THE BOTANICAL IMPORTANCE RATING OF THE ESTUARIES IN FORMER CISKEI / TRANSKEI

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FINAL REPORT TO THE

WATER RESEARCH COMMISSION

BY THE

DEPARTMENT OF BOTANY

UNIVERSITY OF PORT ELIZABETH

WRC REPORT NO. TT 160/01

Obtainable from:

Water Research Commission
PO Box 824
Pretoria
0001

The publication of this report emanates from a project entitled: *The Botanical Importance rating of Estuaries in former Ciskei and Transkei* (WRC Project No K5/812)

ISBN 1 86845 790 7

Printed in the Republic of South Africa

The Jujura Estuary, one of several unique estuaries observed in this study. This small estuary had an above average depth of 2.8 m, remained open for extensive periods and was colonized by *Zostera capensis*.

EXECUTIVE SUMMARY

BACKGROUND AND MOTIVATION FOR THE RESEARCH

There are an increasing number of people utilising the South African coastline. This is creating a need to evaluate estuary and coastal resources and to identify sensitive areas where careful planning and management must take place. Management tools such as importance rating systems and state or condition assessments have become necessary to summarise and express scientific information. The botanical importance rating system is one such method and was developed in a previous Water Research Commission Project (Adams et al*.* 1996). That project rated the botanical importance of 33 Cape estuaries according to the area covered by estuarine plants, their condition, the number of plant community types and the association between the plants and the estuary. The report suggested that the remainder of the coastline be included in the survey. This project funded by the Water Research Commission for three years, developed the botanical importance rating further and was applied to the former Ciskei and Transkei regions of the Eastern Cape Province.

TERMINOLOGY

Botanical importance refers to the contribution of the plants to the conservation status of an estuary. In this study botanical importance is the sum of functional importance, species richness, community richness and community type rarity. Functional importance is the area covered by the different plant community types multiplied by an average productivity value for the different community types.

The term plant community type is used instead of plant communities because botanical groups such as intertidal salt marsh fail to adhere to the definition of a true community, i.e. a clearly defined assemblage of plants and/or animals distinguishable from other such assemblages.

STUDY APPROACH

Botanical surveys were conducted in 92 estuaries found in the former Transkei and Ciskei region. Data available for each estuary includes:

- Once-off measurement of salinity, temperature, depth, secchi depth, water column chlorophyll-a and nitrate concentrations.
- Number of different plant community types and species composition.
- Area covered by the different plant community types.

These data were then used to determine:

1) *Botanical importance* of an estuary that includes species and community richness, plant community type rarity and functional importance. The botanical importance scores were calculated for all Ciskei / Transkei estuaries and for 87 other South African estuaries. The distribution of plants in the Ciskei / Transkei estuaries in relation to physical factors was described.

2) The *habitat integrity* or health of an estuary can be determined using the functional importance scores. The change in area covered by the different plant community types is measured from past and present aerial photographs. The functional importance is then calculated using the earliest and most recent area values and the habitat integrity score is calculated as the deviation from natural, i.e. 100 less the difference in past and present functional importance scores. The application of habitat integrity was tested on 16 Northern Pondoland estuaries and the Swartkops Estuary. Overall habitat integrity scores were calculated for 129 South African estuaries.

PROJECT OBJECTIVES (as specified in the original contract)

The extent to which the project objectives were met is outlined below. Recommendations or actions as a result of the project findings are provided in boxes.

1. To extend the botanical importance rating system of Cape estuaries to include estuaries of the former Ciskei and Transkei region.

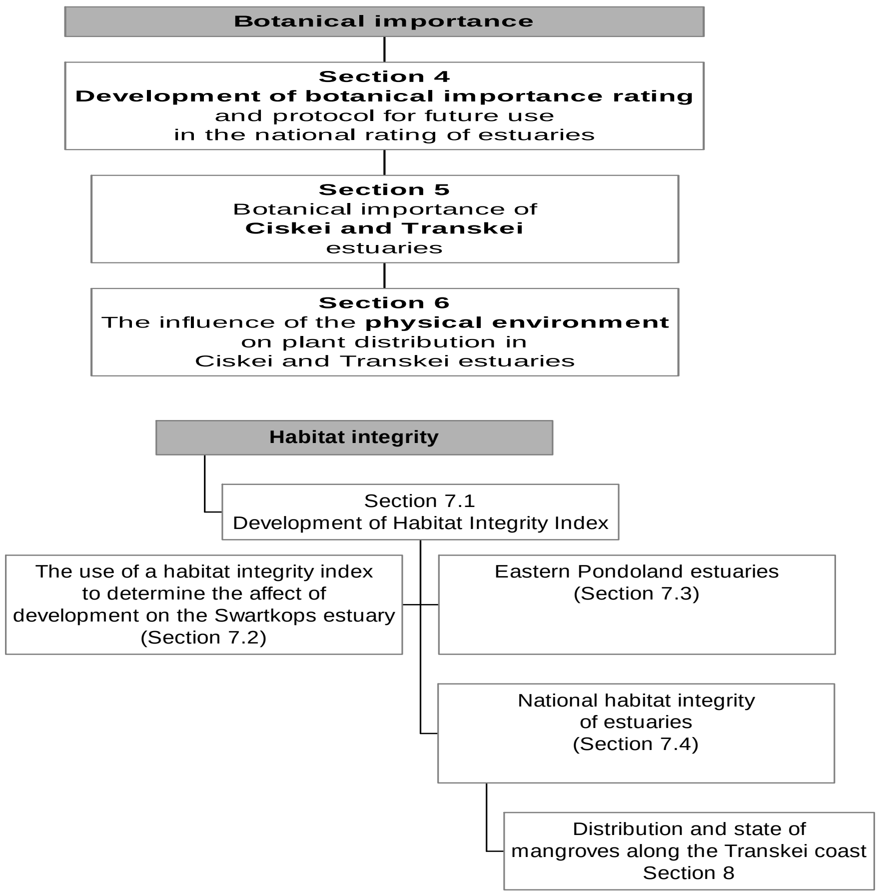
Ninety-two estuaries in the Ciskei / Transkei regions were surveyed and the botanical importance calculated. The revised importance rating was also applied to the 33 estuaries studied by Ms Coetzee (Adams et al*.* 1996). In addition to this, Ms T Riddin (M.Sc., UPE) completed surveys of 6 northern KwaZulu-Natal estuaries including Lake St Lucia. The survey of Lake St Lucia was done in collaboration with Mr. R Taylor (KwaZulu-Natal Nature Conservation Services). Ms S Pillay (CSIR, Durban) has provided information on the estuaries in the Durban Metropolitan area. Mr. D Walker (Ph.D. student, UPE) surveyed estuaries in the East London area and the revised importance rating was also applied to those estuaries. All the information was collated in a database constructed in Microsoft Access. This database is a final product from this project and includes information on all South African estuaries with sufficient information to rate 179 estuaries. This objective of the project was successfully met and also extended by including estuaries outside of the study area.

> *Recommendation:*
>
> That the botanical importance database is made available on the WRC and CERM (Consortium for Estuarine Research and Management) websites.

2. To incorporate a fifth plant community type, i.e. mangroves into the botanical importance rating system.

This objective was met and extended because mangroves, microalgae and swamp forest were included in the revised importance rating system. Nine estuarine plant community types are now included; phytoplankton, intertidal benthic microalgae, macroalgae, submerged macrophytes, intertidal salt marsh, supratidal salt marsh, reeds and sedges, mangroves and swamp forest. Other refinements to the original importance rating formula (Coetzee et al. 1996, 1997) are the inclusion of functional importance, species richness, plant community type richness and plant community type rarity.

The revised formula can now be applied to any South African estuary and, in this study, was used to rate the estuaries within both the study region and other estuaries that had information available. The revised botanical importance rating has also been used in the Resource Directed Measures for estuaries to determine estuary importance and health. These methods have been developed to allow implementation of the National Water Act (Act 36 of 1998).



Flow chart depicting the components of the botanical importance rating and habitat integrity index developed in this study.

3. To provide baseline data on plant structure and distribution in relation to freshwater input in a region where little data existed previously.

Data from the field surveys have been summarised in the botanical importance database. This includes water quality at the time of sampling, past and present area covered by the different plant community types, comments on the impacts and activities in the vicinity of the estuary and photographs of the estuaries. Ordination was used to relate the distribution of the plants to physical variables. There was a transition from more saline to freshwater plant community types moving from south to north in the study region. This was a result of the transition in biogeographic regions coupled to an increase in mean annual rainfall together with the morphology of the estuaries.

4. To translate scientific information on the freshwater requirements of mangroves into management tools to be used in decision support systems.

Salinity and inundation tolerance ranges for the different South African mangrove species was obtained from the literature. For example, it is known that mangroves can survive permanently inundated for only 4 - 5 months before die-back. This type of information is used in estuarine freshwater requirement studies because it indicates the permissible period of mouth closure. This information is summarised in the literature review section of the report.

The study identified that the current threat to mangroves in the study area was uncontrolled harvesting rather than reduced freshwater input. Section 7 focuses on this aspect and compares the past and present distribution of mangroves.

SUMMARY OF FINDINGS

The botanical importance of South African estuaries

Sixty five percent of the estuaries found in South Africa (179 estuaries) had information that could be used to determine their botanical importance. The St Lucia, Mngazana, Nxaxo and Mbashe Estuaries were important because they had high functional importance scores, community richness and community rarity. Sixteen percent of the Transkei estuaries and 44% of Ciskei estuaries were included in the 20 estuaries with the highest scores. The combination of the components in the botanical importance rating allowed the small estuaries with low functional importance scores, but with rich or rare plant community types to have high importance scores, e.g. the Kabeljous, Seekoei and Uilkraals Estuaries. These three estuaries contained extensive submerged macrophyte and macroalgal areas. Submerged macrophytes have a high rarity weighting, as they only occur in 39 South African estuaries.

Recommendation:

Note must be taken of the importance of the Nxaxo Estuary. The state of the estuary is currently under threat from proposed dune mining at Wavecrest.

The influence of the physical environment on the distribution of estuarine plants in the former Ciskei and Transkei region.

For the first time a comprehensive botanical survey has taken place in the Ciskei and Transkei estuaries. In total 54 plant species were found in the 92 estuaries surveyed. These plants could be divided into the following five plant community types; reeds and sedges (23 species), salt marsh (20 species), mangroves (4 species), macroalgae (3 species) and swamp forest (4 species).

Ordination techniques were used to describe the relationships between species distribution and physical variables (average nitrate concentration, light attenuation, salinity, temperature, water column depth and size of estuary). Estuaries could be divided into 7 broad classes based on the spatial separation of plant species using multivariate analysis. These were;

- permanently open estuaries with extensive salt marshes occurring south of the Great Kei River Estuary,
- permanently open estuaries with mangroves and salt marsh south of the Mngazana Estuary,
- the Mngazana Estuary which is separated from the other permanently open estuaries because it has mangroves, salt marsh and swamp forest,
- permanently open estuaries with mangroves and swamp forest north of the Mngazana Estuary,
- large temporarily open/closed estuaries with salt marsh and macroalgae occurring south of the Great Kei River Estuary,
- small temporarily open/closed estuaries with only reeds and sedges occurring north of the Great Kei River Estuary and
- small temporarily open/closed estuaries with reeds, sedges and swamp forest occurring north of the Mngazana Estuary.

The Mngazana Estuary was classified on its own due to its unique geomorphology and floodplain features. It has the third largest mangrove area in the country and contained 8 out of the 9 possible plant community types. There was a transition from more saline to freshwater plant community types moving from south to north in the study region. This was a result of the transition in biogeographic regions (warm temperate to subtropical) coupled to an increase in mean annual rainfall together with the morphology of the estuaries. The transition, in turn, caused an increase in species richness and habitat diversity and this was reflected in the high botanical importance scores for estuaries in this region.

> *Recommendation:*
>
> That the national importance of Mngazana Estuary is recognised and the estuary receives protection.

Habitat integrity of South African estuaries

The habitat integrity or health of an estuary can be determined using the change in the botanical functional importance score over time. Habitat integrity was determined for the Swartkops Estuary over a period of 60 years, as well as for 16 Pondoland (northern Transkei) estuaries. Habitat integrity scores were calculated for all South African estuaries (129) that had available information and compared on a national basis.

Swartkops Estuary

Human impacts have reduced the habitat integrity of the Swartkops Estuary by 50%. Industrial and residential developments including roads and bridges have encroached into areas that were previously salt marsh. Supratidal salt marsh was estimated to cover an area of approximately 40 ha before any development occurred. However, only 5 ha remains (a reduction of 88%). The intertidal salt marsh was reduced in cover from 215 ha to 165 ha (a reduction of 23%). Supratidal salt marsh has been most affected probably because it is only periodically inundated and, with suitable engineering, is more prone to development. This is a common scenario in a number of South African estuaries.

> *Recommendation*:
>
> Habitat integrity can effectively be used as a long-term monitoring tool. All that is required are vertical aerial photographs of an estuary (preferred scale 1: 5 000).

Pondoland estuaries

A regional assessment of the Pondoland estuaries showed that although the area covered by the estuarine plant community types was small, these estuaries are nationally important as they have been the least impacted over time i.e. they have high habitat integrity scores. These estuaries also have unique species such as the mangrove fern and fringe mangrove stands i.e. the mangroves occur as a double or single row of trees.

Recommendation:

Pondoland estuaries must receive a high protection status, the proposal by Marine and Coastal Management for a marine protected area from Mntafufu Estuary north of Port St Johns to Mpenjati Estuary in southern KwaZulu-Natal must be supported.

Ciskei / Transkei estuaries

The national habitat integrity assessment showed that the Ciskei and Transkei estuaries have changed little over time. This is evident from aerial photographs taken in 1961. Of the 129 estuaries included in the national habitat integrity assessment ,44 estuaries showed no change in area cover over time and, thus, had habitat integrity scores of 100. Of these, 40 estuaries were found in Transkei and 4 estuaries in Ciskei.

In the Transkei estuaries, plant cover has been removed as a result of agriculture and mangrove harvesting. In the Ciskei estuaries, plant cover has been removed as a result of road construction (e.g. Great Fish, Mgwalana, Mtati and Gqutywa Estuaries), residential developments (Bira and Mpekweni estuaries) and agriculture (Keiskamma Estuary). The greatest threats to the conservation status of the Ciskei and Transkei estuaries include agriculture in the floodplains and unsustainable harvesting of mangroves.

Future recreational and industrial development also poses a threat as the need for water abstraction will increase. Because of the past political history of this region we are presented with a collection of pristine or near pristine estuaries. With environmental legislation such as Resource-Directed Measures in the National Water Act and the National Environmental Management Act 1998, future urban, industrial or agricultural development can hopefully be dealt with in a manner that will protect the estuarine environment.

Distribution and state of mangroves along the Transkei coast

Mangroves previously occurred in 17 estuaries (Ward and Steinke 1982), but were found in only 14 of the 76 estuaries visited. Complete loss of trees (7.5 ha) was evident in the Mnyameni, Mzimvubu and Bulungula Estuaries. Mangroves in the Mzimvubu Estuary were lost due to flooding and bank scour, while mangroves in the Bulungula Estuary were lost due to drought. The drought resulted in the mouth of the estuary closing and inundated of the mangroves for five months (Knight pers. comm.). Consequently the trees died and have since been harvested leaving only dead stumps. Mangroves in the Mnyameni Estuary have been completely removed for wood leaving only dead tree stumps. Ward and Steinke (1982) recorded both *B. gymnorrhiza* and *A. marina* in this estuary.

No new occurrences of mangroves were recorded in the estuaries surveyed, although tree cover has increased by a total of 17.6 ha in eight of the estuaries. Overall there has been little change in species composition of the different estuaries and the species recorded included *Avicennia marina*, *Bruguiera gymnorrhiza* and *Rhizophora mucronata.* The mangrove fern *Acrostichum aureum* was recorded for the first time in this area in the Mkozi Estuary.

Estuaries in which mangrove survival is threatened include Mdumbi, Mzamba, Kobonqaba and Mtamvuna. Only *Bruguiera gymnorrhiza* occurred in the Mtamvuna and Mzamba Estuaries. These estuaries receive no conservation protection and harvesting has resulted in more than 50% of the trees being removed. The density of dead tree stumps was greater than the number of living trees and no seedlings or juvenile trees were found. In protected estuaries such as the Mtentu and Xora, the density of juvenile trees was higher. Only 18% of the mangroves occur in protected areas such as nature reserves. Further removal of mangroves within the estuaries south of the Mzimvubu River is expected in the fringe mangroves, as most are unprotected and easily accessible.

> *Recommendation*:
>
> The problem of unsustainable harvesting of mangroves needs to be addressed at both a research and management level.

TECHNOLOGY TRANSFER

Since the project commenced the botanical importance rating system has been used in a number of ***freshwater requirement studies*** to determine the present status and botanical importance of estuaries. These are contract studies funded by the Department of Waters Affair and Forestry and included the following estuaries: Swartkops, Palmiet, Nhlabane and Mhlathuze studies.

Recently, the botanical importance rating system has been used in ***estuary reserve studies*** (Nahoon, Northern Pondoland estuaries, Mtata and ten adjacent estuaries) to determine the ecological integrity, regional and national importance and sensitivity of estuaries to flow reduction. The study on the desktop reserve estimate for the sixteen Pondoland estuaries was possible because of the baseline information provided by the botanical importance-rating project. Too little data regarding other aspects were available.

Links have been established with ***CSIR (Durban)*** **and** ***KwaZulu-Natal Wildlife*** to apply the botanical importance rating system to estuaries in that province. A proposal was also submitted to Marine and Coastal Management to apply the botanical importance rating system to the small northern KwaZulu-Natal estuaries.

Information on estuarine plant distribution and biodiversity was provided to the ***CAPE (Cape Action Plan for the Environment)*** project for estuaries in the Cape region.

SA-ISIS (South African Integrated Information System) is a project funded by the National Innovation Fund of DACST (Department of Arts, Culture, Science and Technology). The objective of that project is to develop GIS and decision support-systems to aid government decision-making. The botanical importance rating project has provided input on ***State of the Environment indicators for estuaries***. State of the Coast and State of the Environment Reports will become a legal obligation in the future.

Input was provided on the distribution of estuarine plants to Ms R van der Walt of DEAT ***(South African Wetlands Conservation Programme)*** for the South African National Wetland Inventory

Social and Ecological Services (DWAF) funded a project on the prioritisation of South African estuaries, led by Dr J Turpie (UCT). This project rated estuaries based on their ecological importance. The information for the plants was obtained from the botanical importance-rating project.

> *Recommendation:*
>
> That the results from the Prioritisation project be supported by all Government Departments.

FURTHER RESEARCH

The dynamic nature of estuaries and the influence of this on conservation importance needs further understanding. This applies not only to botany but to other fields as well.

The KwaZulu-Natal estuaries require more attention, as these estuaries were not adequately represented in the analyses. This would aid the testing of the hypothesis that the northern KwaZulu-Natal region should have a high number of important estuaries, as it is the transition zone between the subtropical and tropical regions.

The Cape estuaries should be surveyed again, as there are a number of discrepancies with regard to species identification in the past literature. This would clarify the classification of the plant community types in this region.

Sustainable utilisation of mangroves needs investigation. Management plans need to be initiated for those estuaries where mangrove survival is threatened.

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ACKNOWLEDGEMENTS

We would like to express our sincere thanks to the following organisations and people:

The Water Research Commission for funding this research;

Dr Steve Mitchell, WRC Research Manager, for his support and input;

Members of the Steering Committee (Prof. Charles Breen, Mr. Mike Burns, Prof. Digby Cyrus, Mr. Duncan Hay, Prof. T. Jacobs, Prof. Roy Lubke, Prof. Sageran Naidoo, Ms. Barbara Weston, Prof. Tris Wooldridge, Dr. Alan Whitfield and Dr. Dirk van Driel) for their valuable input and support;

The field assistants who survived: Gavin Snow, Tim van Hattum, Ayanda Matoti and Alida Badenhorst. To the Botany Department for allowing the use of their facilities and to Andrew Gouws and Mike Brassil for keeping the equipment in order;

Mrs. Joy Kritzinger for excellent secretarial support;

The Institute for Coastal Resources and Management, Departments of Geology and Geography, University of Port Elizabeth, for the use of their aerial photographs and maps;

All those whom we met in the Transkei, especially those that provided a warm shelter or meal. These folks deserve their own story as it made for a remarkable journey.

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LIST OF ABBREVIATIONS

BHI	-	Biological Health Index
BI	-	Botanical Importance
BIR	-	Botanical Importance Rating
CCA	-	Canonical Correspondence Analysis
CDI	-	Community Degradation Index
CERM	-	Consortium for Estuarine Research and Management
CSIR	-	Council for Scientific and Industrial Research
DBH	-	Diameter at Breast Height
EHI	-	Estuarine Health Index included in the RDM of the National Water Act
FHI	-	Fish Health Index (East Coast Programme – CSIR, KwaZulu-Natal)
FIS	-	Functional Importance Score
MSHWM	-	Mean Spring High Water Mark
RDM	-	Resource Directed Measures of the Department of Water Affairs in terms of the National Water Act No 36 of 1998

GLOSSARY OF TERMS

Benthic	Bottom-living
Biomass	A quantitative estimation of the total weight of living material found in a particular area or volume.
Biome	Major ecological regions identified by the type of vegetation in a landscape.
Botanical importance	The contribution of the estuarine plants to the total conservation status of an estuary based on energy input.
Community	A clearly defined assemblage of plants and/or animals distinguishable from other such assemblages.
Detritus	Organic debris from decomposing plants and animals.
Diatoms	A class of algae with distinct pigments and siliceous cell walls. They are an important component of the phytoplankton.
Dynamic	Relating to ongoing and natural change.
Ecology	The study of the structure and functions of ecosystems, particularly the dynamic co-evolution of relationships of organisms, communities and habitats.
Ecosystem	An interacting and interdependent natural system of organisms, biotic communities and their habitats.
Epiphyte	A plant living on the surface of any substrate without necessarily deriving water or nourishment from it.
Estuarine bay	Estuarine bays have permanently open deep mouths (> 3 m). They have a large tidal prism allowing for regular replacement of the estuarine water. These systems might either be natural (Knysna lagoon) or artificial such as the dredging activities in the mouth and harbour of Durban Bay.
Estuarine classification	A classification system used to classify the different types of estuaries, viz. permanently open estuaries, temporarily open/closed estuaries, estuarine lakes, estuarine bays and river mouths (Whitfield 1992). Cooper et al. (1999) have defined a geomorphologic classification for estuaries based on morphology, barrier type and physical conditions.
Estuarine condition	The condition of each estuary, based on the degree to which human activities have changed the function or viability of a particular system.
Estuarine health	The state, condition or performance of an estuary as defined in terms of some desired endpoint (Fairweather 1999). The botanical health of an estuary can be determined by comparing the present day botanical importance score with the score of the "pristine" or past condition.
Estuarine lake	The lower reaches of these systems are typically a narrow estuarine channel that arises from expansive lake areas forming the upper reaches. An

	example of such a system is the Swartvlei on the southern cape coast.
Estuary	A partially enclosed coastal body of water that is either permanently or temporarily open to the sea and within which there is a measurable variation of salinity due to the mixture of sea water with river water derived from land drainage.
Eutrophication	The process by which a body of water is greatly enriched by the natural or artificial addition of nutrients. Botanically this may result in both beneficial (increased productivity) and adverse affects (smothering by dominant plant types.
Flocculation	The settlement or coagulation of river-borne particles when they come into contact with seawater.
Fluvial	Originating from rivers.
Geomorphology	The study of land form or topography.
Habitat	Area of natural environment in which the requirements of a specific animal or plant are met.
Halophytes	Plants which can tolerate saline conditions.
Intertidal	An area between the highest and lowest tidal levels.
Macrophyte	Any large multicellular plant as opposed to small ones. Aquatic macrophytes may float at the surface or be submerged and/or rooted on the bottom.
Mangrove forest (mangal)	Associated with saline or brackish water, develops on tropical and subtropical coasts and tidal flats of protected bays and estuaries. Dominant South African species include; *Avicennia marina, Bruguiera gymnorrhiza, Rhizophora mucronata*.
Periphyton	Plants adhering to parts of rooted aquatic plants.
Permanently open estuary	Open to the sea and experience daily tidal fluctuations. There is normally a horizontal salinity gradient between the head and mouth of the estuary. The catchments of these estuaries may be large and the rivers are perennial in their natural condition and ensure the mouths remain open.
Phytoplankton	Usually single cell plants comprised of species belonging to groups such as green, blue green algae, dinoflagellates, diatoms and flagellate microalgae.
Plankton	Microscopic animals or plants which float or drift passively in the water.
Plant community type	A term used to describe estuarine botanical groups such as intertidal salt marsh, which fail to adhere to the definition of a true community.
Primary productivity	The hourly, daily or annual production of biomass, i.e. the conversion of inorganic carbon and water through photosynthesis into carbohydrates and plant structural components.
Reeds	Plants belonging to the family Poaceae that are rooted within or near a water source. One typical species is the common reed *Phragmites australis*.

Riparian	Adjacent to or on the banks of rivers, streams or lakes.
River mouth	These systems have large catchments with high mean annual runoff that dominate the system. Tidal prisms are restricted, e.g. Great Fish and Mzimvubu Rivers.
Salinity	A measure of the total quantity of dissolved ions in water, measured in $g.\ell^{-1}$. In estuaries the ions are mainly NaCl.
Salt marsh	Areas in estuaries showing regular zonation reflecting the length of time different areas are inundated by tides. Plants that have adapted to survive within these areas are termed halophytes due to their ability to survive the high salt loads which induce osmotic stresses.
Sedges	Plants of a brackish wet habitat that are found as components of estuarine, riverine, lacustrine, bog (vlei) and temporary moist areas. Species include; *Schoenoplectus littoralis, Scirpus nodosus.*
Standing biomass/stock	The total mass of all living organisms (producers, consumers and decomposers) or a particular set of these (e.g. species) present in an ecosystem, usually expressed as dry weight per unit area.
Submerged macrophytes	Submerged macrophytes are plants rooted in both soft subtidal and low intertidal substrata, whose leaves and stems are completely submerged for most states of the tide. Species include *Zostera capensis, Halophila ovalis*, *Ruppia spp*.
Supratidal	That portion of a tidal flat that lies above the level of mean high spring water and is inundated only occasionally by exceptional tides or tides augmented by storm surges .
Swamp forest	Swamp forest species are associated with brackish estuaries. Characteristic species are *Hibiscus tiliaceus* and *Barringtonia racemosa*.
Temporarily open/closed estuary	Such estuaries are blocked from the sea for varying lengths of time by a sand bar which forms at the mouth. The closure of the mouth is usually a result of low river flow, combined with longshore sand movement in the nearshore marine environment. Most of these estuaries have small catchments, e.g. Mpekweni, Mgwalana and Bira Estuaries along the Ciskei coast.
Trophic level	A division of a food chain defined by the method of obtaining food either as primary producers, or as secondary or tertiary consumers.
Wetlands	Areas that are inundated or saturated by surface or groundwaters frequently enough to support vegetation adapted to life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs and similar areas.

1. INTRODUCTION

With increasing demands being placed on natural resources caused by an increase in the human population (Blake 1991), management of our resources has become crucial (Morant and Quinn 1999). It has become necessary to report and summarise scientific information that can focus policy, planning and regulation of land and water use. Without this the functioning of the natural environment will be impeded (Kotze 1999).

The development of importance rating indices for estuaries in recent years has become essential to summarise and communicate scientific information to water resource managers. The botanical importance rating is one such method that could be used in the implementation of management decisions or objectives. These decisions or objectives could include the determination of estuarine flow requirements, conservation importance or priority and the habitat integrity of individual estuaries.

Protection of water resources (e.g. estuaries) in the National Water Act of 1998 requires the implementation of 'Resource Directed Measures' (RDM). RDM will optimise South Africa's water resources on a catchment basis, while ensuring sufficient water to sustain the environment. Furthermore, RDM require the identification of priority or important estuaries that are currently under pressure or face future pressures (Turpie et al. 1999). The conservation of estuaries in South Africa is an important issue. These are productive systems that provide habitat for a number of estuarine plants and animal species (Day 1981; Grindley and Heydorn 1979). The functions of an estuary are severely restricted if freshwater flow is altered through abstraction or changes in water quality of the river water (Allanson 1992; Adams et al. 1992). These estuaries can only function properly if some form of habitat integrity is maintained.

The botanical importance of South African estuaries and the relationship between plants and water supply were discussed in a previous Water Research Commission Project (Adams et al. 1996). That project developed a formula that rated estuaries according to the area of estuarine plants, its condition, the number of plant community types and the closeness of the association between the plants and the estuary. Along the Cape coast 33 estuaries were rated (Coetzee et al. 1997). A recommendation from the Water Research Commission Project (Adams et al. 1996) was that the rating should be extended to identify estuaries with a high conservation status along the whole South African coast. The focus of this project has been to survey the estuaries of Ciskei and Transkei. New community types were included in the importance rating, namely phytoplankton, mangroves, macroalgae and swamp forests. Hence, a number of refinements and improvements to the botanical importance rating formula were necessary. Botanical importance, as used in the refined formula, is defined as the contribution of the plants to the conservation importance of the estuary. This is based on the size and number of different plant community types and their contribution in the form of energy input to higher trophic levels (i.e. primary production). Means of assessing species richness, plant community type richness and plant community type rarity have also been included.

The revised formula can now be applied to any South African estuary and in this study was used to rate the estuaries within both the study region and the remainder of the South African estuaries that had available information. The revised botanical importance rating has also been used in the RDM for estuaries to determine botanical importance and estuarine health.

In summary the objectives of this project were:

1. To extend the botanical importance rating system of Cape estuaries to include estuaries in the former Ciskei and Transkei region (Section 4, 5 and 7).

2. To incorporate a fifth plant community type, i.e. mangroves into the botanical importance rating system (Section 4)

3. To provide baseline data on plant community structure and distribution in relation to freshwater input in a region where little data exists presently (Sections 6 and 8).

4. To translate scientific information on the freshwater requirement of mangroves into management tolls to be used in decision support (Section 3).

For each estuary visited the major species composition of the different plant community types were assessed and the associated physical conditions (salinity, temperature and inundation patterns) measured. In estuaries where mangroves occurred, species composition, tree density and age were used to determine the structure and status of the mangroves found in this region.

1.2 STUDY APPROACH

Botanical surveys were conducted within the 92 estuaries found in the former Transkei and Ciskei regions of the Eastern Cape Province (September 1997 – July 1998). The data available for each estuary include:

- once-off measurement of salinity, temperature, depth, secchi depth, water column chlorophyll-a and nitrate concentrations
- number of different plant community types (habitat types)
- area covered by different plant community types (past and present values)
- species composition
- identification of rare or endemic plant species or those with limited populations

A database was constructed using Microsoft Access 97 (version for Office 2000 also available). All the information was captured and stored in a series of forms (data input windows – Plates 1.1 and 1.2). The database will be available as a stand-alone program that will include not only information on the Ciskei and Transkei estuaries, but all South African systems. Currently information on 274 (94% of the total in South

Africa) estuaries has been included. Any of the fields (see Plate 1.1. and 1.2) can be used in a search. For example, if one wanted to know how many South African estuaries have supratidal salt marsh, type in >1 ha in the supratidal salt marsh field (Plate 1.2) and 54 estuaries will be retrieved.

These data were then used to determine:

Botanical importance of an estuary which includes species and community richness, plant community type rarity and functional importance (i.e. area covered by different plant community types multiplied by an average productivity value for each plant community type Figure 2.1). In Sections 4 and 5 the application of the botanical importance rating is demonstrated by comparing the Ciskei and Transkei estuaries with 93 other South African systems. In Section 6 (Figure 1.2) the information on the physical environment obtained in the field surveys was used to establish which factors contributed to the high botanical importance of Ciskei and Transkei estuaries.

The ***habitat integrity*** or health of an estuary can be determined using the functional importance score. The changes in area covered by the different plant community types is measured over time (Fig. 1.1) using past and present aerial photographs. The functional importance is then calculated using the earliest and most recent area values and the habitat integrity score is calculated as the deviation from natural, i.e. 100 less the difference in past and present functional importance scores (Fig. 1.1). This was tested in a study of the Swartkops Estuary measuring changes in plant cover from photographs and maps that spanned a period of fifty years (Colloty *et al.* 2000). The habitat integrity was also determined for 16 estuaries in a planning estimate of the estuarine water reserve. These 16 estuaries are found in the Pondoland region of the Eastern Cape Province (Northern Transkei). These case studies also lead to further refinement of the habitat integrity index and in total 129 estuaries were compared on a national basis (Section 7, Fig. 1.2). Section 8 (Fig. 1.2) discusses the distribution and status of mangroves in the study region. Estuaries where the greatest mangrove losses have occurred were identified and the factors causing mangrove loss were identified. Section 9 (Fig. 1.2) is a summary that discusses the use of the information obtained in the botanical importance rating and how this can be used to set management objectives or make recommendations for the conservation of estuaries.

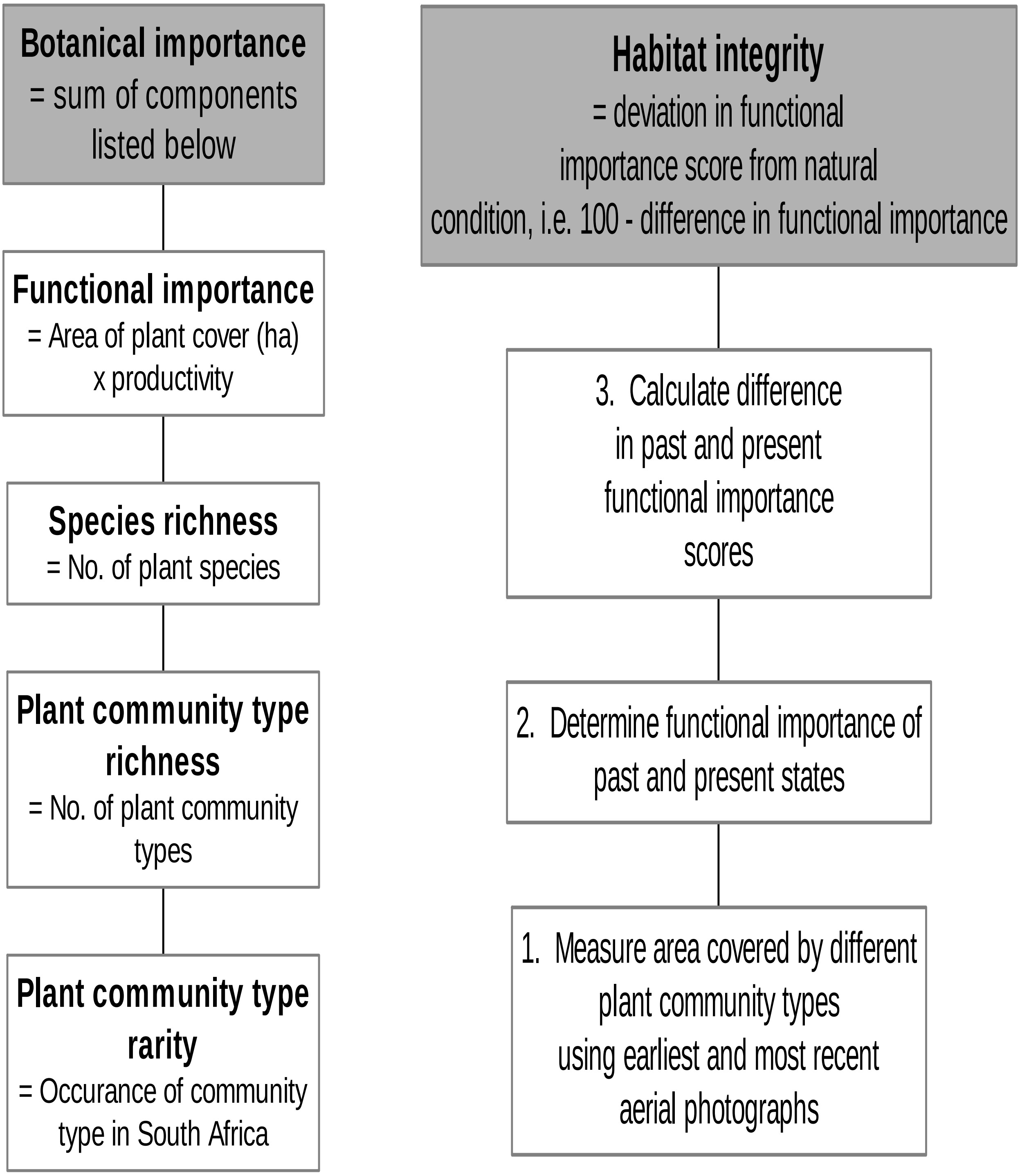


Figure 1.1: Flow chart depicting the components of the botanical importance rating and habitat integrity index developed in this study.

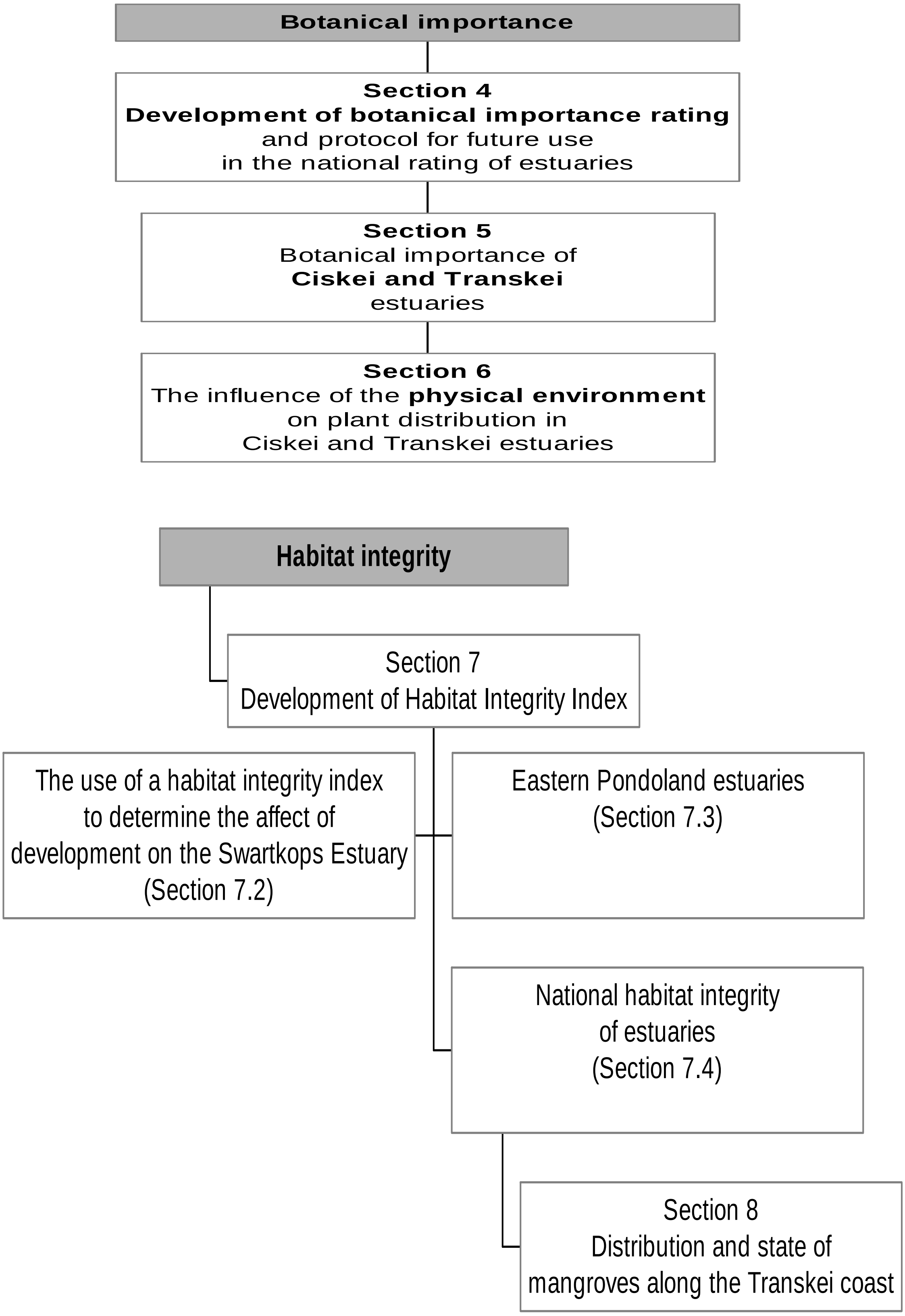


Figure 1.2: Flow diagram showing the layout of the sections in this study.

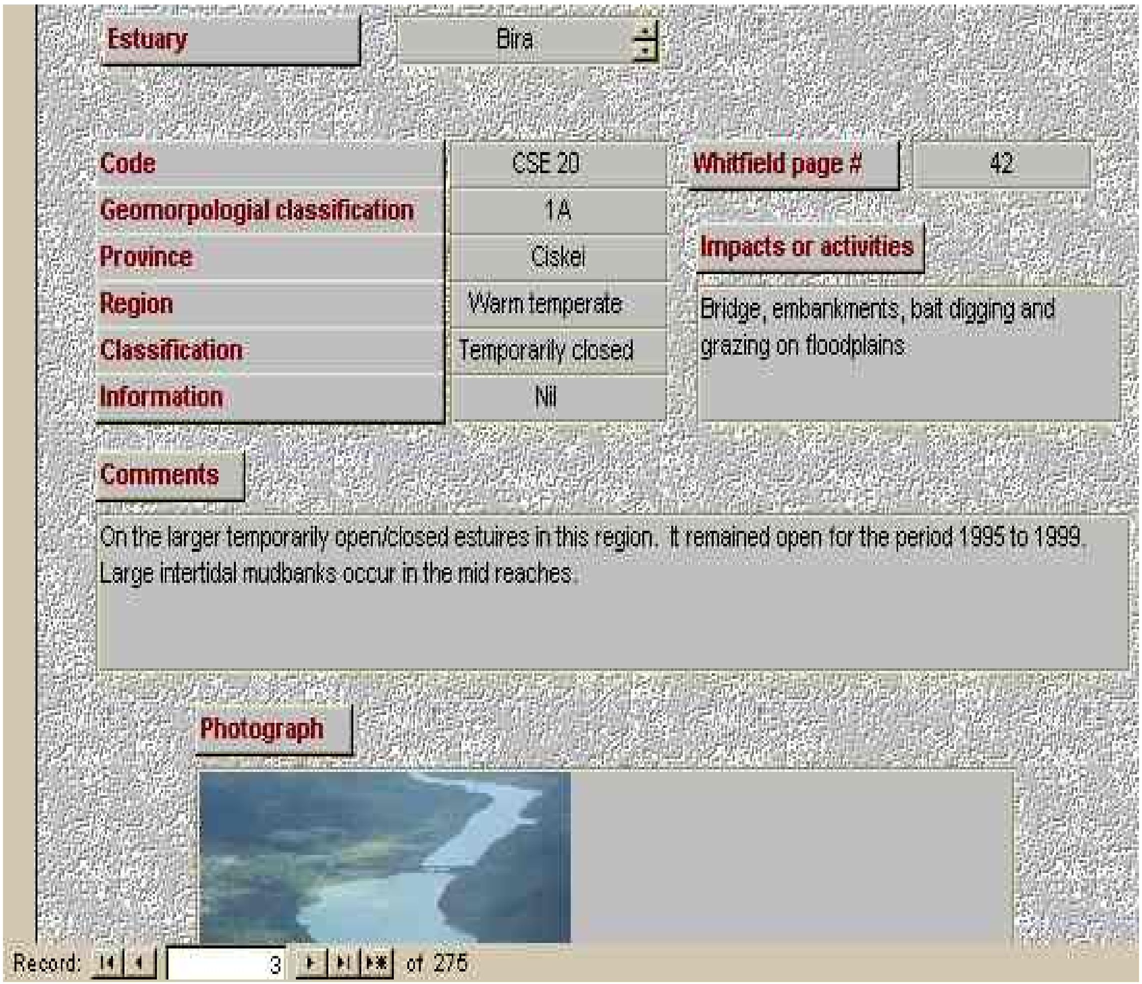


Plate 1.1: The database form that displays general information on each South African estuary. This includes biogeographic region, province, estuary classification and the page number where further information on this estuary can be found in Whitfield (2000). There is also a photograph for each estuary and a place for comments. Each of these fields can be used to search or sort the estuaries.

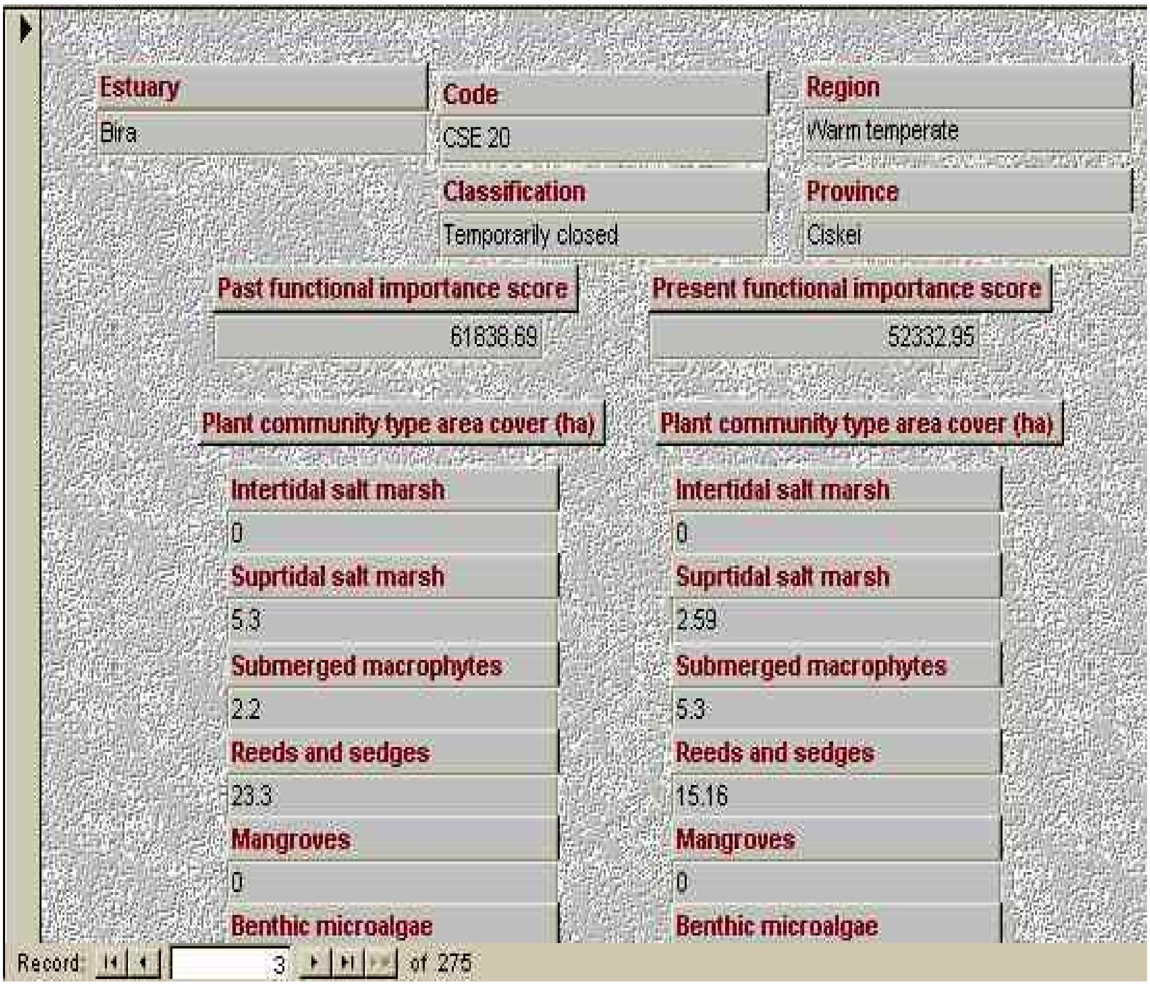


Plate 1.2: The botanical data in the database includes past and present area cover of each of the plant community types found in the estuary and the calculated functional importance scores.

2. THE STUDY AREA

The Ciskei and Transkei region were, until, 1994 South African political elections independent homelands. This region was politically unstable due to a series of military coups and research activities were almost nil. There has been no previous botanical research on estuaries in Ciskei (Whitfield 2000). Estuaries in the Transkei were excluded from botanical study for more than 11 years and little is known about the current structure and status of mangroves in this region. Muir (1937), West (1944), MacNae (1963) and Branch and Grindley (1979) conducted earlier studies on the Mtata, Mbashe, Mngazana, Mntafufu and Mtentu Estuaries. Moll et al. (1971) were the first to give a complete account of the distribution of all mangroves in 37 South African estuaries, while Ward and Steinke (1982) described the distribution and extent of mangrove communities cover in 37 estuaries, including the Transkei. Research by the University of Transkei concentrated on the ethnobotanical value of the terrestrial forest plants(Johnson and Cawe 1987). Zoological studies by the Universities of Transkei and Port Elizabeth considered zooplankton, crustacea and fish of the Great Kei, Mbashe, Mtata and Mngazana Estuaries respectively (Dye 1977, 1978, 1983a, 1983b; Emmerson and McGwynne 1992; Plumstead 1984, 1990; Plumstead et al*.* 1989a, 1989b, 1991 and Wooldridge 1974 and 1977).

The Ciskei lies between the Great Fish (33^0 30` S; $27^0$ 08` E) and Tyolomnqa (33^0 14`S; $27^0$ 35` E) Rivers a distance of ca. 75 km (Fig. 2.1). This portion of the coast is made up of a series of small bays with rocky headlands joined by a sandy beach. These 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 Transke,i the Ciskei has numerous recreation and residential developments on the banks of eight estuaries. These are mostly holiday houses, while the Mpekweni, Old Woman's and Great Fish Estuaries have casino/hotel developments.

The Transkei coast is a rugged and undeveloped region extending from the Great Kei River (32^o 41' S 28^o 23' E) to the boundary between the Eastern Cape and KwaZulu-Natal provinces (Mtamvuna River, 31^o 04' S 30^o 11' E) (Fig. 2.2). The average temperatures ranged between 16^0C (winter) and 26^0C (summer) and rainfall ranged between 750 mm.y^{-1} (southern Transkei) and 1100 mm.y^{-1} (northern Transkei) (South African Weather Bureau 1997-1999).

The Transkei coast, also known as the Wild Coast, is approximately 270 km 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 (Fig. 2.2). Seventeen of these estuaries are permanently open, 58 temporarily open/closed and one is a river mouth (Fig. 2.2). Five marine and nature reserves cover nineteen percent of the coastline, while the remaining coastal land is under tribal tenure. The only estuaries that are afforded conservation protection include 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. About half the coastline is covered by indigenous coastal forest that has a high biodiversity. Some 900 grass and forest plant species with commercial and homeopathic value have been identified (Johnson and Cawe 1987).

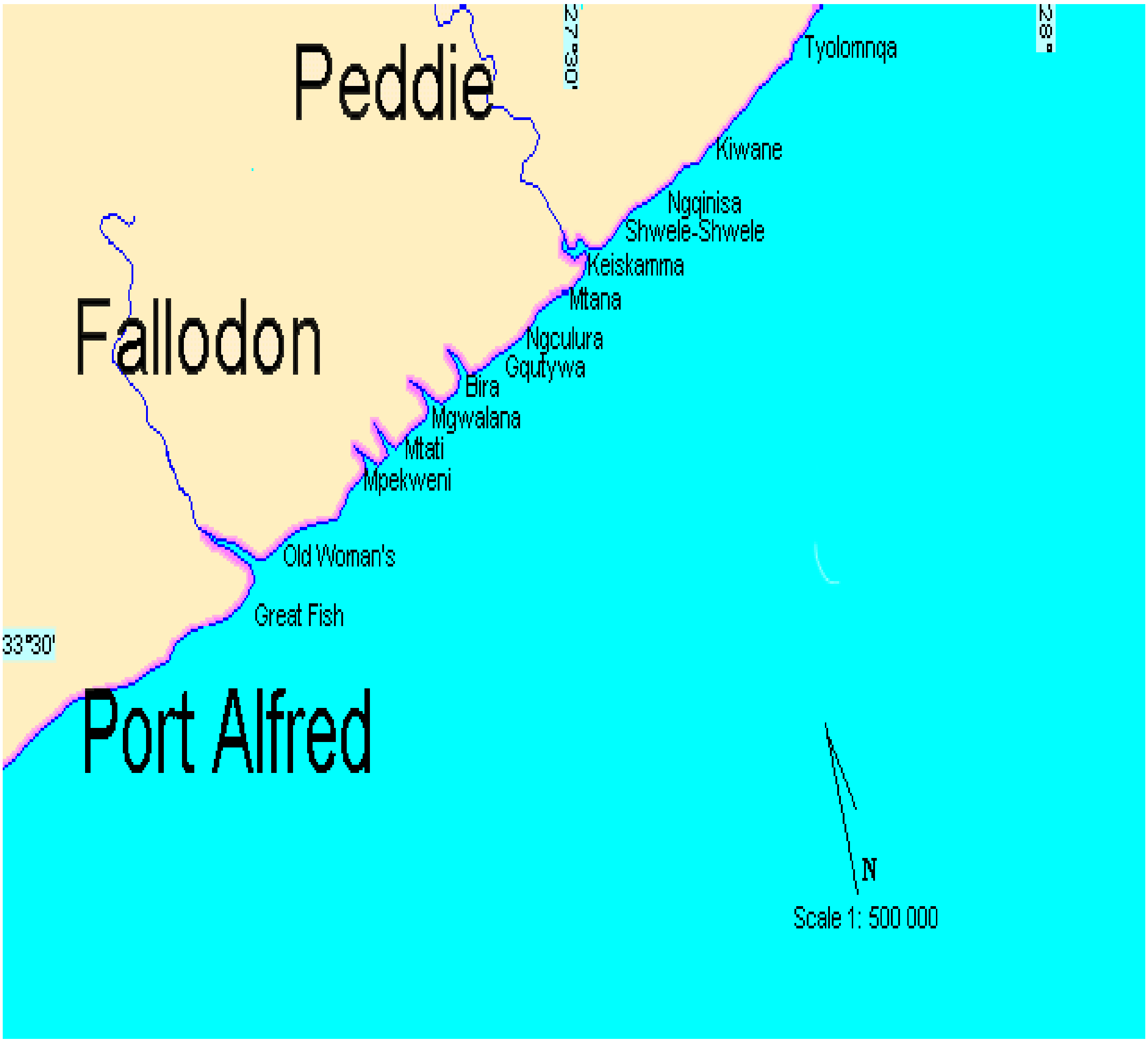


Figure 2.1: The Ciskei study region, with sixteen estuaries. The Great Fish, Keiskamma and Tyolomnqa Estuaries are the only permanently open estuaries.

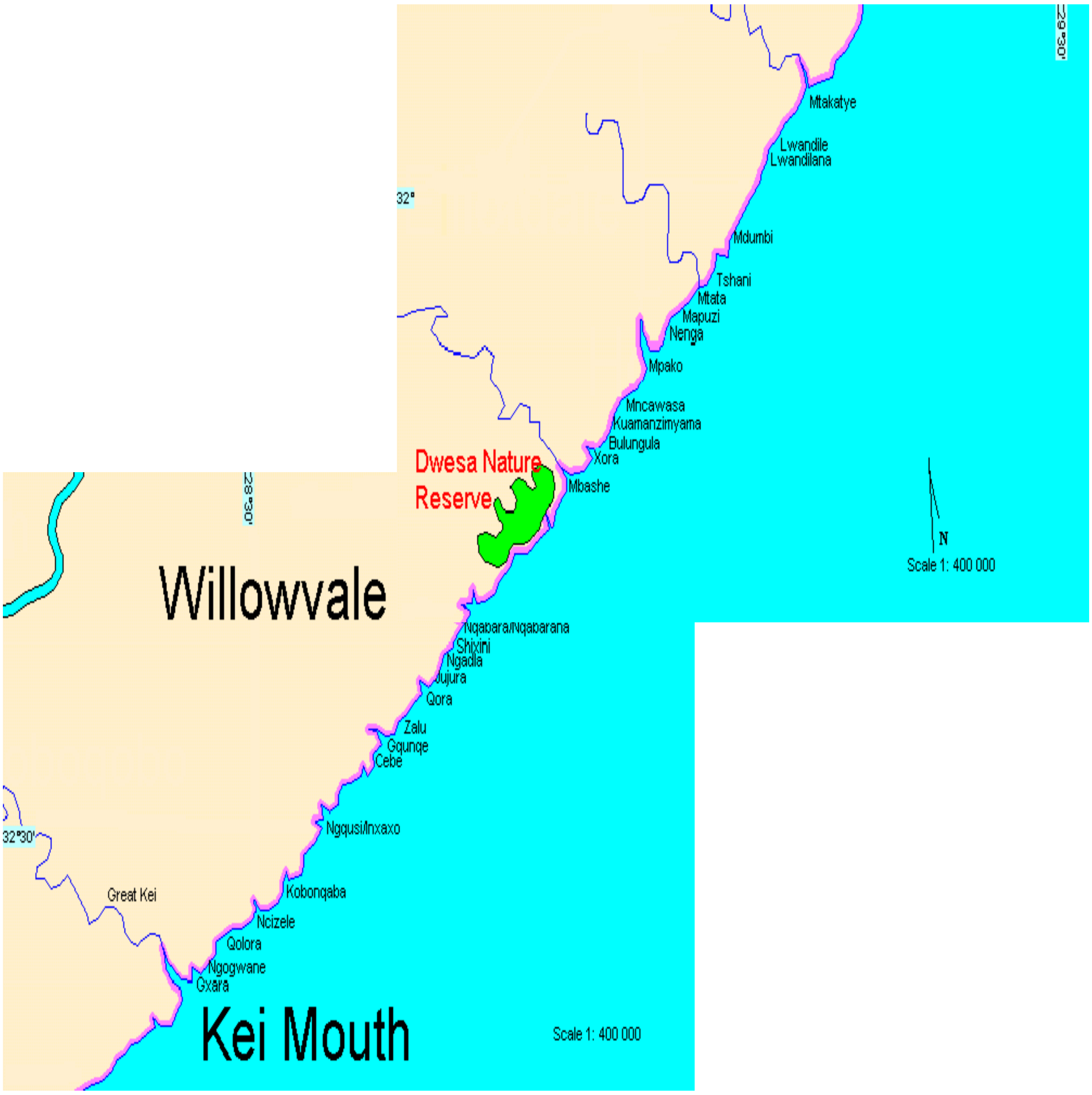


Figure 2.2a: The Transkei study region. There are 120 river outlets, but only 76 of these are considered estuarine. Estuaries shown are from Kei Mouth (Great Kei River) to Mtakatye River.

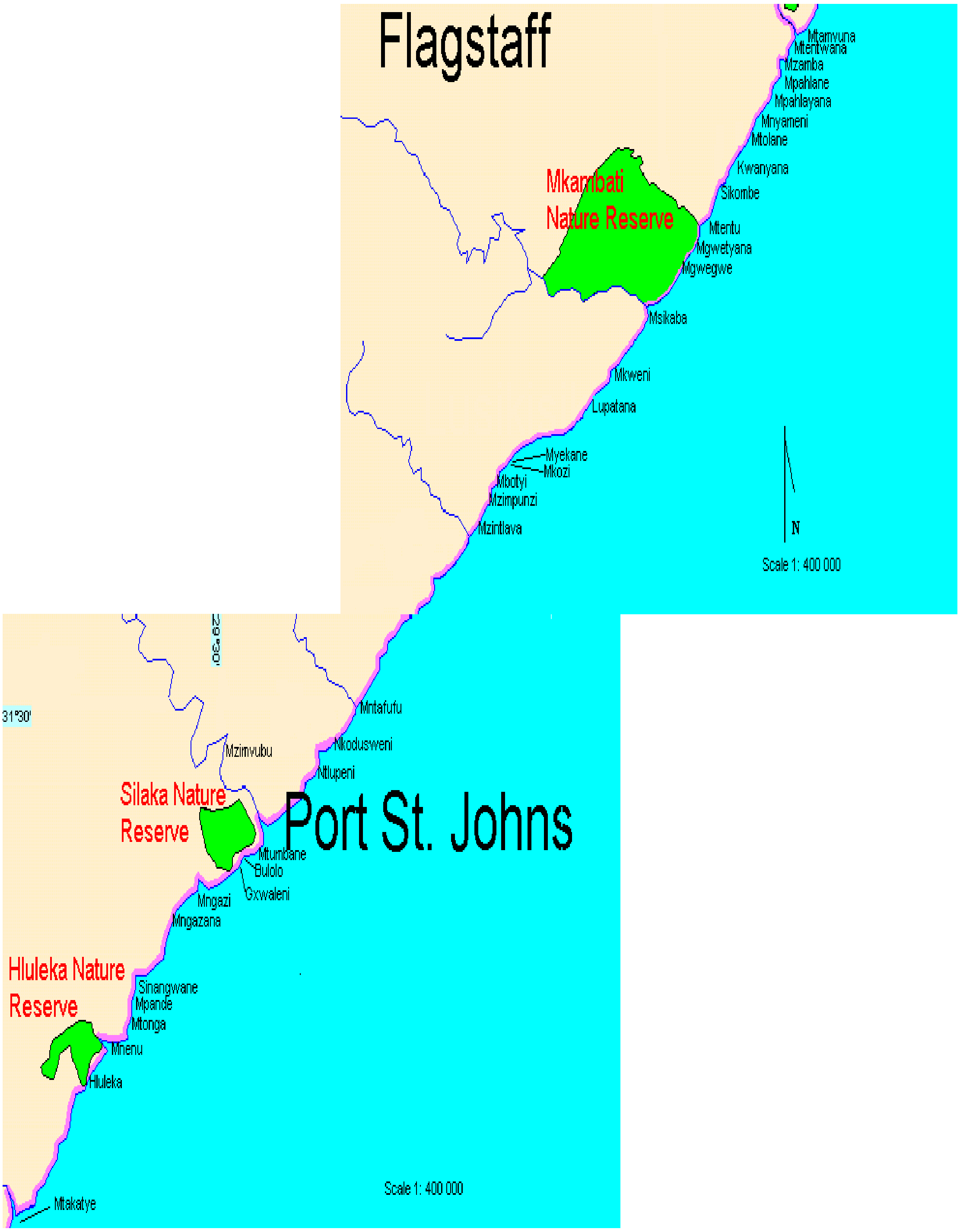


Figure 2.2b: The Transkei study region, from the Mtakatye River to the Mtamvuna River (Port Edward).

3. LITERATURE REVIEW

3.1 INTRODUCTION

In this study a number of topics have been included. These range from biological conservation to the distribution of mangroves and their environmental tolerances. Thus, this literature review summarises current trends in each of the sections. It must be acknowledged that although all the information used in this review has been peer reviewed and published, a vast amount of information exists on the World Wide Web and is updated on a monthly basis.

3.2 BIOLOGICAL CONSERVATION

One aspect that the botanical importance rating is concerned with is identifying the conservation importance of estuaries. However, it also intended that in this review a few reasons for the need to conserve estuarine plants is also presented (Richardson 1995). The corner-stone of biological conservation is the species or biological diversity and the ecosystem. The major aim of biological conservation is to place value or importance on natural resources and justify the protection of species or ecosystems either using a selected species or argument for biodiversity (Bryant 1998). Arguments that are used for the protection of the natural environment for future generations include:

3.2.1 Food supplies

About 80 000 plants species are thought to be edible with only about 150 species being used for human consumption. As the global economy strengthens, man has concentrated on fewer species so that today 90% of the world's food comes from 15 species (Bryant 1998). The red mangrove *Rhizophora mucronata* Lam. seedlings have been used as a food source in times of famine, as well as, fuel, tannin, dye, wine, tea and a type of fruit juice. The black mangrove *Bruguiera gymnorrhiza* (L.) Lam., is used as a source of starch (fruits) and eaten as a vegetable (fruit, seedlings and terminal buds) (Bandaranayake 1998).

3.2.2 Genes

Wild plants are also important sources of genes that can confer useful properties to conventional crops. The potato was brought from Peru to Europe in the 15th century and eventually it was cultivated as a crop plant all over Europe (Richardson 1995). In Ireland it became the staple diet. A disease of potatoes caused a major crop disaster in the 19th Century and millions of people in Ireland starved. A wild relative of the potato was found in Peru and when it was hybridized with the standard crop plant, a disease-resistant variety was obtained (Bryant 1998). This emphasises the reasons for conservation of not only the genera and species, but also the genomes.

3.2.3 Biological control agents

On many occasions, introduced exotic animals or plants have become serious invaders of the natural systems. Usually, the best control methods consist of having to find the natural antagonists of the species in its original home (Dugan 1993).

3.2.4 Natural products

The potential for discovering medical compounds in wild organisms is enormous, and provides one of the most powerful arguments for conservation of biological diversity (Bryant 1998). The pharmaceutical industry is much more dependent on natural products than is generally realized. About a quarter of all prescription drugs are taken directly from plants or are chemically modified versions of plant substances. About 121 prescription drugs are derived from higher plants. Some include morphine, codeine, quinine, atropine, and digitalis (Bryant 1998). *Sarcocornia* salt marsh species have been used in remedies for stomach ailments in South Africa, while the leaves of *Suaeda maritima* L. can be used as treatment against hepatitis. The bark of certain *Atriplex* species, also found in salt marshes, has anti-leukemia properties (Bandaranayake 1998).

3.2.5 Environmental services

Others terms used include ecosystem services (Richardson 1995) or functional importance (Turpie et al. 1999). A few decades ago, the water in the Chesapeake Bay was clear because oysters were filtering out particles at a rate estimated to be the equivalent of the entire volume of the bay every three days. With 99% of the oyster removed through over-harvesting, the accumulation of silt and other particulates no longer occurs (Bryant 1998). The environmental or functional service that estuarine plants provide is discussed in further detail in Sections 3.3 and 3.6, as this is probably the strongest argument currently available for the conservation of these ecosystems. Second, to this is the indirect economic value that estuaries generate in terms of fisheries, materials and recreation/tourism (Richardson 1995).

3.2.6 Future options

The future value of our systems to our successors is unknown. Perhaps they will need vast quantities of some species that we now consider insignificant or even harmful. Many of the natural sources of medicines are in fact poisonous (Bryant 1998). Nobody could have predicted that bread mould would be the source of one of the most useful antibiotics or the Madagascar periwinkle (*Catharanthus roseus*), common in South African gardens, would be a source of an anti-leukemia drug. The main reason for preserving not only species but also genetic variability of wild and domesticated species is so that we, and the other animals and plants on the planet, can adapt to unforeseen changing circumstances that we are not capable of imagining (Bryant 1998).

3.2.7 Economic and recreational value of biodiversity

The economic value of mangroves has been widely researched. Value has been placed on ecosystems services or function of the mangroves, i.e. protection of property through bank stabilisation, filtration of water, nursery habitat for fish. Mangroves have also been valued on the basis of yield of materials such as wood products or food (Table 3.1). Estuaries are also popular for recreational activities. Swimming, boating, angling, canoeing and sailing are all common on estuaries (Ramm 1990; Begg 1978). This is an added tourist attraction for the ecotourism trade in southern Africa. The revenue generated by this ecotourism can form an integral part of the local economic development of an area (Begg 1978).

Table 3.1: A summary (Ruitenbeek 1992) of the economic value of mangroves based on potential gain in US$ per ha per annum.

Date of Study	Country	Ecosystem Product/Service	Value (US$/ha/year)
1973	Puerto Rico, USA	Mangrove ecosystem	1 550
1974	Trinidad and Tobago	Mangrove ecosystem	500
1974	Trinidad and Tobago	Fishery products	125
1974	Trinidad and Tobago	Forestry products	70
1974	Trinidad and Tobago	Recreation, tourism	200
1976	Fiji	Mangrove ecosystem	950 -1 250
1976	Fiji	Fishery products	640
1976	Queensland, Australia	Fishery products	1 975
1978	Indonesia	Fishery products	50
1978	Indonesia	Forestry products	10 - 20
1979	Thailand	Fishery products	130
1979	Malaysia	Fishery products	2 772
1980	Malaysia	Forestry products	25
1982	Malaysia	Forestry products	225
1982	Malaysia	Fishery products	750
1982	Thailand	Fishery products	30-2 000
1982	Thailand	Forestry products	30 - 400
1981-82	Brazil	Fishery products	769
1985	India	Mangrove ecosystem	11 314
1986	Malaysia	Forestry products	11 561
1992	Indonesia	Mangrove ecosystem	4 800

3.3 IMPORTANCE OF CONSERVING ESTUARINE PLANTS

Estuaries are important because they have a number of functional roles (ecosystem services) in the coastal environment. Estuaries are dynamic ecosystems that occur at the interface between land and sea. Thus, the form and character of an estuary will be determined by a number of factors. These physical factors are discussed later in Section 5 with particular reference to the study region in this study.

Specialised salt tolerant or halophytic plant species have colonised the intertidal and supratidal areas of estuaries. These species occur in distinct community types of submerged macrophyte beds, inter and supratidal salt marshes as well as reed and sedge areas. These community types function not only as important filters of sediment, pollutants and barriers against floods, but also form an essential habitat for a large number of invertebrate and fish species (Hennessey 1994).

3.3.1 Submerged macrophytes

Submerged macrophytes, consisting either of *Zostera, Potamogeton, Zannichellia, Chara* or *Ruppia* species (Adams et al*.* 1999), can support more diverse and abundant invertebrate and juvenile fish communities than bare soft-bottomed habitats and marshes (Fredette et al. 1990; Connolly 1994). The submerged macrophytes are important for juvenile fish as they provide protection from predators, as well as providing food in the form of the epiphytes that grow on these plants. These plants also serve to oxygenate the water (Adams et al*.* 1999). Submerged macrophytes not only serve as a habitat for juvenile fishes and invertebrate fauna, but are important for secondary production (Fredette et al*.* 1990). A submerged macrophyte bed (140 ha) in the lower Chesapeake Bay was shown to support 75 resident macrofaunal species with densities of 12 000 to 70 000 individuals.m^{-2} (Fredette et al*.* 1990). Furthermore, it was predicted that the same 140 ha submerged macrophyte bed and only 13 of the macrofaunal species could produce 60.7 metric t dry tissue, representing approximately 60 billion individuals (Fredette et al*.* 1990). These would then be a potential source available for consumption by higher trophic levels. The proportion of this estimation that is actually consumed is unknown. The possibility of such productive macrophyte beds in South African estuaries is unlikely, but the example given illustrates the function of submerged macrophytes in the secondary production of an estuary (Coetzee 1995).

3.3.2 Salt marshes

Salt marshes occur only in certain estuaries and embayments along the South African coast. It has been estimated that the marshes cover approximately 17 000 ha, with more than 75% of this area confined to five estuaries, i.e. Langebaan Lagoon, Knysna Lagoon, Swartkops River, Berg River and Olifants River (Adams et al. 1999). Salt marshes are important inorganic and organic nutrient sources for estuaries (Childers and Day 1990). Although estuarine water levels and the degree of flushing are important in determining how much of the nutrient is released into the water column, if a marsh is rarely flooded its importance in the ecosystem decreases (Childers and Day 1990). The importance as a habitat for invertebrate and bird species, however, does not decrease. In the Mira Estuary, Portugal, the salt marsh-water column ecotone was more important for juvenile fish species than the sea grass beds in the estuary (Costa et al*.* 1994). The primary production of *Spartina maritima* (Curtis) Fenald, in the Swartkops Estuary, has been estimated at over 10 000 kJ.m^{-2}.yr^{-1} or 602 $g.^{-2}$.yr^{-1} (Pierce 1983). Only half of this is estimated to accumulate in the detritus chain and the remainder is either deposited in the estuary or washed out to sea (Day 1981). Kokkinn and Allanson (1985) showed that the import of organic carbon from marine sources is substantially higher than those exported. This suggests that the organic carbon produced by the marshes remains in the estuary and is utilised by the organisms that live there or alternatively it remains bound in the food chain.

3.3.3 Reeds and sedges

The reed and sedge plant community types are found in freshwater and brackish zones of estuaries, usually as emergent plants lining the banks. The plants are rooted in the soft substrata of either intertidal or subtidal regions (Adams et al*.* 1999). Reed and sedge beds are capable of removing large amounts of nutrients from the water column. They act as nutrient sinks in the natural environment and are so effective that they are used for water purification in artificial wastewater treatment systems (Brix 1993; Martin and Fernandez 1992). Reeds and sedges can also act as indicators of eutrophication from riparian land, very lush growth indicating lots of nutrient, or freshwater, runoff into the estuary. A change in the species composition from salt marshes to more brackish sedge/reed species can be the result of high nutrient input (Brix 1993). *Phragmites australis* (Cav.) Steud. contributed approximately 90% to the total littoral primary production of the Swartvlei, a brackish estuarine lake (Taylor 1983).

3.3.4 Mangroves

Mangroves have been identified as being important to the maintenance of estuarine function. Mangroves provide a food source or habitat for numerous organisms, but are also a valuable food, provide timber and are the reason for fisheries in parts of the world. Mangrove swamps serve as vital nursery grounds for the economically important nearshore species such as snappers (Lutjanidae), jacks (Carangidae) and mullets (Mugilidae). Snedaker (1978) estimated that upwards of 90% of nearshore marine species were found in the mangroves during one or more parts of their life cycles. The success of nearshore fisheries in many tropical regions depends as much on the mangrove habitats themselves, rather than the detrital foods for recruitment success.

3.4 ESTUARINE IMPORTANCE RATING INDICES

Due to the increasing number of people utilising the coastline (Allanson 1992; Begg 1978), there is now a need to evaluate estuarine and coastal resources and to determine sensitive areas where careful planning and management must take place. The National Water Act 1998 has also identified the need to incorporate the environmental water needs. This requires biological and physical information to be presented in an easily readable and understandable format. Comprehensive reports summarising the information, like the Green Books (CSIR, Estuaries of the Cape Report Series) and Estuaries of Natal Report (Begg 1984), are daunting as a large amount of time is required for the reading and interpretation of the information in order to determine the health, importance or sensitivity of an estuary. A simple way to summarise biological information is to develop an index which gives an indication of the status of certain aspects of the area or community in question (Ramm 1988). Planners, developers, managers and conservationists can then see at a glance which areas are sensitive and require more attention and which have a high conservation priority. This prioritisation of sensitive areas is foremost in the implementation of the Water Act and requires estuaries that are at risk to be identified (Turpie et al*.* 1999).

One way to achieve this is to develop a method that summarises the biological information into an index or score for the estuary. The choice of a multi- or single criteria index is important, considering that there are a number of other factors which are also important in the estuary, not just the factor used to obtain the index (Turpie 1994). The use of indices sacrifices detail for the sake of perspective, as no index can summarise all the aspects which are important in an estuary (Ramm 1988). Using a number of indices in conjunction with each other, instead of just one, is a way to achieve a more holistic impression of the condition of an estuary. Also, provided the details are available showing how an index is obtained, specific management options can be determined (Turpie et al. 1999). This is the concept behind the development of the estuary importance rating developed by Turpie et al. (1999) in order to prioritize estuaries for the implementation of the RDM approach of the National Water Act. Physical factors, biological characteristics (of which the botanical importance rating forms part) and sensitivity to future threats of the estuary are taken into consideration to achieve a final estuary importance rating (Turpie et al. 1999). Arguments for the use of certain components in the estuarine importance rating has been used in the refinement of the botanical importance rating and is discussed in detail in Section 4.

O'Callaghan (1990a, 1990b) developed the only other botanical rating method for estuaries. Past and present aerial photographs were used to observe the changes in the plant cover as a result of industrial or residential action, of the False Bay estuaries. The increase or decrease in key vegetation types (wetlands, riverine shrub, dune vegetation) and water surface area were used to calculate the relative environmental importance (I), the relative environmental state (E), the coefficient of change (A) and the conservability (C) of each of the False Bay estuaries. The conservability of an estuary was calculated by determining how much that estuary had changed as a result of the surrounding development. No change, or an increase in wetland or water area, was seen as a positive effect and such an estuary would receive a high conservability rating (O'Callaghan 1990a, 1990b). A decrease in overall wetland or water area was regarded as negative and such an estuary would receive a low conservability rating. Estuaries with the highest conservability were Rooiels, Steenbras and Buffels (Oos), due to very little residential and industrial development around them. The Zeekoei obtained the lowest conservability rating due to the presence of sewage ponds and encroaching alien vegetation. Residential, recreational and industrial development as well as alien plant encroachment, were all given as the major factors causing changes to the vegetation observed in these False Bay estuaries (O'Callaghan 1990a, 1990b).

The examination of past and present aerial photographs can be valuable in determining the effects of development on the estuarine environment and has been incorporated into the habitat integrity index developed in this project. O'Callaghan's (1990a, 1990b) study, however, was restricted to False Bay estuaries only. The interpretation of the aerial photographs can be subjective, as it is necessary to determine the extent to which a development has had either a positive or negative influence on the plants or estuary. For this study (O'Callaghan 1990b) an expert panel was used to provide their opinions on both negative and positive impacts.

Ramm (1988) developed the community degradation index (CDI) to compare "...the present biological community to the community that would exist in the absence of (or prior to) degradation...." In the implementation of his CDI no subjective decisions are made with respect to the sensitivity of particular species to a pollutant or mix of pollutants. The subjectivity is in the interpretation and in the use of the index for planning purposes. Cooper et al*.* (1993) and Harrison et al*.* (1994) used the CDI (Ramm 1988) to calculate the estuarine health of Natal estuaries and west and south western Cape estuaries respectively. The biological health, water quality and aesthetic conditions of the estuaries were used to compile a final estuarine health index (EHI) for different estuaries.

(a) Biological Health Index (BHI)

This index was calculated after surveying the existing fish communities and comparing them to historical data on the same estuary. The CDI (Ramm 1988) was adapted to measure the degree of similarity between the historical (potential) community and the actual community found in a survey.

(b) Water quality index

Selected chemical and bacteriological parameters were used to obtain an index number for the water quality of an estuary. The parameters used were dissolved oxygen, oxygen absorbed, ammonia, *E. coli* counts, nitrate, phosphate and chlorophyll-a concentration.

(c) Aesthetic health index

This aspect took into account the appearance of an estuary by comparison with its pristine state. Parameters taken into account to determine the difference were floodplain landuse, degree to which channel margins were natural, persistent odours, presence of exotic vegetation, oil sheen, mouth stabilisation, presence of bridges and degree of visual impact from industrial or residential buildings.

An EHI is derived from three components, namely, a biological health, water quality and aesthetics index. The final value obtained, for the EHI, is more representative of the overall condition of the estuary than if only one of the indices had been used. If an index is used that considers historical data, the data have to exist in fairly extensive format and in such a format that adequate comparisons can be made with present-day information. Should changes have occurred in the data being used to develop the index, it must be clear that such changes were as a result of anthropogenic habitat degradation and not natural causes (Ramm 1988).

The deviation from perceived reference state or condition of South African estuaries could be valuable for conservation management. An indication of the extent that an estuary has been altered by human impacts can then be compared to its reference condition. The reference conservation condition can be used as a benchmark for management objectives. The National Water Act states that water resources must be classified. One way to address this requirement is to classify estuaries according to their conservation status.

A number of human impacts affect the habitat integrity of estuaries. These include physical habitat destruction, water quality impacts, modification of the flow regime and over-exploitation of the natural biota.

In order to improve the accuracy and confidence levels of estuary habitat assessments, the above assessment criteria have been selected and weightings were given to each of the criteria. Each of the criteria is then given a score, which is combined into a single representative score for estuaries. This procedure follows that of Kleynhans (1996) described for rivers, and has been duly adapted for South African estuaries. The Swartkops Estuary near Port Elizabeth has been selected as a case study for the implementation of the habitat assessment procedure. Despite the standardisation, the procedure is still based on a degree of speculation. High flow modification probably has the greatest single effect on South African estuary habitat integrity and was given the largest weight. Tidal flow and low flow modification that, in turn, followed by the other listed impacts followed this. The tidal flow and low flow modifications were given the same weights, for it was unknown what their proper weights should be. Likewise, the weighting of all the other impacts were equally rated, although it was conceived that their impacts are probably of less importance than tidal and low flows. It was hoped that future experience would lead to more appropriate weighting of the impacts. The weightings could then be adjusted for other types of estuaries. This assessment required literature study and expert opinion, but no actual scientific field measurements. Confidence in final score was dependent on available information and knowledge of an estuary (van Driel pers. comm.).

3.5 PAST SCIENTIFIC INFORMATION PUBLISHED ON TRANSKEI AND CISKEI ESTUARIES

There is little published information available on specific estuaries within the study region. Publications are available for only twelve of the seventy six estuaries. Some of the previous research included, physico-chemical properties (Read 1982, 1983, 1985a, 1985b; Grobbler et al*.* 1987), crustacea (Emmerson and McGwynne 1992; Robertson 1996), zooplankton (Connell 1974; Wooldridge 1974, 1977) and fish communities (Blaber 1974; van der Elst 1978; Whitfield 1979; Marais and Prinsloo 1980; Plumstead 1984, 1990; Plumstead et al*.* 1989a, 1989b, 1991) of the estuaries (Whitfield 2000). Previous botanical research in the Transkei estuaries concentrated on the distribution (Ward and Steinke 1982) and species composition of the mangrove forests found in seventeen of the Transkei estuaries (Muir 1937; West 1944; MacNae 1963; Moll et al*.* 1971; Branch and Grindley 1979).

Whitfield (2000) in his report on the literature available on South African estuaries classified those of the Ciskei and Transkei in terms of mouth status, biogeographical region and condition. The Ciskei estuaries are predominately temporarily open with only the Great Fish and Keiskamma Estuaries classified as permanently open. The condition of each estuary was based on the degree of anthropogenic influence within the estuary and upper catchment. The Ciskei estuaries were all assessed as being in a good condition, i.e. no major negative anthropogenic impacts in either the estuary or catchment. An exception was the Keiskamma Estuary that was assessed as being in a poor condition. The Transkei estuaries were predominately classified as temporarily open. Sixteen estuaries were permanently open and one was a river mouth

(Whitfield 2000). Conditions of these estuaries vary more than those found in the Ciskei region, ranging from excellent to poor. Forty five of the sixty-one estuaries found in the Transkei are found in the subtropical biogeographic region, the remaining sixteen fall in the warm temperate region.

3.5.1 Physical environment and geomorphology

The Durban-based East Coast programme of the CSIR has developed the Estuarine Health Index which, based on a physical classification scheme, incorporates an index of biological health using fishes, a water quality index and an aesthetic or naturalness index. The objective of that programme was to study estuaries along the entire South African coastline. Forty eight of the east coast estuaries from Old Woman's to the Great Kei were sampled during 1997. These included the seventeen estuaries found in the former Ciskei region (Harrison et al*.* 1997a; 1997b). Forty three estuaries were surveyed in the Transkei (Harrison *et al.* 1999a; 1999b).

The Transkei region is unique for three reasons. Firstly, it is situated in the transition zone between the warm temperate and subtropical biogeographic regions along the east coast of Africa. Secondly, a change in geomorphology occurs from low-lying areas in the south to steep, deeply incised river valleys in the north. Thirdly, the Transkei region receives approximately 200 - 300 mm more rain than any other southern part of the South African coast. These three factors are assumed to create a transition between the more xeric salt marsh community types in the south towards mangrove forest in the north.

3.5.2 Estuarine classification - a geomorphologic approach

Whitfield (1992) developed an estuarine classification system based on mouth condition of estuaries. In identifying this single characteristic, a number of physical processes could be summarised. Five different types were identified namely: temporarily open/closed, permanently open, river mouths, estuarine lakes and estuarine bays. For example, permanently open estuaries have a large mean annual runoff that is important in keeping the mouth open. The open mouth allows tidal inundation to occur within the estuary. However, the range of estuaries in South Africa is such that a variety of environmental conditions exist in different systems. Geomorphological classification of estuaries not only tries to summarise the physical conditions of estuaries as in the Whitfield classification system, but it describes estuaries, as they should be under natural conditions (Harrison et al*.* 1999a; 1999b). Geomorphological classification not only includes mouth condition, but also allows for the further subdivision of the five 'Whitfield' groups. This subdivision was intended to identify available habitat in terms of floodplain width, channel size, mouth barrier morphology, climate and catchment size (Harrison et al*.* 1997a; 1997b). Harrison et al*.* (1997a; 1997b) surveyed 16 estuaries in the Ciskei region and 5 estuarine classes were established (Table 3.2), while Harrison et al*.* (1999a; 1999b) were able to survey 43 Transkei estuaries and 7 classes were established (Table 3.3).

Table 3.2: The classification of estuaries compiled by Harrison et al. (1997a; 1997b) for 16 of the Ciskei estuaries. The Whitfield estuarine classification is also shown.

Estuary class	Whitfield class	Harrison class	Size (ha)	Barrier type	Salinity ($g.l^{-1}$)	Estuaries
1A	Temporarily open/closed	Frequently closed	Moderately small 9 – 25	Long wide barriers	near marine, overwash 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	-	Range of 0 – 35	Great Fish, Keiskamma, Tyolomnqa
3	Not considered estuarine	Small dry river beds or freshwater 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 3.3: The classification of estuaries derived by Harrison *et al.* (1999a; 1999b) for 43 of the Transkei estuaries. The Whitfield estuarine classification is also shown.

Estuary class	Whitfield class	Harrison class	Size (ha)	Salinity ($g\ l^{-1}$)	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 (Plate 4), 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 and Mtentu
4	Permanently open or River mouth	River dominated	50	Small tidal range, <2 km	-	Mbashe, Mtata, Mzimvubu and Great Kei.

3.6 MANGROVES

3.6.1 Introduction

Probably no other distinct plant community has attracted as much curiosity and scientific attention for as long as the mangrove forests have. Rollet (1981) in a bibliography lists 5 608 published titles up until 1975 with one of the first being the written account from the chronicle of Nearchus, a Greek mariner circa 325 BC (Dugan 1993). Mangroves are perceived as a jagged forest protruding from the surface of the sea, roots anchored in deep, black, foul-smelling mud, with verdant crowns (Klause et al*.* 1996). Mangroves, estimated to cover an area of 22 million ha, dominate the majority of the world's subtropical and tropical coastlines. However, over the past several decades, the global area in mangroves has increasingly diminished as a result of a variety of human activities, such as over-harvesting, freshwater diversion and conversion to other uses such as shrimp or prawn ponds (Snedaker 1993). Mangrove forests are comprised of taxonomically diverse, salt-tolerant tree and other plant species that thrive in intertidal zones of sheltered shores, overwash islands and estuaries. Mangrove trees have specially adapted aerial and salt-filtering roots and salt-excreting leaves that enable them to occupy the saline wetlands where other plant life cannot survive (Dugan 1993).

Mangrove forests are vital for healthy coastal ecosystems. The forest detritus, consisting mainly of fallen leaves and branches from the mangroves, provides nutrients for the marine environment and supports immense varieties of sea life in intricate food webs associated directly through detritus or indirectly through the planktonic and epiphytic algal food chains. Plankton and benthic algae are primary sources of carbon in the mangrove ecosystem, in addition to detritus (Dugan 1993).

The shallow inter-tidal reaches that characterize the mangrove wetlands offer refuge and nursery grounds for juvenile fish, crabs, shrimps, and molluscs. In both temperate and tropical estuaries, sesarmid crabs together with ocypodids, comprise a large proportion of the intertidal macrofauna. As detritivores they form an important link between primary producers and predators. Energy flow in mangroves is based largely on the production of organic matter as leaf litter that enters estuarine systems and forms part of a complex food web (Snedaker 1978).

In the Mngazana Estuary five species of *Sesarma* have been recorded, including *S. catenata*, *S. eulimene*, *S. guttata*, *S. longipes* and *S. meinerti* (Branch and Grindley 1979). Consumption of *Avicennia marina* (white mangrove) leaves by the detritivorous *Sesarma meinerti* was measured in the laboratory and compared to field observations in the Mngazana Estuary (Emmerson and McGwynne 1992). Although a significant correlation existed between crab size and the amount of leaf litter consumed per day, no correlation was found between crab size and assimilation efficiency. Seasonal trends in leaf litter fall were evident with a mean annual rate of 1.79 $g.m^{-2}.d^{-1}$ (653.4 $g.m^{-2}.y^{-1}$). With mean crab densities estimated at 4 $individuals.m^{-2}$ and mean crab size of 40g, leaf consumption was calculated at 0.78 $g.m^{-2}.d^{-1}$ dry mass (284.7 $g.m^{-2}.y^{-1}$), accounting for 43.5% of the leaf litter fall (Emmerson and McGwynne 1992). For the entire mangrove area of 150 ha (Ward and Steinke 1982) and with a mean biomass of 4 $g.m^{-2}$, the Mngazana Estuary supports a *S.*

meinerti population of 6 million crabs (240 t fresh mass). An annual total of 980 t dry mass of leaves abscise throughout the forest, of which 427 t dry mass are eaten directly by *S. meinerti*, producing 75 t of frasse. This contributes a considerable amount to the detrital pool of the estuary. The balance is assimilated by *S. meinerti* (7 990 million kJ) (Emmerson and McGwynne 1992).

Mangroves are also prime nesting and migratory sites for hundreds of bird species. In Belize, for example, there are over 500 species of birds recorded in mangrove areas. Additionally, manatees, crab-eating monkeys, fishing cats, monitor lizards, sea turtles, and mudskipper fish utilise the mangrove communities (Dugan 1993).

3.6.2 The ecology of mangroves

These complex ecosystems are found between the latitudes of 32^0 N and 38^0 S, along the tropical coasts of Africa, Australia, Asia, and the Americas. There are varying scientific classifications of what constitutes a mangrove plant. According to two scientific studies, mangroves include approximately 16 - 24 families and 54 - 75 species (Tomlinson 1986; Field 1995). The greatest diversity of mangrove species exists in Southeast Asia. For example, there are only twelve mangrove species in the New World and only four species of mangroves exist along portions of the coasts of the southern USA.

Mangrove forests literally live in two worlds at once, acting as the interface between land and sea. Mangroves help protect coastlines from erosion, storm damage, and wave action. The stability that mangroves provide is of immense importance. They prevent shoreline erosion by acting as buffers and catch alluvial materials, thus stabilizing land elevation by sediment accretion that balances sediment loss. Important coral reefs and seagrass beds are also protected from damaging siltation (Snedaker 1993).

A primary factor of the natural environment that affects mangroves over the long term is sea level fluctuations. Other shorter-term factors are air temperature, salinity, ocean currents, storms, shore slope and soil substrate. Most mangroves live on muddy soils, but they also grow on sand, peat, and coral rock. If tidal conditions are optimal, mangroves can flourish far inland, along the upper reaches of coastal estuaries (Snedaker 1978).

Mangroves vary in height according to species and environment, from mere shrubs to 40 m trees. The prop roots of some mangrove species, such as *Rhizophora* or "red mangrove", and the pneumatophores of others, such as *Avicennia*, contain many small "breathing" pores, called lenticels. These allow oxygen to diffuse into the plant, and down to the underground roots by means of air space tissue in the cortex termed aerenchyma. The lenticels are inactive during high tide. Evolutionary adjustments to varying coastal marine environments have produced some astounding biological characteristics within mangrove plant communities. Certain species of mangroves exclude salt from their systems, others actually excrete the salt that they absorb via their leaves, roots or branches. In salt-excluding mangrove species, the mangrove root system is so effective in filtering out salt that a thirsty traveler could drink fresh water from a cut root, although the tree itself stands in saline soil (Berjak et al*.* 1986).

Certain mangrove species can propagate successfully in a marine environment because of special adaptations. Through viviparity, embryo germination begins on the tree itself; the tree later drops its developed seedlings, which may take root in the soil beneath. Viviparity may have evolved as an adaptive mechanism to prepare the seedlings for long-distance dispersal, and survival and growth within a harsh saline environment (Steinke 1995). During this viviparous development, the propagules are nourished on the parent tree, thus accumulating the carbohydrates and other compounds required for later autonomous growth. The structural complexity achieved by the seedlings at this early stage of plant development helps acclimate the seedlings to extreme physical conditions which otherwise might preclude normal seed germination (Berjak et al. 1986). Another special adaptation is the dispersal of certain mangroves propagules which hang from the branches of mature trees. These fall off and eventually take root in the soil surrounding the parent tree or are carried to distant shorelines. Depending on the species, these propagules may float for extended periods, up to a year, and still remain viable. Viviparity and the long-lived propagules allow these mangrove species to disperse over wide areas (Steinke 1982).

Water circulation is an important variable in the ecology of mangroves. The water circulation in mangrove swamps operates at many scales, from the large-scale tidal dynamics to the small-scale flows around individual roots and pneumatophores. Water is trapped in a mangrove creek. The residence time of water for a typical 5 km long creek is about 7 d. The residence time of water in a large swamp comprising many mangrove creeks can be as high as 50 d. Freshwater inflow, via surface and groundwater flow, and evapotranspiration affect water quality by generating stagnation and aeration zones. In the dry season all the freshwater from riverine inflow evaporates, a salinity maximum zone exists, isolating the upstream mangroves from the ocean. Hydrodynamic trapping can lead to anoxic conditions near the bottom. Bioturbation, principally by crabs, facilitates groundwater flow which ventilates the soils and help flush out the excess salts in the soils (Wolanski and Chapell 1996).

Under usual circumstances, when there is significant freshwater in a mangrove-fringed estuary, cross river circulation aggregates floating mangrove seeds in the middle of the channel at rising tide. However, if hypersaline conditions occur, midstream aggregation occurs at falling tides. Generally, the net movement of floating material is upstream when significant freshwater inflow is present and downstream when evaporation greatly exceeds freshwater inflow. As a result, the recruitment of floating mangrove seeds in the swamp is enhanced only in the dry season. This may control mangrove zonation at geomorphological time scales. Groundwater inflow ventilates the bottom waters of mangrove creeks and destroys the anoxic conditions, while groundwater outflow entrains algae into the sediment and removes them from the system (Wolanski and Chapell 1996).

There is a strong feedback between the water circulation and the sediment dynamics. The topography and the vegetation generate a tidal asymmetry of the currents. As a result, mangrove creeks are naturally self-scouring even without freshwater runoff. Land reclamation of mangrove swamps for human development reduces the tidal asymmetry and the natural self-scouring effect, resulting in siltation of mangrove channels (Wolanski and Chapell 1996).

The plants generate small-scale turbulence, maintaining the sediment in suspension in the tidally inundated forest except for a few minutes near slack high tide. As a result, the fine sediment from the rivers and the muddy coast spreads all through the mangroves without forming natural levees along the banks. The deposition zones of riverine and oceanic sediment are distinct. The response of mangroves to a sea level rise depends largely on the availability of fine sediment to infill the swamp. Mangroves are very efficient in reducing wave energy and can be used as an environmentally friendly, soft-engineering option along muddy shores to protect the coast from erosion. In shallow coastal waters the detritus from mangrove plants and the plankton mucus facilitate the flocculation of fine sediment in suspension. This generates huge, muddy, micro-aggregates that settle rapidly. This process, together with hydrodynamic trapping effects, enables mangroves, seagrass and coral reefs to exist in close proximity. The water circulation over the mud shoals fringing the mangroves encourages the recruitment of prawn larvae spawned offshore. The mangroves appear to be vital to the maintenance of prawn fisheries (Wolanski and Chapell 1996).

3.6.3 Mangrove distribution

It is thought that the earliest mangrove species originated in the Indo-Malayan region. This may account for the fact that there are far more mangrove species present in this region than anywhere else. Because of their unique floating propagules and seeds, certain of these early mangrove species spread westward, borne by ocean currents, to India and East Africa, and eastward to the Americas. These arrived in Central and South America during the upper Cretaceous period and lower Miocene epoch, between 66 and 23 million years ago (Dugan 1993). During that time, mangroves spread throughout the Caribbean Sea across an open seaway which once existed where Panama lies today. Later, sea currents may have carried mangrove seeds to the western coast of Africa and as far south as New Zealand. This might explain why the mangroves of West Africa and the Americas contain fewer, but similar colonizing species, whereas those of Asia, India and East Africa contain a much fuller range of mangrove species (Bryant 1998).

3.6.3.1 Mangrove swamps along the east coast of South Africa

Mangroves extend form the Kosi system (26^{o}S) in the north to the Nahoon River (33^{o}S) in the south (Ward and Steinke 1982). In the Kosi system six mangroves are present: *Avicennia marina* (Forrsk.) Vierh. (White mangrove), *Bruguiera gymnorrhiza* (L.) Lam. (black mangrove), *Rhizophora mucronata* Lam. (red mangrove), *Acrostichum aureum* L. (mangrove fern), *Ceriops tagal* Perr. C B Robinson (tagal mangrove) and *Lumnitzera racemosa* Willd. (Kosi mangrove). The latter two species do not occur further south except as transplanted material in the Beachwood area of the Mgeni Estuary. In the estuaries of the southern Transkei *Avicennia marina* is common up until the Kobonqaba Estuary whilst further south this species occurs sporadically. The existence of this species is threatened by periodic floods and predatory sesarmid crabs that limit the spread further south. *Bruguiera gymnorrhiza* is sparse south of the Mbashe Estuary and its natural distribution ends at Wavecrest (Nxaxo Estuary*). Rhizophora mucronata*, which is common as far south as the Mtata Estuary and reaches its southern limit at the Bulungula River. *Acrostichum aureum* the mangrove fern extends into Pondoland (northern Transkei regions). The freshwater mangrove *Hibiscus tiliaceus*, which is a frequent associate of mangroves, is common to Mbashe Estuary, whereafter it may be found further south sporadically to the Nahoon River.

MacNae (1963) suggested that temperature was the most important limiting factor of the southward distribution of mangroves along the South African coast. He proposed, based on the then known distribution of mangroves, that mangroves only occur where the mean annual temperature does not drop below 19^0C. However, growth *of Avicennia marina* to maturity occurs under much colder conditions in Australia and New Zealand, as far south as the 38^0S (Clarke and Hannon 1967).

The southernmost distribution of *Avicennia marina* is found at the Nahoon Estuary, owing to the transplanting of propagules from Durban Bay, although it is possible that a stand further upstream did arise from the natural distribution of propagules (Steinke 1982). *A. marina* seedlings show vigorous growth, even in the face of competition from salt marsh species. *Bruguiera gymnorrhiza* has grown to the heights of 3 m to 4 m within sheltered regions of the Nahoon Estuary. This suggests that temperature is not a limiting factor of mangrove distribution. Research in South Africa and Australia has shown that the distribution of mangroves is limited by the paucity, longevity and limited dispersal of range of propagules (Steinke 1982; Clarke 1984). In a preliminary study Steinke experimented with *Avicennia marina* propagules from different estuaries. Propagules were shown to be either sinkers i.e. sink on shedding their pericarp, or floaters, i.e. remain buoyant on shedding their pericarp. While the different propagules showed large variations in buoyancy of floaters, those from the south produced mainly 'sinkers'. The difference was assumed to be climatic, with the colder climate (warm temperate region of the Transkei) in the south being responsible for the propagules of high density. However, samples obtained from the Kobonqaba River in 1978, 1981 and 1983 had a higher percentage of 'floaters' than surrounding estuaries showing that this was not always the case. Steinke further suggested that drought periods and resultant increases in salinity within these estuaries were likely causes.

It is probable that mangroves found in the southern Transkei (Mbashe Estuary to Nahoon Estuary) that produce a high proportion of sinking propagules, will contribute little propogative material for distribution elsewhere. In the absence of evidence for the involvement of environmental factors in determining buoyancy behaviour, it is suggested that estuaries such as the Mbashe, where almost all propagules are sinkers, there would appear to be little propogative material from fresh sources entering and becoming established in that estuary. In that case there is cause for concern for the future of these mangrove communities, because re-establishment would not follow easily on destruction of these mangroves (Steinke 1986).

3.6.3.2 Location of mangroves in South African estuaries

In addition to their geographical spread, mangroves are distributed within estuaries according to at least two other gradients, namely; freshwater input and their position along the intertidal profile (Duke 1992). Since the mangroves of South Africa exhibit such low species diversity compared to mangroves found in the Indo-pacific region i.e. six versus in excess of forty species, complex patterns of arrangement are not in evidence here (Watson 1928).

Steinke (1995) has described the two gradients with each having three different categories, including downstream, intermediate and upstream estuarine; and low, mid and high intertidal profiles. The physical conditions ascribed to these gradients have not been fully understood or quantified. Estuarine location categories are based on salinity where downstream represents values approaching 35 $g\ l^{-1}$, intermediate 5 $g\ l^{-1}$ to 20 $g\ l^{-1}$ and upstream approaches fresh water. The intertidal categories are essentially based on extent and frequency of tidal inundation. These categories only serve as guidelines as species can show marked variations, e.g., *Avicennia marina* can occur in the mouth of upper reaches and in the intertidal of supratidal areas of estuaries, while *Rhizophora mucronata* is very restricted in its distribution within an estuary (Steinke 1995). Table 3.4 summarises the distribution of the six mangrove species along the South African coast and within estuaries, while Table 3.5 summarises salinity and inundation tolerance of mangroves found in South Africa.

Table 3.4: Distribution of mangroves along the South African coast and within estuaries (adapted from Steinke, 1995). Key - Estuarine location: D = Downstream; I = Intermediate; U = Upstream Intertidal position; H = High; M = Mid; L = Low.

Mangrove	**Southern most natural distribution**	**Latitude**	**Estuarine location**	**Intertidal position**
Acrostichum aureum	Pondoland	31^{o}	I	H
Lumnitzera racemosa	Kosi Bay	26^{o}27’	D,I,U	M,H
Bruguiera gymnorrhiza	Wavecrest (Nxaxo Estuary)	32^{o}35’	D,I,U	M,H
Ceriops tagal	Kosi Bay	26^{o}54’	D,I	M,H
Rhizophora mucronata	Nahoon Estuary	32^{o}08’	D,I	L,M
Avicennia marina	Gqunube Estuary	32^{o}56’	D,I,U	L,M,H
Hibiscus tiliaceus	Nahoon Estuary	32^{o}59’	I,U	H

Table 3.5: Summary of mangroves species found along the South African coast with inundation and salinity tolerances as well as plant succession status.

Genus and Species	**Inundation tolerances**	**Salinity ranges** ($g.l^{-1}$)	**General**
Bruguiera gymnorrhiza	Roots better adapted to periodic submersion dieback after 4 - 5 months of submersion	15 – 20	Late pioneer. Seedlings prefer shade
Rhizophora mucronata	Intolerant of frequent periods of submersion	15 – 20	Late pioneer and found in dense stands along marginal creeks.
Ceriops tagal	Found on high ground flooded only by high spring tides	5 –16	Not a pioneer. Found on the interior of mangroves stands
Lumnitzera racemosa	Low inundation tolerance prefers high ground		Prefers landward margins of mangroves, i.e. Freshwater input
Avicennia marina	Sensitive to long periods of submersion (4 - 5 months)	5 – 35	Seedlings shade intolerant, optimum 15 - 20 $g.\ell^{-1}$
Acrostichum aureum	intolerant of frequent tidal inundation		Landward margins of mangrove

The fauna and certain elements of the KwaZulu-Natal coast have been shown to have affinities with the tropical Indo-West Pacific. Studies along the coast have indicated that within sheltered shores of the South African east coast, the communities show tropical affinities as opposed to the temperate organisms found along shores exposed to the open ocean. The mangroves along the east coast can be divided into two groups: The northerly group found along the Natal/Mozambique coast and the southerly group found along the Transkei coast down to East London. The southern group of mangroves are more typical in pattern and arrangement than are the northern mangroves. Examples of the zonation of the southern mangrove swamps are those found at the mouth of the Mngazana Estuary (31^{o}50’ S). The transition between the terrestrial plants and that of the mangroves influenced by the sea is abrupt even though there may be little change in elevation between zones. The highest of the mangroves zone is characterised by salt marsh plants at the spring high water mark. *Chenolea diffusa* Thunb., occupies this metre wide zone, forming dense stands, approximately 25 cm in vertical height. It is usually invaded from above by grasses that are tolerant of occasional submersion; *Stenotaphrum secundatum* (Walt.) O. Kuntze, *Sporobolus virginicus* (L.) Kunth. and *Paspalum vaginatum* Sw. The first two are more conspicuous and *Sporobolus virginicus* extends furthest towards the sea. This zone is followed by a zone of *Juncus kraussii* Hochst., a sedge which occupies exclusive areas, with conspicuous associates along the upper edges are the grasses listed above, while *Samolus porosus* Thunb. is scattered throughout. Under more waterlogged conditions the *Juncus kraussii* stands are sparser and *Sarcocornia pillansii* becomes more evident. The zone that follows has been termed the *Avicennia* parkland. Stands of *A. marina* occupy the intertidal flats, with the open areas covered by *Cotula coronopifolia* L., *Triglochin striata* Ruiz and Pav. and *Sarcocornia perennis* (Mill) A.J. Scott (Berjak et al. 1986). The mangroves extend down to the level of high water neap tides. *Avicennia marina* is the pioneer on the seaward and landward edges. Rarely is there more than one row of *A. marina* trees on the seaward edge in the Mngazana Estuary. Between the two ranges of *Avicennia* there is a thicket of *Bruguiera gymnorrhiza*. This thicket is reasonably open and individual trees are quite tall, some exceeding 7 m in height. *Rhizophora mucronata* is found to be more prevalent along channels, where the water is deeper. The final zone within the mangrove swamps of the Mngazana is a stretch of the submerged macrophyte *Zostera capensis* Setchel. on the steeply sloping outer banks of meanders below the pneumatophores of the *Avicennia marina* trees. On firm sand below the low watermark *Halophila ovalis* (R. Br.) Hook f. is found (MacNae 1963).

Plate 3.1: The Mngazana Estuary, the largest and most complex mangrove system along the Transkei coast. Three mangrove species are present and cover approximately 145 ha.

3.6.4 Factors affecting the colonisation and succession of mangroves

Naidoo (1986, 1987, 1990) studied the possible role of soils, osmotic potentials and salinity in influencing the establishment of different mangrove zones in the Beachwood area on the Mgeni Estuary and in the laboratory. Soil samples were collected from pure stands of *Avicennia marina* and *Bruguiera gymnorrhiza*. It was shown that there was an increase in sand content in the seaward edge of the *Avicennia* zone. This was attributed to the turbulent and churning action of tidal waters that only permitted the coarse fraction to settle out of suspension. *Avicennia* was also identified as the pioneer species at Beachwood and is able to colonise sandy substrates. Colonisation results in consolidation and stabilisation of the substrate. This, in turn, permits the accretion of finer particulate matter such as silt and clay. Once the nature of the substrate is altered sufficiently, not only by *Avicennia* colonisation, but also through soil forming processes, *Bruguiera* becomes established. The particle size distribution suggests that greater deposition of finer sediments is occurring further away from the water's edge. The higher proportion of fine soil fractions in the surface layers of the *Bruguiera* zone is probably due to slow rates of inundation of the swamp and to the low slope that allows water to remain in the swamp for prolonged periods. Most of the silt and clay deposited in the swamp originates from coastal rivers and the offshore sea areas.

Wolanski and Chapell (1996) identified that tidal currents in mangrove forests found in the Florida region are impeded by the friction caused by the high plant density. The currents are complex, comprising eddies, jets and stagnation zones. The sediment particles carried in suspension into the forest during tidal inundation are cohesive, mainly clay and fine silt, and form large flocs. These flocs remain in suspension as a result of the turbulence created by the flow around the vegetation. The turbulent intensity is largest for trees forming a complex matrix of roots such as *Rhizophora mangle* and smallest for single trees such as *Ceriops tagal*. The flocs settle in the forest around slack high tide. At ebb tides the water currents are too small to re-suspend this sediment. Hence, the inundation of coastal mangrove forests at tidal frequency works as a pump preferentially transporting fine, cohesive sediment from coastal waters to the mangroves. About 80% of the suspended sediment brought in from coastal waters at spring flood tide, was trapped in the mangroves, corresponding to about 10-12 kg of sediment.m^{-1} of creek length/spring tide, resulting in a rise of the substrate about 0.1 cm.y^{-1}. The selective trapping of clay was caused by flocculation of the finer particles in the mangroves (Wolanski and Chapell 1996). Mangroves are thus not just opportunistic trees colonising mud banks, but actively contribute to the creation of mud banks (Wolanski and Chapell 1996).

3.6.5 Vegetation change with tidal flat evolution

The variety of plant habitats within a deltaic-estuarine region are affected by geomorphic processes which strongly influence the habitats topographic form of the habitat, the frequency with which it is inundated by tides, the sediment type, the salinity of the soil water and the degree of soil aeration. Distribution and growth form of mangroves are also closely related to these interacting environmental factors. A short-term model of mangrove tidal flat development has been proposed with the consequent plant colonisation and succession of mangroves and associated vegetation (Thom et al. 1975). The short-term model covers erosion and deposition tendencies for up to twenty years over which changes can be documented. Short-term model changes in the Ord River, Northern Australia, can be divided into five stages:

Stage 1

Depending on the velocity of tidal currents, fine sediments are deposited forming small tidal flats not greater than 3 m in height above Mean Low Sea Levels (MLSL). The grass *Sporobolus virginicus* colonises the tidal flats with *Avicennia marina* mangrove seedlings being present, particularly when the surface rises to above 6 m above MLSL.

Stage 2

Dense *Avicennia marina* thickets develop rapidly on the recently emerged islands in the Ord channel over a period of 21 years (1948 - 1969). At this stage, with the flat between 6 and 7 m above MLSL and a monospecific community cover mid tidal flats. Surface sediments are wet, dark in colour and contain high levels of organic detritus. In the outer estuary, where wave processes are effective, it is apparent that after periods of mudflat progradation short periods of erosion occur.

Stage 3

In this stage most of the tidal flats are fixed in position. Vertical accretion as a result of tidal sedimentation is the dominant process. As the tidal flat rises toward the mean high water mark (MHWM), there is a reduction in tidal inundation, with sites furthest away from tidal channels receiving less tidal coverage. This stage is accompanied by the invasion of other mangrove species that are tolerant of shade (*Bruguiera* sp. *Ceriops tagal*). However, the innermost fringe of the mixed mangrove community, which locally may be internally zoned, is becoming progressively more open. At these dry, infrequently inundated sites, die-back is first evident, and *Avicennia* and *Ceriops* form a low shrub community mixed with *Sarcocornia* and *Sporobolus*.

Stage 4

The tidal flat has now reached mean high water spring mark (MHWS). At this stage dieback is a frequent phenomenon especially in those areas inundated only at the highest spring tides. Hypersalinity (ca. 40 $g\ l^{-1}$) of the soils is a feature of such sites and *Sarcocornia* may develop meadows surrounding the mangrove stumps. Bare areas also develop at this stage. In the outer estuary the inner margins of the *Rhizophora* and *Avicennia* - *Ceriops* zones also undergo initial dieback once the sloping flat attains an elevation at or slightly above MHWS.

Stage 5

With the bulk of tidal flat lying perched at or above MHWS, the bare high tidal surface at this stage reaches its maximum extent. Mangroves, either zoned or mixed, have contracted to the margins of channels. It is as though the retreat of plants from the rising flat has left a denuded surface in its wake. The salt marsh zone remains relatively constant in width and retreats with the mangrove. Small levees develop along the banks of tidal creeks and gullies.

3.6.6 Mangrove vegetation change in response to floods, cyclones and changes in tidal regime

Through natural and man-made events, mangroves along the northern Kwazulu-Natal coast have been subjected to a number of changes in the physical environment. Processes include physical removal due to cyclones and alteration of tidal regimes. The earliest account of mangrove loss is in the St Lucia Estuary (Breen and Hill 1969). A period of low flow resulted in mouth closure of the Kosi Estuary following Cyclone Claude and the level of the estuary was raised by 1.6 m. The mangrove swamps were inundated for a period of five months (August 1965 -January 1966) until the mouth was breached artificially. This resulted in dieback of the mangrove species inhabiting the lower elevated regions of the estuary. The greatest dieback was thus evidenced in the *Avicennia marina* and *Bruguiera gymnorrhiza* stands in which almost 90% of the mangroves were lost. In 1971 most of the mangrove swamps had been recolonised and species previously present had regenerated (Moll et al*.* 1971), but it was estimated that it would be a decade before the mangrove swamps would return to their former state (Bruton et al*.* 1975).

A similar scenario was seen in the Mgobezeleni lake-system at Sodwana, but as result of the construction of a low-level bridge in the upper reaches of the estuary. The bridge led to the restriction of tidal flow. Average salinity for this part of the estuaries was measured at 0.3 $g.l^{-1}$. MacNae (1963) had also surveyed this system, and found it to have the largest trees (all > 10 m) and suggested that this was due to the low salinity found in this lake-system. However, faunal species recorded in his survey had disappeared and had been replaced by freshwater species (mainly molluscs). Bruton (1980) further indicated that due to the construction of the bridge, resulting in this constant low salinity found in the system, further species would be replaced.

A further consequence of the bridge was the backflooding of the *Bruguiera gymnorrhiza* mangroves found in the upper reaches of the estuary which were then inundated for a period of four months (Bruton 1980). Attempts of alleviating the problem of poor tidal flow were made by reconstructing the bridge. However, this has only led to partial recovery of the mangroves. It is also estimated that complete recovery of the mangrove swamps would occur after a decade (Bruton et al*.* 1975).

The cyclones Domoina and Imboa struck the St Lucia area in 1984. Research at that time on the mangroves in the estuary made it possible to establish the effects of these cyclones (Steinke and Ward 1989). The heavy rains that accompanied the cyclones and the subsequent flooding of rivers raised lake levels (1.5 - 2.5 m) and the inundation of the mangrove stands resulted in mortality. Total counts of trees greater than one metre in height showed that *B. gymnorrhiza* suffered the greatest mortality (32.9% dead) followed by *A. marina* (16.2% dead) after four months of elevated lake water levels. The effects of the cyclones were both immediate and long term. The immediate effects comprised the breakage, uprooting and collapse of trees caused by the impact of floodwaters or on the substrate. Long-term effects on the mangroves were seen in the form of lowered propagative material produced for the first two seasons after the cyclones (1985/86). There was a further delayed effect on the mangroves that were manifested eight months after the floods. The trees showed signs of stress and leaf loss as a result of the fine fluvial sediments that retained moisture, but later compacted and formed hard impervious crusts. This possibly resulted in reduction in soil gaseous exchange and disturbance of soil root water relations, resulting in the visible stress and death of trees. Five years after the flood, recovery of the mangroves had occurred, with little damage evident. This further underlies the role of mangroves as stabilisers of highly dynamic coasts (Steinke and Ward 1989).

3.6.7 Importance and function of mangroves

Throughout the world there is a general realisation about the ecological and economic importance of the forests. Mangroves, being intertidal forests, are no exception. Their value as forests is no less than any tropical forest. Moreover, the importance of the mangroves is not merely in its forest value, but it is due to its strategic location between the land and the sea. Mangroves are the lifeline for any coastal area (Snedaker 1993).

Mangroves are buffers between the land and the sea. All shorelines are under the constant threat of erosion due to wave action and tidal motions. Mangrove plants stabilise shorelines and the banks of rivers and estuaries, providing them with some protection from these tidal bores, ocean currents and storm surges. There is a belief that the increasing floods in Bangladesh are due to loss of mangroves in the past few decades and there is not much disagreement regarding this view in the scientific community (Chapman 1984). Mangroves not only help in preventing soil erosion, but also reclaim land from seas. This is a very unique phenomenon, since there is a general tendency of water to engulf land. Mangrove forests and estuaries are the breeding and nursery grounds for a number of marine organisms including the commercially important shrimp, crab and fish species. Hence, loss of mangroves not only affects us indirectly but there are direct economic repercussions through the loss of the fishing industry (Blasco et al*.* 1998)

In many countries of Southeast Asia and the Pacific, mangroves are used commercially for the production of timber for building, firewood and charcoal. Experience has shown that when these activities are managed appropriately it is possible to derive timber products from mangrove forests without significant environmental degradation, and while maintaining their value as a nursery and a source of food for commercial capture fisheries (Blasco et al. 1998).

In many coastal areas mangroves are a substitute for fodder. Thus, mangroves reduce pressures from the scarce pasturelands. Till recently, mangroves were the main source of tannin for the leather industry and are still exploited in many areas in India. Mangrove wood has a high calorific value and burns very well. This ability of mangroves has become a curse for it since in most coastal areas, rural or urban, communities are heavily dependent on mangrove wood for fuel. Honey collection from mangrove areas is practised exclusively in West Bengal and Orissa. The finest quality of honey that fetches a good price is collected from mangroves. Above all, mangroves are now looked after by scientists as saviours in today's scenario of global warming. We all know that most of the coastal areas throughout the world are going to be affected by sea level rise due to global warming, the effects of which are already visible. Therefore, when most of the coastal areas will be flooded, mangroves can possibly provide a gene bank for cultivating salt tolerant species of crops that could be our future resource (Bandaranayake 1998).

3.6.8 The importance for local communities

Local populations for the production of food, medicines, tannins, fuel wood, and construction materials have traditionally managed mangrove ecosystems sustainably. For millions of indigenous coastal residents, mangrove forests offer dependable, basic livelihoods and sustain their traditional cultures (Bryant 1998).

The protective mangrove buffer zone helps minimise damage of property and losses of life from hurricanes and storms. In regions where these coastal fringe forests have been cleared, tremendous problems of erosion and siltation have arisen, and sometimes terrible losses to human life and property have occurred due to destructive storms. Mangroves have also been useful in treating effluent, as the plants absorb excess nitrates and phosphates, thereby preventing contamination of nearshore waters (Snedaker 1993).

3.6.9 Future threats and management

Naturally resilient, mangrove forests have withstood severe storms and changing tides for many millennia, but they are now being devastated by modern encroachments. Today, mangrove forests are among the most threatened habitats in the world, disappearing at an accelerating rate, yet with little public notice. Lenticels in the exposed portions of mangrove roots are highly susceptible to clogging by crude oil and other pollutants, attacks by parasites, and prolonged flooding from artificial dikes or causeways (Chapman 1984). Over time, environmental stress can kill large numbers of mangrove trees. In addition, the charcoal and timber industries have also severely impacted mangrove forests, as well as tourism and other coastal developments (Blasco et al. 1998).

The rapidly expanding shrimp aquaculture industry poses the gravest threat to the world's remaining mangroves. Literally, thousands of hectares of lush mangrove forests have been cleared to make room for the artificial shrimp ponds of this boom and bust industry. This highly volatile enterprise has grown exponentially over the last 15 years, leaving devastating ruin in its wake (Dugan 1993).

Until recently, mangrove forests have been classified by many governments and industries alike as "wastelands", or useless swamps. This erroneous designation has made it easier to exploit mangrove forests as cheap and unprotected sources of land and water for shrimp farming. The amount of mangrove forest destruction is alarming. Thailand has lost more than half of its mangrove forests since 1960. In the Philippines, mangroves have declined from an estimated 448 000 ha in the 1920s to only 110 000 ha by 1990. In Ecuador, estimates of mangrove loss range from 20% to nearly one half of Ecuador's once 362 000 ha. of mangrove forested coastline. The Muisne region of Ecuador alone has lost nearly 90% of its mangroves. Globally, as much as 50% percent of mangrove destruction in recent years has been due to clear cutting for shrimp farms (Bryant 1998).

3.6.10 Protecting mangrove forests

The failure of the national government to adequately regulate the shrimp industry, and the headlong rush of multilateral lending agencies to fund aquaculture development without meeting their own stated ecological and social criteria, are other important pieces to this unfortunate puzzle (Dugan 1993). The fate of remaining mangrove forests may now rest in the hands of the consumers from the wealthy nations that import these luxury shrimp products. Meanwhile, stricter local governmental regulations and enforcement protecting mangroves are necessary. Also, involvement of local communities in sustainably managing and protecting their coastal resource base, including the nearby mangrove forests, is essential (Bryant 1998).

4 A BOTANICAL IMPORTANCE RATING SYSTEM FOR ESTUARIES

4.1 INTRODUCTION

The need to classify and rate estuaries along the South African coast has become necessary due to increasing human demand for freshwater resources. Emphasis has been placed by the Department of Water Affairs and Forestry (DWAF) on the need for rapid determinations of the conservation status and habitat integrity of an estuary which is considered potentially suitable for water abstraction. Estuaries are protected under the National Water Act as they have a right to water. The ecological reserve has to be determined i.e. the amount of water required by the estuary.

There are a number of ways to assess estuary importance and status. These are either based on the status of the estuarine plants (Coetzee et al*.* 1996, 1997; Riddin 1999; Colloty et al*.* 2000), birds (Turpie 1995) or the Fish health index (Harrison et al*.* 1999a; 1999b). The Fish health index (FHI) rates an estuary based on its fish communities, water quality and aesthetic qualities (Harrison et al*.* 1999a; 1999b). Botanical importance can also be used, as an indicator of ecosystem status because plants are the primary producers and will influence the status or condition of all higher trophic levels.

A botanical importance rating was developed by Coetzee et al*.* (1996, 1997). Botanical importance was defined as the contribution of the estuarine plants to the conservation status of an estuary. This rating system was revised to include swamp forest, mangroves, macro- and microalgae. Subsequently, the concept of functional importance was introduced, i.e. the sum of the area covered by the different plant community types multiplied by an average productivity value. An estuary will have a high function importance score if it contains a large or diverse number of habitats (Colloty et al*.* 1998). The more plant community types in an estuary the greater the number of interactions that occur between plants and other organisms (Adams and Bate 1994).

Estuarine management and conservation must incorporate the maintenance of estuarine habitat, and protect the maximum variety of habitat types (Riddin 1999). However to assess the conservation importance of any system, criteria that are related to biodiversity must also be considered. Measures of biodiversity include the number of species, biological communities or ecosystems (Bryant 1998). Biodiversity can also be assessed through the description of species distribution patterns. Areas that contain high levels of rare or endemic species need protection. The term “hot spot” has been used to describe regions that contain a high level of endemism (Myers 1990). Seven botanical “hot spots” have been identified in South Africa, but they only include terrestrial species (Cowling and Hilton-Taylor 1994, Hilton-Taylor 1996).

The most appropriate way to protect biodiversity would be to conserve all habitats that have a high biodiversity, a large number of rare species or endemics. However, this is not possible and conservation efforts need to be prioritised in terms of areas that have high levels of conservation importance (Dugan 1993).

Turpie et al*.* (1999) suggested that the conservation importance of an estuary could be determined if a rating method included aspects such as species richness, community richness and habitat rarity. An assessment of the botanical importance of an estuary should include the following: functional importance, species richness, plant community type richness and habitat rarity. Usual measures of conservation importance such as species rarity or endemism do not apply to estuarine plants, as most are common or widespread. (O'Callaghan 1990a, 1990b).

Use of multi-criteria indices have been criticized because they hide the value of the individual components (Turpie 1995), but if the separate components of an index or rating system are kept transparent, then the final values can remain meaningful to the user. The value should also communicate valid summaries of information (Hopkinson et al*.* 1978). It is the intention of the revised botanical importance system to rate the botanical importance of an estuary through the summation of a number of components. Each of these components are then used to interpret the final score or rate an estuary without loss of information.

The change in functional importance over time can be used as a measure of botanical habitat integrity. Other terms synonymous with integrity include habitat status and habitat condition (Turpie et al*.* 1999). An ecosystem exhibits integrity if, when subjected to disturbance, it retains the ability to recover toward a state that is normal for that system. Habitat integrity has been determined using the change in plant cover over time, measured from past records or aerial photos for the Swartkops Estuary (Colloty et al*.* 2000). Habitat integrity has also been used to highlight the conservation importance of estuaries in the northern Eastern Cape Province (Pondoland – Transkei) (Colloty et al. 1999).

4.2 MATERIALS AND METHODS

4.2.1 Assessment of area from aerial photographs, past literature and field surveys

The area (ha) covered by the different plant community types was measured from 1:50 000 topographic maps, aerial photographs (Directorate Surveys and Institute for Coastal Resource Management, University of Port Elizabeth) and published values. Vertical aerial photographs were converted into digital images (Hewlett-Packard Scanner 4C). The digital images were then scaled using known distances calculated from topographic maps. The area covered by the different plant community types was measured using image analysis software (analySIS 3.0 - ISAT). The minimal area considered was 0.1 ha because this was the smallest accurate area that could be measured on aerial photographs. Available information on other South African estuaries was obtained from Riddin (1999) and Walker (pers. comm.), who extended the application of the botanical importance rating to estuaries in regions where little or no information was previously available. Coetzee et al*.* (1997) summarised information contained in the CSIR Estuaries of the Cape report series for 33 estuaries.

4.2.2 Application of the botanical importance rating formula

The botanical importance rating is as follows:

Botanical importance = Functional importance + Species richness + Community richness + Sum of habitat rarity scores of each plant community type present.

All the component scores were tested for correlation with the existing functional importance index scores. If there was a high degree of correlation between any of the components there would be a risk of double counting the importance criteria. If any correlations were found then that particular component could be left out. However, no correlations were found between the different components ($r<0.45$, $p>0.05$, $n=179$) and all components could be retained.

In order to sum the various scores, they have to be normalised. Normalised scores are used to reduce the size of scores and simplify comparisons between estuaries. The functional importance score was normalised by assigning the estuary with the highest score a value of 100. All other estuaries were then expressed as a percentage of that. Each of the components (i.e. species richness, functional importance, plant community type richness and plant community type rarity) was assigned a set of ranges to convert the raw data scores into smaller numbers. If raw data scores were used then one would have to compare a wide range of score values for the different components, for example the St Lucia Estuary had a functional importance score of ca. 2 009 023 and a species richness score of 27 (Fig. 4.1). All the score ranges are from zero to one hundred and the ranges were determined using a percentile test for each of the component scores (Statistica – Statsoft Inc. version 98). A percentile (Galton 1885) of a distribution of values is a number that indicates the percentage of values between a range of scores that occur in that percentile (see the first and second column of Table 4.3). The score data were not normally distributed (geometric distribution, $p<0.05$, $n=179$) and thus the percentiles for the ranges could be skewed towards the scores that occurred less frequently. Using the percentiles, the number of estuaries that occurred within each of the ranges could be determined. In turn, the number of estuaries that occurred within each percentile was subtracted from 100 and rounded up to the nearest multiple of 5 to maintain the skewed distribution of scores, i.e. 1 estuary had a normalised functional importance score >70.57 (Table 4.3). Therefore, the final functional importance score for any estuary within this range (>70.57) of normalised scores is 100 (100–1=99 rounded up to 100). This was done for all the components of the botanical importance rating as shown in the example (Table 4.3). Converting scores into ranges simplifies the construction of a rating formula while retaining information and has consequently also been used in the estuarine importance rating (Turpie et al. 1999).

None of the components receive any further weighting in order to ensure that the botanical importance rating system is objective and each of the components can contribute equally to the overall importance of the estuary. This is possible as the separate components bear no relationship to each other and allow for the summation of the components.

4.2.2.1 Functional importance

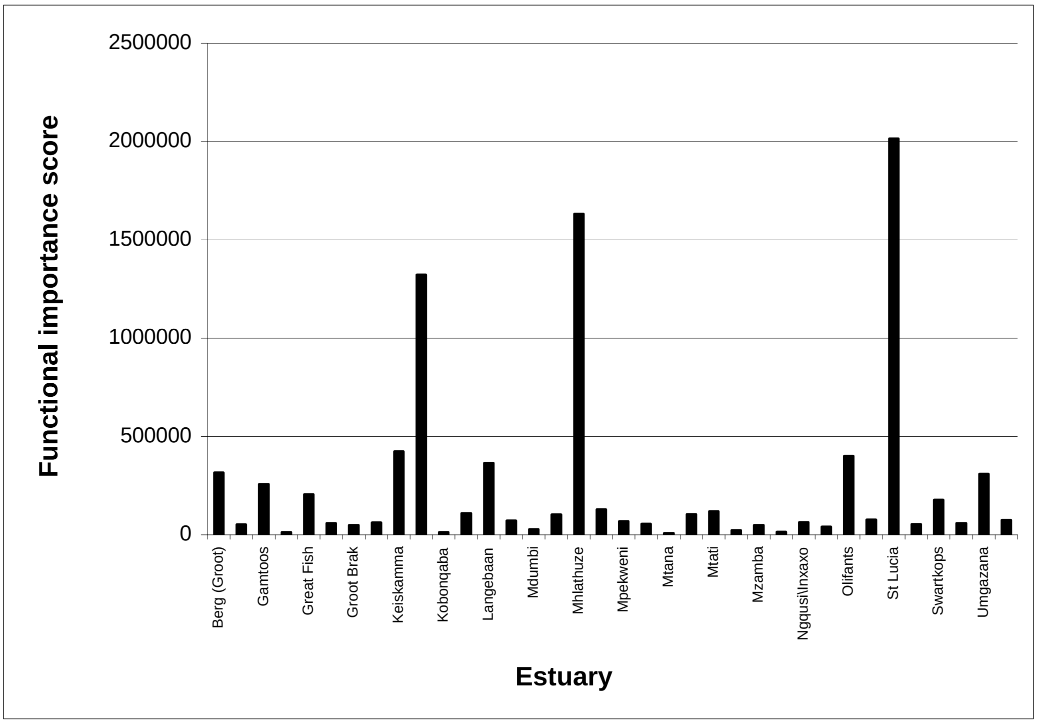
Functional importance was based on the area and number of different plant community types and their contribution in the form of energy input (i.e. primary productivity). The functional importance formula includes all estuarine plant community types, namely, salt marsh, reeds and sedges, benthic microalgae (found in the intertidal sand and mudflats) and phytoplankton. The term plant community type is used as the plants do not exist as separate communities or populations. At times these plant community types are found as monospecific stands. The extent of the phytoplankton community type was calculated as the area covered by water on the slack low tide. This allowed for comparison with other plant community types without including intertidal communities twice. Average primary productivity values were calculated from available South African literature (Table 4.1). The exception was the values for the supratidal salt marsh (Colloty et al. 2000) and similar genera found in overseas publications have been used for the present.

Table 4.1: Primary productivity values for the nine estuarine plant community types.

Species	Productivity (g biomass d.w. $m^{-2}.y^{-1}$)	Locality (Estuary)	Reference	Methods
Supratidal salt marsh				
Sarcocornia cynosuroides	792	Louisiana, USA	Hopkinson et a*l.* 1978	Change in biomass
Sarcocornia oleyni	880	Louisiana, USA	Hopkinson et al*.* 1978	Change in biomass
Average	**836**			
Intertidal salt marsh				
Spartina maritima	651	Swartkops	Pierce 1979	Change in biomass
Average	**651**			
Reeds and sedges				
Typha latifolia	1 249	Swartvlei	Howard-Williams and Liptrot 1980	Production/biomass ratios
Schoenoplectus littoralis	1 004	Swartvlei	Howard-Williams and Liptrot 1980	Production/biomass ratios
Schoenoplectus littoralis	960	Bot River	Bally et al*.* 1985	Change in biomass
Phragmites australis	930	Swartvlei	Howard-Williams and Liptrot 1980	Production/biomass ratios
Phragmites australis	1 621	Swartvlei	Howard-Williams and Allanson 1981	Unknown
Phragmites autralis	1 790	Bot River	Bally et al*.* 1985	Change in biomass
Phragmites australis	2 140	Siyaya	Benfield 1984	Change in biomass
Average	**1 384**			
Submerged macrophytes				
Chara globularis	231	Swartvlei	Howard-Williams and Liptrot 1980	O_2 Light/dark bottle method
Chara globularis	236	Swartvlei	Howard-Williams 1978	O_2 Light/dark bottle method
Chara globularis	2 230	Bot River	Bally et al*.* 1985	Change in biomass
Potamogeton pectinatus	415	Swartvlei	Howard-Williams and Liptrot 1980	Production/biomass ratios
Potamogeton pectinatus	2 506	Swartvlei	Howard-Williams and Allanson 1981	O_2 Light/dark bottle method

Table 4.1 continued

Species	Productivity (g biomass d.w. m^{-2} y^{-1})	Locality (Estuary)	Reference	Methods
Potamogeton pectinus	4 124	Bot River	Bally et al. 1985	Change in biomass
Ruppia cirrhosa	83	Swarvlei	Howard-Williams and Liptrot 1980	Production/biomass ratios
Average	**1 316**			
Mangroves				
Avicennia marina	6 013	St Lucia	Steinke 1995	Litter production
Avicennia marina	1 056	Mhlathuze	Steinke 1995	Litter production
Brugueria gymnorrhiza	1 498	Mgeni	Steinke 1995	Litter production
Brugueria gymnorrhiza	702	St Lucia	Steinke 1995	Litter production
Brugueria gymnorrhiza	824	Mgeni	Steinke 1995	Litter production
Rhizophora mucronata	917	Mhlathuze	Steinke 1995	Litter production
Average	**1 835**			
Intertidal benthic microalgae				
	57	Swartkops	Pierce 1979	Fielding and Damstra conversion (Fielding et al. 1988)
	150	Sundays	Rodriguez 1994	Fielding and Damstra conversion (Fielding et al. 1988)
	182	Bot River	Bally et al. 1985	Fielding and Damstra conversion (Fielding et al. 1988)
Average	**163**			
Phytoplankton				
	57	Swartkops	Pierce 1979	Henry et al. (1977) conversion
	250	Sundays	Hilmer et al. 1990	$^{14}CO_2$
	182	Bot River	Bally et al. 1985	Henry et al. (1977) conversion
Average	**163**			
Macroalgae				
Enteromorpha sp.	129	Swartvlei	Whitfield 1988	Change in biomass
Caulerpa filiformis	329	Sundays	Talbot et al.1990	Production/biomass ratio
Cladophora sp	132	Palmiet	Branch et al. 1984	Change in biomass
Average	**196**			
Swamp forest				
Hibiscus tiliaceus	2 220	Siyaya	Schleyer and Roberts 1987	Litter production
Barringtonia racemosa	1 560	Siyaya	Schleyer and Roberts 1987	Litter production
Average	**1 890**			



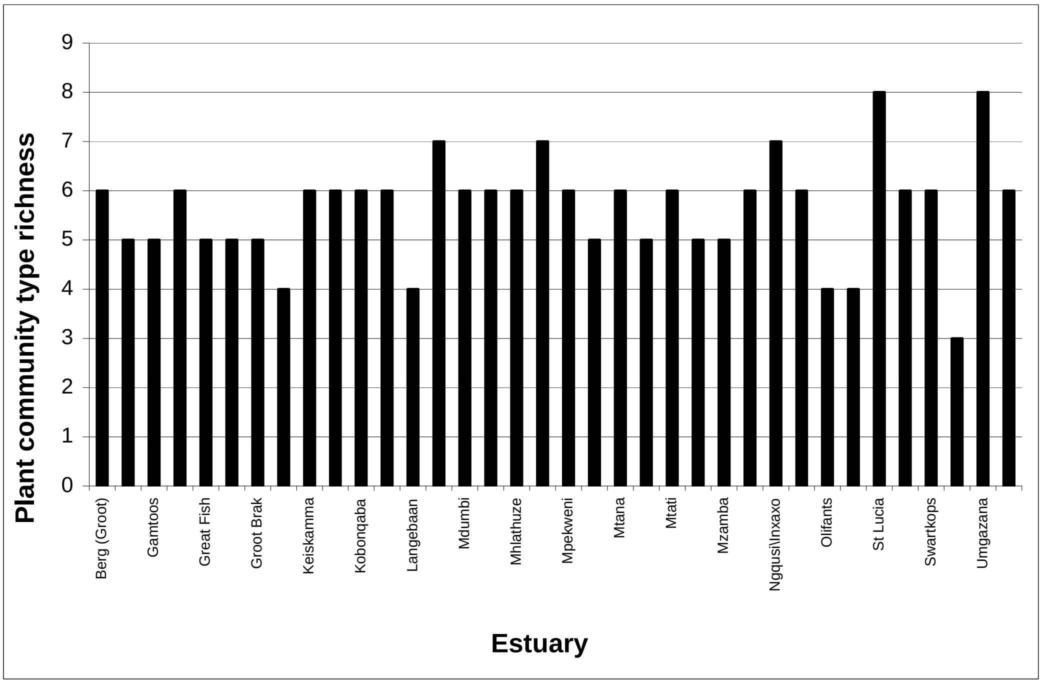
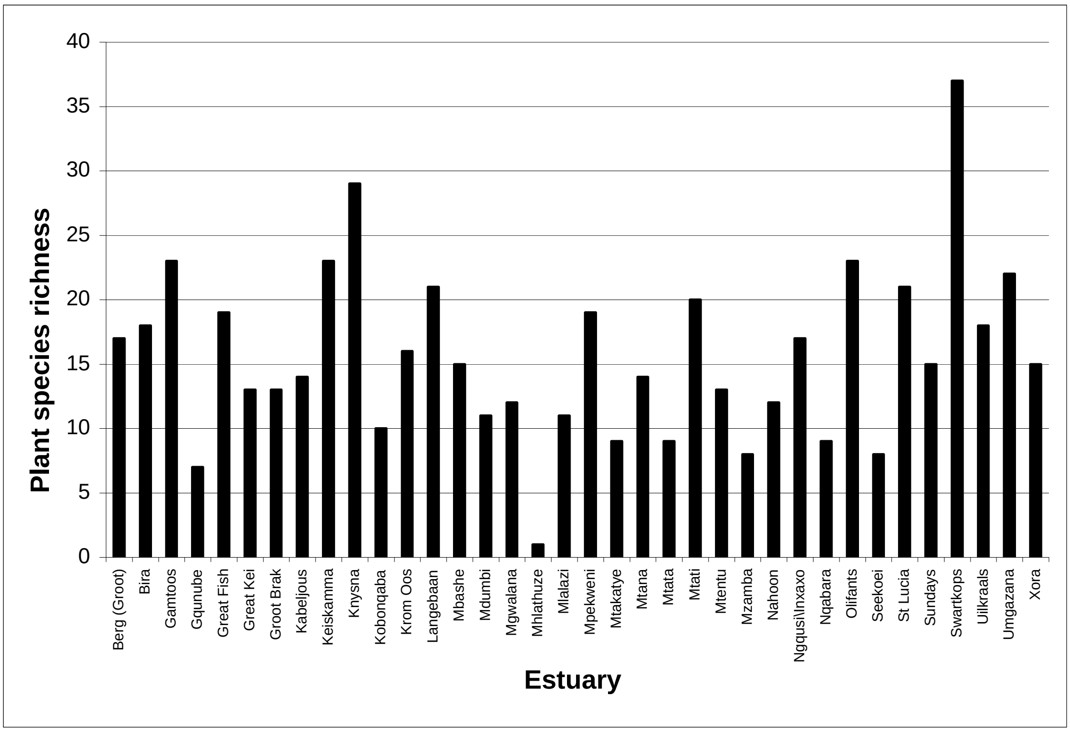


Figure 4.1a: Graphic representation of the wide range of raw data scores for each of the individual components used in the botanical importance rating. Only ten estuaries with the highest scores are shown.



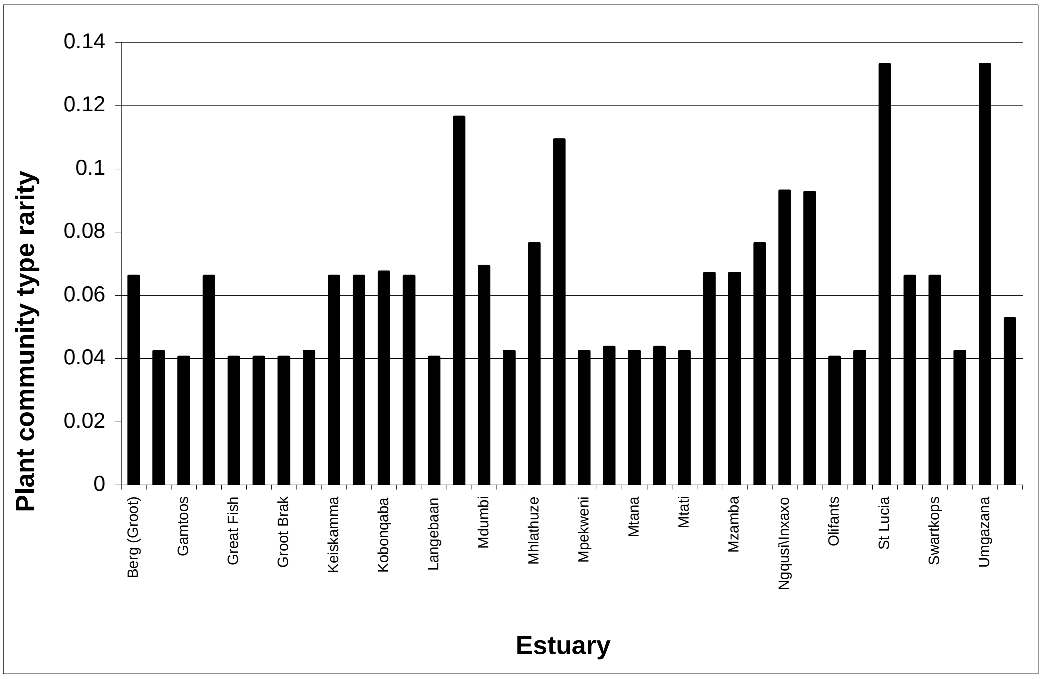


Figure 4.1b: Graphic representation of the wide range of raw data scores for each of the individual components used in the botanical importance rating. Only ten estuaries with the highest scores are shown.

The formula for the functional importance is as follows (Table 4.2):

Functional importance = $a(Area_{sup}) + b(Area_{int}) + c(Area_{sub}) + d(Area_{ree}) + e(Area_{man}) + f(Area_{ben}) + g(Area_{phy}) + h(Area_{macro}) + i(Area_{swamp})$

Table 4.2: The community types and average productivity values for the different estuarine plant community types used in the functional importance rating.

Plant community type (cover in ha)	**Productivity abbreviation**	**Productivity value ($g\ m^{-2}\ y^{-1}$)**
$Area_{sup}$ = Supratidal salt marsh	a	836
$Area_{int}$ = Intertidal salt marsh	b	651
$Area_{sub}$ = Submerged macrophytes	c	1 316
$Area_{ree}$ = Reeds and sedges	d	1 384
$Area_{man}$ = Mangroves	e	1 835
$Area_{ben}$ = Intertidal benthic microalgae	f	124
$Area_{phy}$ = Phytoplankton	g	163
$Area_{macro}$ = Macroalgae	h	196
$Area_{swamp}$ = Swamp forest	i	1 890

The functional importance scores were then applied to the following ranges in Table 4.3. This was done for each of the rating components separately, but the following will serve as the example of score generation.

Table 4.3: The range of normalised functional importance scores and the respective functional importance scores used in the botanical importance rating system.

Percentile	Number of estuaries	Range of normalised functional importance scores	Functional importance score
0.0	100	< 0.1	0
0.2	79	0.1-0.2	20
0.7	69	0.2-1.5	30
0.8	60	1.4-2.1	40
1.5	47	2.1-2.7	50
3.4	34	2.8-5.0	65
6.2	22	5.0-14.3	75
36.9	13	14.4-70.5	85
81.0	1	>70.5	100

Example: Calculation of the functional importance score for the Mngazana Estuary, found in the Transkei region, is shown in Table 4.4

Table 4.4: Functional importance of the Mngazana Estuary found in the Transkei region of the Eastern Cape Province.

Plant community type	**Area cover (ha)**	**Area x productivity**
Intertidal salt marsh	1.3	813.7
Supratidal salt marsh	7.4	6 186.4
Submerged macrophytes	0.8	1 052.8
Reeds and sedges	11.4	15 777.6
Mangroves	145.0	266 075.0
Intertidal benthic microalgae	5.6	694.4
Phytoplankton	49.8	8 120.1
Swamp forest	7.8	13 884.0
Functional importance score		312 604.0
Normalised score		15.6

The Mngazana Estuary had a normalised score of 15.56 when it was normalised against St Lucia which obtained the highest functional importance score of 2 009 023. Therefore, the Mngazana Estuary obtained a final functional importance score of 85 when applied to the set of ranges shown in Table 4.3.

4.2.2.2 Species richness

A species list was compiled for the 179 estuaries included in the national importance rating. The total number of plant species for each estuary was used as a species richness value. The species richness score was obtained using the ranges in Table 4.5.

Table 4.5: The number of species that might be found in an estuary and the respective species richness score. The species richness scores were obtained using a percentile range test.

Number of species	**Species richness score**
1-4	40
5-11	60
12-16	80
17-20	90
>20	100

Example: The Mngazana Estuary contains 22 estuarine plant species. This estuary received a species richness score of 100 as determined from Table 4.5.

4.2.2.3 Plant community type richness

The number of community types present was applied to the ranges in Table 4.6 to obtain the community richness score. The plant community type richness scores are obtained from a percentile range test.

Table 4.6: The number of community types that might be found in an estuary and the respective community richness score.

Number of plant community types	Plant community richness score
1-3	20
4	40
5	60
6	80
7-9	100

Example: The Mngazana Estuary contains eight of the nine plant community types and received a plant community type richness score of 100 as determined from Table 4.6.

4.2.2.4 Plant community type rarity

A weight has been assigned to the six least common community types found in South Africa. For example, if that community type only occurs once, it receives a score of one. If a community type is found in 35 estuaries it receives a weight of 1/35. The weights of each community type found in each estuary are then added, to obtain a final score. An estuary will have a high score if it contains many community types that are rare. To obtain a plant community type rarity score, the sum of weights was then applied to the ranges in Table 4.7.

Table 4.7: Rarity weights and the respective community rarity scores.

Sum of weights	Plant community type rarity score
0.000-0.019	20
0.020-0.029	40
0.030-0.040	60
0.041-0.050	80
0.051-0.067	95
0.068-0.130	100

Example: The Mngazana Estuary contains five plant community types used in the plant community type rarity calculation:

Intertidal salt marsh - 0.024 (found in 42 estuaries)
Supratidal salt marsh - 0.016 (found in 61 estuaries)
Submerged macrophytes - 0.026 (found in 39 estuaries)
Mangroves - 0.027 (found in 37 estuaries)
Swamp forest - 0.04 (found in 25 estuaries)
Total = 0.1331

Therefore, the Mngazana Estuary receives a community rarity score of 100 (Table 4.7) as it contains a high number of plant community types that are rare.

4.3 RESULTS

Sixty five percent of the estuaries found in South Africa (179 estuaries) had information that could be used to determine their botanical importance. The raw data of the estuaries are given in the Appendix. Table 4.8 summarises the national botanical importance of the 36 estuaries with the highest scores. The scores of these estuaries ranged from 245 – 400, whereas for all South African estuaries the scores ranged from 20 to 400. Twelve of these estuaries occur in the former Transkei region and seven in the former Ciskei region of the Eastern Cape Province. This means that 16% of Transkei estuaries and 44% of Ciskei estuaries are included in the estuaries with the highest scores.

The combination of the four components in the botanical importance rating system allowed estuaries to be rated important for different reasons and not only according to size. This was because the individual components were not weighted and all scores ranged between 0 and 100. This allowed each of the components to influence the final score for an estuary.

The St Lucia, Mngazana, Knysna and Swartkops Estuaries were important because they had high functional importance scores, community richness and community rarity (Table 4.8). The Berg, Mbashe and Nxaxo Estuaries were ranked high because of their high functional importance and species richness scores, plant community type richness scores or plant community type rarity (Table 4.8).

Five estuaries that were expected to have higher importance scores included the Berg, Mhlathuze, Olifants, Orange and Langebaan Estuaries. These estuaries were ranked lower than expected through either having low species richness, community richness or community rarity (Table 4.8). In particular, the Mhlathuze Estuary was expected to have a high national importance as it contains the largest mangrove stand in South Africa. However, although these mangroves cover 652 ha, species richness overall is low (11 species).

The combination of the components in the botanical importance rating allowed the small estuaries with low functional importance scores, which have rich or rare plant community types, and led to high importance scores. For example, the moderately sized (between 141 and 286 ha), temporarily open Mtati, Mgwalana and Mpekweni Estuaries found in the former Ciskei region were rated 11th and 16th respectively (Table 4.8). The remaining estuaries in Table 4.8 all had lower functional importance of between 50 and 75, such as the Mlalazi, Nqabara, Nahoon, Mdumbi and Kobonqaba. However, these estuaries were included in the 36 estuaries with the highest scores because they had mangroves that are found in only 37 South African estuaries.

Three estuaries that were not expected to be ranked in amongst these 36 estuaries were the Kabeljous, Seekoei and Uilkraals. These three estuaries are found in the South Cape region of South Africa, are moderately small and temporarily open/closed. However, these three estuaries have large areas of macroalgae or submerged macrophytes that depend on mouth condition. Past area assessments for these estuaries were undertaken during their closed states when large areas of the submerged macrophytes had developed. In some cases, these plant community types dominate up to 65% of the entire estuary area (Appendix). This coupled with the high productivity value of this plant community type, elevates the functional importance of these estuaries. Consequently, these estuaries received high botanical importance scores.

Table 4.8: The 36 estuaries with the highest botanical importance scores in South Africa. The components of the botanical importance formula are shown and the final botanical importance scores are indicated in bold.

Estuary	**Functional importance**	**Species richness**	**Plant community type richness**	**Plant community type rarity**	**Botanical importance**
St Lucia	100	100	100	100	**400**
Mngazana	85	100	100	100	**385**
Knysna	85	100	80	95	**360**
Swartkops	75	100	80	95	**350**
Berg (Groot)	85	90	80	95	**350**
Mbashe	65	80	100	100	**345**
Olifants	85	100	80	80	**345**
Nxaxo	50	90	100	100	**340**
Keiskamma	65	100	80	95	**340**
Mlalazi	75	60	100	100	**335**
Krom Oos	75	80	80	95	**330**
Mhlathuze	85	60	80	100	**325**
Langebaan	85	100	60	80	**325**
Xora	65	80	80	95	**320**
Mtati	65	90	80	80	**315**
Mgwalana	75	80	80	80	**315**
Gamtoos	75	100	60	80	**315**
Sundays	50	80	80	95	**305**
Great Fish	75	90	60	80	**305**
Nahoon	30	80	80	100	**290**
Great Kei	65	80	60	80	**285**
Nqabara	40	60	80	100	**280**
Mpekweni	50	90	60	80	**280**
Bira	50	90	60	80	**280**
Mtata	75	60	60	80	**275**
Groot Brak	50	80	60	80	**270**
Mdumbi	30	60	80	100	**270**
Kobonqaba	30	60	80	100	**270**
Mtana	30	80	80	80	**270**
Mzamba	50	60	60	95	**265**
Kabeljous	65	80	40	80	**265**
Gqunube	30	60	80	95	**265**
Mtentu	30	80	60	95	**265**
Uilkraals	65	90	20	80	**255**
Mtakatye	50	60	60	80	**250**
Seekoei	65	60	40	80	**245**

4.3.1 Botanical importance in the different biogeographic regions

Warm temperate estuaries

Thirty estuaries had the twenty highest botanical importance scores in the warm temperate region of the South African coastline (Table 4.9). Nine of these are found in Ciskei and four in Transkei (Table 4.9). The Knysna, Swartkops, Nxaxo and Keiskamma Estuaries had the highest scores as a result of their high functional importance and species-richness scores (Table 4.9). The Nxaxo Estuary contains a fringe of mangroves that resulted in the high community richness and rarity scores. The Keiskamma, Knysna and Swartkops Estuaries contain extensive inter- and supratidal salt marshes, reed, sedges and submerged macrophytes. When the large subtropical and cool temperate estuaries are not considered (Mngazana, Mhlathuze, Berg and Olifants Estuaries) then the Koega, Bot/Kleinemond, Gqutywa, Hartenbos, Qinira, Keurbooms, Tyolomnqa and Silvermine Estuaries were ranked more important in this comparison (Table 4.9). This increased the range of botanical importance scores from 230 - 374, while for the national comparison, the scores ranged from 245 – 400. The estuaries that had the twenty highest scores all contain salt marsh that increased the species richness and community richness scores (Table 4.8).

Table 4.9: Thirty warm temperate estuaries with the highest botanical importance scores.

Estuary	Functional importance	Species richness	Plant community type richness	Plant community type rarity	Botanical importance
Knysna	85	100	80	95	360
Swartkops	75	100	80	95	350
Nxaxo	50	90	100	100	340
Keiskamma	65	100	80	95	340
Krom Oos	75	80	80	95	330
Gamtoos	75	100	60	80	315
Sundays	50	80	80	95	305
Mgwalana	65	80	80	80	305
Great Fish	75	90	60	80	305
Mtati	50	90	80	80	300
Nahoon	30	80	80	100	290
Great Kei	65	80	60	80	285
Nqabara	40	60	80	100	280
Mpekweni	50	90	60	80	280
Bira	50	90	60	80	280
Groot Brak	50	80	60	80	270
Kobonqaba	30	60	80	100	270
Mtana	30	80	80	80	270
Kabeljous	65	80	40	80	265
Gqunube	30	60	80	95	265
Uilkraals	65	90	20	80	255
Bot/Kleinmond	85	90	60	20	255
Koega	30	80	60	80	250
Gqutywa	30	60	80	80	250
Hartenbos	30	100	40	80	250
Seekoei	65	60	40	80	245
Keurbooms	65	90	40	40	235
Silvermine	30	60	60	80	230
Qinira	40	60	40	80	220
Tyolomnqa	40	80	60	40	220

Subtropical estuaries

Twenty-eight estuaries had the top twenty highest scores in the subtropical biogeographic region. Permanently open estuaries that contained mangroves and swamp forest (Table 4.10) had the highest scores. St Lucia Estuary is the largest system in South Africa and covers approximately 38 290 ha. This estuary received the highest scores in all components of the botanical importance rating as it has extensive areas of all the plant community types. Sixteen of the subtropical estuaries were found in Transkei (Table 4.10). No Ciskei estuaries occur in the subtropical region. The estuary with the second highest score, the Mngazana is characterised by extensive mangrove (145 ha) and salt marsh areas (25 ha). This resulted in a high functional importance, species richness and community richness and rarity. The remaining estuaries showed a wide range of scores from 160 to 400 as shown in Table 4.10. Low scores could generally be attributed to low functional importance and community richness scores. Most of these estuaries are small or channel-like and contain only reeds, sedges and swamp forest species, with some containing submerged macrophytes. Swamp forest only occurs in 25 of the 179 estuaries, whereas reeds and sedges occur in 151 of the estuaries surveyed. This elevated the scores of the small estuaries that contained swamp forest and submerged macrophytes such as the Siyaya (7.69 ha) and Mdlotane (25.42 ha) Estuaries (Table 4.10).

Table 4.10: Twenty eight estuaries with the highest scores in the subtropical region.

Estuary	Functional importance	Species richness	Community richness	Habitat rarity	Botanical importance
St Lucia	100	100	100	100	400
Mngazana	85	100	100	100	385
Mbashe	65	80	100	100	345
Mlalazi	75	60	100	100	335
Mhlathuze	85	60	80	100	325
Xora	65	80	80	95	320
Mtata	75	60	60	80	275
Mdumbi	30	60	80	100	270
Mzamba	50	60	60	95	265
Mtentu	30	80	60	95	265
Mtakatye	50	60	60	80	250
Mntafufu	30	60	60	95	245
Mzintlava	30	60	60	95	245
Siyaya	30	60	60	95	245
Mhlanga	75	40	20	95	230
Mdlotane	75	20	40	95	230
Mzimvubu	65	60	40	60	225
Nhlabane	30	60	40	95	225
Mdloti	40	60	40	60	200
Mbotyi	30	60	40	60	190
Mgwegwe	30	60	40	60	190
Mkomazi	30	80	40	40	190
Mnyameni	30	60	40	60	190
Mtamvuna	30	80	40	40	190
Zinkwazi	65	40	20	60	185
Msikaba	20	60	40	60	180
Kwa-Suka	30	60	40	40	170
Tongati	40	20	40	60	160

4.4 DISCUSSION

To summarise the importance of the South African coastal vegetation, mapping the coastal region using aerial photographs and satellite imagery has been found to be cost effective (Raal and Burns 1996; Knight pers. comm.). However, although both these studies have been able to determine the extent and status of the different vegetation units (biomes and vegetation types), neither could determine the importance and status of small-scale vegetation units that occur in estuaries.

The botanical importance of an estuary has previously been assessed using the functional importance rating and more recently, the habitat integrity of an estuary (Coetzee et al. 1997; Colloty et al. 1999, Colloty et al. 2000; Riddin 1999). Criticisms of the functional importance rating system have been that it does not include species richness and the use of area measurements, will always bias larger estuaries as more important. Large estuaries such as the Olifants, Mhlathuze and St Lucia are important, but other estuaries that have more species or community types such as those estuaries in the Ciskei and Transkei also need to be identified. These include estuaries such as the Mngazana, Nxaxo and Keiskamma that have diverse plant community types and support a high number of species.

In this section a revised botanical importance rating system was used to rate the estuaries found in Ciskei and Transkei and compared these to other South African estuaries. The largest estuaries such as St Lucia, Berg, Knysna and Langebaan Estuaries were rated important on a national basis. These estuaries contain extensive areas of estuarine plants that contribute large proportions to the total estuarine plant cover in South Africa. For example, St Lucia has the third largest mangrove area of 279 ha, while the Berg, Knysna and Langebaan Estuaries have large salt marshes. The large area (morphology) coupled to the diversity of different physical environments have led to the creation of different habitats, i.e. intertidal, subtidal and supratidal zones in these permanently open estuaries. Different plant community types occupy these habitats and thus these permanently open estuaries had a high botanical importance.

However, a number of small estuaries were also rated important within the twenty most important South African systems. This has occurred through the inclusion of additional components to the botanical importance formula. An estuary is important if it has a high functional importance and contains a significant proportion of species, plant community types and community type rarity.

All the components that have been included in the botanical importance rating system have been shown to have an independent effect on the rating of an estuary as there was no correlation between them. This was due to a wide range of scores found between estuaries. For example a large estuary such as the Olifants had a lower number of species and plant community types than the smaller Mngazana Estuary. Estuaries that were previously regarded as unimportant because of their small size now have higher importance scores due to either a high number of species, plant community types or these estuaries contribute a significant portion of a particular community type to total cover in South Africa.

A number of small estuaries in the Cape region also received high botanical importance rating scores. However, if the Kabeljous, Seekoei and Uilkraals Estuaries had been assessed when their mouths were open, changes in water level and salinity occur. These changes in physical conditions resulted in the replacement of the submerged macrophytes by the less productive macroalgae species and their functional importance and overall botanical importance would have been lower. Care has to be taken in rating the botanical importance of an estuary, especially those that fluctuate between different states. Measuring the area covered by submerged plants from aerial photographs is difficult at times. This is especially true when black-and-white photographs are used. The maximum available habitat suitable for that particular plant community type could be used as an area cover value. This could be a solution if the particular estuary is well understood and confidence based on expert opinion is high.

The botanical importance rating formula can be used in decision support, estuary prioritisation, management plans or identification of conservation needs. Components of the botanical importance rating have been used in a system to assess the overall health and conservation importance of South African estuaries. This forms part of the RDM approach in determining the ecological reserve required by the Water Act of 1998 (Turpie et al*.* 1999). Estuaries were prioritised based on size, type, habitat rarity, botanical importance, invertebrate, fish and bird importance. Other aspects that were included were degree of protection, threats and futher demand for water from a particular system. The 20 estuaries with the highest scores in this prioritisation were as follows: Knysna, Orange, Mhlathuze, Olifants, St Lucia, Berg, Kosi, Mhlathuze, Tugela, Klein, Bot/Kleinmond, Mngazana, Great Fish, Swartkops, Krom, Gamtoos, Keiskamma and Mlalazi Estuaries (Turpie et al*.* 1999). In this study the botanical importance of estuaries are rated in a similar order. The Ciskei and Transkei estuaries show a wide range of very important to the least botanically important estuaries in South Africa. This is discussed further in the following section. In this study only these two regions have been compared. However, this can easily be done for the other biogeographic regions, provinces or types of estuaries once sufficient information becomes available. The Transkei region probably has the highest number of important estuaries than any other region. Overall, 16% of the Transkei estuaries were included in the group of 20 estuaries with the highest scores. This is because the Transkei region is a transition zone between the warm temperate and subtropical.

The information used in the national rating was obtained from various sources. This study surveyed all the Ciskei and Transkei estuaries. A high level of confidence can be assigned to information for estuaries in the East London region (Walker pers. comm 1999) and KwaZulu-Natal (Riddin 1999 and Pillay 1998 – cited Riddin 1999) estuaries. However, species information for the Western Cape estuaries needs to be updated. The remaining estuaries in the KwaZulu-Natal region also need investigation. In particular, the distribution of macroalgae and swamp forest species are not well known for the small KwaZulu-Natal estuaries.

5 THE BOTANICAL IMPORTANCE OF ESTUARIES IN THE FORMER CISKEI AND TRANSKEI REGION

5.1. INTRODUCTION

In this study, botanical surveys were conducted in 92 estuaries found in the former Ciskei and Transkei regions (Eastern Cape Province, South Africa) and the revised botanical importance rating system was applied to these estuaries. These two regions were independent states before the present political dispensation of the country was introduced in 1994. The areas involved were largely unmanaged during that time and their condition was believed to be important for two reasons, viz., can unmanaged estuaries survive for a period of approximately 30 years in a heavily populated region without being seriously degraded, and secondly, what was the state of these estuaries bearing in mind the rapid expansion of water use in the South Africa.

5.2 MATERIALS AND METHODS

The methods used in this section are explained in Section 4.

5.3 RESULTS

All sixteen Ciskei estuaries are shown in Table 5.1. The Keiskamma Estuary received the highest botanical importance score as it had the highest functional importance, species richness, community richness and community rarity scores in this region. The Keiskamma is a large permanently open estuary with intertidal, supratidal salt marsh, reeds, sedges, submerged macrophytes and extensive intertidal sand and mud flats. The remaining estuaries were ranked in order of decreasing functional importance. This was because these estuaries had the same plant community types with only variation in the number of plant species they contained. The Great Fish and Tyolomnqa estuaries were the exception. Both these estuaries had low botanical importance scores due to their narrow channel-like nature with small floodplains. This restricted the development of extensive areas of estuarine plants. Only salt marshes and reed beds were found in these estuaries (Table 5.1).

The most important estuaries in Transkei were the permanently open ones that had mangroves. Eleven of the 20 most important Transkei estuaries contained mangroves (Table 5.1). The functional importance component of the botanical importance formula contributed to the high scores of these estuaries. The Great Kei and Gqwara Estuaries were also included in the twenty estuaries with the highest scores because they had large salt marsh areas and, thus, high habitat rarity scores (Table 5.1). The remaining estuaries such as the Mbotyi, Bulolo and Hluleka contained extensive areas of reed and sedges. The Msikaba, Mgwegwe and

Mzamba Estuaries are moderately small and contain swamp forest. These swamp forests added to the functional importance and community rarity scores of these estuaries.

Table 5.1: Botanical importance of all 16 Ciskei estuaries and the 30 Transkei estuaries with the highest scores.

Ciskei		Transkei	
Estuary	**Botanical importance**	**Estuary**	**Botanical importance**
Keiskamma	365	Mngazana	385
Mtati	350	Nxaxo	370
Mpekweni	310	Mbashe	370
Mgwalana	335	Xora	350
Great Fish	330	Nqabara	330
Bira	310	Great Kei	310
Mtana	295	Mtata	310
Gqutywa	270	Mzamba	310
Tyolomnqa	255	Kobonqaba	305
Kiwane	225	Mdumbi	305
Old woman's	195	Mtakatye	295
Ngqinisa	185	Mtentu	285
Blue Krans	160	Mntafufu	265
Shwele-Shwele	160	Mzintlava	265
Freshwater Poort	145	Mzimvubu	250
Ngculura	85	Mbotyi	225
		Mgwegwe	225
		Qora	215
		Mnyameni	210
		Kwa-Suka	205
		Msikaba	200
		Gqwara	190
		Mnenu	190
		Bulungulu	185
		Mbhanyana	185
		Qolora	185
		Gxara	170
		Ku-Mpenzu	170
		Ngqwara	170
		Butsha	165

5.4 DISCUSSION AND CONCLUSION

The botanical importance rating for the Ciskei and Transkei estuaries indicated that large permanently open estuaries were important as they had high functional importance scores. The smaller estuaries were of similar size with similar species and plant community types. On a national basis estuaries were clearly ranked on the basis of the combination of all the components in the rating system. On a regional scale, as seen in the Ciskei, variation in species richness and plant community type richness is less and the functional importance scores became the dominant variable. This must be taken into account when the scale of management decisions is determined. For example, the estuaries found in the Transkei should be managed in terms of improving agricultural practices as shown by the number affected by this activity (Section 7).

6: THE INFLUENCE OF THE PHYSICAL ENVIRONMENT ON THE DISTRIBUTION OF ESTUARINE PLANTS IN THE FORMER CISKEI AND TRANSKEI REGION.

6.1 INTRODUCTION

For the first time a survey of all the macrophytic plant community types was undertaken along the Ciskei and Transkei regions of the South African coast. In the previous section it was shown that the estuaries of the study region had a high botanical importance. This was unexpected as most of these systems are small temporarily closed estuaries. However, these estuaries had a high species richness, plant community type richness and plant community type rarity. Functional importance was low due to the small size of the estuaries (Section 5).

It has been well documented that habitats that form at the interface between land and the sea show a wide variation of morphology (Cooper et al*.* 1999). They may form lagoons, estuaries, coastal pans or river mouths (Harrison et al*.* 1999a; 1999b). Furthermore the hydrology and geomorphology of each system largely determines the type of environment that is produced. This has resulted in a number of unique habitats that have been colonised by specialised halophytic plants. These can be divided into a number of separate groups based on their interaction with the estuarine environment, specifically the degree of tolerance to periodic tidal inundation. These include salt marshes, submerged macrophytes, reeds and sedges and mangroves.

Further variations in the morphology of estuaries are so varied that little apparent order exists. This has necessitated the development of a geomorphologic classification system for estuaries. The hope is that with such a system a summary of the physical environment would aid the determination of inter-estuary patterns and relationships (Cooper et al*.* 1999). Such a system has been applied to the fish fauna of the South African coastline (Harrison et al*.* 1997a; 1997b; Harrison et al*.* 1999a; 1999b). Several groups of estuaries were identified within the two study regions and each group showed a transition along the coastline depending on the estuary type and consequent fish assemblages. (Harrison et al*.* 1999a; 1999b).

It is suggested that the variation in estuarine morphology coupled with changes in hydrology and climate as well as the study regions being a transition zone between the warm temperate and subtropical biogeographic regions have led to the increase in plant richness and community type richness. This has consequently led to the increased botanical importance of this region. In order to describe the distribution of plant community types, plant presence and absence was related to measured physical variables. Coetzee (1995) showed that plant community cover could not accurately describe the variation in estuary types, whereas species composition was better correlated. Using ordination, the different groups of estuaries can then be identified based on species composition in relation to the physical environment. These groups were then compared to those in the geomorphologic classification.

6.2 MATERIALS AND METHODS

6.2.1 Botanical surveys

A standard procedure was adopted for investigating all the Ciskei and Transkei estuaries. Water column samples were collected from five stations, approximately equidistant, 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 plant community type richness as well as species composition. This information was used to determine the area covered by the plant community types using maps and aerial photographs as described in Section 4.

6.2.2 Physical variables

Salinity ($g.l^{-1}$) and temperature (^{0}C) were measured using a conductivity / 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.

Water samples (250 ml 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 450 nm.

6.2.3 Ordination

Ordination techniques were chosen to describe the relationships between species distribution, physical variables and the geomorphology of the estuaries. Presence/absence of the estuarine plant species were analysed using canonical correspondence analysis (CCA; Ter Braak 1986). CCA was utilised to determine species-environment relationships with the PCORDWIN (1996) package. Environmental variables included were average nitrate concentration, light attenuation, salinity, temperature, water column depth and size of estuary.

6.2.4 Estuarine classification - a geomorphologic approach

All 16 Ciskei estuaries were surveyed by Harrison et al. (1997a; 1997b) (Table 6.1) and 43 of the 76 Transkei estuaries have been classified by Harrison et al. (1999a; 1999b) (Table 6.2). They were placed into one of the seven different geomorphologic classes. A few examples of these are shown in plate 6.1 to 6.5.

Table 6.1: The classification of estuaries compiled by Harrison et al. (1999a; 1999b) for the 16 Ciskei estuaries. (The estuarine classes (Whitfield 1992) are also shown.)

Estuary class	Whitfield class	Harrison class	Size (ha)	Barrier type	Salinity ($g.l^{-1}$)	Estuaries
1A	Temporarily open/closed	Frequently closed	Moderately small 9 – 25	Long wide barriers	near marine, overwash 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	-	Range of 0 – 35	Great Fish, Keiskamma, Tyolomnqa
3	Not considered estuarine	Small dry river beds or freshwater 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 6.2: The classification of estuaries derived by Harrison et al. (1999a) for 43 of the Transkei estuaries. The Whitfield estuarine classification is also shown.

Estuary class	Whitfield class	Harrison class	Size (ha)	Salinity ($g.l^{-1}$)	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 (Plate 4), 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 and Mtentu
4	Permanently open or River mouth	River dominated	50	Small tidal range, <2 km	-	Mbashe, Mtata, Mzimvubu and Great Kei.

Plate 6.1: The Sinangwana Estuary found in the former Transkei region is classified as a temporarily open/closed estuary (Class 1A). It has a surface area of ca. 4.5 ha.

Plate 6.2: The Jujura Estuary in the former Transkei is classified as a Class 1B estuary. It is an example of a near permanently open system due to its large catchment rather than the tidal prism. The tidal amplitude was 1.2 m at the mouth during a spring tide on 19/04/98.

Plate 6.3: The Qolora Estuary is a large temporarily open estuary, typical of Class 2 estuaries. This type of estuary has a perched barrier and only breaches after extended rainfall events. The mouth closes quickly due to the high wave energy conditions along the coast.

Kobonqaba Estuary (Class 3A)

Mngazana Estuary (Class 3B)

Plate 6.4: An example of a Class 3 estuary which is a large system with a tidal prism that maintains a near permanently open inlet. Differences in the size and location of sand/mudflats are due to the local geology. The Kobonqaba Estuary (Class 3A) has sand flats at the mouth; the Mngazana Estuary (Class 3B) is characterised by tidal mud flats.

Plate 6.5: Class 4 estuaries, such as the Mbashe, include all river-dominated estuaries.

6.3 RESULTS

A total of 54 estuarine plant species occurred in the 92 estuaries observed in the study region. Plant species could be divided into the following five plant community types: reeds and sedges (23 species), salt marshes (20 species), mangroves (4 species), macroalgae (3 species) and swamp forest (4 species). Species and physical environment data are presented in Section 11 - Appendix.

Fifty five of the estuaries had sufficient physical and species information to be used in a CCA multivariate analysis which indicated that salinity, average water column nitrate concentrations and size of estuary were the driving environmental factors in the spatial separation of estuaries and the plants within them ($r > 0.05$). The highest correlation was shown between axis one and two for species ($r = 0.534$) and estuary ($r = 0.653$) ordinations (Figs. 6.1 and 6.2). The species and estuaries had the highest correlation between salinity ($r = 0.530$) and water column nitrate concentrations ($r = 0.431$), while light attenuation ($r = 0.384$) and depth ($r = 0.241$) had less of an effect on distribution. Estuaries could thus be grouped according to similar physical characteristics that were a function of geomorphology (surface area) and physico-chemical factors (average salinity, nitrate concentrations and light attenuation). These groups also showed similarities in species composition. All the estuaries had reeds and sedges, but there was sufficient separation within the other plant species to define 8 different groups. These groups were as follows:

Permanently open estuaries with extensive salt marshes occurring south of the Great Kei River Estuary.

The Great Kei River (222 ha), Tyolomnqa (107 ha), Keiskamma (344 ha) and Great Fish River (365 ha) Estuaries all had intertidal and supratidal salt marshes. All four estuaries had large salt marshes greater than 25 ha. However, the Keiskamma and Great Fish River Estuaries had larger areas of intertidal salt marsh. This was reflected in the intertidal species composition associated with these two estuaries seen in the ordination (Fig. 6.1, Group A). These species included *Triglochin striata*, *Sarcocornia perennis*, *Sarcocornia natalensis* (Bunge ex Ung.-Sternb.) A.J. Scott, *Chenolea diffusa* Thunb., *Cotula filifolia* Thunb. and *Limonium scabrum* Thunb. The Tyolomnqa and Great Kei River Estuaries had more supratidal species present as shown in the ordination (Fig. 6.1, Group A and Fig. 6.2, Group A). These species included *Triglochin bulbosa* L., *Disphyma crassifolium* (L.) L. Bol., *Sporobolus virginicus*, *Stenotaphrum secundatum, Salicornia meyeriana* Moss and *Sarcocornia pillansii* (Moss) A.J. Scott. Both the Great Kei and Tyolomnqa Estuaries have incised river banks caused by erosion. This erosion takes place during high flow periods that exist when the estuaries receive the largest proportion of their mean annual runoff within a three-to-four month period each year. This is usually in the form of floods (Midgley et al. 1994). During the remainder of the year normal tidal exchange takes place, but is limited due to the raised banks and the marshes are only inundated by spring high tides that result in the supratidal conditions.

Permanently open estuaries with mangroves and salt marsh south of the Mngazana Estuary

These estuaries are moderately sized permanently open (Fig. 6.2, Group B), namely the Kobonqaba (62 ha), Nxaxo (159 ha), Nqabara (109 ha), Mbashe (132 ha), Xora (151 ha), Mdumbi (76 ha) and Mtata (169 ha) Estuaries. These estuaries had high average salinity (between 18 and 23 $g.l^{-1}$) and high average depth (between 1.84 and 1.94 m) resulting in the close correlation with the depth, area and salinity vectors shown in Figs. 6.1 and 6.2. Species found in these estuaries included the mangrove *Avicennia marina*, *Bruguiera gymnorrhiza* and *Rhizophora mucronata*. Salt marsh species found in these estuaries included *Triglochin bulbosa*, *Disphyma crassifolium, Sporobolus virginicus* and *Sarcocornia pillansii*.

The presence of the red mangrove, *Rhizophora mucronata,* in the Mtata and Nxaxo Estuaries was possibly due to the higher freshwater inputs. The Mtata is a Class 4 river-dominated estuary indicated by its higher mean annual runoff of 392 x $10^6.m^3$ (Midgley et al*.* 1994). The Nxaxo Estuary only has a small juvenile *R. mucronata* tree of less than 1,5 m in height and will need further monitoring to establish if this estuary is suitable for its survival, i.e. can this species survive in an estuary with a higher average salinity than estuaries further north.

The Mngazana Estuary

The Mngazana Estuary is a permanently open one of 224 ha and differs from all estuaries in the study region. It shares affinities with the all the estuary groups and has all the plant community types present with the exception of macroalgae. 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). It also receives regular tidal exchange so that it exhibits a range of salinity from 0 $g.l^{-1}$ at the head of the estuary to 37 $g.l^{-1}$ at the mouth. Species found in the Mngazana Estuary include the salt marsh plants *Triglochin striata*, *Sarcocornia perennis*, *Sarcocornia natalensis*, *Chenolea diffusa, Cotula filifolia*, *Salicornia meyeriana* and *Limonium scabrum*. These species are better adapted to high salinity conditions and this caused the close correlation of these species to the salinity vector in the ordination (Fig. 6.2).

Permanently open estuaries north of the Mngazana Estuary.

The following moderately sized estuaries (23 – 70 ha) were grouped together in the ordination; Mntafufu, Mzintlava, Mtentu and Mzamba (Group C, Fig. 6.2). These estuaries had an average salinity of between 26 and 27 $g.l^{-1}$ and average depths exceeding 1.6 m. 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. This group of estuaries are large deep estuaries and were classified by Harrison et al*.* (1999a; 1999b) to be steep channel-like estuaries with a small floodplain or intertidal area. Fig. 6.1 shows that these estuaries are all closely associated with depth. These estuaries are mostly colonised by mangrove swamp forest (*Hibiscus tiliaceus*) and reed species in the small areas available.

Large temporarily open estuaries with salt marsh and macroalgae

The large estuaries (15 – 186 ha) found in this group had salt marsh, macroalgal and submerged macrophyte species present (Fig. 6.1, Group B and Fig. 6.2 Group D). This 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* (L.) Thunb. and macroalgae (*Enteromorpha sp.* or *Cladophora sp*.). This was as a result of the high salinity conditions due to overwash present in these estuaries.

Small temporarily closed estuaries with reeds and sedges only

These estuaries are those found between the Gxara and the Gxwaleni found south of Port St Johns. These are shown as group E and C (Figs. 6.1 and 6.2) and are made up of the estuaries classified by Harrison et al*.* (1999a; 1999b) 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 1.29 and 41 ha in size. These estuaries are characterised by salinity of between 11 and 17 $g\ l^{-1}$ and varying depths not exceeding 1.4 m. Species found in these estuaries (Fig. 6.2, Group F) are of the reed and sedge plant community type that prefer these brackish conditions.

Small temporarily closed estuaries with reeds, sedges and swamp forest

The swamp forest species *Hibiscus tiliaceus* is found from the Gxwaleni Estuary north towards Port Edward (Fig. 6.2, Group F; Fig. 6.4). Estuaries that are included in this group are between 1.92 and 50 ha in size. Two estuaries not found in this group, but which the ordination placed with the remaining group B estuaries (Mtumbane and Ntlupeni) did not have the lagoon hibiscus (*H. tiliaceus*) present.

Outliers

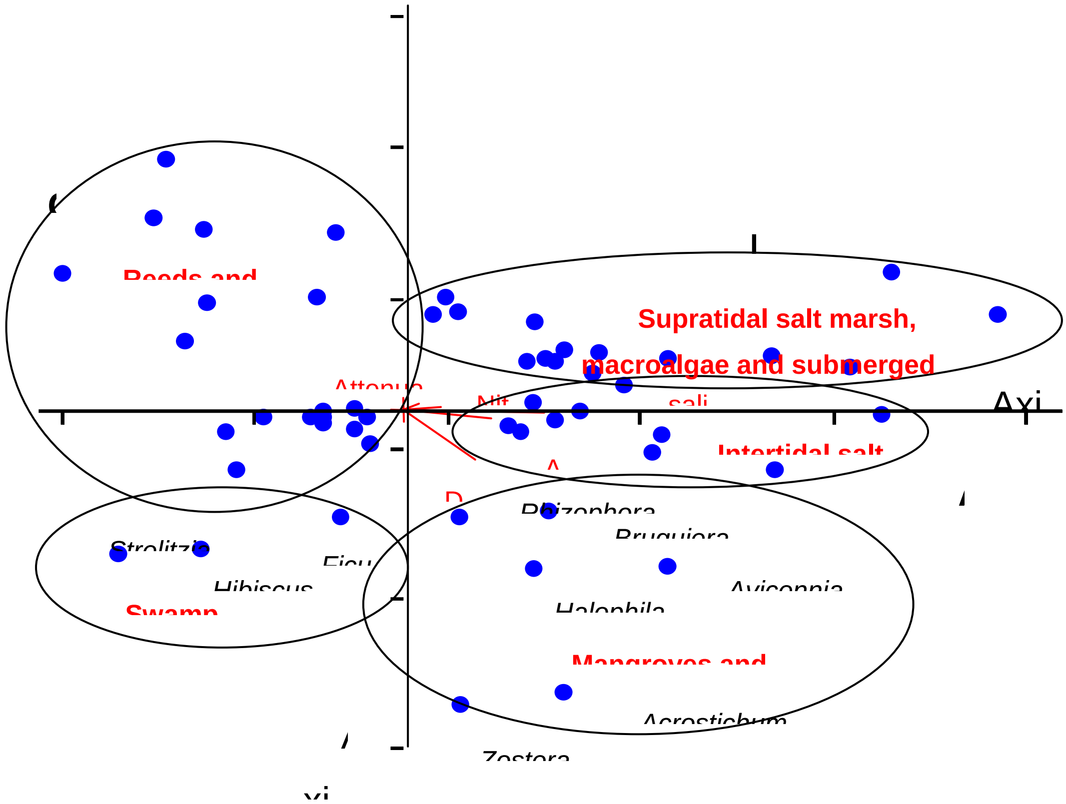
The Mzimvubu was classified by Harrison et al*.* (1999a; 1999b) as a river-dominated estuary (Class 4). The Mzimvubu Estuary contained reed and sedge species as well as *Hibiscus tiliaceus*. Steinke (1982) reported mangroves in this system. These have subsequently disappeared (Section 8). If the mangroves were still present the estuary may have been classified in the group of northern permanently open estuaries that had mangroves and swamp forest.

The Msikaba Estuary was classified 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, the Msikaba could have possibly been colonised by mangroves. This was shown by the close ordination of this system to the physical factors associated with tidal exchange and other mangrove systems

(Fig. 6.1). There are no published accounts of mangroves present in this estuary, however, they were observed by Wooldridge (pers. comm 1999) 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 closed estuary. The Jujura Estuary was also shown as an outlier as it was a temporarily closed estuary with the submerged macrophyte, *Zostera capensis* Setchell. This species is usually found in the intertidal zone of permanently open estuaries.

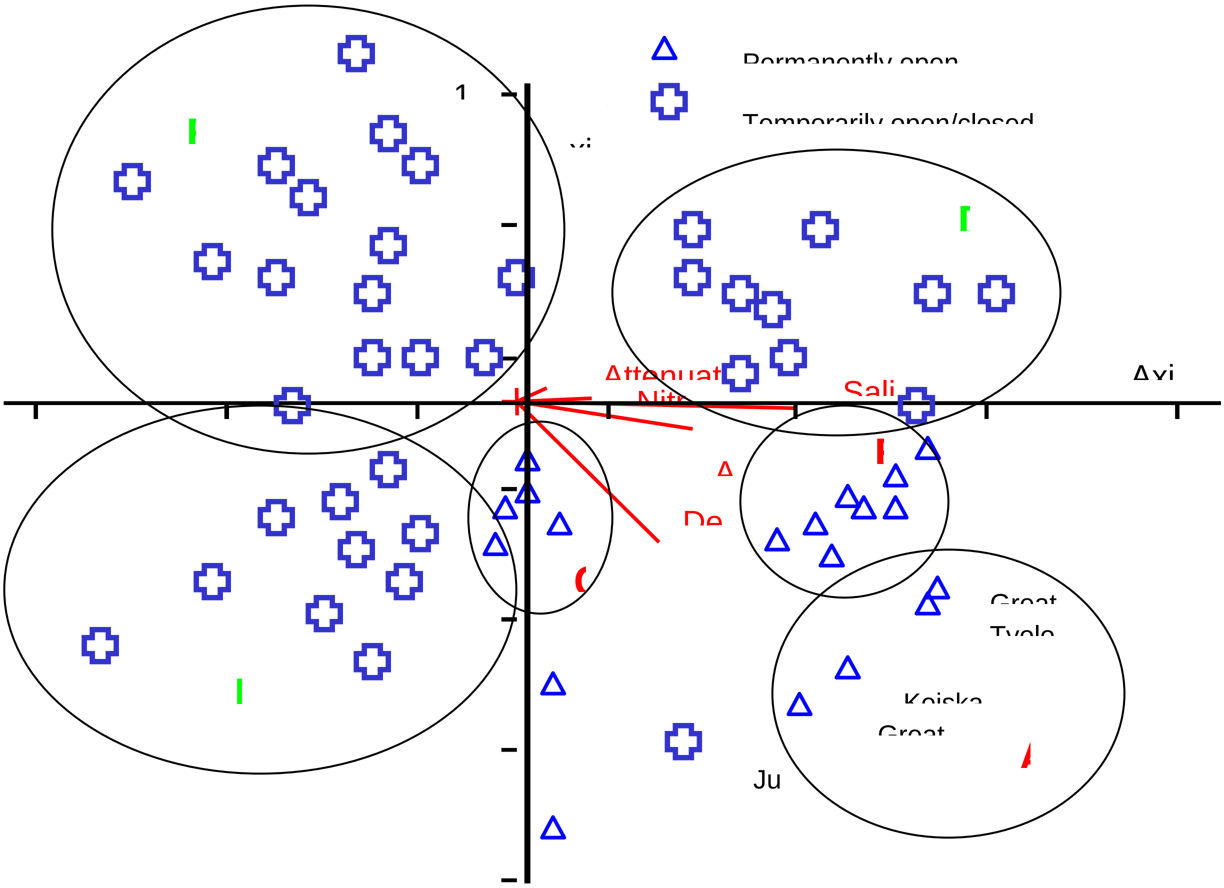
Figs. 6.3 and 6.4 summarise the 7 groups of estuaries found in the study regions together with the estuaries and the associated plant community types.



Group A	**Group B**	**Group C**
Sarcocornia decumbens	*Disphyma crassifolium*	*Phragmites australis*
Sarcocornia natalensis	*Crassula expansa*	*Scirpus maritima*
Sarcocornia perennis	*Salicornia meyeriana*	*Pycreus polystrachus*
Spartina maritima	*Sarcocornia pillansia*	*Scirpus nodusus*
	Samolus porosus	

Axes	1	2	3
Axis 1 and 2	Salinity	Depth	Light attenuation
Eigenvalues:	0.9	0.7	0.6
Species – Environment correlations	0.5	0.4	0.4

Figure 6.1: CCA ordination of plant species presence/absence in Ciskei and Transkei estuaries that were surveyed. Spatial separation of the estuaries in relation to environmental variables and the distribution of plant species are shown. Environmental variables include, water column depth, average salinity and secchi depth. The table insert shows the eigenvalues and species - environmental correlation for the first three axes.



Group B	Group C	Group D	Group E		Group F
Kobonqaba	Mntafufu	Old Woman's	Gxara	Ngogwane	Gxwaleni
Nxaxo	Mzintlava	Shwele-	Qolora	Cebe	Mzimpu
			Gqunqe	Ngqwara	

Axes	1	2	3
Axis 1 and 2	Salinity	Depth	Light attenuation
Eigenvalues:	0.9	0.7	0.6
Species – Environment correlations	0.5	0.4	0.4

Figure 6.2: CCA ordination of estuaries based on plant species presence/absence in the Ciskei and Transkei regions. Spatial separation of the estuaries in relation to environmental variables and the distribution patterns of plant species are shown. Environmental variables include, water column depth, average salinity and secchi depth.

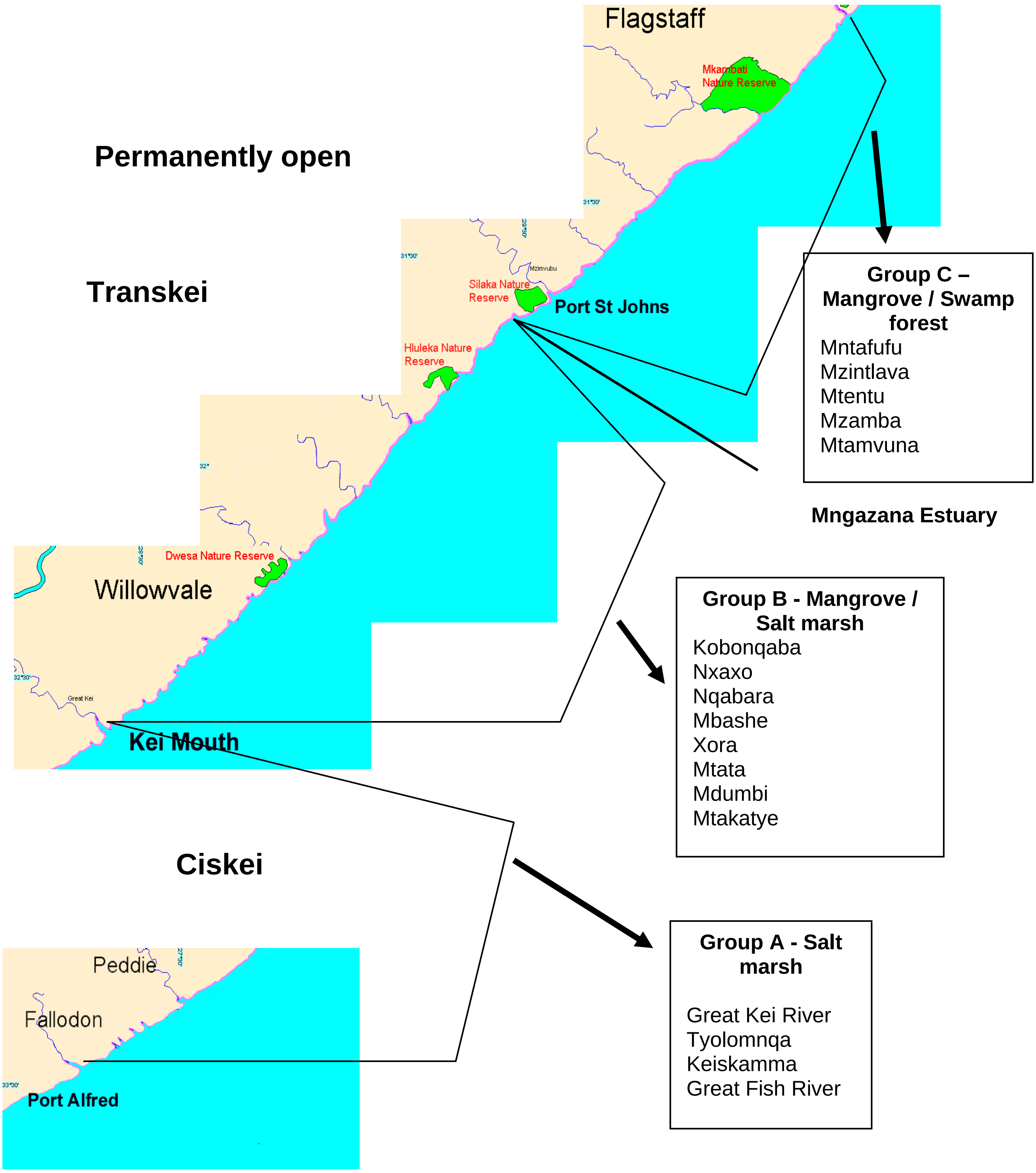


Figure 6.3: A summary of the three groups of permanently open estuaries and associated plant community types found in this study. There is a transition at the Mngazana Estuary between the estuaries dominated by salt marsh and those containing swamp forest species.

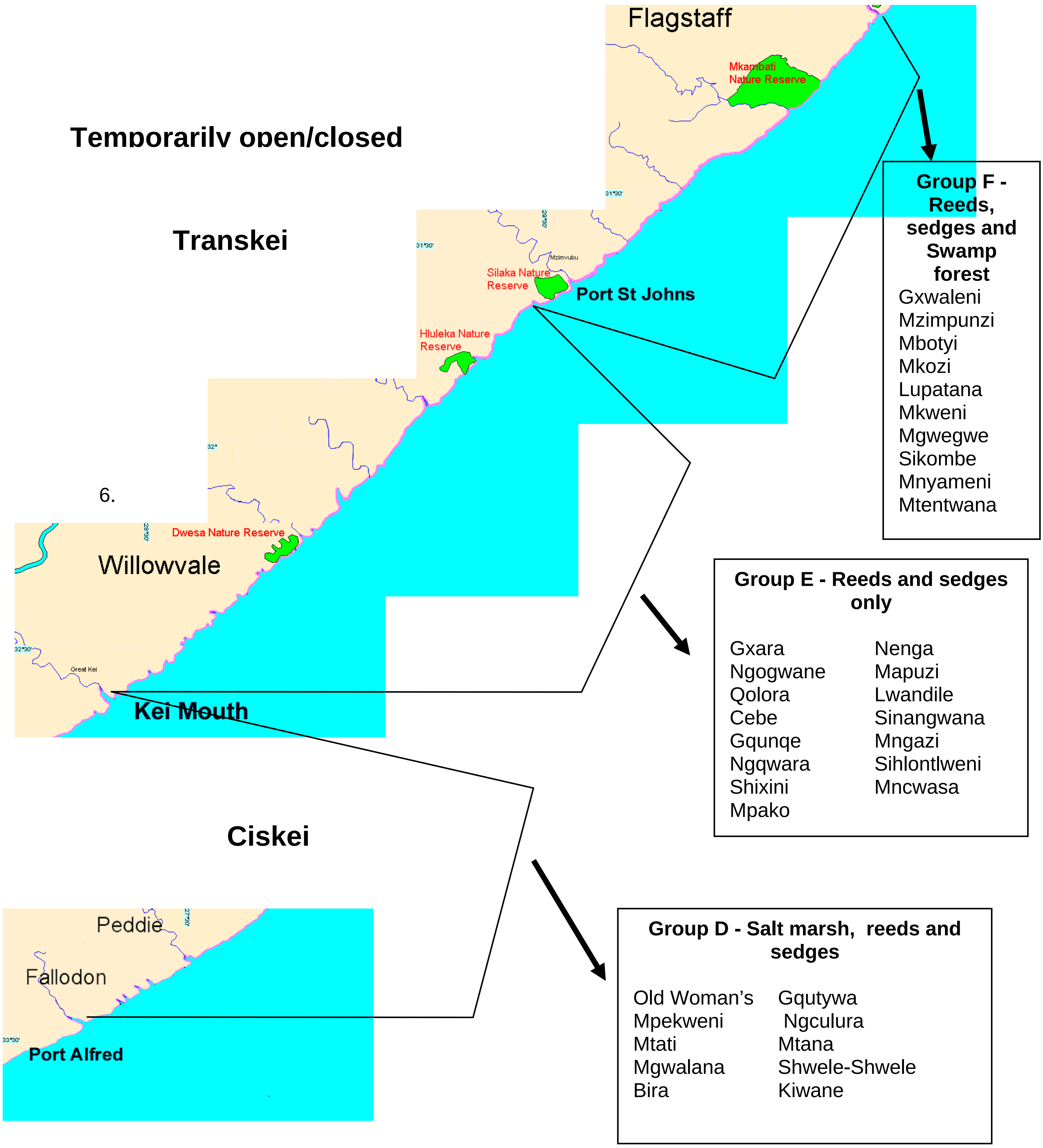


Figure 6.4: A summary of the three groups of temporarily open/closed estuaries and associated plant community types found in this study. A transition is shown between estuaries that have salt marsh and those that contain swamp forest.

6.4 DISCUSSION AND CONCLUSION

The characteristics of estuaries are by definition dependent on their surrounding environment (Cooper et al. 1993). Factors such as geomorphology, salinity, light attenuation and depth were highlighted as important in influencing the distribution of macrophytes in the Transkei region. Estuaries could be divided into 7 broad classes based on the spatial separation of plant species. The difference in the distribution of plant species in the different estuaries was more closely related to the Whitfield classification system than the geomorphologic classes proposed by Harrison et al. 1999a; 1999b. Coetzee et al. (1997) showed a similar pattern for plant distribution for the western Cape estuaries. The geomorphologic classes could explain the outliers in the ordination.

The temporarily open/closed estuaries showed the greatest variation in terms of size and morphology resulting in three geomorphologic classes (1A, 1B and 2) (Harrison et al. 1999a; 1999b). However, this could not describe the changes in species distribution. The probable cause was due to the increase in mean annual rainfall of approximately 100 mm every 120 km between the Ciskei and Port Edward (South African Weather Bureau rainfall data). This is reflected in the increase in species that are associated with freshwater or brackish conditions, i.e. reeds, sedges and swamp forest species.

The Transkei region is considered to be the transition zone between the warm temperate and subtropical region (Steinke 1995). The transition from more xeric salt marsh plant community types to plant community types that were characteristic of brackish estuaries, such as swamp forest and the reed and sedges, was evident. Harrison et al. (1999a; 1999b) in their survey also noted this transition along the coast. In the case of the ichthyofuana, 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 Estuary, 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 Mzimvubu Rivers for all the plant community types 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 morphology also plays a role. The Msikaba Estuary was associated with permanently open estuaries that have mangrove/swamp forest community types. This was because of its unique morphology and limited intertidal areas. Harrison et al. (1999a; 1999b) also regarded this estuary as well as the Mtentu Estuary as being 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 estuary also had 8 out of the 9 possible plant community types present. The Jujura and the Mkozi are two temporarily closed estuaries that, due to their unique geomorphology, have been colonised by plant community types typical of permanently open estuaries (mangrove associates and submerged macrophytes). Interestingly, the Jujura was placed in a separate geomorphologic class by

Harrison et al. (1999a; 1999b). The catchment of this estuary is formed by a narrow valley that has a low storage capacity. 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 present.

Similar relationships between geomorphology and plant distribution were found along the western and eastern coasts of Australia. Evidence has shown that certain plant community types are associated with certain types of estuaries, e.g. mangroves with the permanently open estuaries. However, the exact distribution of species coincided more with local physical conditions found in Australia. Local variation in habitat was found to increase the diversity of habitats and species richness (Thom et al. 1975). This was apparent for the Ciskei and Transkei estuaries that received high botanical importance scores when compared with estuaries on a national basis (Section 4 and 5). The variation in physical environment and transition between biogeographic regions has resulted in regions of increased biodiversity. Mangroves, salt marshes and swamp forest species are found in the same region. The botanical importance rating records this as a high species richness and plant community type richness and, in the case of the estuaries with swamp forest, high habitat rarity. By sharing environments at the limit of their environmental tolerance and competing with species with the same habitat requirements, there is high genetic variability within species (Bryant 1998).

The distribution of estuarine plants in relation to geomorphologic classes has important implications in management strategies related to estuaries. A summary of dominant plant species can be presented using the geomorphologic characters; e.g., Class 2 estuaries are permanently open and are characterised by either mangrove or salt marshes. Both these plant community types require regular tidal exchange. Thus, such estuaries require sufficient freshwater runoff to maintain open mouth conditions. This summary of information is especially important in the Transkei where little is known about the estuaries. 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. These estuaries had high national botanical importance scores (Sections 4 and 5).

7: THE DEVELOPMENT OF A HABITAT INTEGRITY INDEX

7.1 INTRODUCTION

The change in functional importance over time can be used as a measure of botanical habitat integrity. Other terms which are synonymous with integrity include habitat status and habitat condition (Turpie et al*.* 1999). An ecosystem exhibits integrity if, when subjected to disturbance, it retains the ability to recover toward a state that is normal for that system. Habitat integrity was determined using the change in plant cover over time from past records or aerial photos for the Swartkops Estuary (Colloty et al. 2000). Habitat integrity has also been used to highlight the conservation importance of estuaries in the northern Eastern Cape Province (Pondoland – Transkei) (Colloty et al*.* 1999). The case studies above necessitated the determination of the habitat integrity of as many other estuaries as possible. This also led to some refinements with the final habitat integrity index tested at the end of this section.

7.2 THE USE OF A HABITAT INTEGRITY INDEX TO DETERMINE THE EFFECT OF DEVELOPMENT ON THE SWARTKOPS ESTUARY

Encroaching residential and industrial development and the increase in demand for freshwater threaten South African estuaries. In order to ensure their continued survival, there is a need to identify estuaries that have a high conservation status. An estuary might have a high conservation status if it is a reservoir of high species diversity, contains a high number of plant community types or its state of intactness is adequate to ensure continued functioning. The botanical importance rating system can be used to assess changes in the botanical condition of an estuary over time. By comparing the present condition to the past, or pristine condition, an assessment can be made of the present botanical status of an estuary. The botanical status can be used as an indicator of ecosystem status as the plants are the primary producers and their condition will influence the status of higher trophic levels.

The Swartkops Estuary has the third largest area of salt marsh along the South African coastline and exhibits a variety of estuarine plants (Baird et al*.* 1986). There are six different plant community types, namely supra- and intertidal salt marsh, submerged macrophytes, reeds, sedges, phytoplankton and benthic microalgae. Plant community types not found in the estuary include mangroves and swamp forest. Macroalgae species occur in the Swartkops Estuary (Hilmer et al. 1988), but the area covered by this plant community type could not be measured from available maps or aerial photographs.

Maintenance of habitat has long been recognised as the essential issue in conservation and environmental management. In addition, the greater the number of different plant community types in an estuary the greater the variety of habitats. Ecologically, estuarine plants are a source of primary production and the community types which they comprise provide habitats for a large variety of faunal species (Davies 1982, Bally et al*.*

1985; Whitfield 1984; Adams et al. 1999). These species range from planktonic and benthic filter feeders to birds that utilise the marshes for food and breeding (Adams et al. 1999). The ability of plants to improve water quality by retaining pollutants and excess nutrients can have important implications for many beneficial water uses in the marine environment; for example mariculture, recreation and subsistence fishing. A large salt marsh will provide a more effective habitat than a small one (Daly and Mathieson 1981). A comparison of maintaining single large versus numerous small seagrass beds has shown that density and diversity of species was higher in the many small seagrass beds. However, it was later shown that the single large seagrass continued to function longer if artificial changes were made to the surrounding environment (Fairweather 1999).

The Swartkops Estuary is surrounded by urban and industrial developments of the Port Elizabeth metropolitan area. These developments have resulted in a number of changes to the estuarine plants. These include physical elimination of plant community types as well as changes to the physical environment such as obstruction of water flow in the supratidal regions that has resulted in invasion by terrestrial plant species.

The objective of this study was to determine the effects of human impacts on the extent and distribution of the estuarine plants in the Swartkops Estuary. These effects were assessed from available literature, past aerial photographs, orthophoto maps and the application of a formula to calculate the comparative botanical importance score for the estuary under 'pristine' and present conditions.

7.2.1 Materials and Methods

7.2.1.1 Assessment of aerial photographs, orthophoto maps and past literature

The area covered by the different plant community types (ha) was measured from 1:50 000 topographic maps, aerial photographs (Directorate Surveys and Institute for Coastal Resource Management, UPE) and photographs and maps published in past reports (Jacot - Guillard 1974; Baird et al. 1986). These were converted into scaled digital images (Hewlett-Packard Scanner 4C). The digital images were then calibrated and the area covered by the plant community types was measured using image analysis software (AnalySIS 3.0). The area covered by residential and industrial developments and constructions such as road bridges was also measured from maps (Fig. 7.1). Development has mainly encroached onto the supratidal salt marsh area. To estimate the past cover of this plant community type, plant distribution was assessed at six sites where development has encroached onto the marsh. The area of supratidal marsh was measured as the area above the mean high water spring tide mark (MHWST) and below the 2.5 m contour line.

The functional importance rating formula (Section 4) was applied to the Swartkops Estuary to show the effect of human activities on the estuarine plants over time. The formula includes all estuarine plant community types namely; salt marsh, reeds and sedges, benthic microalgae found in the intertidal sand and mudflats and phytoplankton. The extent of the phytoplankton community type within the Swartkops Estuary was calculated as the area covered by water on the slack tide in hectares, thus allowing comparison with other plant community types.

Estuaries were rated on a national basis using the functional importance rating and compared in order to gain a better perspective on the importance of an estuary. Seven estuaries were selected from the Cape and KwaZulu-Natal regions and compared with the present botanical importance score of the Swartkops Estuary.

7.2.2 Results

7.2.2.1 Phytoplankton

The water surface area of 135 ha was used as a measure of phytoplankton and extended from the mouth of the estuary to Perseverance Bridge (16 km upstream of the mouth) (Fig. 7.5, Appendix Table 7.2). For use in the botanical importance rating, this area was considered to have remained unchanged despite the changes caused by development. Changes in freshwater input (water quantity) and water quality may have affected phytoplankton production within the estuary. These changes, however, are not included in the botanical importance formula because, as yet, we have no way of estimating the magnitude of this effect, as it is impossible to predict what phytoplankton production may have been under pristine conditions.

7.2.2.2 Benthic microalgae

The area covered by intertidal benthic microalgae was based on the extent of exposed intertidal mud and sandbanks in the estuary. This was calculated to be 174 to 180 ha. An average value of 177 ha was used in the botanical importance formula (Fig. 7.5, Appendix Table 7.2). It was assumed that there has been no significant reduction in size or change to the geomorphology of these banks over time. The scour of one bank generally results in the deposition and creation of a new bank on the opposite side (Reddering and Esterhuysen 1988).

7.2.2.3 Submerged macrophytes - Zostera capensis *Setchell (eelgrass)*

MacNae (1957) found the seagrass *Zostera capensis* was abundant along the entire length of the Swartkops Estuary and covered an area of 15 ha (Table 7.1). *Z. capensis* was found in the subtidal zone in the upper reaches of the estuary, but was most abundant in the intertidal regions of the middle and lower reaches. In the upper reaches of the estuary the species was observed growing on sandy substrata in contrast to the lower and middle reaches, where it grew on mud banks.

Talbot and Bate (1987) studied the population dynamics of *Z. capensis* in the Swartkops Estuary and showed that the plant is sensitive to flooding and sediment deposition. Thorough surveys of seagrass beds during the winter and summer of 1981 indicated the presence of a thriving community with up to 90% of the beds found within the first 6 km of the estuary. A significant but small difference was observed between the winter area coverage of 13.7 ha and the summer extent of 16.1 ha in 1981 (Table 7.1).

A survey of the Swartkops Estuary in late 1984 (Hilmer et al*.* 1988) indicated a complete disappearance of the entire *Z. capensis* population from the estuary after heavy flooding. Recolonisation of the estuary by this species was only apparent in August 1988 when about 4% of the 1981 population size had returned, covering approximately 0.6 ha (Table 7.1) mostly in the mouth region (Hilmer et al. 1988). In this study the area covered by *Z. capensis* was 12.5 ha (Table 7.1, Figures 7.1 and 7.2).

Table 7.1: Summary of the characteristics of *Zostera capensis* found in the Swartkops Estuary.

Survey	**Standing biomass – d. w. g.m^{-2}**	**Productivity** g.C.y^{-1}	**Cover (ha)**	**Comment**
MacNae (1957)	-	-	15	Pristine
Talbot and Bate (1987) – surveyed in 1981	76 - 125	20 x 10^6	Increased from 13.7 - 16.1	Fluctuations due to floods
Emmerson (1983)	160 decreased to 40	-	-	Between 1982 - 1984 flood led to complete removal
Hilmer et al. (1988)	-	-	0.6	Slow recovery phase
Adams and Haschick (pers. comm)	250 - 310	-	-	Recovery hampered by trampling
Aerial photographs 1996	-	-	12.5	-

7.2.2.4 Salt marsh

Intertidal salt marsh

For this study, it was estimated that the intertidal salt marsh covered an area of 215 ha before any development took place in the basin of the Swartkops Estuary (Table 7.2, Fig. 2). This would represent the pristine condition for intertidal salt marsh. Aerial photographs taken in 1939 indicate that large areas of intertidal salt marsh (45 ha) were lost when the Swartkops and Redhouse Villages were developed (Table 7.2, Fig. 7.2). In later years, smaller areas of marsh were lost to the solar salt works, the power station, the Uitenhage road and to other roads and bridges. MacNae (1957) described the Swartkops Estuary plants found in the lower estuarine reaches, between Amsterdamhoek and Swartkops Village. From MacNae's vegetation map it was estimated that in 1957 the intertidal salt marsh covered 168 ha. Above the railway bridge, salt marsh occurs mainly along the north bank as far as the saltworks, while beyond Redhouse Village it extends along the southern bank approximately 10 km from the mouth ('Bar – None") in a narrow belt (Fig. 7.1). From later maps and aerial photographs the area covered by the intertidal salt marsh was 166 ha for the period 1983 to 1987 (Table 7.2). Since the construction of Settlers Bridge (N2 Highway) in 1974 there has been little change in the area covered by intertidal salt marsh (165.8 ha, Table 7.2, Fig.re 7.3). In 1996 the intertidal salt marsh covered 165 ha, the reduction of 0.8 ha was due to the upgrading of road interchanges in the Fishwater Flats region (Table 7.2).

Figure 7.1: The Swartkops Estuary showing the distribution of surrounding developments.

Figure 7.2: The past plant cover of the Swartkops Estuary before 1939.

Figure 7.3: The 1998 estuarine plant cover of the Swartkops Estuary.

Table 7.2: Summary of the change in the area covered by intertidal salt marsh as calculated from available maps, aerial photographs (Trig. Survey and Department of Environmental Affairs) and orthophoto maps (1:10 000)

Survey/Author	Cover (ha)	Comments
Aerial photos and field survey	215	Estimate of intertidal area before any development at current MSHWM
Aerial photos 1939	170	Post development of Swartkops and Redhouse Village
MacNae 1957 - estimated from maps	168	Post-construction of power station, salt works, Uitenhage road and railway bridges
Jacot - Guillard (Hill, Kaplan and Scott) 1974 - Aerial photographs	165.3	Reduction in intertidal salt marsh after construction of Settlers Bridge (N2), 1968-1974
Orthophoto maps 1983	166	-
Aerial photographs 1985	165.8	-
Talbot and Bate 1987	166	-
Orthophoto maps 1996	165	Reduction due to further road construction (M19 to Uitenhage)

Supratidal salt marsh

The area covered by supratidal salt marsh was measured from aerial photographs and maps drawn in previous studies (Table 7.3). For the pristine or pre-development condition, supratidal salt marsh was estimated to cover approximately 40 ha in extent (Fig. 7.2). Approximately 31 ha of supratidal salt marsh had already been eliminated by 1957 because of developments (Table 7.3) . From 1957 to 1997 construction of Fishwater Flats Sewage Works, Settlers Bridge (N2) and the M19 bridge to Uitenhage resulted in the further removal of approximately 4 ha of marsh (Fig. 7.3).

Table 7.3: Summary of the change in the area covered by supratidal salt marsh calculated from available maps, aerial photographs (Trig. Survey and Department of Environmental Affairs) and orthophoto maps (1:10 000). MSHWM = Mean spring high water mark.

Survey/Source	**Cover (ha)**	**Comments**
Aerial photos 1939	40	Estimate of supratidal area before any development at 2.5 m contour
MacNae 1957 - estimated from maps	9	Post development of Swartkops Village and Redhouse Village, power station, salt works, Uitenhage road and railway bridges, Neave industrial area
Jacot - Guillard 1974	8	Post construction of Fishwater Flats Sewage Works (1972) and the Settlers Bridge (1968-1974)
Orthophoto maps 1983	6	Road construction (M19 to Uitenhage)
Aerial survey 1996/1997	5	Further road construction and extension of Fishwater Flats

7.2.2.5 Reeds and sedges

The area covered by reeds and sedges has not been documented nor identified in previous reports. For this study, estimates of the area covered by reeds and sedges were based on visual presence in photographs provided in reports and from recent colour aerial photographs (Table 7.4). Dense reed and sedge beds are usually found in the upper reaches of estuaries where the salinity is less than 15 $g.l^{-1}$. *Phragmites australis* (common reed) is the dominant species in the Swartkops Estuary and extends from Redhouse Village to Perseverance causeway (head of the estuary, Fig. 7.1). Table 7.4 shows that for the pristine condition or until 1957 reeds covered approximately 10 ha. Thereafter, a series of floods and bank erosion reduced the cover to 6 ha in 1983. Futher floods and quarrying in the channel and floodplain for stone at the head of the estuary reduced the cover to 4.5 ha in 1997.

Table 7.4: Summary of the change in the area covered by reeds and sedges calculated from available maps, aerial photographs (Trig. Survey and Department of Environmental Affairs) and orthophoto maps (1:10 000). MSHWM = Mean spring high water mark.

Survey/Source	**Cover (ha)**	**Comments**
Aerial photos	10	Estimate of area before any development at current MSHWM
MacNae 1957 – estimated from maps	10	-
Jacot - Guillard 1974	9.5	Reduction in cover after flooding events
Orthophoto maps 1984	6	Increased bank erosion below Perseverance causeway
Coetzee *et al.* 1997	5	Further erosion and quarries
Present cover (1997)	4.5	Reduction in cover after November 1996 floods

7.2.2.6 Functional importance rating

The data for the calculations of the functional importance scores are shown in Table 7.2 of the appendix. Also see Section 4 for the method of determining the functional importance. Changes in the functional importance score over time have been summarised in Fig. 7.4. In the pristine state the Swartkops Estuary had the highest normalised functional importance score (100) with a steady reduction in score over time as shown in Fig. 7.4.

The pristine condition (Fig. 7.4) represents the estuary without any development and where the estuarine plants are assumed to have colonised all available habitats. There was a decrease in the functional importance score for the Swartkops Estuary over time. A major decrease in area covered by supratidal and intertidal salt marsh is seen in the earlier years of development, with large-scale elimination becoming less evident in subsequent years. This is shown by the 49% reduction in the functional importance score once development started taking place within the Swartkops Estuary (pristine condition to 1939, Fig. 7.4). Developments such as Swartkops and Redhouse Villages, roads and bridges and the power station led to the removal of large areas of supratidal salt marsh. In later years (1939 - present, Fig. 7.4) the gradual loss of plant cover leads to a 6% reduction in the functional importance score (51 to 45). The removal of the highly productive submerged macrophyte *Zostera capensis* by flood accounts for the low importance scores for 1984 and 1988. Presently, the most important botanical components in the Swartkops Estuary are the intertidal salt marsh and intertidal benthic microalgae.

Changes in plant cover also alter the functional importance of an estuary on a national basis when compared to other estuaries of different sizes or with other plant community types present. For example, the Quko Estuary covers a total area of 78 ha compared to the Mngazana Estuary that covers an area of 615 ha. The high importance score for the Olifants Estuary is a result of the large area covered by supratidal salt marsh. The Mngazana Estuary has a high importance score because it has the largest mangrove community present in the Eastern Cape Province. In its pristine condition the Swartkops Estuary would have had a higher ranking (second place) in terms of its national functional importance than it presently has (third place) (Table 7.5). This is due to the loss of area covered by the estuarine plants. Despite this, because of the large area of estuarine plants still present in the Swartkops Estuary, it is still ranked third, based on its present condition within this group of estuaries.

Table 7.5: Functional importance scores ranked in decreasing order of importance for a number of South African estuaries. Normalised scores are also presented.

Estuary	**Functional importance score**	**Normalised score**
Olifants	402 567	100
Swartkops (pristine)	397 027	99
Mngazana	312 604	78
Swartkops 1939	203 857	51
Swartkops 1998	179 936	45
Gamtoos	90 704	23
Kieskamma	83 298	21
Goukou	62 107	15
Groot Brak	47 536	12
Quko	32 303	8

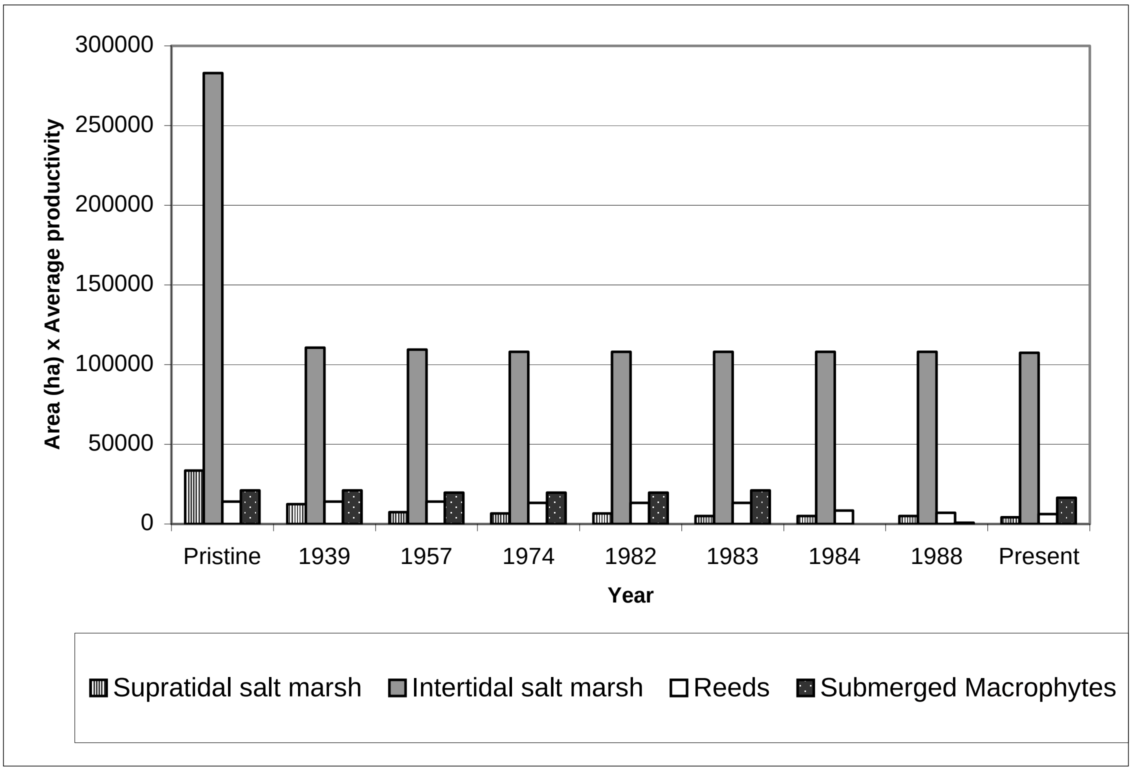


Figure 7.4: The change in area cover x productivity values over time for the respective plant community types in the Swartkops Estuary.

7.2.3 Discussion

The majority of plant community types found in the Swartkops Estuary have been affected by anthropogenic development within the estuary basin. Bridges and roads have caused major changes in the Swartkops Estuary. As early as MacNae's (1957) study, changes in sediment deposition were noted to have led to the loss of intertidal salt marsh after the construction of the railway bridge near Swartkops Village. The embankments of this bridge and the N2 Settlers bridge led to the removal of both intertidal and supratidal salt marsh. Because of this, there has been a decrease in the botanical functional importance score of the Swartkops Estuary over the last 40 years. In order to protect river front properties in Swartkops Village and Amsterdamhoek area, retaining walls were constructed. In the case of the Swartkops Village, areas adjacent to the retaining walls have been built up, whereas the Bluewater Bay walls were constructed in an area of steep cliffs, where no intertidal area occurred.

Small-scale anthropogenic impacts include footpaths and trampling, littering, bait digging, mooring of boats in plants and overgrazing. The effects of these impacts are not recorded in the functional importance score, as it is difficult to determine the amount of area or productivity lost as a result of these activities. The extensive intertidal mudflats are an ideal habitat for bait organisms such as the mud prawn (*Upogebia africana*) and pencil bait (*Solen cyclindraceus*). Extensive bait digging has resulted in impacts such as trampling and uprooting of the *Zostera capensis* beds, littering (plastic bags containers and discarded fishing tackle) and numerous footpaths in the supra- and intertidal salt marshes.

The salt marsh has been divided into two plant community types. These are the intertidal marsh that occurs from the mean high water neap mark to the mean high water spring mark, and the supratidal marsh that occurs above the spring high-tide watermark. These two salt marsh types differ in species composition (Adams et al. 1999). Supratidal salt marsh species may have similar salinity tolerance ranges to that of intertidal species, but they are more sensitive to inundation (Adams et al. 1992, Adams and Bate 1994). Salt marsh has been affected by human development and subjected to higher pressures than the other plant community types. This is possibly due to the ease at which these areas are reclaimed for residential or industrial development by the reduction of tidal flow and the drying out of such areas.

The reed and submerged macrophyte plant community types have shown greater variation in area cover due to natural disturbance. Large floods have been shown to remove the reeds resulting in bank erosion and loss of potential habitat for subsequent recolonization. Floods remove the riparian plants and scour the banks leaving behind unstable steep sided river banks where there appears to be little subsequent sediment deposition. These banks are later colonised by grasses and invasive plants such as *Acacia* spp. Quarrying activities in the Perseverance area have altered the channel geomorphology, thus preventing reed establishment in this region of the estuary. Alien invasive plants such as *Acacia cyclops*, *Lantana camara* and *Senna didimobtyra* are found in small isolated clumps in the upper reaches of the estuary. Large floods remove the riparian plants that are mostly reeds, erode the river banks and open up areas for invasion by alien species, thus removing a habitat previously colonised by reeds.

The submerged macrophytes have also shown variation due to floods, with little seasonal variation evident. Seagrasses in more temperate climates have stable standing stocks with variation often correlated to flooding periodicity (Talbot and Bate 1987)

In its pristine condition, the Swartkops Estuary would have had a higher ranking (second place) in terms of its national functional importance than it presently has (third place). This is due to the loss of area covered by the estuarine plant community types. Despite this and because of the large area of estuarine plants still present in the Swartkops Estuary, it is still ranked third, based on its present state.

7.2.4 Conclusion

Application of the functional importance rating system identified salt marsh as the estuarine plant community that has experienced the greatest loss due to human development. Emphasis should be placed on the protection of salt marsh as these areas make a significant contribution to the secondary production of the estuary. Any reduction in their area will affect higher trophic levels (Davies 1982, Bally et al*.* 1985; Whitfield 1984). The most important botanical components in the Swartkops Estuary are the intertidal salt marsh and intertidal benthic microalgae. These areas should continue to function optimally provided the mouth of the estuary is allowed to remain open, thus ensuring regular tidal flushing. Supratidal salt marsh areas have suffered the greatest losses probably because they are only periodically inundated, and with suitable engineering are more prone to development (i.e. Fishwater Flats Sewage Works, Neave industrial area). In the future, the supratidal salt marsh may be the most vulnerable plant community type in terms of loss due to further developments.

7.3 EASTERN PONDOLAND ESTUARIES

7.3.1 Introduction

There are 45 rivers that enter the sea along the 150 km of Pondoland coast. Only 23 of these are considered to be estuaries. The remaining rivers are either ephemeral or seep into the foredunes along the coast, while several flow directly into the sea over cliffs (Plate 7.1). Whitfield (2000) described 18 of these estuaries as temporarily closed with five being permanently open. All these estuaries are remote with access limited to either off-road vehicles, bridal or footpaths. The only estuaries that are easily accessed are those protected within the Mkambati Nature Reserve. These estuaries (Table 7.6) are mostly small and not really suitable for fishing or harvesting of any resources. This has all contributed to the high conservation status of these estuaries.

7.3.2 Materials and methods

See Section 7.2.1 for the method of determining the habitat integrity of an estuary.

7.3.3 Results

7.3.3.1 Botanical surveys

Botanical surveys were conducted in all 23 estuaries during February 1999. Plant community types were identified as well as species composition. Aerial photographs were used to calculate past and present plant cover for all estuaries. Fourteen plant species were found in the Pondoland estuaries (Table 7.6) and were representative of three of the seven possible macrophyte community types namely; mangroves (4 species), reeds and sedges (8 species) and swamp forest (2 species). Phytoplankton (measured as water surface area) and benthic microalgae (measured as exposed sand and mud banks) were found in all estuaries.

The total estuarine surface area for the Pondoland region was approximately 342.7 ha. Reeds and sedges made up 15.2%, phytoplankton measured as water surface area was 61% of the total and benthic microalgae, measured as intertidal sand and mudflats, was 10.9%. These were the dominant community types in all of the Pondoland estuaries. The remaining plant community types, i.e. mangroves and swamp forest covered 5.5% and 6.3% respectively. Further analysis (Section 6) of the species composition of the Pondoland estuaries has shown that plant species were related to the freshwater components of the estuaries, i.e. reeds, sedges and swamp forest species. This is because of the higher mean annual runoff and changes in geomorphology that occur within this region.

Table 7.6: List of plant species found in the estuaries of the Pondoland region.

Species	**Family**	**Plant community type**
Acrostichum aureum L.	Adiantaceae	Mangrove associate
Avicennia marina Forssk. Vierh.	Verbenaceae	Mangrove
Bruguiera gymnorrhiza (L.) Lam.	Rhizophoraceae	Mangrove
Cyperus textilis Thunb.	Cyperaceae	Reeds and sedges
Juncus kraussii Hochst	Juncaceae	Reeds and sedges
Phragmites australis (Cav.) Steud.	Poaceae	Reeds and sedges
Phragmites mauritianus Kunth.	Poaceae	Reeds and sedges
Prionium serratum (L. f.) Dreg ex Mey.	Juncaceae	Reeds and sedges
Rhizophora mucronata Lam.	Rhizophoraceae	Mangrove
Sporobolus virginicus (L.) Kunth.	Poaceae	Reeds and sedges associate
Stenotaphrum secundatum (Walt.) Kuntze	Poaceae	Reeds and sedges associate
Strelitzia nicolai Regel and Koern.	Strelitziaceae	Swamp forest
Typha capensis (Rhorb.) N.E. Br.	Typhaceae	Reeds and sedges
Hibiscus tiliaceus L.	Malvaceae	Swamp forest

Plate 7.1: The Mkambati River is not considered to be an estuary as it flows directly into the sea over a series of waterfalls.

7.3.3 2 Regional functional importance

Estuaries can be compared on a regional basis using the functional importance rating. The data in Table 7.7 show that the permanently open estuaries had the highest functional importance scores. They also had the highest community richness (number of plant community types present). The smaller closed estuaries have less available habitat and this, coupled to the lack of tidal exchange, resulted in low plant-community richness. Although the Msikaba Estuary is a large (15 ha) permanently open estuary in this region, it had a low functional importance. It has a steep valley formation and there is little area available for estuarine plant colonisation, hence the low score. The Mbotyi and Mnyameni Estuaries are also exceptions that have been classified as temporarily open estuaries. These estuaries both have high functional importance scores because of the large delta areas at their mouths that are colonized by reeds.

Table 7.7: Present (1998) community richness and functional importance rating of estuaries found in the Pondoland region. Estuaries are ranked in decreasing order of functional importance. Permanently open estuaries are shown in bold.

Estuary	Community richness	Functional importance score	Normalised score
Mzamba	5	49 468	100
Mntafufu	5	29 116	59
Mtentu	5	22 889	46
Mbotyi	4	17169	35
Mnyameni	4	14 815	30
Mzintlava	5	11 833	24
Nkodusweni	3	10 842	22
Mgwegwe	4	9 270	19
Msikaba	3	4 492	9
Sikombe	4	4 244	9
Butsha	3	3 903	8
Mkweni	4	3 830	8
Mkozi	4	3 385	7
Mzimpunzi	3	2 527	5
Kwanyana	3	2 025	4
Mtentwana	2	1 815	4
Lupatana	4	1 618	3
Mpahlanyana	3	1 527	3
Mpahlane	3	1 434	3
Ntlupeni	3	865	2
Mgwetyana	3	842	2
Myekane	3	660	1
Mtolane	2	204	0

Photographs, taken in 1961, were available for the Pondoland region. These photographs showed that for 52% of the estuaries the area covered by the different plant community types and, hence the functional importance, has not changed over the last 33 years (Table 7.8). Twenty eight percent of estuaries showed a decrease in functional importance due to the loss of mangrove or reed cover. This decrease was, however, not as great as in those estuaries subjected to higher levels of anthropogenic disturbances, such as in the Cape and KwaZulu-Natal regions (e.g. Swartkops, Nhlabane and Mlalazi Estuaries). The exception was the Mtentwana Estuary where reed cover had been lost due to the construction of a small dam and golf course at the head of the estuary. On a national basis, the Pondoland region (Table 7.8) has a high conservation status with a greater percentage of estuaries either showing an increase in functional importance or remaining unchanged.

7.3.3.4 Botanical rarity of Pondoland estuaries

It is important to identify estuaries that have unique features or species composition. The Mkozi Estuary is small but it is the only estuary in the Eastern Cape where the mangrove fern *Acrostichum aureum* occurs. The Mtentu and Msikaba Estuaries have unique geomorphology and are also the only two South African estuaries where the rare Mkambati palm, *Jubaeopsis caffra* is found. This species is not part of any estuarine plant community. However, these palms are only a few metres from the high water mark and their rarity increases the importance of the estuaries, even though their presence is not reflected in the functional importance score.

Table 7.8: Past (1961) and present (1998) functional importance scores of selected estuaries found along the South African coastline. Estuaries are ranked in decreasing order of importance. The normalised scores are calculated for each estuary in order to illustrate the change in functional importance as a percentage. Pondoland estuaries are shown in bold.

Estuary	**Past functional importance scores**	**Present functional importance score**	**Normalised score**	**% Change**
Mgwegwe	1 710	9 270	18	82
Msikaba	2 810	4 492	62	38
Kwanyana	1 665	2 025	82	18
Mtentu	19 268	22 889	84	16
Mbotyi	14 807	17 169	86	14
Zinkwazi	72 115	79 351	90	10
Mzintlava	11 833	11 833	100	0
Sikombe	4 244	4 244	100	0
Mkweni	3 830	3 830	100	0
Mkozi	3 385	3 385	100	0
Mzimpunzi	2 527	2 527	100	0
Mpahlane	1 434	1 434	100	0
Mpahlanyana	1 527	1 527	100	0
Mgwetyana	842	842	100	0
Myekane	660	660	100	0
Nkodusweni	10 843	10 843	100	0
Ntlupeni	866	866	100	0
Mtolane	204	204	100	0
Mzamba	50 827	49 468	97	- 3
Lupatana	1 562	1 618	96	- 4
Mngazana	329 685	312 604	99	- 6
Mntafufu	38 134	29 116	76	- 24
Mnyameni	20 248	14 815	73	- 27
Butsha	6 096	3 903	64	-36
Swartkops	280 357	182 666	65	- 37
Mlalazi	224 042	128 816	57	- 43
Mtentwana	4 253	1 815	42	- 58
Nhlabane	120 585	13 666	11	- 89

7.3.4 Discussion and conclusion

The study showed that although the area covered by the estuarine plant community types was small, the Pondoland estuaries are nationally important as they have been the least impacted over time. Their present state is very similar to what their natural state may have been. These estuaries also have unique species such as the mangrove fern and fringe mangrove communities. The mangrove physiognomy is unique to the Pondoland region. This is due to the geomorphology that only allows small areas for mangrove colonisation in the permanently open estuaries. The mangrove stands found in these estuaries usually occur as a double row or, in some cases, a single row of mangrove trees. In Australia and Japan where such rare stands occur, these types of mangroves have been termed fringe mangrove forests. Mangroves found elsewhere along the South African coast have developed into large complex communities with a large number of associated species. These larger communities are more resilient to disturbance, whereas fringe mangrove forest exhibits lower juvenile recruitment rates and are more susceptible to disturbance. Thus, these Pondoland estuaries require a high degree of protection as has been shown in similar cases found in regions of Australia and Japan (Clough and Andrews 1981).

KwaZulu-Natal Nature Conservation Services and the Oceanographic Research Institute have proposed that the Pondoland area become part of a larger marine protected area stretching from Mpenjati Estuary in southern KwaZulu-Natal to Mntafufu Estuary just north of Port St Johns. This study highlighted the conservation importance of the Pondoland estuaries from a botanical perspective.

7.4 NATIONAL HABITAT INTEGRITY OF ESTUARIES

Botanical importance and habitat integrity were determined for the remainder of South Africa's estuaries for which information was available. To aid the rapid determination of botanical importance and habitat integrity a database was constructed for 274 South African estuaries. This would help identify South African estuaries that remain unimpacted and the regions they occur in. Those estuaries that have been impacted could be used to determine the number and type of impacts occurring in South Africa.

7.4.1 Materials and methods

Habitat integrity was determined by calculating the functional importance of an estuary in its past and present state. The area covered by the different plant community types was measured from the oldest available aerial photographs, maps or literature and compared with recent information. The difference in functional importance scores was calculated as a percentage and this was subtracted from 100 and expressed as deviation from the natural condition or as the habitat integrity of an estuary. All estuaries that have not changed were given a score of 100, while for other estuaries that have changed, the percentage change is applied to the ranges in Table 7.9. Change in scores over time, positive or negative, are regarded as a deviation from the natural condition. These scores where tested using a range percentile test and assigned relative scores as per the botanical importance rating (Section 4, Section 4.2).

Table 7.9: The habitat integrity scores applied to the ranges for percentage deviation from natural scores.

Percentage deviation from natural	Habitat integrity score
0	100
0.5-7.6	60
7.7-14	40
15-30	20
31-90	10

Example: Over the last eleven years the area covered by mangroves in the Mngazana Estuary has been reduced by 5 ha. Other changes in plant cover were a 0.25 reduction in intertidal salt marsh, 1.5 ha reduction in supratidal salt marsh and 1.7 ha reduction in submerged macrophyte area cover. Together these have resulted in a reduction in the functional importance score from 317 935.2 to 312 604.05 for the Mngazana Estuary. This was expressed as a 6% deviation from the natural condition and the estuary thus obtained a habitat integrity score of 60 (Table 7.9).

7.4.2 Results

The raw data and list of impacts applicable to estuaries is shown in the Appendix and database. The information used for the calculation of habitat integrity is the change in area covered by the different plant community types. Most of the information was obtained from the Green Books (CSIR, Estuaries of the Cape Series) spanning the mid to late 1980's. For the Ciskei and Transkei estuaries, this change was measured for a thirty-year period. For estuaries such as the Swartkops and St Lucia, aerial photographs taken in 1937 were used to measure past plant cover.

Table 7.10 indicates that of the 124 estuaries used in this study, 44 estuaries (35%) showed no change in area cover over time with habitat integrity scores of 100. Of these 40 (91%) were found in Transkei and 3 (7%) in Ciskei. The remainder of the Transkei estuaries were distributed as follows; 12 had a habitat integrity score of 60, 4 had a score of 40, 12 had a score of 20 and 8 had a score of 10. Ten of the Transkei estuaries showed an increase in either reed and sedge or swamp forest cover. Twenty-six (35%) of the Transkei estuaries showed a decrease in plant cover over time due to removal for agriculture or wood utilization in the case of mangroves (Table 7.10). There was a similar trend for the Ciskei estuaries where 43% (7) showed a decrease in plant cover over time (Table 7.10). The estuaries that had the lowest habitat integrity scores were those where plant cover had been lost due to road construction at or near their mouths. These roads resulted in the removal of salt marsh, as seen in the Great Fish, Mgwalana, Mtati and Gqutywa Estuaries. The greatest reduction in plant cover occurred in the Keiskamma, Bira, Mpekweni and Kiwane Estuaries (Table 7.10). In the case of the Keiskamma Estuary, large areas of salt marsh have been converted into croplands, while the Bira and Mpekweni Estuaries were impacted by road and residential developments. Invasive Acacia trees had replaced 30% of the reed beds in the Kiwane Estuary. The remainder of the 124 estuaries occurred in the Western and Eastern Cape or KwaZulu-Natal Provinces (Table 7.10). These 32 estuaries with the exception of the Mdlotane Estuary all had low habitat integrity scores as a result of a reduction in plant cover due to residential developments in the Cape systems and farming in the KwaZulu-Natal estuaries.

Estuaries found in the Transkei and Ciskei that received the lowest habitat integrity score of 10 included the Bulungula (-41%), Keiskamma (-30%), Kiwane (-30%) and Mtentwana (-57.3%). Highly productive plant community types such as salt marshes, mangroves and swamp forest have been lost from these estuaries. The regional rating of the Ciskei and Transkei region has highlighted agriculture as a major threat to these estuaries. Agriculture has resulted in the greatest reduction in area (34%) covered by the estuarine plants (Appendix – Table 1 list of impacts). An example of this is the Nenga Estuary which is rated 179th in South

Africa. Not only does the town of Coffee Bay occupy the floodplain, but the islands within this system have also been used for crop production. The Bulungula Estuary was the only system where there has been a loss in mangrove cover due to a natural drought event (Knight pers. comm. 1999). This system has lost all 3.5 ha of mangrove cover. The Mtentwana Estuary had the greatest decrease in functional importance over time with a loss of 1.7 ha of reed bed. This was due to the construction of a weir and golf course that resulted in the 14% reduction in total plant cover of this estuary.

Table 7.10: The habitat integrity scores of 124 South African estuaries. A score of 100 represents no change over time, while lower scores reflect a degree of change to the estuary.

Habitat integrity									
100		**60**		**40**		**20**		**10**	
Estuary	**% Change**	**Estuary**	**% Change**	**Estuary**	**% Change**	**Estuary**	**% Change**	**Estuary**	**% Change**
Blue Krans	0.0	Bot/Kleinmond	-3.7	Duiwenhoks	13.6	Bira	-15.4	Buffels Oos	47.1
Freshwater Poort	0.0	Cebe	-2.9	Gourits	-11.1	Bululo	25.6	Bulungulu	-41.1
Gqunqe	0.0	Great Fish	-0.6	Hartenbos	-9.0	Elsies	25.8	Butsha	-36.0
Gqwara	0.0	Great Kei	2.5	Heuningnes	-11.1	Gqutywa	15.8	Gamtoos	-31.3
Gxara	0.0	Jujura	2.3	Mbotyi	13.8	Hluleka	22.6	Kabeljous	70.1
Gxwaleni	0.0	Krom Oos	6.7	Mgwalana	10.5	Knysna	-16.5	Keiskamma	-30.3
Ku-amanzimuzama	0.0	Lupatana	3.5	Mnenu	-13.1	Kobonqaba	-21.0	Keurbooms	-53.3
Ku-Bhula	0.0	Mbashe	6.1	Mtata	-9.1	Kwanyana	17.8	Kiwane	-30.3
Ku-Mpenzu	0.0	Mhlathuze	2.1	Mtati	-8.5	Mdumbi	-22.9	Mdlotane	42.7
Kwa-Nyambalala	0.0	Mtakatye	7.6	Nhlabane	-9.9	Mkomazi	-28.9	Mdloti	38.0
Kwa-Suka	0.0	Mtana	2.1	Rooiels	-10.2	Mntafufu	-23.6	Mgwegwe	81.6
Lwandilana	0.0	Mzamba	-2.7	Steenbras	-11.5	Mnyameni	-26.8	Mlalazi	-42.5
Lwandile	0.0	Mzimvubu	-6.1	Uilkraals	14.3	Mpako	-20.3	Mncwasa	-42.0
Mapuzi	0.0	Ngqusi\Inxaxo	-2.7	Zinkwazi	9.1	Mtambane	17.4	Mpekweni	31.0
Mbhanyana	0.0	Nqabara	-2.2			Mtentu	15.8	Msikaba	37.4
Mendu	0.0	Palmiet	1.9			Ngqinisa	29.5	Mtentwana	-57.3
Mgwetyana	0.0	Qolora	-6.1			Old woman	-24.8	Nenga	-49.5
Mhlanga	0.0	Qora	4.0			Sinangwana	-15.7	Ngculura	40.6
Mkozi	0.0	Mngazana	-2.4			St Lucia	-20.4	Ntlonyane	-43.8
Mkweni	0.0	Wildevoëlvlei	-0.5			Swartkops	-29.3	Seekoei	49.3
Mpahlane	0.0					Umgazi	-17.7	Silvermine	50.9
Mpahlanyana	0.0					Xora	-16.0	Siyaya	86.5
Mpande	0.0							Tyolomnqa	-35.3
Mtolane	0.0								
Mtonga	0.0								
Mtumbane	0.0								
Myekane	0.0								
Mzimpunzi	0.0								
Mzintlava	0.0								
Ncizele	0.0								
Ngadla	0.0								
Ngogwane	0.0								
Ngoma	0.0								
Ngqwara	0.0								
Nkanya	0.0								
Nkodusweni	0.0								
Ntlupeni	0.0								
Shixini	0.0								
Shwele-Shwele	0.0								
Sihlontlweni	0.0								
Sikombe	0.0								
Sundwana	0.0								
Tongati	0.0								
Tshani	0.0								
Zalu	0.0								

7.4.3 Discussion

The habitat integrity assessment indicated that the Ciskei and Transkei estuaries are important on a national scale as they have changed little over time and have high habitat integrity scores. Estuaries found in the northern Transkei are particularly unimpacted.

Estuaries are dynamic systems with great temporal changes. Using once-off measurements in rating systems would not be valid in reporting the importance or health of an estuary (Turpie et al*.* 1999). However, the area covered by the different plant community types can be measured from available maps and photographs and botanical importance can be measured at any time if information is available. The change in botanical importance over time can then indicate habitat integrity. Habitat integrity scores of 100 (i.e. no change) were calculated for a number of Ciskei and Transkei estuaries. The areas covered by the different plant community types in these estuaries have not changed over the last 30 years. This is in contrast to estuaries in KwaZulu-Natal where floods can alter plant cover and botanical importance by 10% (Riddin 1999).

Estuaries in the south Eastern Cape have shown a large variation in functional importance scores over time. This was due to the change in submerged macrophyte cover in the small temporarily open Kabeljous and Seekoei Estuaries. For both of these estuaries there was between 30 and 45% variation in habitat integrity scores over a twenty-year period (Freckelton 1999). This was due to rapid growth of submerged macrophytes when the estuaries were closed and salinity and water currents were reduced. (Adams et al*.* 1992; van Hattum 1998). In the large permanently open estuaries such as the Swartkops Estuary, the variability in submerged macrophyte cover resulted in a 8% variation in the habitat integrity score over a 45 year period (Colloty et al*.* 2000). The variation in plant cover was thus dependent on the type of estuary. The inherent stability of larger estuaries has been documented elsewhere (Branch and Grindley 1979; Coetzee et al. 1997; Riddin 1999), resulting is less change over time with natural fluctuations only evident during large flood or drought events. However, if individual estuaries are monitored over time, a threshold of natural variation could be set. Changes in land use or water abstraction could alter the functioning of an estuary and would cause a change in the habitat integrity scores. If these changes altered the natural threshold of a system, the management should be altered to not exceed the threshold of natural variation. The habitat integrity scores can be used as a tool to measure the status of an estuary, but can also be used to determine the sensitivity of an estuary to modification. This has already been used in understanding the negative effects of development in the most important estuary in South Africa. Changing salinity levels in the lake section of the St Lucia Estuary (northern KwaZulu-Natal) also influences the submerged macrophytes. When the salinity is low, *Potamogeton pectinatus* colonises much of the lake section of the St Lucia Estuary (Ward 1976, Taylor 1991). *P. pectinatus* dies out when salinity reaches half that of seawater and is replaced by *Ruppia cirrhosa* and *Zostera capensis* (Taylor 1991). *Potamogeton pectinatus* is then limited to areas of freshwater input, i.e. at the entrance of rivers. Quibell (1996) has shown that the mean annual runoff to the St Lucia system has been reduced by 19% due to development in the catchment. This has resulted in higher and more variable salinity conditions with longer periods of near marine salinity. This increase in both salinity and variability affects the dynamics of the submerged macrophytes of the St Lucia Estuary.

The botanical importance rating system can thus be used to identify important estuaries as well as threatened systems. Richardson (1995) stated that an adequate measure of conservation importance should also include a monitoring function to determine the effects of management plans. With the use of the habitat integrity rating, threatened or sensitive estuaries could be identified. In the case of the Transkei region, the plant community type that is threatened the most is the mangroves. This warranted further investigation into the status and future regeneration capacity of these plants within the Transkei (Section 8).

A monitoring programme of this type would be easy to implement, as all that is required is a time sequence of vertical aerial photographs of a region. The number of surveys would, however, be dependent on the type of estuary, for example the small temporarily open estuaries of the Western Cape Province alternate between closed and open conditions more frequently and thus could have a greater variation in plant cover than estuaries found in the KwaZulu-Natal region. The Kwazulu-Natal estuaries are under-represented in the botanical importance rating due to insufficient information on the change in plant community cover over time.

8 DISTRIBUTION AND STATE OF TRANSKEI MANGROVES

8.1 INTRODUCTION

Mangroves cover approximately one quarter of the world's tropical coastline. They extend over an approximate area of 15.5 million ha along the coasts of North America, South America, Australia and Asia. Three million ha occur along the east and west African coasts (Blasco et al*.* 1998). Mangrove communities are important systems in stabilising coasts, providing a nursery habitat and refuge for invertebrates, fish and birds (Snedaker 1978). They are a source of primary production with energy transfer taking place through detrital food chains (Chapman 1984, Snedaker 1978; Robertson 1996).

Along the east coast of South Africa mangroves occur in 37 estuaries and cover approximately 1 688 ha (0.05% of Africa's total). The largest mangroves occur at the Mhlathuze (652 ha) (Riddin 1999) and St Lucia (571ha) Estuaries in KwaZulu-Natal. Considerably lower mangrove tree cover is found at the Mngazana Estuary (145 ha) in the former Transkei. This is evidence of a natural decline towards the southern distribution limits. The size (area cover) and species composition of South African mangrove communities differ from those in the northern hemisphere tropics, with the exception of the Kosi Bay system that has tropical affinities and contains *Avicennia marina, Bruguiera gymnorrhiza, Rhizophora mucronata, Ceriops tagal* and *Lumnitzera racemosa* trees. The latter two species are only found along tropical coasts, for example Mozambique, Tanzania and Kenya.

The Transkei region bordering the east coast of South Africa between the Great Kei and Mtamvuna Rivers was an independent homeland from 1963 until 1976 when it became a republic. After 1994, it was re-incorporated into South Africa and became part of the Eastern Cape Province. Political instability, poor infrastructure and lack of funds have limited research activities in the region. Consequently ecological studies on estuaries were limited to a few (Dye 1977, 1978, 1983a, 1983b; Emmerson and McGwynne 1992; Plumstead 1984, 1990, Plumstead et al*.* 1989a, 1989b, 1991; and Wooldridge 1974, 1977). Estuaries were excluded from botanical research for more than 11 years and little is known about current structure and state of mangroves in this region. The most recent account of distribution and extent of mangroves in the region is that of Ward and Steinke in 1982.

The mangrove communities along the Transkei region are threatened chiefly by the chopping of trees to make poles for animal enclosures (Moll et al*.* 1971). In addition, smothering deposits of silt resulting from poorly managed land development programmes and poor soil conservation practices in river catchments has led to an increase in suspended sediment loads. This sediment is then trapped by mangrove communities at a rate that often exceeds those optimum for tree survival and growth (Moll et al*.* 1971, Steinke 1995).

Until recently in many countries, mangroves were considered to be wasteland (Bryant 1998), particularly in economically advancing countries rapidly developing their coastal lands. In Europe and Asia, for example, most mangroves have been destroyed or modified to make way for housing, roads, harbours and aquaculture industries (Dierberg and Kiattisimkul 1996). Within KwaZulu-Natal, mangroves have been removed from the Isipingo, Mgeni and Mkomazi Estuaries and have been replaced by industrial, residential or agricultural areas. One of the richest mangrove communities in South Africa occurred in Durban Bay, where harbour and industrial development have removed approximately 200 ha of mangrove trees (Moll et al. 1971).

For the effective protection of mangrove stands, scientists and managers require information on the structure and function of the community types and their sensitivity to disturbance (Steinke 1995; Tam et al. 1997). In this section the following are addressed:

(1) the distribution, size and composition of mangrove stands along the coast of former Transkei;

(2) the rates of colonisation and removal of trees on a regional scale;

(3) the reasons for change in mangrove cover and

(4) the proportion of the mangrove community that occurs in declared conservation areas.

8.2 MATERIALS AND METHODS

8.2.1 Field surveys

All 76 estuaries were surveyed in at least two field visits during the period December 1997 to August 1999. Mangrove stands were identified using aerial photographs (Institute for Coastal Resource Management collection 1996 (Scale 1:5000) and Surveys and Mapping 1961 and 1974 (Scale 1:10 000)) and from the field surveys. Mangrove species composition and the extent of cover of each species were identified for each system through a combination of transects and digital image analyses. Species nomenclature was based on Arnold and De Wet (1993).

8.2.2 Mapping and image analysis

The area (ha) covered by the mangrove communities was measured using 1:50 000 topographic maps and aerial photographs. These were converted into scaled digital images (Hewlett-Packard Scanner 4C). The digital images were then calibrated and the area covered by each plant community type was measured using image analysis software (analySIS 3.0). These measurements were verified through field assessments. Mangrove cover and species composition in each estuary were compared with Ward and Steinke's (1988) observations. This information was then used to determine the direction and rate of change in mangrove cover.

8.2.3 Mangrove state

Line intercept transect measurements were used to assess the condition or state of each of the mangrove communities. In past surveys in Transkei, mention has been made of the impacts such as wood harvesting and high sediment loads in the rivers affecting the state or condition of the mangroves in this region. However, the degree to which the communities are being affected has never been quantified. Transects were each 20 m long and 5 replicate transects were measured in each mangrove stand. Seedlings (part of propagule still visible), juveniles (< 1 m in height) and trees (> 1m in height) were identified and counted along each transect to compare the state of the different mangrove communities. Species included all mangroves and mangrove associates such as the freshwater mangrove *Hibiscus tiliaceus* L. and the mangrove fern *Acrostichum aureum*.

Ideally, the state of mangroves is monitored using permanent transects visited on a monthly basis for a minimum of two years (Ward and Steinke 1982). Due to the inaccessibility of some Transkei estuaries, this was not possible. Tree density was used as a measure of state by counting the number of individuals along a transect. This information was then used in conjunction with aerial photographs (1:10 000) to determine the number of individuals per unit area in each estuary.

8.3 RESULTS

Mangroves were recorded in 14 of the 76 estuaries surveyed, with complete loss of trees evident in the Mnyameni, Mzimvubu and Bulungula Estuaries. This amounted to a loss of 17 ha of mangrove area (Fig. 8.1). No new occurrences of stands were recorded in the remaining estuaries. The total extent of mangroves in Transkei differed from that of past surveys (Fig. 8.1). There has been an increase in mangrove area in eight of the estuaries, i.e. the Mtentu (50%), Mzintlava (15%), Mntafufu (20%), Mtakatye (17%), Mtata (19%), Xora (4%), Mbashe (11%) and Nxaxo (7%) Estuaries. These increases were randomly distributed amongst the estuaries, i.e. no distribution trends from a north versus southern perspective. Compared to the survey by Ward and Steinke (1982), this increase represents a total of 17.6 ha over the past eleven years. The larger estuaries i.e. Mtentu, Mtakatye, Mntafufu, Mbashe and Mtata showed the greatest increase in mangrove area. The loss in total mangrove cover for the same period was approximately 17 ha. Thus, a net gain of 0.6 ha was observed.

From estimates in this survey (Fig. 8.1 and Table 8.1), approximately 48 ha (18 %) of the current mangrove area occur in protected areas along the Mtamvuna, Mtentu and Mbashe Estuaries. The Xora and Nxaxo Estuaries have shown increases in mangrove cover probably attributed to conservation measures implemented by hotel owners and residents along the estuaries (Hewson pers. comm.). The coastal areas included in conservancies are not yet part of proclaimed conservation areas.

The only mangrove species recorded during the surveys include *Avicennia marina*, *Bruguiera gymnorrhiza* and *Rhizophora mucronata* (Table 8.1). The mangrove fern *Acrostichum aureum* was recorded for the first time during this survey. The fern dominated the middle and upper reaches of the Mkozi Estuary, 15 km north of the coastal town of Mbotyi (Fig. 8.1) and covered approximately 1.3 ha of the estuary fringe (55 % of the total estuary surface area).

Overall there has been little change in mangrove species composition in the different estuaries (Table 8.1). Previously the Mtentu Estuary was recorded as having only *Bruguiera gymnorrhiza* in the middle reaches. However, a number of *Avicennia marina* trees were found. Previous research indicated that *Bruguiera gymnorrhiza* had been removed from the Nxaxo Estuary by floods (Ward and Steinke 1982). This study recorded juveniles of this species and *Rhizophora mucronata. Avicennia marina* was the most common mangrove tree occurring in 75% of the estuaries while *Bruguiera gymnorrhiza* occurred in 65 % of the estuaries surveyed. The Mtamvuna and Mzamba Estuaries were only colonised by *B. gymnorrhiza* and *Hibiscus tiliaceus* (Table 8.1).

Highest tree densities of 2 594 tree.ha^{--1}were recorded in the Mngazana Estuary followed by the Mntafufu (1 402 trees.ha^{-1}), Mtata (210 trees.ha^{-1}) and the Mbashe (174 trees.ha^{-1}) (Table 8.2). No significant correlation was found between the area covered by the mangrove stands and tree densities ($r=0.2$, $p<0.05$). Moderate size estuaries such as the Nqabara Estuary (9 ha) had low tree densities of 74 trees.ha^{--1}, whereas the Mtakatye Estuary of the same size had 162 trees.ha^{-1}. The Mntafufu Estuary, 12 ha in size, had a high tree density of 1 402 trees.ha^{-1}. The Mbashe, Xora, Mtakatye, Mtata and Nxaxo Estuaries were characterised by fringe mangrove stands and intertidal islands that were also colonised by mangroves. This resulted in high tree densities (between 121 - 210 trees.ha^{-1}, Table 8.2).

Densities of dead trees recorded as stumps were greater or equal to that of the living trees in the Mdumbi, Mtamvuna, and Kobonqaba Estuaries (Table 8.2). Tree removal has had the largest impact on the fringe mangroves. Mangroves found in protected areas such as the Mtentu and Xora Estuaries had high juvenile densities (between 20 - 26 trees.ha^{-1}, Table 8.2). Field surveys showed that tree removal no longer occurs in these estuaries as no tree stumps were observed. The other 12 estuaries, with the exception of the Mngazana Estuary, had juvenile densities of between 32 and 603 trees.ha^{--1}.

Estuaries in which mangrove survival is threatened include the Mdumbi, Mzamba, Kobonqaba and Mtamvuna. These estuaries receive no form of conservation protection and large-scale tree removal has resulted in more than 50 % of the trees being removed. No seedlings or juveniles were found in these estuaries and the regeneration potential of the stands is limited.

Figure 8.1: A map of the Eastern Cape Province showing estuaries that support mangrove communities. Present area (ha) and percentage of total area cover for the region is given. The past area cover values were taken from Ward and Steinke (1982). Key: + = increase in area cover, 0 = no change and **-** = decrease in mangrove cover.

Table 8.1: A comparison of species found in this survey compared with past surveys, including comments on possible reason for changes in composition and total area covered, as well as conservation protection.

Estuary	Species present in past literature (Ward and Steinke 1982)	Present in this survey	Comments	Conservation status
Mtamvuna	*B. gymnorrhiza*	*B. gymnorrhiza*	A total of five trees in the upper reaches of the estuary	Protected
Mzamba	*B. gymnorrhiza*	*B. gymnorrhiza*	A total of three trees in the mid reaches of the estuary	Unprotected
Mnyameni	*A. marina B. gymnorrhiza*	8. None	Cause of loss not known possibly due to harvesting	Unprotected
Mtentu	*B. gymnorrhiza*	*A. marina B. gymnorrhiza*	Small *A. marina* trees are found on the mudflats in the mid reaches	Mkambati Nature reserve
Mzintlava	*B. gymnorrhiza*	*B. gymnorrhiza*	Increase in stand cover	Unprotected, but inaccessible
Mntafufu	*A. marina, R. mucronata B. gymnorrhiza*	*A. marina*, R. mucronata *B. gymnorrhiza*	Increase in stand cover	Unprotected, but inaccessible
Mzimvubu	*A. marina B. gymnorrhiza*	None	Loss possibly due to scouring by floods	Unprotected
Mngazana	*A. marina, R. mucronata B. gymnorrhiza*	*A. marina, R. mucronata B. gymnorrhiza*	Decrease in mangrove cover due to harvesting	Unprotected
Mtakatye	*A. marina, R. mucronata* and *B. gymnorrhiza*	*A. marina, R. mucronata* and *B. gymnorrhiza*	Increase in mangrove cover	Unprotected
Mdumbi	*A. marina*	*A. marina*	Decrease in mangrove cover due to harvesting	Unprotected
Mtata	*A. marina, R. mucronata* and *B. gymnorrhiza*	*A. marina, R. mucronata B. gymnorrhiza*	Increase in mangrove cover	Unprotected
Bulungula	*A. marina, R. mucronata* and *B. gymnorrhiza*	None	Complete loss of mangrove cover due to drought that resulted in mouth closure	Unprotected
Xora	*A. marina* and *B. gymnorrhiza*	*A. marina B. gymnorrhiza*	No evidence of change	Protected by local community
Mbashe	*A. marina* and *B. gymnorrhiza*	*A. marina B. gymnorrhiza*	Increase in mangrove cover	Dwesa and Cebe Nature reserves
Nqabara	*A. marina*	*A. marina*	No evidence of change	Unprotected
Nxaxo	*A. marina* and *B. gymnorrhiza*	*A. marina, B. gymnorrhiza R. mucronata*	Increase in cover, with *B. gymnorrhiza* juvenile trees and *R. mucronata* found	Protected by local community
Kobonqaba	*A. marina*	*A. marina*	Loss due to harvesting of trees	Unprotected

Table 8.2: Tree density of respective mangrove species found in the Transkei estuaries.

	Trees ha^{-1}				
	Living	Dead	Height <1m	Height >1m	Total
Mntafufu					
Avicennia marina	749	40	54	735	789
Bruguiera gymnorrhiza	201	4	31	174	205
Rhizophora mucronata	256	0	36	220	256
Hibiscus tiliaceus	152	0	0	152	152
					1 402
Mngazana					
Avicennia marina	952	148	289	811	1 100
Bruguiera gymnorrhiza	754	78	602	230	832
Rhizophora mucronata	436	85	32	489	521
Hibiscus tiliaceus	141	0	0	141	141
					2 594
Mtakatye					
Avicennia marina	77	20	14	85	97
Bruguiera gymnorrhiza	35	20	8	47	55
Rhizophora mucronata	10	0	0	10	10
Hibiscus tiliaceus	0	0	0	0	0
					162
Mtata					
Avicennia marina	89	65	16	138	154
Bruguiera gymnorrhiza	42	6	1	47	48
Rhizophora mucronata	8	0	0	8	8
Hibiscus tiliaceus	0	0	0	0	0
					210
Mbashe					
Avicennia marina	141	23	12	152	164
Bruguiera gymnorrhiza	102	97	5	45	5
Rhizophora mucronata	0	0	0	0	0
Hibiscus tiliaceus	5	0	0	5	5
					174
Mzamba					
Avicennia marina	0	0	0	0	0
Bruguiera gymnorrhiza	5	0	0	5	5
Rhizophora mucronata	0	0	0	0	0
Hibiscus tiliaceus	5	0	0	5	5
					10
Mtentu					
Avicennia marina	15	0	15	0	15
Bruguiera gymnorrhiza	18	2	4	16	20
Rhizophora mucronata	0	0	0	0	0
Hibiscus tiliaceus	5	0	0	5	5
Kobonqaba					
Avicennia marina	8	9	8	9	17
Bruguiera gymnorrhiza	0	0	0	0	0
Rhizophora mucronata	0	0	0	0	0
Hibiscus tiliaceus	0	0	0	0	0
					17

Table 8.2 continued.

	Trees ha^{-1}				
	Living	Dead	Height <1m	Height >1m	Total
Nxaxo					
Avicennia marina	87	15	7	95	102
Bruguiera gymnorrhiza	5	0	2	3	5
Rhizophora mucronata	14	0	14	0	14
Hibiscus tiliaceus	0	0	0	0	0
					121
Nqabara					
Avicennia marina	62	12	8	66	74
Bruguiera gymnorrhiza	0	0	0	0	0
Rhizophora mucronata	0	0	0	0	0
Hibiscus tiliaceus	0	0	0	0	0
					74
Xora					
Avicennia marina	117	31	11	75	86
Bruguiera gymnorrhiza	91	20	15	56	71
Rhizophora mucronata	0	0	0	0	0
Hibiscus tiliaceus	0	0	0	0	0
					157
Mdumbi					
Avicennia marina	10	15	1	24	25
Bruguiera gymnorrhiza	0	0	0	0	0
Rhizophora mucronata	0	0	0	0	0
Hibiscus tiliaceus	0	0	0	0	0
					25
Mtamvuna					
Avicennia marina	0	0	0	0	0
Bruguiera gymnorrhiza	4	4	0	4	5
Rhizophora mucronata	0	0	0	0	0
Hibiscus tiliaceus	0	0	0	0	0
					5
Mzintlava					
Avicennia marina	23	0	4	19	23
Bruguiera gymnorrhiza	57	2	0	59	59
Rhizophora mucronata	0	0	0	0	0
Hibiscus tiliaceus	0	0	0	0	0
					82

8.4 DISCUSSION AND CONCLUSION

With no major developments occurring in Transkei compared to the rest of the South African coast, it was expected that there would be a negligible change in mangrove cover over time in the study region. However, 17 ha have been lost in 4 estuaries while there was an increase of 17.6 ha in 6 estuaries over the last eleven years; therefore a net increase of 0.6 ha (no evidence of overall decline). Four estuaries showed no change in mangrove cover in the 11-year period. No new occurrences of mangrove stands were recorded. Mangroves previously occurred in 17 estuaries but are now found in 14. Stands of *Bruguiera gymnorrhiza* and *Avicennia marina* have been lost in the Mzimvubu River due to excessive bank scour due to a high incidence of floods, while mangrove stands in the Bulungula Estuary have been lost due to a drought. This resulted in the mouth of the Bulungula Estuary closing and because of back flooding the mangrove stands were inundated for a five month period (Knight pers. comm. 1998). Consequently the trees died and have since been harvested leaving only tree stumps. This estuary was one of five estuaries that previously contained all three species (A*. marina*, *Bruguiera gymnorrhiza* and *Rhizophora mucronata*). Mangroves communities in the Mnyameni Estuary have been completely removed for wood leaving dead tree stumps. Ward and Steinke (1982) had observed both *Bruguiera gymnorrhiza* and *Avicennia marina* in this system.

The development of large mangrove stands is restricted by the natural geomorphology of an area. Some estuaries, such as the Mngazana and Mntafufu, have extensive intertidal floodplain deltas that support mangrove trees in the form of complex riverine forests. The high tree densities that were recorded in the Mngazana and Mntafufu Estuaries testify to the dense form of mangrove that occur in these two estuaries. The foliage on these trees are currently grazed by cattle. A browse line occurred on the trees at approximately 1.5 m, while the upper canopy remained intact.

Fringe mangrove communities are different to the riverine mangrove forest mentioned above (Lugo and Snedaker 1974). These trees are adapted to a lower freshwater input and narrow channel geomorphology (Medina and Francisco 1997). This type of mangrove community was found in the other 14 Transkei estuaries. These estuaries had low tree densities and usually no mangrove associates such as *Hibiscus tiliaceus*. Areas still available for colonisation by mangroves are limited by the steep geomorphology that has led to a lack of floodplain habitats. Other mangroves found in South Africa could also be considered mangrove fringe communities with the exception of St Lucia and Mhlathuze estuaries (KwaZulu-Natal coast). The fringe mangrove communities are highest at risk, with the low tree density in these estuaries having a lowered sustainable yield.

The overall protection status of mangroves in Transkei was low with only 18% of the mangroves being found in nature reserves. Further removal of mangroves within the estuaries south of the Mzimvubu River is expected in the fringe mangrove communities as most are unprotected and easily accessible. Mature trees are usually selected and this has affected mangrove regeneration as there is a low percentage of juveniles present in the Mtamvuna, Mzamba, Mtakatye, Mtata, Mdumbi, Mzintlava and Kobonqaba Estuaries. This inhibits the future generation of propagules as mangrove stands can only survive if there is sufficient parent stock to produce enough propagules that can saturate the seed predators such as the coleoptera and lepidoptera (Dahdouh-Geubas et al*.* 1997) and keep the colonised banks stabile. Copicing was only evident in four estuaries, namely: Mbashe, Mtakatye, Nxaxo and Mngazana, and only by *Avicennia marina.* The conservation of mangrove areas in the Mdumbi, Mzamba and Mtamvuna Estuaries are of particular concern due to the high levels of use of these systems, with little or no recruitment observed (no juveniles).

The mangrove fern, *Acrostichum aureum,* was only found in the Mkozi Estuary. The future distribution of propagules to the north is unlikely as few suitable estuaries exist. The Mkozi Estuary has large intertidal areas and is almost permanently open (Harrison et al*.* 1999a; 1999b). Possible colonisation of the fern in estuaries to the south could include the Mbotyi and Mzimpunzi Estuaries as they have similar mouth dynamics and geomorphology. No major developments or settlements occur around the Mkozi Estuary and the only factor that could threaten the fern's existence is the expansion of forestry from the adjacent Mbotyi River catchment to the Mkozi River catchment. Impacts usually associated with forestry include runoff that contains elevated sediment loads that can affect the mouth dynamics of the estuary. If the mouth remains closed for an extended period, back flooding could occur and result in the drowning of the fern.

Mangrove species found in Transkei are mostly primary colonisers of intertidal mud and sandflats. This is seen in the overall increase in dominance of *Bruguiera gymnorrhiza* and *Avicennia marina* in estuaries futher southwards along the Eastern Cape coast. These species are particularly dominant in estuaries found near to the southern most limit of their distribution. World wide *Rhizophora mucronata* usually replaces the above-mentioned species over a 20 to 30 year period (Zakir 1996), but along the South African coast this species is only found in 10 of the 37 estuaries (Ward and Steinke 1982), four of which are found in Transkei. Estuaries that have a high density of this species are the Mngazana and Mntafufu Estuaries. This elevates the importance of these two estuaries in terms of them being the only riverine forest community that have the most complexity in terms of succession along the Transkei coast.

Compared to mangrove systems in North America, South America, North Africa and Austral-Asia (Blasco et al*.* 1998), Transkei systems appear insignificant. It is estimated that the present mangrove cover in the world is between 100 000 and 200 000 km^2, with the greatest proportion contained in Indonesia (42 550 km^2), Brazil (13 400 km^2) and Australia (11 500 km^2) (Blasco et al*.* 1998). The wide range in area estimates is due to the variety of mangroves types and their associates when cover measurements are made (Blasco et al*.* 1998). The mangroves on the east and west African continent, excluding those found on Madagascar, are estimated to cover approximately 54 000 ha. In Africa with estimated rates of loss between 1 500 to 2 000 ha per annum, because of tree removal and expansion of agriculture, the loss of mangroves in the Transkei region appears insignificant (Blasco pers. comm. 1999). This does not mean that the South African mangroves should be ignored. They should be protected because of their unique species composition as described by MacNae 1963. Secondly, they are at the southern most limit of their distribution (Saegner et al. 1995). Saegner and Bellan (1995) suggested that mangroves found along the east coast of Africa are threatened with over-utilisation (wood harvesting). This increases the conservation importance of such systems and must be a consideration for the mangrove estuaries in the Transkei.

Presently mangrove ecosystems world-wide are valued as a timber resource, and for the contribution they make to the stabilisation of coastlines and the creation of land, filtration of runoff, as well as providing habitats and nurseries for invertebrates and fish. The fish and invertebrates provide a protein resource for rural communities surrounding the mangroves. An economic evaluation of mangroves in Bintuni Bay, Indonesia, indicated that undisturbed mangrove forest is worth US$ 4 800,00.ha^{-1}. This was based on the economic value of the ecosystem services the mangrove communities provide, such as coast stabilisation storm protection and fisheries. Compared to this the market value of mangrove, timber is only worth US$ 3 600,00. ha^{-1} (Ruitenbeek 1992). The importance of mangrove systems to the estuarine and surrounding environments has been highlighted by the loss of such systems in North America and the Philippines. These losses have adversely affected fish recruitment and led to a decline in fisheries in these regions (Sheridan 1997; Gilbert and Janssen (1998). Subsistence and recreational fishermen predominantly use estuaries in South Africa. With no large-scale fishery associated with any of the mangrove systems along the Transkei coast and due to agriculture activities that dominate this region, South African mangroves are considered to be more important as a wood resource.

Although there was no net change in mangrove cover, through a combination of natural events and human activities, mangroves have been lost completely from three estuaries. Any reduction in mangrove cover was also reflected in the habitat integrity of these estuaries. Conservation of the mangroves is important and should be the focus of future conservation proposals. The Transkei mangroves are at the southerly limit of their distribution and there is a lack of suitable habitat for colonisation of additional estuaries due to the limited number of permanently open estuaries with intertidal regions. The future proposal of a Marine Protected Area for the northern area of the Transkei coast would increase the conserved area of mangroves by 5% to 23%. This protected area would include the Mtamvuna and Mzamba Estuaries as well as the unique Mkozi Estuary that contains the mangrove fern. The Mtentu Estuary is already protected within the Mkambati Nature Reserve. With the increased demand for crops, water and land for development, the value and conservation priority need to be set for the remaining mangroves.

9 GENERAL CONCLUSIONS AND RECOMMENDATIONS

The requirement for an importance rating has arisen due to the need for accessible scientific information that can be used in decision-making and setting management objectives. With 0% population growth only being attained by countries in Europe that are 90% urbanised (Blake 1991), which is not likely in Africa, the demands for resources by an increasing human population will continue. The management of water resources and the protection of natural ecosystems have become crucial. This study targeted the Ciskei and Transkei areas as they are underdeveloped and there is little available information on the rivers or estuaries.

The major objective of this study was to revise the botanical importance rating formula and apply it to the estuaries of the Ciskei and Transkei. Additional plant community types were incorporated into the formula. These included microalgae, mangroves and swamp forest. In the previous botanical importance rating (Coetzee et al. 1996, 1997) the contribution of the plants to secondary production was not included. With the inclusion of productivity the relative importance of the different individual plant community types could be indicated as the area (ha) component was retained. Aerial photographs were a valuable source of information from which the area covered (ha) by the plant community types could be determined. These areas were then verified in the field.

Once the 92 estuaries were surveyed, the functional importance of the Ciskei and Transkei estuaries could be determined. It was expected that functional importance would be low, as most estuaries were small and covered by reeds. This was true for the majority of the estuaries. However, the large permanently open estuaries had extensive salt marsh or mangrove areas and, thus, high functional importance scores.

The concept of botanical importance was extended further to include species and community type richness and plant community type rarity. The study on the Pondoland estuaries, part of a Rapid Reserve estimate for estuaries, showed that functional importance (area x productivity value) was inadequate to describe botanical importance. Traditional measures of conservation importance (species diversity, richness, habitat richness and rarity) were included in the overall assessment of botanical importance. The revised rating system was applied to the Ciskei and Transkei estuaries and successfully highlighted importance of estuaries based on functional importance as well as those that had a diverse or rare assemblage of species or habitats.

The reasons for the botanical importance of estuaries in the Ciskei and Transkei regions were described by relating the distribution of the plants to the physical environment. Based on the plant species composition, the estuaries could be divided into those that were permanently open versus those that were temporarily closed. The characteristic plant community types for the permanently open estuaries were intertidal salt marsh and mangroves. This region is a transition between the warm temperate and subtropical biogeographic zones and both permanently open and temporarily closed estuaries showed divisions at the Great Kei and Mngazana Estuaries. In permanently open estuaries the mangroves occurred north of the Great Kei Estuary and swamp forest north of the Mngazana Estuary. The temporarily closed estuaries in the Ciskei were characterised by salt marsh and reeds. Salt marsh occurred because of the high salinity and wide intertidal and supratidal zones. These estuaries were characterised by over wash from the sea and, thus, had high salinity. Macroalgae were also common. Reeds and sedges occurred north of the Great Kei River and reeds, sedges and swamp forest occurred north of the Mngazana Estuary where they replaced the salt marsh. Variations in the physical environment (MAR and morphology and temperature) resulted in a unique group of estuaries characterised by a high diversity of plant types. This was also evident in the fish assemblages that were unique for each of the different types of estuaries (Maree and Whitfield 1998; Harrison et al*.* 1999b).

Although a rating index should summarise information, the factors or components that determine the overall importance of an estuary should also be highlighted. This has been achieved in the botanical importance rating as the components that make up the rating are identified. Secondly, an importance rating or index that is related to management of resources should also have a monitoring function. This has been achieved in the creation of the habitat integrity index that shows the effects of development as well as natural change. This was demonstrated using the change in functional importance over time in the Swartkops Estuary. Development within the Swartkops Estuary basin has reduced the functional importance by almost half over the last sixty years, compared to the Nhlabane Estuary that had its functional importance reduced by 80% in half that time when a weir was constructed in this system (Riddin 1999). The Nhlabane was an estuarine lake, the weir has divided the system into a freshwater lake and a temporarily closed estuary with loss of a large brackish reed community. The effects of little or no management were evident in the study on the Pondoland estuaries. This small region had the highest density of unimpacted estuaries in South Africa.

The greatest threat to the Ciskei and Transkei estuaries is agriculture in the floodplains and unsustainable harvesting of mangroves. No new mangrove stands were found with almost no gain in mangrove area in the last eleven years. A further conservation concern is that harvesters are targeting *Bruguiera gymnorrhiza* and *Rhizophora mucronata,* two species that have been completely removed from three estuaries. The most threatened mangrove systems are those in the southern region of the Transkei. These are fringe communities that cover a small area and are easily accessed by harvesters. The intense rate of harvesting has reduced the number of adults. Seedling recruitment was affected as the density of mangroves less than 1m in height was low compared to mangroves where harvesting does not take place. Thus, the remaining communities have a limited regeneration capacity. Copicing was only evident in larger more complex mangrove forests such as those found at the Mntafufu and Mngazana Estuaries.

Other threats include the proposed dune mining at the Nxaxo Estuary (Wavecrest). Mining of the dunes will result in a physical disturbance and possible mouth closure due to the need for water abstraction from the river. These mangroves are important as they exist at the southern most limit of their distribution along the east coast of Africa. It is not known whether these are pioneer or climax communities and how resilient they will be to further impacts. The value of mangroves in terms of sustaining the subsistence and recreational fisheries (an important ecotourism attraction) is also not well understood in this region.

Future development of agriculture and industrial centres in the interior of the study region will increase pressure on the available resources. The large estuaries have been shown to be important as they are usually characterised by more species or habitats. Because of their large catchment areas and high mean annual runoff, these rivers will be targeted first for water abstraction. Currently the Lusikisiki Water Scheme is to be upgraded and either the Mzintlava or Msikaba Rivers have been earmarked for the construction of dams. This is inevitable in this region as increased industrial and agricultural development is foreseen. However, there are unused dams such as the Magwa Dam near Lusikisiki. This dam is not considered viable because water would have to be pumped to the required sites. Magwa Dam was constructed to supply the tea plantations. Fortunately, the Department of Water Affairs and Forestry have initiated studies on both the Msikaba and Mtata Estuaries. In the Mtata River study 12 other estuaries in the surrounding area will also be studied and through a process of either a rapid or intermediate determinations, the environmental water reserve will be established for these estuaries.

As mentioned, the larger river systems will be targeted for water use. Most of these larger estuaries are permanently open and contain salt marshes or mangroves. The potential threats of freshwater reduction include a change in salinity gradients and mouth closure. This has already occurred in the Bulungula estuary when the mouth closed during a drought period. The mangroves were back-flooded and drowned after an extended period of inundation. This has occurred in other South African estuaries, such as St. Lucia and Mgobezeleni Estuaries. Mangroves can only tolerate ca. five months of submersion. Thus, the allocation and maintenance of base flow that maintains salinity gradients and keeps the mouth of the estuary open can be based on these case studies and past ecophysiological studies on the mangrove species.

9.1 FUTURE RESEARCH

The dynamic nature of estuaries and the influence of this on conservation importance needs further understanding. This applies not only to the botanists but to other fields as well. This need is particularly apparent in terms of the need for adaptive management of water.

The KwaZulu-Natal estuaries require more attention as these estuaries were not adequately represented in the analyses. This would aid the testing of the hypothesis that the northern KwaZulu-Natal region should have a high number of important estuaries, as it is the transition zone between the subtropical and tropical regions. Also, this region has the greatest number of estuarine lakes such as St. Lucia and Kosi Bay.

The Cape estuaries should be surveyed as the past information needs to be updated for accuracy. There are a number of discrepancies with regard to species identification in the past literature. This would clarify the classification of the plant community types in this region.

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11 APPENDICES