formed a grouping to the right of the plot. Type B and E estuaries were situated in the centre and to the right of the ordination respectively. Type D estuaries formed a loose but distinct grouping near the top of the 'map' while the remaining systems (Type A) were spread along the bottom of the plot (Figure 3.7).

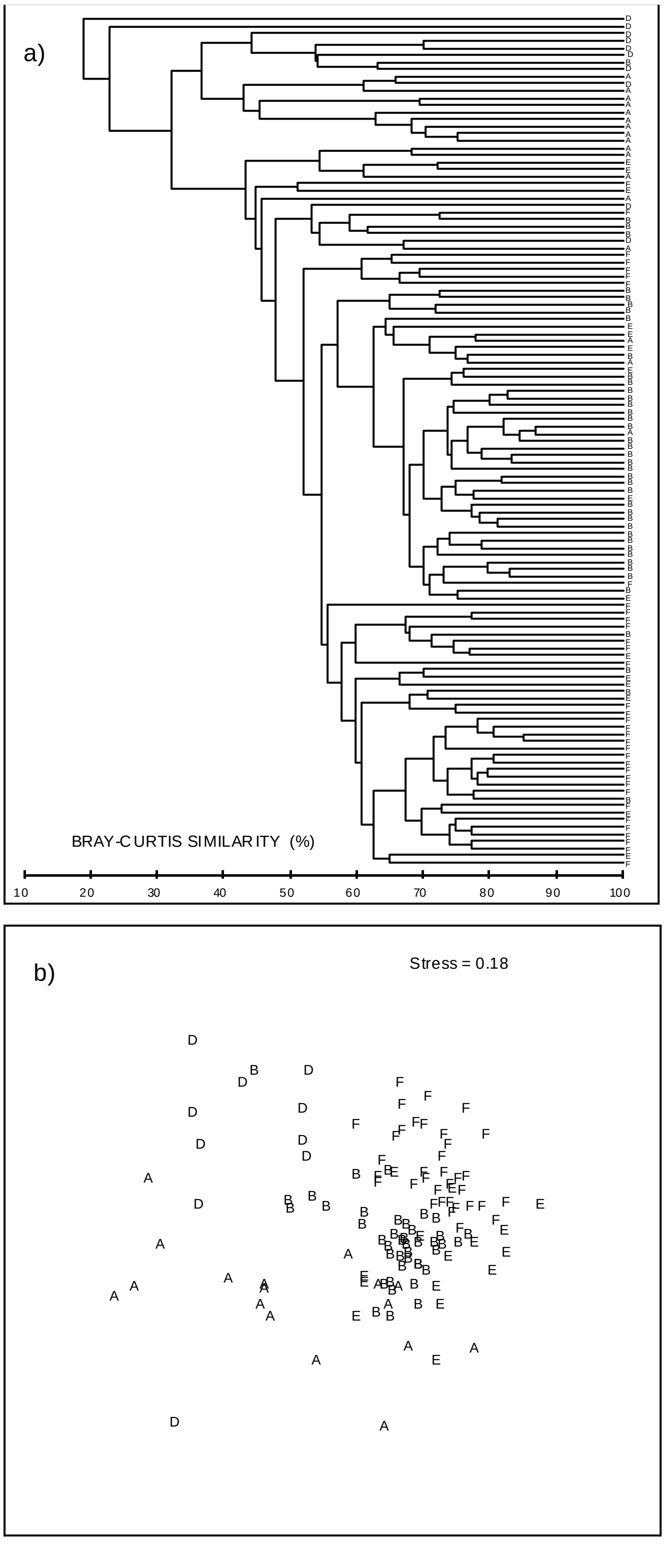

Figure 3.7. Dendogram (a) and MDS ordination (b) of warm-temperate estuaries on the South African coast.

The results of the ANOSIM test revealed that estuary types D and F had relatively high R statistics indicating significant differences compared to all other estuary types. Only type E estuaries yielded relatively low R values in relation to type A and B systems. Overall, estuaries in the warm-temperate region had a global R value of 0.539 (p = 0.000) indicating that the various estuary types had distinctive fish communities (Table 3.4).

Table 3.4. Test statistic (R) and significance (p) of the ANOSIM test applied to estuaries in the warm-temperate zone (Global R = 0.539, p = 0.000).

Estuary Type	A	B	C	D	E	F
A		0.576 (p = 0.000)		0.345 (p = 0.000)	0.294 (p = 0.000)	0.830 (p = 0.000)
B	0.576 (p = 0.000)			0.861 (p = 0.000)	0.291 (p = 0.001)	0.452 (p = 0.000)
C						
D	0.345 (p = 0.000)	0.861 (p = 0.000)			0.753 (p = 0.000)	0.890 (p = 0.000)
E	0.294 (p = 0.000)	0.291 (p = 0.001)		0.753 (p = 0.000)		0.432 (p = 0.000)
F	0.830 (p = 0.000)	0.452 (p = 0.000)		0.890 (p = 0.000)	0.432 (p = 0.000)	

Subtropical estuaries

From the dendogram of subtropical estuaries, four systems appeared to separate out as outliers at approximately 32% and 35% similarity. These included Kosi Bay and Mgobezeleni (types F and E respectively), and the Mvoti and Thukela (Type F). At approximately 40% similarity a group comprising a mixture of type A and B estuaries was formed. The remaining estuaries formed two groups at approximately 45% similarity. One group comprised a combination of type B and E estuaries while the remaining group comprised almost entirely of type F systems (Figure 3.8).

The MDS plot of the subtropical estuaries yielded a moderately high stress value (S = 0.17). The ordination showed a gradation from type F systems to the right of the plot to type B and E estuaries in the centre to type A systems to the left of the ordination (Figure 3.8).

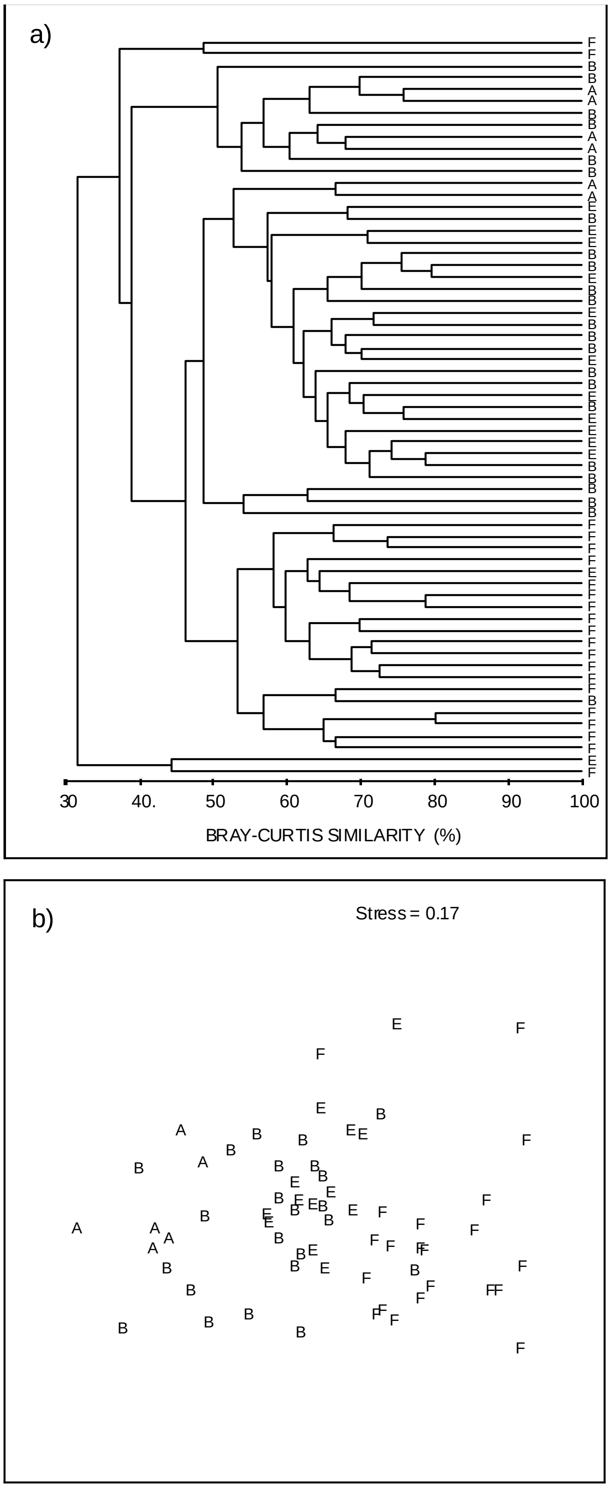

Figure 3.8. Dendogram (a) and MDS ordination (b) of subtropical estuaries on the South African coast.

Subtropical estuaries had a global R value of 0.406 (p = 0.000) (Table 3.5). Only four types of estuary were identified in this region. Type F estuaries had relatively high R values throughout indicating significant differences in the fish community in relation to all the other estuary types. In the ordination, type B estuaries exhibited a wide scatter and this is reflected in the ANOSIM results where relatively low R values were recorded when compared with type A and E systems. The remaining estuary types exhibited significant differences in their similarities suggesting distinctive fish communities (Table 3.5).

Table 3.5. Test statistic (R) and significance (p) of the ANOSIM test applied to estuaries in the subtropical zone (Global R = 0.406, p = 0.000).

Estuary Type	A	B	C	D	E	F
A		0.237 (p = 0.016)			0.671 (p = 0.000)	0.874 (p = 0.000)
B	0.237 (p = 0.016)				0.009 (p = 0.397)	0.525 (p = 0.000)
C						
D						
E	0.671 (p = 0.000)	0.009 (p = 0.397)				0.421 (p = 0.000)
F	0.874 (p = 0.000)	0.525 (p = 0.000)			0.421 (p = 0.000)	

Based on their physical/geomorphological characteristics, six basic estuary types were identified (although sub-groups within some of these also exist). Estuaries in the cool-temperate region are characterised by a relatively low species diversity and are typically dominated by a few abundant species (Whitfield, 1998). Although all the estuary types occur in this region, the low species diversity may account for the lack of distinctive faunas within each estuary type by virtue of their dominance by a few very common species. In the warm-temperate and subtropical regions most estuary types appeared to have distinctive fish communities which suggests that estuaries with similar physical/geomorphological characteristics contain similar fish assemblages.

3.5 Fish community characteristics

3.5.1 *Introduction*

Having determined the biogeography of the estuaries along the coast as well as the range of estuary types, a broad characterisation of the fish community structure of South Africa's estuaries is attempted. Biological communities can be described according to a number of attributes including species diversity, relative abundance, life-history characteristics and trophic structure (Krebbs, 1985). In this section only aspects of species diversity and composition will be considered.

The simplest measure of species diversity is to count the number of species, this is often referred to as species richness or species density (Odum, 1983). Not all species in the community, however, are equally important in determining the nature of the community and linked to this is the concept of dominance. Most biotic communities typically consist of many common species and a few rare species (Odum, 1983; Krebbs, 1985). A description of the fish community structure which typifies the various estuarine types in the various biogeographic regions may provide a baseline or reference against which individual estuaries can be measured and monitored in the future.

3.5.2 *Methods*

The estuaries were first divided according to biogeographic region and the systems within each region grouped according to estuary type, based on the classification provided in Chapter 2. Because the aim here is to describe the fish community structure of the various estuary types within each biogeographic region, exotic or translocated species were removed from the analysis. Juvenile mullet (Mugilidae, *Liza* spp. and *Valamugil* spp.) which were not fully identified, however, were retained due to the fact that this group comprises an important component of the ichthyofauna of South Africa's estuaries by virtue of their dependence on these systems as nursery areas.

The average number of taxa (and the standard deviation (SD)) was calculated for each group of estuary types within each biogeographic region. The species composition of each group of estuary types was also determined based on the frequency of occurrence of each taxa as well their average total abundance.

3.5.3 *Results & discussion*

Cool-temperate estuaries (Gariep – Cape Agulhas)

Type A estuaries (n = 3)

Only two species (*Liza richardsonii* and *Lithognathus lithognathus*) were captured in this group of estuaries. *Liza richardsonii* was captured in all the systems and comprised over 99% of the total catch numerically (Table 3.6).

Type B estuaries (n = 6)

An average of four species (SD = 3.31) was captured in type B estuaries in the cool-temperate region. The most frequently captured species included *L. richardsonii*, *Mugil cephalus*, *Atherina breviceps*, *Psammogobius knysnaensis*, *Caffrogobius nudiceps*, and *Heteromycteris capensis*. In terms of abundance, *Gilchristella aestuaria* was the dominant species (46.7%) followed by *L. richardsonii* (35.8%), *A. breviceps* (5.5%), *M. cephalus* (5.5%), *P. knysnaensis* (3.1%) and *C. nudiceps* (2.5%) (Table 3.6).

Type C estuaries (n = 2)

Only two systems, the Bot and Klein were classified as type C systems. Eight species were captured in the Bot and 11 species were captured in the Klein during this study; six species were common to both systems. Numerically *A. breviceps* (84.2%) was the dominant species followed by *G. aestuaria* (8.4%) and *L. richardsonii* (5.0%) (Table 3.6).

Type D estuaries (n = 1)

Only one system (Steenbras) was classified as type D in this region. Four species were captured in this system. *Liza richardsonii* was the numerically dominant species (62.5%) followed by *Sarpa salpa* (26.1%), *Diplodus sargus* (8.0%) and *G. aestuaria* (3.4%) (Table 3.6).

Type E estuaries (n = 6)

An average of four species (SD = 1.10) was captured in type E estuaries in the cool-temperate region. The most frequently captured fishes were *L. richardsonii*, *P. knysnaensis*, *M. cephalus*, *G. aestuaria*, and *Myxus capensis*. Numerically, *L. richardsonii* (92.3%), *P. knysnaensis* (4.8%) and *M. cephalus* (1.9%) were the dominant species (Table 3.6).

Type F estuaries (n = 6)

In type F estuaries an average of seven species (SD = 2.48) was captured. *Liza richardsonii*, *P. knysnaensis*, *M. cephalus*, *A. breviceps*, *G. aestuaria* and *Galeichthys feliceps* were the most frequently captured taxa. In terms of abundance, *L. richardsonii* (84.6%), *A. breviceps* (10.6%), *G. aestuaria* (2.2%) and *Barbus aeneus* (1.6%) were the dominant species (Table 3.6). The relatively high numerical dominance of *B. aeneus* is due to large numbers of this species being captured in the Gariep estuary. The natural distribution of this species, however, appears to be restricted to this system although some specimens have been translocated to larger coastal rivers in the south-east coastal region (Skelton, 1993).

Estuaries in the cool-temperate region are characterised by a relatively low species diversity and only 24 species are commonly associated with estuaries in this region (Whitfield, 1998). Overall, a total of 28 species were captured in estuaries in the cool-temperate region during this study of which, 19 were common to those listed in Whitfield (1998). The most frequently captured species included *L. richardsonii*, *P. knysnaensis, M. cephalus, G. aestuaria,* and *A. breviceps*. *Liza richardsonii* (60.5%), *A. breviceps* (28.9%) and *G. aestuaria* (7.1%) were the numerically dominant species overall. A noteworthy characteristic of cool-temperate estuaries is the overwhelming dominance of *L. richardsonii* and relative scarcity of most other species (Whitfield, 1998).

Table 3.6. Percent frequency of occurrence (%f) and abundance (%n) of fishes captured in estuaries in the cool-temperate region.

	Type 'A'		Type 'B'		Type 'C'		Type 'D'		Type 'E'		Type 'F'		Total	
Species	%f	%n	%f	%n	%f	%n	%f	%n	%f	%n	%f	%n	%f	%n
Amblyrhynchotes honckenii											16.7	0.0	4.2	0.0
Argyrosomus spp.											33.3	0.0	8.3	0.0
Atherina breviceps			33.3	5.5	100	84.2			16.7	0.1	66.7	10.6	37.5	28.9
Barbus aeneus											16.7	1.6	4.2	0.9
Caffrogobius gilchristi					50.0	0.2							4.2	0.0
Caffrogobius nudiceps			33.3	2.4							33.3	0.4	16.7	0.4
Chelidonichthys capensis											16.7	0.0	4.2	0.0
Clinus spatulatus					50.0	0.0							4.2	0.0
Clinus superciliosus					50.0	0.4							4.2	0.1
Diplodus sargus							100	8.0					4.2	0.0
Etrumeus whiteheadi											16.7	0.0	4.2	0.0
Galeichthys feliceps					100	0.3					50.0	0.0	20.8	0.1
Gilchristella aestuaria			16.7	46.7	100	8.4	100	3.4	50.0	0.4	50.0	2.2	41.7	7.1
Haploblepharus pictus											16.7	0.0	4.2	0.0
Heteromycteris capensis			33.3	0.5					16.7	0.0			12.5	0.0
Lichia amia			16.7	0.2									4.2	0.0
Lithognathus lithognathus	33.3	0.1							16.7	0.1			8.3	0.0
Liza dumerilii			16.7	0.2									4.2	0.0
Liza richardsonii	100	99.9	100	35.8	100	5.0	100	62.5	100	92.2	100	84.6	100	60.5
Mugil cephalus			66.7	5.5	100	0.3			50.0	1.9	83.3	0.1	58.3	0.7
Myxus capensis									33.3	0.1			8.3	0.0
Pomatomus saltatrix					50.0	0.0					33.3	0.1	12.5	0.0
Psammogobius knysnaensis			33.3	3.1	100	0.6			100	4.8	83.3	0.4	62.5	0.9
Rhabdosargus globiceps			16.7	0.1							16.7	0.0	8.3	0.0
Rhabdosargus holubi					50.0	0.0			16.7	0.2			8.3	0.0
Sardinops sagax											16.7	0.0	4.2	0.0
Sarpa salpa							100	26.1					4.2	0.1
Syngnathus acus			16.7	0.0	100	0.7					33.3	0.0	20.8	0.2

Warm-temperate estuaries (Cape Agulhas – Mdumbi)

Type A estuaries (n = 17)

An average of 8 taxa (SD = 3.51) was captured in type A estuaries in the warm-temperate region. The most frequently captured fishes included *M. cephalus*, *M. capensis*, *Rhabdosargus holubi*, *L. richardsonii*, juvenile mullet (Mugilidae), *G. aestuaria*, *P. knysnaensis*, *L. lithognathus* and *Monodactylus falciformis*. In terms of overall abundance, *M. cephalus* (29.8%), *M. capensis* (20.4%), *R. holubi* (15.1%), *G. aestuaria* (14.9%), *L. richardsonii* (8.1%), juvenile mullet (Mugilidae) (4.8%), *A. breviceps* (3.4%), and *Glossogobius callidus* (1.4%) were the dominant taxa (Table 3.7).

Type B estuaries (n = 42)

In type B estuaries an average of 17 taxa (SD = 5.06) was captured during this study. The most frequently captured fishes included *G. aestuaria*, *L. richardsonii*, *R. holubi*, *M. falciformis*, *M. capensis*, *M. cephalus*, *A. breviceps*, *G. callidus*, *Liza dumerilii*, *L. lithognathus*, *Liza tricuspidens*, *P. knysnaensis*, *Oreochromis mossambicus*, *Pomadasys commersonnii*, Mugilidae, *Liza* spp., *Argyrosomus japonicus*, and *Lichia amia*. *Gilchristella aestuaria* (42.8%), *A. brevicep*s (20.1%), *R. holubi* (14.2%), *M. capensis* (4.0%), *L. richardsonii* (4.0%), *G. callidus* (3.5%), *Liza* spp. (2.4%), *L. dumerilii* (1.9%), *L. lithognathus* (1.1%), *L. tricuspidens* (1.0%), *M. cephalus* (1.0%), and juvenile mullet (Mugilidae) (1.0%) were the dominant taxa numerically (Table 3.7).

Type D estuaries (n = 10)

An average of 8 taxa (SD = 2.99) was captured in type D estuaries during this study. *Liza richardsonii*, *L. lithognathus*, *P. knysnaensis*, *R. holubi*, *M. capensis*, juvenile mullet (Mugilidae), *M. falciformis*, and *H. capensis* were among the most frequently captured fishes. In terms of overall abundance, *G. aestuaria* (49.5%), *L. richardsonii* (23.5%), *M. cephalus* (8.5%), *P. knysnaensis* (3.3%), *Liza* spp. (2.6%), *L. lithognathus* (2.4%), *M. capensis* (2.2%), juvenile mullet (Mugilidae) (2.1%), *R. holubi* (1.8%), *M. falciformis* (1.1%), and *H. capensis* (1.1%) were the dominant taxa (Table 3.7).

Type E estuaries (n = 15)

For estuaries belonging to type E, an average of 18 taxa (SD = 3.73) was captured during this study. Fishes that were most frequently recorded included *R. holubi*, *M. capensis*, *A. breviceps*, juvenile mullet (Mugilidae), *G. aestuaria*, *M. cephalus*, *L. dumerilii*, *M. falciformis*, *L. richardsonii*, *L. tricuspidens*, *G. callidus*, *Liza macrolepis*, *Caffrogobius gilchristi*, *P. commersonnii*, *P. knysnaensis*, *A. japonicus*, *Solea bleekeri*, *O. mossambicus*, *Valamugil robustus*, and *L. lithognathus*. Numerically dominant taxa included *R. holubi* (30.2%), *G. aestuaria* (23.6%), *M. capensis* (9.9%), *M. cephalus* (6.9%), *A. breviceps* (6.3%), *L. dumerilii* (5.8%), *G. callidus* (4.7%), *L. richardsonii* (2.6%), *O. mossambicus* (1.7%), *C. gilchristi* (1.0%), *L. tricuspidens* (1.0%), and *Liza* spp. (1.0%) (Table 3.7).

Type F estuaries (n = 35)

An average of 27 taxa (SD = 6.91) was captured in type F estuaries during this study. *Liza dumerilii*, *R. holubi*, *L. richardsonii*, *C. gilchristi*, *P. knysnaensis*, *A. japonicus*, *G. aestuaria*, *M. cephalus*, *L. tricuspidens*, *Liza* spp., *P. commersonnii*, juvenile mullet (Mugilidae), *L. lithognathus*, *S. bleekeri*, *M. falciformis*, *A. breviceps*, *M. capensis*, *G. feliceps*, *L. amia*, *Elops machnata*, *H. capensis*, *G. callidus*, *D. sargus*, *C. nudiceps*, *L. macrolepis*, *Pomatomus saltatrix*, and *Clinus superciliosus* were the most frequently captured fishes. In terms of abundance, *G. aestuaria* (33.4%), *R. holubi* (13.0%), *Liza* spp. (7.6%), *L. richardsonii* (6.7%), *L. dumerilii* (6.4%), *A. breviceps* (5.6%), juvenile mullet (Mugilidae) (4.0%), *G. callidus* (3.6%), *M. cephalus* (3.5%), *P. commersonnii* (2.4%), *C. gilchristi* (2.1%), *P. knysnaensis* (1.2%), *S. salpa* (1.2%), *D. sargus* (1.2%), *L. lithognathus* (1.0%), and *L. tricuspidens* (1.0%) dominated this group of estuaries (Table 3.7).

A total of 78 estuary-associated fish species commonly occur in warm-temperate estuaries on the South African coast (Whitfield, 1998). Type A and D systems had the lowest average species richness in the region (eight species) and this is probably a result of the limited habitat offered by these systems. Type A estuaries are small temporarily closed systems while, although permanently open, type D estuaries are small systems which lie in deeply incised valleys. It is interesting to note that type B and E estuaries had a similar average species richness suggesting that, although different in terms of their predominant mouth condition, both offer a similar habitat for fishes. This is also indicated by the results of the ANOSIM test where their fish communities did not appear to be significantly different (Table 3.4). Permanently open type F estuaries had the highest average species richness in the region and is probably a result of the greater habitat diversity offered by these systems.

Table 3.7. Percent frequency of occurrence (%f) and abundance (%n) of fishes captured in estuaries in the warm-temperate region.

	Type 'A'		Type 'B'		Type 'D'		Type 'E'		Type 'F'	
Species	%f	%n	%f	%n	%f	%n	%f	%n	%f	%n
Acanthopagrus berda			2.4	0.0			26.7	0.0	17.1	0.1
Ambassis gymnocephalus			2.4	0.0			6.7	0.0	11.4	0.1
Ambassis natalensis							6.7	0.0	2.9	0.0
Ambassis productus									5.7	0.0
Amblyrhynchotes honckenii			2.4	0.0					22.9	0.0
Anguilla mossambica									5.7	0.0
Antennarius striatus									2.9	0.0
Argyrosomus japonicus			42.9	0.2	10.0	0.0	60.0	0.4	97.1	0.6
Atherina breviceps	29.4	3.4	88.1	20.1	10.0	0.0	93.3	6.3	77.1	5.6
Caffrogobius gilchristi	5.9	0.0	28.6	0.1	20.0	0.1	66.7	1.0	97.1	2.1
Caffrogobius natalensis			4.8	0.0	10.0	0.1	6.7	0.0	37.1	0.2
Caffrogobius nudiceps			4.8	0.1			6.7	0.0	48.6	0.5
Caranx ignobilis									2.9	0.0
Caranx sexfasciatus			4.8	0.0			6.7	0.0	8.6	0.0
Chaetodon marleyi									2.9	0.0
Clinus superciliosus									40.0	0.5
Dasyatis kuhlii									2.9	0.0
Diplodus cervinus									28.6	0.0
Diplodus sargus			28.6	0.3	20.0	0.1	6.7	0.0	54.3	1.2
Elops machnata			16.7	0.1			6.7	0.0	65.7	0.2
Etrumeus whiteheadi							6.7	0.0	5.7	0.0
Eugomphodus taurus									5.7	0.0
Galeichthys feliceps			19.0	0.0	30.0	0.5	13.3	0.0	68.6	0.4
Gerres methueni			2.4	0.0						
Gilchristella aestuaria	47.1	14.9	100.0	42.8	20.0	49.5	86.7	23.6	94.3	33.4
Glossogobius callidus	35.3	1.4	85.7	3.5			73.3	4.7	57.1	3.6
Gobiidae			2.4	0.0					2.9	0.0
Gymnocrotaphus curvidens									2.9	0.0
Hemiramphus far									14.3	0.0
Heteromycteris capensis	11.8	0.0	31.0	0.1	40.0	1.1	20.0	0.1	60.0	0.4
Hippichthys spicifer									2.9	0.0
Hippocampus capensis									2.9	0.0
Johnius dorsalis									2.9	0.0
Leiognathus equula									5.7	0.0
Lichia amia			42.9	0.0			13.3	0.0	68.6	0.1
Lithognathus lithognathus	41.2	0.5	76.2	1.1	80.0	2.3	40.0	0.1	82.9	1.0
Lithognathus mormyrus									2.9	0.0
Liza alata	5.9	0.0	2.4	0.0			26.7	0.1		
Liza dumerilii	23.5	0.2	83.3	1.9	10.0	0.1	86.7	5.7	100.0	6.4
Liza macrolepis	11.8	0.0	26.2	0.1			73.3	0.7	45.7	0.1
Liza melinoptera							6.7	0.0		
Liza richardsonii	76.5	8.1	100.0	4.0	100.0	23.5	80.0	2.6	97.1	6.7
Liza spp.	11.8	0.1	42.9	2.4	30.0	2.6	33.3	1.0	91.4	7.6
Liza tricuspidens	23.5	0.2	76.2	1.0	10.0	0.0	80.0	1.0	94.3	1.0
Lutjanus argentimaculatus			2.4	0.0					2.9	0.0
Monodactylus falciformis	41.2	0.4	92.9	0.6	50.0	1.1	86.7	0.7	80.0	0.4
Mugil cephalus	88.2	29.8	90.5	1.0	20.0	8.5	86.7	6.9	94.3	3.5
Mugilidae	70.6	4.8	45.2	0.9	50.0	2.1	93.3	0.4	82.9	4.0
Myliobatis aquila									5.7	0.0
Myxus capensis	82.4	20.3	90.5	4.0	50.0	2.2	93.3	9.9	71.4	0.8

Table 3.7. cont. Percent frequency of occurrence (%f) and abundance (%n) of fishes captured in estuaries in the warm-temperate region.

Species	Type 'A'		Type 'B'		Type 'D'		Type 'E'		Type 'F'	
	%f	%n	%f	%n	%f	%n	%f	%n	%f	%n
Oligolepis acutipennis									8.6	0.0
Oligolepis keiensis			4.8	0.0			20.0	0.1	17.1	0.0
Omobranchus woodi									2.9	0.0
Oreochromis mossambicus	29.4	0.6	64.3	0.6			46.7	1.7	8.6	0.0
Parablennius lodosus			2.4	0.0						
Platycephalus indicus									17.1	0.0
Pomadasys commersonnii	5.9	0.0	61.9	0.2	10.0	0.0	66.7	0.9	91.4	2.4
Pomadasys kaakan									5.7	0.0
Pomadasys olivaceum			7.1	0.0			6.7	0.0	25.7	0.2
Pomatomus saltatrix	5.9	0.0	14.3	0.0	20.0	0.9	6.7	0.0	42.9	0.0
Psammogobius knysnaensis	47.1	0.2	71.4	0.4	70.0	3.3	60.0	0.5	97.1	1.2
Raja miraletes									2.9	0.0
Rhabdosargus globiceps			4.8	0.0	10.0	0.0	6.7	0.0	34.3	0.4
Rhabdosargus holubi	76.5	15.1	97.6	14.2	60.0	1.8	100.0	30.2	97.1	13.0
Rhabdosargus sarba			4.8	0.0					2.9	0.0
Sardinops sagax							13.3	0.0	17.1	0.0
Sarpa salpa			16.7	0.0			6.7	0.0	31.4	1.2
Secutor ruconius									2.9	0.0
Siganus sutor									2.9	0.0
Sillago sihama									2.9	0.0
Solea bleekeri			38.1	0.1	20.0	0.1	53.3	0.3	80.0	0.5
Sphyraena jello									2.9	0.0
Stolephorus holodon									17.1	0.0
Syngnathus acus			2.4	0.0					34.3	0.1
Syngnathus watermeyeri									2.9	0.0
Terapon jarbua			7.1	0.0			33.3	0.1	8.6	0.0
Torpedo fuscumaculata									14.3	0.0
Torpedo sinusperci							6.7	0.0	11.4	0.0
Trachinotus spp.									2.9	0.0
Trachurus trachurus									5.7	0.0
Valamugil buchanani			4.8	0.0			13.3	0.1	37.1	0.1
Valamugil cunnesius			4.8	0.0			26.7	0.1	14.3	0.0
Valamugil robustus			7.1	0.0			40.0	0.5	25.7	0.1
Valamugil seheli									2.9	0.0
Valamugil spp.							6.7	0.0	8.6	0.0

Subtropical estuaries (Mdumbi – Kosi Bay)

Type A estuaries (n = 6)

An average of nine taxa (SD = 2.37) was recorded in type A systems in the subtropical region. *Oreochromis mossambicus*, *M. capensis*, *M. cephalus*, *G. aestuaria*, *G. callidus*, *M. falciformis*, *R. holubi*, and *V. robustus* were the most frequently occurring fishes. Numerically dominant species included *G. aestuaria* (34.3%), *O. mossambicus* (33.1%), *M. capensis* (13.8%), *M. cephalus* (13.6%), *R. holubi* (2.1%), and *G. callidus* (1.9%) (Table 3.8).

Type B estuaries (n = 23)

In type B estuaries an average of 17 taxa (SD = 5.65) was captured. The most frequently captured fishes included *M. capensis*, *O. mossambicus*, *M. cephalus*, *Valamugil cunnesius*, *G. callidus*, *R. holubi*, *L. dumerilii*, *G. aestuaria*, *M. falciformis*, *Liza* spp., *L. macrolepis*, *P. commersonnii*, *Liza alata*, *Ambassis productus*, *Terapon jarbua*, *V. robustus*, and *C. gariepinus*. In terms of overall abundance, *G. aestuaria* (42.9%), *O. mossambicus* (16.3%), *M. capensis* (9.1%), *M. cephalus* (5.0%), *V. cunnesius* (4.5%), *R. holubi* (4.5%), *G. callidus* (2.6%), *L. dumerilii* (2.6%), *M. falciformis* (1.9%), *A. productus* (1.4%), juvenile mullet (Mugilidae) (1.3%), *V. robustus* (1.3%), and *Liza* spp. (1.1%) were the dominant taxa (Table 3.8).

Type E estuaries (n = 13)

An average of 19 taxa (SD = 4.13) was recorded in type E estuaries during this study. *Mugil cephalus*, *M. capensis*, *V. robustus*, *L. dumerilii*, *L. macrolepis*, *O. mossambicus*, *R. holubi*, *M. falciformis*, *L. alata*, *T. jarbua*, *V. cunnesius*, *G. callidus*, *Liza* spp., *P. commersonnii*, *A. productus*, *G. aestuaria*, juvenile mullet (Mugilidae), *Ambassis natalensis*, and *S. bleekeri* were the most frequently recorded fishes. Numerically dominant taxa included *G. aestuaria* (19.4%), *R. holubi* (13.7%), *M. capensis* (12.4%), *V. robustus* (11.0%), *M. cephalus* (7.9%), *O. mossambicus* (7.7%), *L. dumerilii* (4.7%), juvenile mullet (Mugilidae) (3.7%), *L. macrolepis* (3.4%), *V. cunnesius* (3.3%), *Liza* spp. (2.6%), *G. callidus* (2.5%), *T. jarbua* (1.7%), and *L. tricuspidens* (1.0%) (Table 3.8).

Type F estuaries (n = 21)

In type F estuaries an average of 33 taxa (SD = 10.99) was recorded. Fishes that were most frequently captured included *M. cephalus*, *T. jarbua*, *V. cunnesius*, *G. callidus*, *L. dumerilii*, juvenile mullet (Mugilidae), *Acanthopagrus berda*, *A. japonicus*, *Caranx sexfasciatus*, *Liza* spp., *L. macrolepis*, *P. commersonnii*, *M. capensis*, *R. holubi*, *A. natalensis*, *Valamugil* spp., *Caranx ignobilis*, *G. aestuaria*, *L. alata*, *Oligolepis acutipennis*, *Valamugil buchanani*, *E. machnata*, *Leiognathus equula*, *Oligolepis keiensis*, *S. bleekeri*, *V. robustus*, *Hilsa kelee*, *L. tricuspidens*, *Ambassis gymnocephalus*, *A. productus*, *O. mossambicus*, *Megalops cyprinoides*, *Rhabdosargus sarba*, *Scomberoides lysan*, and *Thryssa vitrirostris* (Table 3.8).

In terms of overall abundance, *G. aestuaria* (17.7%), *A. gymnocephalus* (9.3%), *L. dumerilii* (8.1%), *Liza* spp., (5.6%), *R. holubi* (5.6%), *V. cunnesius* (5.6%), Mugilidae (5.0%), *L. macrolepis* (3.8%), *P. commersonnii* (3.2%), *L. equula* (2.9%), *G. callidus* (2.8%), *M. cephalus* (2.7%), *T. jarbua* (2.2%), *H. kelee* (1.9%), *A. natalensis* (1.9%), *V. robustus* (1.8%), *Valamugil* spp. (1.5%), *M. capensis* (1.3%), *T. vitrirostris* (1.3%), *O. acutipennis* (1.3%), and *C. gilchristi* (1.1%) were the dominant taxa (Table 3.8).

In the subtropical region, small temporarily closed type A systems had the lowest average species richness. Although different physically/geomorphologically, type B and E estuaries had a similar average species richness. This together with the results of the ANOSIM test (Table 3.5) suggests that both offer a similar habitat for fishes. The greater habitat diversity offered by the permanently open type F estuaries probably accounts for their high average species richness. According to Whitfield (1998) 142 species are commonly associated with subtropical estuaries.

Table 3.8. Percent frequency of occurrence (%f) and abundance (%n) of fishes captured in estuaries in the subtropical region.

Species	Type 'A'		Type 'B'		Type 'E'		Type 'F'	
	%f	%n	%f	%n	%f	%n	%f	%n
Abudefduf sordidus							4.8	0.0
Acanthopagrus berda			13.0	0.0	15.4	0.0	90.5	0.8
Ambassis gymnocephalus			8.7	0.1			47.6	9.3
Ambassis natalensis			21.7	0.3	46.2	0.3	76.2	1.8
Ambassis productus			52.2	1.4	61.5	0.5	47.6	0.5
Amblyrhynchotes honckenii					7.7	0.0	33.3	0.3
Argyrosomus japonicus			39.1	0.1	30.8	0.1	85.7	0.6
Arothron immaculatus							23.8	0.0
Atherina breviceps							14.3	0.6
Awaous aeneofuscus	16.7	0.0	13.0	0.0			4.8	0.0
Barbus natalensis			4.3	0.0				
Caffrogobius gilchristi					15.4	0.2	28.6	1.1
Caffrogobius natalensis			17.4	0.1			28.6	0.1
Caranx ignobilis			4.3	0.0	23.1	0.0	71.4	0.9
Caranx heberi							9.5	0.0
Caranx papuensis			8.7	0.0			19.0	0.0
Caranx sexfasciatus	16.7	0.0	34.8	0.1	38.5	0.1	85.7	0.8
Caranx spp.							9.5	0.0
Chanos chanos			4.3	0.0			4.8	0.0
Chelonodon laticeps							23.8	0.1
Clarias gariepinus			43.5	0.6	7.7	0.0	23.8	0.1
Crenidens crenidens							4.8	0.0
Crenimugil crenilabis					15.4	0.0	4.8	0.0
Diplodus sargus							4.8	0.0
Eleotris fusca			8.7	0.0			4.8	0.0
Elops machnata			8.7	0.0			66.7	0.3
Engraulidae							4.8	0.0
Engraulis japonicus							19.0	0.1
Epinephelus coioides							4.8	0.0
Epinephelus malabaricus							14.3	0.0
Epinephelus tauvina							4.8	0.0
Favonigobius melanobranchus							4.8	0.0
Favonigobius reichei					7.7	0.0	14.3	0.0
Gerres acinaces							9.5	0.1
Gerres filamentosus							9.5	0.0
Gerres methueni			21.7	0.3	23.1	0.1	28.6	0.9
Gerres oblongus							4.8	0.0
Gilchristella aestuaria	83.3	34.3	73.9	42.9	61.5	19.4	71.4	17.7
Glossogobius biocellatus							9.5	0.0
Glossogobius callidus	83.3	1.9	82.6	2.6	69.2	2.5	90.5	2.8
Glossogobius giuris	16.7	0.0	26.1	0.1	23.1	0.1	33.3	0.2
Hilsa kelee							61.9	1.9
Hippichthys heptagonus							4.8	0.0
Hippichthys spicifer					7.7	0.0	4.8	0.0
Johnius dorsalis							9.5	0.1
Leiognathus equula			13.0	0.1	7.7	0.2	66.7	2.9
Lichia amia					7.7	0.0	9.5	0.0
Lithognathus lithognathus							4.8	0.0
Liza alata	16.7	0.0	65.2	0.4	76.9	0.8	71.4	0.7
Liza dumerilii	50.0	0.2	78.3	2.5	92.3	4.7	95.2	8.1

Table 3.8. cont. Percent frequency of occurrence (%f) and abundance (%n) of fishes captured in estuaries in the subtropical region.

	Type 'A'		Type 'B'		Type 'E'		Type 'F'	
Species	%f	%n	%f	%n	%f	%n	%f	%n
Liza macrolepis			69.6	0.8	92.3	3.4	85.7	3.8
Liza melinoptera					7.7	0.0	14.3	0.0
Liza richardsonii					7.7	0.0	4.8	0.0
Liza spp.	16.7	0.1	69.6	1.1	69.2	2.6	85.7	5.6
Liza tricuspidens	16.7	0.1	13.0	0.0	38.5	1.0	52.4	0.4
Lutjanus argentimaculatus			13.0	0.0			23.8	0.0
Lutjanus fulviflamma			4.3	0.0			14.3	0.0
Megalops cyprinoides			13.0	0.1	7.7	0.0	38.1	0.1
Monodactylus argenteus			4.3	0.0	7.7	0.0	14.3	0.0
Monodactylus falciformis	83.3	0.2	73.9	1.9	84.6	0.9	33.3	0.3
Mugil cephalus	100.0	13.6	91.3	5.0	100.0	7.9	100.0	2.7
Mugilidae	33.3	0.2	39.1	1.3	53.8	3.7	90.5	5.0
Mugillogobius durbanensis			4.3	0.0				
Myxus capensis	100.0	13.8	100.0	9.1	100.0	12.4	81.0	1.3
Oligolepis acutipennis			13.0	0.1	23.1	0.1	71.4	1.3
Oligolepis keiensis			8.7	0.0	23.1	0.2	66.7	0.7
Oreochromis mossambicus	100.0	33.1	100.0	16.3	92.3	7.7	42.9	0.7
Oxyurichthys opthalmonema			4.3	0.0			4.8	0.2
Periopthalmus koelreuteri							14.3	0.0
Platycephalus indicus							23.8	0.1
Polydactylus plebeius							4.8	0.0
Pomadasys commersonnii			69.6	0.6	69.2	0.4	85.7	3.2
Pomadasys kaakan			4.3	0.0	15.4	0.1	23.8	0.3
Pomadasys multimaculatum							4.8	0.0
Pomadasys olivaceum							4.8	0.2
Pomatomus saltatrix			4.3	0.0			14.3	0.0
Psammogobius knysnaensis			13.0	0.2	23.1	0.2	28.6	0.1
Pseudorhombus arsius			4.3	0.0			9.5	0.0
Redigobius dewaali			4.3	0.0				
Rhabdosargus holubi	66.7	2.1	82.6	4.5	92.3	13.7	81.0	5.6
Rhabdosargus sarba			8.7	0.1	15.4	0.1	38.1	0.1
Scomberoides lysan					7.7	0.0	38.1	0.5
Silhouettea sibayi							9.5	0.1
Sillago sihama			4.3	0.0			14.3	0.1
Solea bleekeri			26.1	0.1	46.2	0.2	66.7	0.8
Sphyraena jello							19.0	0.0
Stolephorus holodon							23.8	0.3
Terapon jarbua	16.7	0.1	52.2	0.4	76.9	1.7	100.0	2.2
Thryssa setirostris							14.3	0.0
Thryssa vitrirostris							38.1	1.3
Thyrsoidea macrura							9.5	0.0
Tilapia rendalli			8.7	0.1			4.8	0.0
Tilapia sparrmanii					7.7	0.0		
Trypauchen microcephalus							4.8	0.0
Upeneus vittatus							9.5	0.0
Valamugil buchanani			21.7	0.1	23.1	0.0	71.4	0.6
Valamugil cunnesius	16.7	0.0	87.0	4.5	76.9	3.3	100.0	5.5
Valamugil robustus	50.0	0.2	52.2	1.3	100.0	11.0	66.7	1.8
Valamugil seheli	16.7	0.0	13.0	0.1	7.7	0.1	28.6	0.3
Valamugil spp.			17.4	0.3	23.1	0.1	76.2	1.5