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Classification of estuaries in the Ciskei and Transkei regions based on physical and botanical characteristics

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For the first time a comprehensive botanical survey has taken place in the Ciskei and Transkei estuaries, Eastern Cape Province, South Africa. In total 54 plant species were found in the 92 estuaries surveyed. These plants could be divided into the following five habitat complexes; reed and sedge beds (23 species), salt marsh (20 species), mangrove forest (4 species), macroalgal assemblages (3 species) and swamp forest (4 species). Ordination showed that salinity and depth were important in influencing the distribution of species. Salinity separated salt marsh from reed and sedge species and depth separated mangrove and associated species (e.g. *Zostera capensis*, *Halophila ovalis* and *Acrostichum aureum*) from reed and sedge species.

Based on the plant species composition the estuaries could be divided into those that were permanently open versus those that were temporarily open/closed. The characteristic habitat complexes for the permanently open estuaries were intertidal salt marsh and mangrove forest. This region is a transition between the warm temperate and subtropical biogeographic zones and both permanently open and temporarily open/closed estuaries showed divisions at the Great Kei and Mngazana estuaries. In permanently open estuaries mangrove forest occurred north of the Great Kei Estuary and swamp forest north of the Mngazana Estuary. In temporarily open/closed estuaries reed and sedge beds occurred north of the Great Kei River and swamp forest, reed and sedge beds occurred north of the Mngazana Estuary where they replaced the salt marsh. The temporarily open/closed estuaries in the Ciskei were characterised by salt marsh and macroalgae. Submerged macrophytes such as *Ruppia cirrhosa* and *Potamogeton pectinatus* were also common. Salt marsh occurred because of high water column salinity and wide intertidal and supratidal zones. These estuaries were characterised by seawater washing into the estuary over the berm at the mouth and thus had high salinity. The variation in physical environment, changes in climate and transition between biogeographic regions has resulted in regions of high biodiversity. Mangrove, salt marsh and swamp forest species are found in the same region.

Introduction

Estuaries are important areas for ecological, social and financial reasons. Ecologically they are important because they are areas of high productivity and diversity. They provide food, refuge and breeding areas for numerous faunal species that are important to both marine and freshwater ecosystems. Socially they are important because people are attracted to them for residential, holiday, sporting and aesthetic reasons. Financially they are important for trade and ecotourism. However, as the population of South Africa increases and more people settle near estuaries and as more freshwater is abstracted from rivers, the ecological integrity of many South African estuaries is being threatened.

Estuaries of the Ciskei and Transkei regions, Eastern Cape Province, were chosen for this study because little to no information was available on the botanical composition of estuaries in this region. Ward and Steinke (1988) give an account of the distribution and extent of mangroves but little attention has been given to the botanical characteristics. For the effective management and conservation of South Africa's estuaries information is necessary on the biodiversity of these systems as well as the important controlling environmental factors. For the first time a survey of the botanical composition was undertaken in 16 Ciskei and 76 Transkei estuaries. Ordination was used to relate the distribution of species to the physical environment and identify specific groups of estuaries. These groups were then compared to those identified in a geomorphologic classification by Harrison *et al*. (1997).

Physical and chemical factors are commonly the driving forces that result in biological responses. A geomorphologic classification system for estuaries has been developed and has been related to the fish fauna (Harrison *et al.* 1997, Cooper *et al.* 1999, Harrison *et al.* 1999). The 16 Ciskei

estuaries (Table 1) and 43 of the 76 Transkei estuaries (Table 2) surveyed in this study were classified by Harrison *et al*. (1997, 1999). They distinguished seven different geomorphologic classes. Each class showed a transition along the coastline dependent on the estuary type and consequent fish assemblages (Harrison *et al.* 1999). We were interested in investigating whether estuarine plants would follow a similar geomorphologic classification suited to fish or whether they were independent, i.e. were the geomorphological factors responsible for driving both of the biological responses or were they independent. The objective of the study was thus to classify estuaries in the Ciskei and Transkei regions based on physical and botanical characteristics.

Study Area

The Ciskei and Transkei region were independent homelands up until the 1994 South African political elections. The Ciskei lies between the Great Fish (33°30'S, 27°08'E) and Tyolomnqa (33°14'S, 27°35'E) Rivers, a distance of approximately 75km. This portion of the coast is made up of a series of small bays with rocky headlands joined by sandy beaches. The mouth barriers of the estuaries are usually perched above the mean spring water mark, sand being placed there by heavy seas. Fourteen estuaries are found in this region but only three are permanently open (Great Fish, Keiskamma and Tyolomnqa estuaries). Compared to the Transkei the Ciskei has numerous recreation and residential

Table 1: The classification of estuaries compiled by Harrison *et al*. (1997) for the 16 Ciskei estuaries. The estuarine classes as described by Whitfield (1992) are also shown

Estuary Class	Whitfield Class	Harrison Class	Size(ha)	Barrier Type	Salinity(gl^{-1})	Estuaries
1A	Temporarily open/closed	Frequently closed	Moderately small 9–25	Long wide barriers overwash	Near marine, dominated when closed	Mpekweni, Mtati, Mgwalana, Bira, Gqutywa, Mtana, Kiwane
1B	Temporarily open/closed	Frequently closed	Moderately small 5–12	Long wide barriers	Near marine, overwash dominated when closed	Old Woman's
2	Permanently open	Near permanently open	Large 40–150	–	0–35	Great Fish, Keiskamma, Tyolomnqa
3	Not considered estuarine	Small dry river beds or freshwater water channels	Small <5	Long	0–5	Thatshana, Fresh Water Poort, Blue Krans, Shwele-Shwele
4	Temporarily closed	Freshwater dominated channels	Small 5	Perched above neap tide level	5–11	Ngculura

Table 2: The classification of estuaries derived by Harrison *et al*. (1999) for 43 of the Transkei estuaries. The estuarine classes as described by Whitfield (1992) are also shown

Estuary Class	Whitfield Class	Harrison Class	Size (ha)	Salinity (gl^{-1})	Barrier Type	Estuaries
1A	Temporarily open/closed	Temporarily open	Moderately small <5	Vary from fresh or brackish 0.03–11	Perched barrier	Ngogwane, Ncizele, Zalu, Ngadla, Ku-Mpenzu, Kwa-Suka, Sundwana, Nenga, Thsani, Sinangwana, Gxwaleni, Bulolo, Mtumbane, Ntlupeni, Butsha
1B	Temporarily open/closed	Near permanently open	Moderately small 5–15	0–35	–	Jujura, Mapuzi
2	Temporarily open/closed	Temporarily open	Moderately small 5–15	16–18	Perched barrier	Gxara, Qolora Cebe, Ngqwara, Ku-Bhula, Ntlonyane, Nkanya, Mpande, Mgwegwe, Mgwetyana, Mtentwana
3A	Permanently open	Near permanently open	>15	Axial gradient 0–36	–	Kobonqaba, Ngqusi/Inxaxo, Qora, Shixini, Xora, Mdumbi, Mngazi, Mntafufu, Mzamba
3B	Permanently open	Near permanently open	250	Axial gradient 0–36	–	Mngazana
3C	Permanently open	Near permanently open	25	Axial gradient 0–36	–	Msikaba, Mtentu
4	Permanently open or river mouth	River dominated	50	Small tidal range, <2km	–	Mbashe, Mtata, Mzimvubu, Great Kei

developments on the banks of eight estuaries. These are mostly holiday houses, while the Mpekweni, Old Woman's and Great Fish estuaries have hotel developments.

The Transkei coast is a rugged and undeveloped region extending from the Great Kei River (32°41'S, 28°23'E) to the boundary between the Eastern Cape and KwaZulu-Natal provinces (Mtamvuna River, 31°04'S, 30°11'E). The Transkei coast, also known as the Wild Coast, is approximately 270 kilometres in length and forms the transition between the warm temperate and subtropical biogeographic regions. One hundred and twenty river outlets occur along the coast of which 76 are estuaries. Seventeen of these estuaries are permanently open, 58 temporarily open/closed and one a river mouth (Whitfield 1992). Five marine and nature reserves cover nineteen percent of the coastline, while the remaining coastal land is under tribal tenure. The estuaries that are afforded conservation are the Mtamvuna, Msikaba, Mtentu, and Mbashe estuaries. The southern portion of this region is composed of coastal lowlands and meandering rivers while the north consists of steep valleys and gorges.

Materials and Methods

A single procedure was adopted for investigating the 92 estuaries in the Ciskei and Transkei regions. Water column samples were collected from five approximately equidistant stations, along each estuary. Salinity, temperature, light attenuation, nitrate concentration, phytoplankton and benthic microalgal biomass were measured. Information on the macrophytes was collected in order to determine species richness as well as the species composition of each habitat complex. Plant species nomenclature was according to Arnold and De Wet (1993). This information was used to locate each of the habitat complexes on maps and aerial photographs and ultimately to determine the areas covered by each. The size of each estuary was measured from maps.

Salinity (gl^{-1}) and temperature (°C) were measured using a conductivity and temperature meter (WTW model LT 340–A). Surface and bottom readings were taken. Secchi disk depth was measured at each station and light attenuation was calculated as follows:

$$K\ (m^{-1}) = 1.7/\text{secchi depth}$$

where K is the light attenuation coefficient and depth is measured in metres (Tyler 1968, Weinberg 1976).

Water samples (250ml each) were collected at the surface and bottom of the water column for the analysis of nitrate concentration. These samples were kept in a cool box with ice packs and analysed within 24 hours of collection. The copper cadmium method for the determination of nitrate was used (Bate and Heelas 1975). Total nitrate concentration was determined as a function of reduced nitrite that was read on a Cecil CE 303 spectrophotometer at 450nm.

With the aid of the computer program PCORDWIN (PCORD Version 4, Multivariate Analysis of Ecological Data, 1996, McCune 1986), Canonical Correspondence Analysis (CCA, Ter Braak 1985) was used to ordinate species, estuaries and environmental factors. Ordination is the collective term for multivariate techniques that arrange sites along axes on the basis of species composition (Gauch 1982). Data matrices were compiled using presence/absence data for the estuarine plant species. CCA was used to detect species-environment relationships between estuaries. The result of CCA is an ordination diagram in which x:y co-ordinates represent species or sites and vectors represent environmental variables. The length of the environmental vector is a measure of how much the species distribution differs along the environmental variable. Important environmental variables therefore tend to be represented by longer vectors (Ter Braak 1986). Species-environment correlations were provided as they can be used to interpret the ordination axes. By examining the signs and magnitudes of these coefficients one can infer the importance of each variable for prediction of species composition (Ter Braak 1987). Environmental variables included were average nitrate concentration, light attenuation, salinity, temperature, water column depth and size of estuary. Fifty five of the estuaries had sufficient physical and species information to be used in the CCA multivariate analysis.

Results

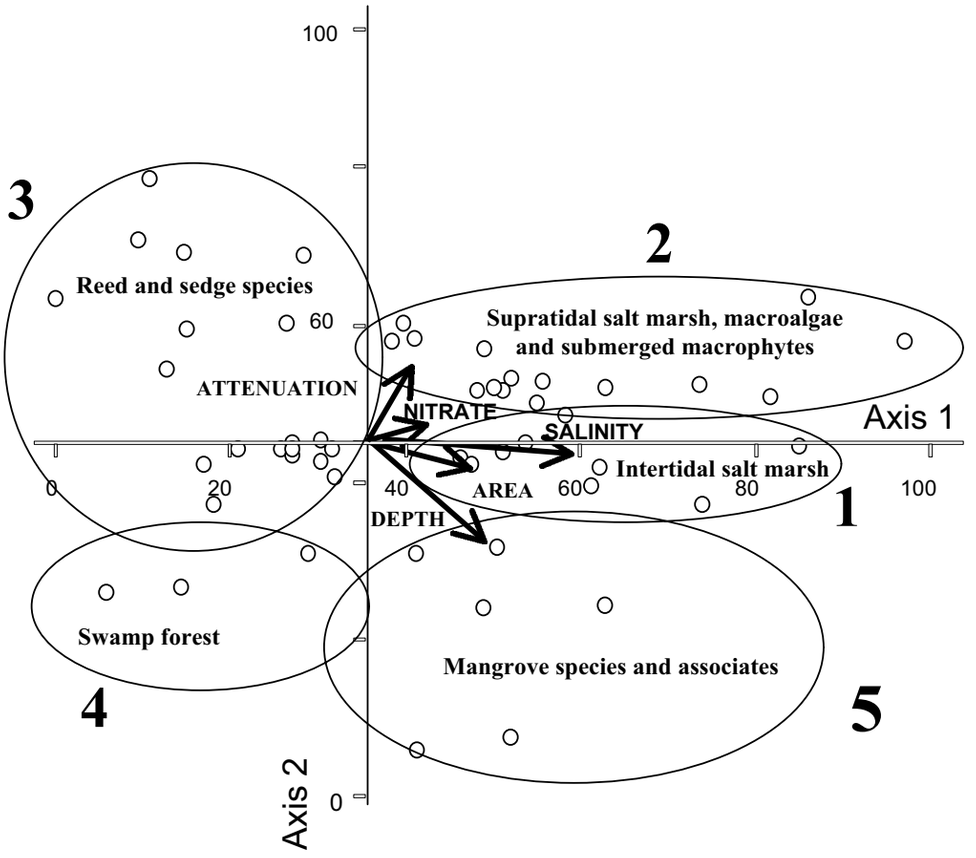
A total of 54 plant species commonly associated with estuaries were found in all of the 92 estuaries studied in the region. The ordination diagram in Figure 1 can be used to define five species groups: 1 (intertidal salt marsh), 2 (supratidal salt marsh, macroalgae and submerged macrophytes), 3 (reed and sedge beds), 4 (swamp forest) and 5 (mangroves and associates e.g. *Acrostichum aureum*, *Zostera capensis*, *Halophila ovalis*). The species-environment correlations indicated that salinity (r = 0.530) and depth (r = 0.431) were important in influencing species distribution. Salt marsh species on the right of the diagram were separated from reed and sedge species on the left of the diagram (Figure 1). Mangroves and other species were associated with greater depth, probably because they occur in permanently open estuaries (Figure 1).

Figure 2 indicates the grouping of estuaries based on species composition (Figure 2). Seven different groups could be identified (A–F and Mngazana). Figures 3 and 4 summarise the seven groups of estuaries found in the study regions together with the estuaries and the associated habitat complexes. Based on the plant species composition the estuaries could be divided into those that were permanently open versus those that were temporarily open/closed. This follows the classification of Whitfield (1992, Table 1 and 2). Harrison *et al*'.s (1999) classification is used to explain some of the patterns of species distribution in the estuaries. The Transkei region is a transition between the warm temperate and subtropical biogeographic zones and both permanently open and temporarily open/closed estuaries showed divisions at the Great Kei and Mngazana estuaries (Figures 3 and 4).

Classification of estuaries in the Ciskei and Transkei regions

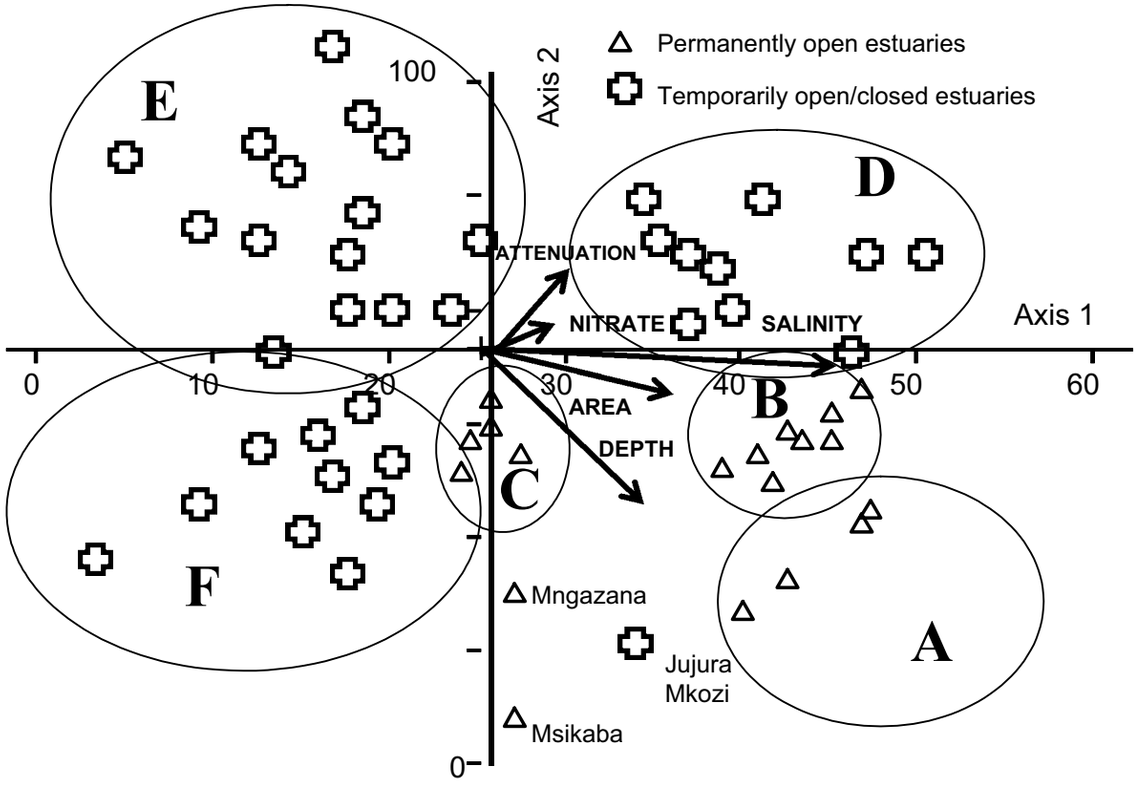
A. Permanently open estuaries with extensive salt marshes (S of Great Kei River Estuary)

The Great Kei River (222ha), Tyolomnqa (107ha),



Group 1	Group 2	Group 3	Group 4	Group 5
Sarcocornia decumbens *Sarcocornia natalensis* *Sarcocornia perennis* *Spartina maritima* *Chenolea diffusa* *Triglochin striata* *Triglochin bulbosa* *Cotula coronopifolia* *Cotula filifolia* *Limonium linifolium* var. *maritinum* *Chondropetalum tectorum*	**Supratidal salt marsh** *Crassula expansa* subsp *expansa* *Cynodon dactylon* *Disphyma crassifolium* *Sarcocornia pillansii* *Samolus porosus* *Stenotaphrum secundatum* *Suaeda caespitosa* **Intertidal salt marsh** *Salicornia meyeriana* **Macroalgae** *Cladophora* sp. *Enteromorpha intestinalis* *Enteromorpha bulbosa* **Submerged macrophytes** *Potamogeton pectinatus* *Ruppia cirrhosa*	*Phragmites australis* *Bulboschoenus maritimus* *Pycreus polystachyos* var. *polystachyos* *Scirpus nodosus* *Schoenoplectus triqueter* *Juncus acutus* *Juncus kraussii* *Eragrostis* sp. *Cyperus textilis* *Juncellus laevigatus* *Schoenoplectus littoralis* *Typha capensis*	*Strelitzia nicolai* *Hibiscus tiliaceus* *Ficus sur*	**Mangrove species** *Avicennia marina* *Bruguiera gymnorrhiza* *Rhizophora mucronata* **Associates: Submerged macrophytes** *Halophila ovalis* *Zostera capensis* **Mangrove fern** *Acrostichum aureum*

Figure 1: CCA ordination of plant species presence/absence in 55 Ciskei and Transkei estuaries that were surveyed. The figure can be used to define species groups 1–5. Environmental variables include light attenuation, nitrate concentration, water column depth, average salinity and size of the estuary



Group A	Group B	Group C	Group D	Group E		Group F
Great Kei	Kobonqaba	Mntafufu	Old Woman's	Gxara	Ngogwane	Gxwaleni
Tyolomnqa	Nxaxo	Mzintlava	ShweleShwele	Qolora	Cebe	Mzimpunzi
Keiskamma	Nqabara	Mtentu	Mpekweni	Gqunqe	Ngqwara	Mbotyi
Great Fish	Mbashe	Mzamba	Kiwane	Sihlontlweni	Shixini	Lupatana
	Xora	Mtamvuna	Mtati	Mncwasa	Mpako	Mkweni
	Mtata		Mgwalana	Nenga	Mapuzi	Mgwegwe
	Mdumbi		Bira	Lwandile	Sinangwana	Sikombe
	Mtakatye		Gqutywa	Mngazi		Mnyameni
			Ngculura			Mtentwana
			Mtana			

Figure 2: CCA ordination of the 55 permanently open and temporarily open/closed estuaries in Ciskei and Transkei regions that were surveyed. The figure can be used to define species groups A, B, C, D, E and F. Environmental variables include, light attenuation, nitrate concentration, water column depth, average salinity and size of the estuary. The eigenvalues for the first and second axes were 0.899 and 0.794 respectively. The correlation coefficient was highest for salinity for axis 1 (0.530) and for depth for axis 2 (0.431)

Keiskamma (344ha) and Great Fish River (365ha) estuaries all had salt marsh areas greater than 25ha in size (Figure 2: Group A). The Keiskamma and Great Fish River estuaries had large areas of intertidal salt marsh that included species such as *Triglochin striata*, *Sarcocornia perennis*, *Sarcocornia natalensis*, *Chenolea diffusa, Cotula filifolia* and *Limonium linifolium* var. *maritinum*. The Tyolomnqa and Great Kei River estuaries had more supratidal species such as *Disphyma crassifolium*, *Sporobolus virginicus*, *Stenotaphrum secundatum* and *Sarcocornia pillansii*. Both the Great Kei and Tyolomnqa estuaries have incised river banks with little intertidal habitat.

B. Permanently open estuaries with mangrove forest and salt marsh (S of Mngazana Estuary)
These estuaries are of moderate size and are permanently open (Figure 2: Group B), namely the Kobonqaba (62ha), Nxaxo (159ha), Nqabara (109ha), Mbashe (132ha), Xora (151ha), Mdumbi (76ha) and Mtata (169ha) estuaries. These estuaries had high average salinity (between 18gl^{-1} and 23gl^{-1}) and high average depth (between 1.84m and 1.94m) resulting in the close correlation with the depth, area and salinity vectors shown in Figures 1 and 2. Species found in these estuaries included the mangroves *Avicennia marina*, *Bruguiera gymnorrhiza* and *Rhizophora mucronata*. Species found in the salt marshes of these estuaries included *Triglochin bulbosa*, *Disphyma crassifolium, Sporobolus virginicus* and *Sarcocornia pillansii*.

C. Permanently open estuaries (N of Mngazana Estuary)
The following moderately sized estuaries (23–70ha) were grouped together in the ordination; Mntafufu, Mzintlava, Mtentu and Mzamba (Figure 2: Group C). These estuaries had an average salinity between 26gl^{-1} and 27gl^{-1} and average depths exceeding 1.6m. Species found in these estuaries included the two mangrove species *Avicennia marina* and *Bruguiera gymnorrhiza*, while *Rhizophora mucronata* was only found in the Mntafufu Estuary. Reed species as well as the swamp forest species, *Hibiscus tiliaceus*, were also found. These estuaries are large deep estuaries and were classified by Harrison *et al*. (1999) to be steep channel-like estuaries with a small floodplain or intertidal area. Figure 1 shows that these estuaries were all closely associated with depth.

D. Large temporarily open/closed estuaries with salt marsh and macroalgae
The large estuaries (15–186ha) found in this group had salt marsh, macroalgae and submerged macrophyte species (Figure 1: Group 2 and Figure 2: Group D). This group includes a high number of temporarily open/closed estuaries found in the Ciskei and southern region of the Transkei coast as far north as the Ncizele Estuary. These estuaries had supratidal salt marsh (*Sarcocornia pillansii*, *Samolus porosus*) and macroalgae (*Enteromorpha* sp., *Cladophora* sp.). This was as a result of the high salinity conditions (average salinity between 13gl^{-1} to 23gl^{-1}) due to overwash from the sea.

E. Small temporarily open/closed estuaries with reed and sedge species only
These estuaries occur between the Gxara and the Gxwaleni south of Port St Johns. These are shown as group E (Figure 2) and are made up of the estuaries classified by Harrison *et al.* (1999) as class 1A, 1B or 2, temporarily open/closed estuaries. These estuaries make up the greatest proportion of the types of system found in the Transkei (ca. 56%) and range between 1.29ha and 41ha in size. These estuaries are characterised by salinity of between 11gl^{-1} and 17gl^{-1} and varying depths not exceeding 1.4m. Reed and sedge species were mostly found (Figure 1, Group 3). These plants prefer brackish conditions (<20gl^{-1}).

F. Small temporarily open/closed estuaries with reed / sedge beds and swamp forest
The swamp forest species *Hibiscus tiliaceus* is found from the Gxwaleni Estuary north towards Port Edward (Figure 2, Group F; Figure 4). *Stelitzia nicolai* often occurred with *Hibiscus tiliaceus*; it is more of a dune forest than swamp forest species. Estuaries that are included in this group are between 1.92ha and 50ha in size and average salinity was between 10gl^{-1} to 18gl^{-1}.

Mngazana estuary

Mngazana is a permanently open estuary of 224ha and differs from all estuaries in the study region. It shares affinities with all the other estuaries and has all the habitat complexes present excluding macroalgal assemblages. In terms of plant species composition it acts as the dividing point between the southern and northern estuaries.

The Mngazana Estuary has a unique geology and tidal flat formation that resulted in its own geomorphologic class (Class 3B — permanently open estuary, Harrison *et al.* 1999). It also receives regular tidal exchange so that it exhibits a range of salinity from 0gl^{-1} at the head of the estuary to 37gl^{-1} at the mouth. Species found in the Mngazana Estuary included the salt marsh plants *Triglochin striata*, *Sarcocornia perennis*, *Sarcocornia natalensis*, *Chenolea diffusa, Cotula filifolia*, *Salicornia meyeriana* and *Limonium linifolium* var. *maritimum.* Mngazana Estuary has the third largest mangrove forest in South Africa covering an area of 145ha. All three mangrove species (*Avicennia marina* and *Bruguiera gymnorrhiza*, and *Rhizophora mucronata)* are present.

Outliers

The Msikaba Estuary was classified by Harrison *et al.* (1999) as Class 3C, permanently open estuaries, with small mouth barriers and small intertidal areas. This lack of habitat has resulted in colonisation by a limited number of species such as reeds and sedges. With similar physical conditions to the northern permanently open mangrove/swamp forest systems (Group C) the Msikaba could have possibly been colonised by mangrove forest. This was shown by the close ordination of this system to the physical factors associated with tidal exchange and other mangrove systems (Figure 1). There are no published accounts of mangroves present in this estuary, however, they were observed by TH Wooldridge (pers. comm.) during his surveys of this system in the early 1970's.

The Mkozi Estuary was the only estuary with the mangrove associate, the mangrove fern *Acrostichum aureum*. This was found on the upper banks of this temporarily open/closed estuary. The Jujura Estuary was also shown as an outlier as it was a temporarily open/closed estuary with the submerged macrophyte *Zostera capensis*. This species is usually found in the intertidal zone of permanently open estuaries.

The Mzimvubu Estuary was classified by Harrison *et al.* (1999) as a river-dominated estuary (Class 4). The Mzimvubu Estuary contained reed and sedge species as well as *H. tiliaceus*. Steinke (1982) reported mangrove

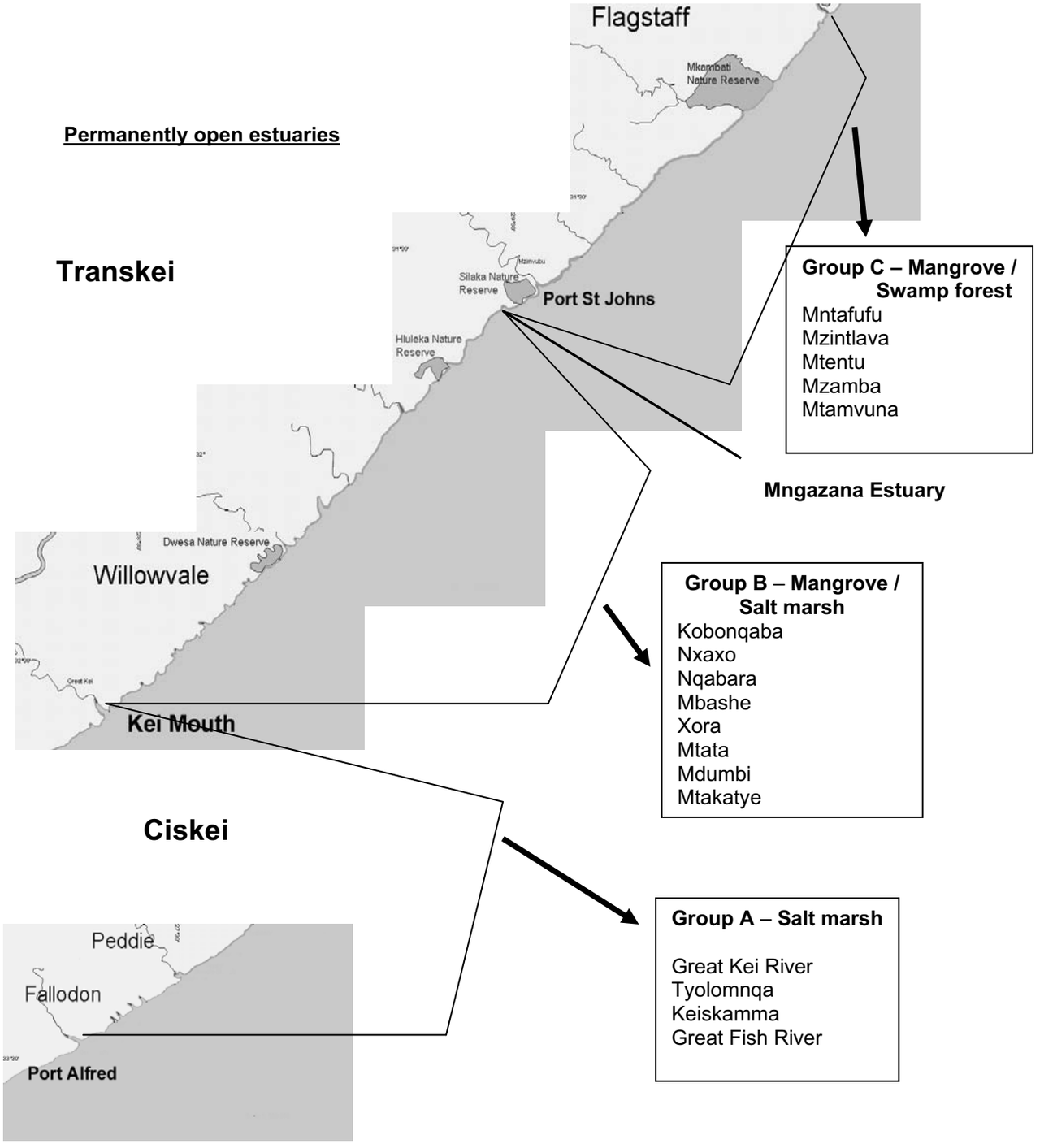


Figure 3: A summary of the three groups of permanently open estuaries and associated habitat complexes found in this study. There is a transition at the Mngazana Estuary between the estuaries dominated by salt marsh and those containing swamp forest species

species in this system. These have subsequently disappeared. If the mangrove species were still present the estuary may have been classified in the group of northern permanently open estuaries that had mangrove and swamp forest (Group C).

Discussion

The estuaries in the study region could be divided into those that were permanently open versus those that were temporarily open/closed based on the distribution of plant

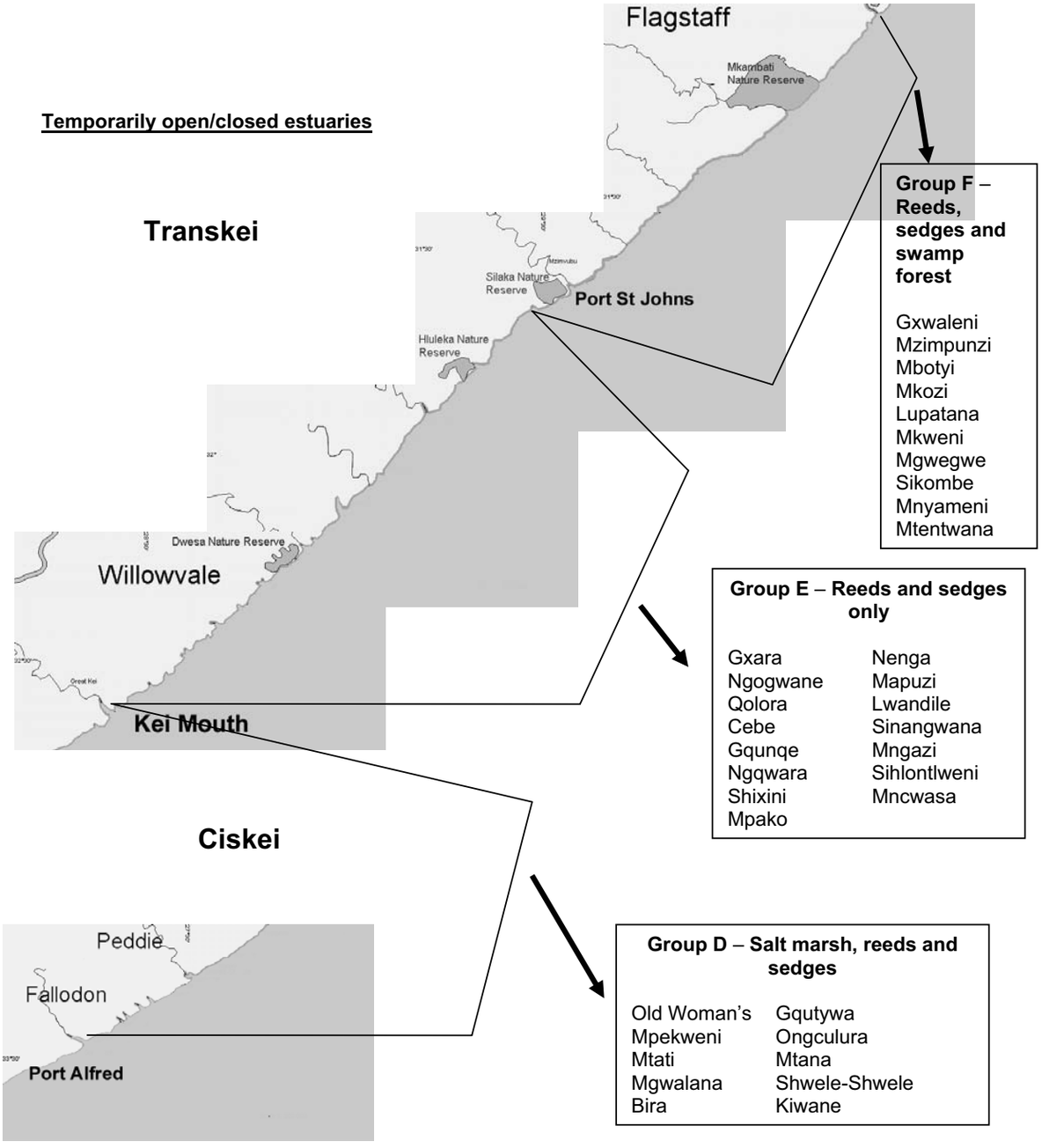


Figure 4: A summary of the three groups of temporarily open/closed estuaries and associated habitat complexes found in this study. A transition is shown between estuaries that have salt marsh and those that contain swamp forest

species. This classification followed that of Whitfield's (1992, Tables 1 and 2). Harrison *et al.*'s geomorphologic classes (1997, 1999) were used to describe the distribution of some of the habitat complexes within estuaries as well as the distribution of outlier estuaries (Msikaba, Jujura and the Mkozi) in the ordination diagram. Harrison *et al.* (1999) classified the temporarily open/closed estuaries into three geomorphologic classes (1A, 1B and 2; Table 2). However, this could not describe the differences in plant species distribution. An analysis of the distribution of plants in Cape estuaries also showed a close relationship with the Whitfield (1992) classification system (Coetzee *et al.* 1997).

The Transkei region is the transition zone between the warm temperate and subtropical regions and both permanently open and temporarily open/closed estuaries showed divisions at the Great Kei and Mngazana estuaries.

Whitfield (1992) has described three biogeographic subdivisions of South African estuaries. These subdivisions range from subtropical on the southeast coast, warm temperate on the south coast to cool temperate on the west coast and has been linked to ichthyofaunal diversity. They originate basically because of the different oceanic regions off the South African east and west coasts, i.e. the warm Agulhas current in the east and the cold Benguela system in the west (Schumann *et al*. 1999). In permanently open estuaries mangrove forest occurred north of the Great Kei Estuary and swamp forest occurred north of the Mngazana Estuary. In temporarily open/closed estuaries salt marsh occurred south of the Great Kei Estuary and swamp forest occurred north of the Mngazana estuaries. Reed and sedge species were common throughout. Temporarily open/ closed estuaries in the Ciskei region were characterised by salt marsh and macroalgae. Salt marsh occurred because of high water column salinity and wide intertidal and supratidal zones. These estuaries were characterised by seawater washing into the estuary over the berm at the mouth.

Ordination showed that factors such as salinity and depth were important in influencing the distribution of plants in the Ciskei and Transkei estuaries. Species distribution could be associated with the increase in mean annual rainfall of approximately 100mm every 120km moving north from the Ciskei region to Port Edward (South African Weather Bureau rainfall data). This was reflected in the increase in species that are associated with freshwater or brackish conditions, i.e. reed, sedge, and swamp forest species as one moves further north. Temperature may also be important in influencing the distribution of mangrove and swamp forest. MacNae (1968) suggested that temperature was the most important limiting factor of the southward distribution of mangrove species along the South African coast. He proposed, based on the then known distribution of mangroves, that mangroves only occur where the mean annual air temperature does not drop below 19°C. However transplants of *Avicennia marina* and *Bruguiera gymnnorrhiza* to the Nahoon estuary have survived, flowered and fruited and thus the distribution of mangroves in the south-eastern areas of South Africa may be limited more by restricted dispersal ranges (Steinke 1982, 1995).

The transition from more xeric salt marsh habitat complexes to habitat complexes that are characteristic of brackish estuaries, such as swamp forest and the reed and sedge beds, was also noted by Harrison *et al.* (1999). In the case of the ichthyofauna, the actual mid point of this transition was not apparent. Previous researchers have assumed that due to a warm Indian Ocean gyre that affects the region between the Mzimvubu and the Mbashe estuaries, the boundary between the temperate and subtropical biogeographic zones would be at the Mbashe River. Maree and Whitfield (1998) using records of fish species in different localities, estimated that this boundary, rather than being a fixed point, was a transitional area between the Great Kei and Mbashe estuaries. In this study the boundaries of transition were between the Great Kei and Mngazana estuaries for all the habitat complexes and estuaries. The only exceptions were the outlier estuaries that have been identified by this study. These data indicate that the biota of estuaries are distributed according to local physical conditions, whereas the outliers imply that estuarine geomorphology also plays a role.

The Msikaba Estuary was an outlier on the ordination diagram and was associated with permanently open estuaries that have mangroves. There are no published accounts of mangroves in this estuary, however, they were observed by TH Wooldridge (pers. comm.) in the early 1970's. Harrison *et al.* (1999) also regarded this estuary as well as the Mtentu Estuary as unique and classified these two estuaries in a separate Class (3C). The Mngazana Estuary was also classified separately due to its unique geomorphology and floodplain features. These floodplains have created conditions for the establishment of the largest mangrove forest in the study region. The Jujura and the Mkozi are two temporarily open/closed estuaries that due to their unique geomorphology have been colonised by plants typical of permanently open estuaries (mangrove associates and submerged macrophytes). Interestingly the Jujura was placed in a separate geomorphologic class by Harrison *et al.* (1999). A narrow valley that has a low storage capacity forms the catchment of this estuary. Thus any runoff flows directly through the estuary and keeps the mouth open for long periods with daily tidal exchange. This has resulted in the colonisation of the mud banks by *Z. capensis* that is adapted to these intertidal conditions (Adams *et al.* 1999). The mangrove fern in the Mkozi Estuary is intolerant of frequent inundation and this system is mostly closed due to its small catchment. This estuary was an outlier as this was the only estuary with this species.

Similar relationships between geomorphology and plant distribution were found along the western and eastern coasts of Australia. Certain habitat complexes were associated with certain types of estuaries, e.g. mangrove forest with the permanently open estuaries. However, the exact distribution of species coincided more with local physical conditions (Thom *et al.* 1975). These authors found that local variations in environment within an estuary increased the diversity of habitats and species richness. This was also apparent for the Ciskei and Transkei estuaries that were characterised by high species richness compared to other South African estuaries (Colloty 2000). The variation in physical environment, changes in climate and transition between biogeographic regions has resulted in regions of increased biodiversity. Mangrove, salt marsh and swamp forest species are found in the same region.

In future the role of the physical environment on the distribution of plants can aid the understanding of the overall trends in the distribution of estuarine plants along the South African coast. It could be expected that the southern KwaZulu-Natal region up to the Tugela region should have similar affinities to that of the northern Transkei region. Cooper *et al.* (1999) point out that there are similarities in geomorphology for these two regions. The northern KwaZulu-Natal coast should then be a transition zone between the tropical and subtropical regions. Steinke (1995) has shown that the most northern estuaries, namely the St Lucia Estuary and Kosi Bay, have affinities with the tropical coast of Africa.

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