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FOR APPLICATION IN THE ECOLOGICAL RESERVE DETERMINATION AND IMPLEMENTATION PROCESS

S Taljaard · L van Niekerk · P Huizinga · W Joubert

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EXECUTIVE SUMMARY

The CSIR, Environmentek was commissioned by the Water Research Commission to develop Resource Monitoring procedures for estuaries for application in the Ecological Reserve determination and implementation process.

A large component of the Resource Directed Measures methods for estuaries, in particular those addressing the Ecological Reserve were developed as part of a Department of Water Affairs and Forestry project in 1999-2000. Due to budget constraints, key components such as the design of monitoring procedures to determine resource status and to monitor responses once the Ecological Reserve is implemented, were not finalized. The aim of this project is to define guidelines and procedures to design resource monitoring programmes for estuaries as part of the Ecological Reserve Determination process for estuaries, including baseline studies and long-term monitoring programmes.

Key to the successful design of resource monitoring programmes is to put forward a conceptual framework of the anticipated abiotic and biotic (biophysical) processes and interactions that take place in a particular estuary, preferably at the inception stage of an Ecological Reserve Determination study.

It must be recognized that each estuary is somewhat unique in its characteristics. To accommodate the high variability in the biophysical functioning of estuaries, the approach in setting procedures for the resource monitoring programmes (as part of the Ecological Reserve determination process) is to provide generic sampling procedures (including recommended spatial and temporal scales) for each abiotic and biotic component, to be applied when a component is selected for inclusion in either baseline studies or the long-term monitoring programme of a particular estuary.

Abiotic components that need to be addressed in the Ecological Reserve determinations for estuaries are:

- Hydrology
- Sediment dynamics
- Hydrodynamics
- Water Quality.

Biotic components that need to be addressed are:

- Microalgae
- Macrophytes
- Invertebrates (including zooplankton, benthic invertebrates and macrocrustaceans)
- Fish (ichthyofauna)
- Birds (avifauna).

For each of the abiotic and biotic components the following is specified in the procedures:

- Sampling procedures
- Recommended spatial scales, i.e. selection of sampling stations
- Recommended temporal scales, i.e. frequency of sampling.

In most instances the sampling procedures and recommendations on spatial scales remain the same for baseline studies and long-term monitoring programmes. However, a distinction is made on the recommended temporal scale between:

- Baseline studies for Ecological Reserve determination (Intermediate level)
- Baseline studies for Ecological Reserve Determination (Comprehensive level)
- Long-term monitoring programmes

The layout of the manner in which procedures are provided for each component is illustrated below:

SAMPLING PROCEDURE	*Description of the sampling (and analytical) procedures that need to be followed for a particular abiotic or biotic component*	
SPATIAL SCALE	*Recommendation on the manner in which spatial scales (i.e. sampling stations) need to be selected for a particular abiotic or biotic component*	
TEMPORAL SCALE	INTERMEDIATE LEVEL RESERVE	COMPREHENSIVE LEVEL RESERVE
	Recommended frequency of sampling for an Ecological Reserve determination at Intermediate level	*Recommended frequency of sampling for an Ecological Reserve determination at Comprehensive level*
	LONG-TERM MONITORING PROGRAMME (where selected as indicator)	
	Recommended frequency of sampling of a component selected as an indicator for a long-term monitoring programme.	

IMPORTANT NOTES
List of important notes that should be taken into account in baseline studies or long-term monitoring programmes for a particular abiotic or biotic component

A summary of recommendations put forward as part of this project is listed below:

Cooperative governance:

- ***Due to fragmentation in the management and control of estuaries, resource monitoring programmes are often developed independently, arising from different departmental and legislative requirements. Therefore, to ensure efficient use of resources, both human and financial, and to prevent prevent duplication, it is recommended that resource monitoring programmes within a particular estuary be coordinated, taking into account sampling procedures, as well as spatial and temporal scales. This supports the principle of cooperative governance as required under the National Environmental Management Act and is also recommended in the proposed National Estuarine Management Protocol (Van Niekerk and Taljaard, in press).***

- ***Different departmental responsibilities must also be clearly indicated and aligned with the necessary funds and human resources. It is, therefore, also recommended that for a particular estuary:***

  - ***Specific responsibilities be allocated to specific authorities or institutions within a resource monitoring programme***
  - ***The appointed authority or institution have sufficient resources, both human and financial, to execute such monitoring or provide a strategy to obtain such resources.***

Guidelines for setting baseline studies and long-term monitoring programmes:

- *The Department of Water Affairs and Forestry, in collaboration with the Water Research Commission, should investigate the use of statistical methods to refine the procedures for setting spatial scales and sample replication in estuarine resource monitoring programmes.*

- *Qualified estuarine specialists should be consulted at the inception stage of an Ecological Reserve determination study (i.e. prior to putting it out to tender) to prepare a conceptual framework of the anticipated biophysical processes and interactions for that particular estuary and to assist with the specifications for the baseline studies, taking into account budgetary constraints, a reality encountered in most Ecological Reserve studies to date. This will provide a means of evening the playing field by including detailed baseline requirements as part of the tender document, rather than individual tenders adapting these themselves to accommodate budgetary constraints, hence making it very difficult for the DWAF to compare 'apples-with-apples' in the selection process.*

  To eliminate unfairness, the DWAF can, for example, use representatives from the organizations it intends to invite to tender to assist in the specification of baseline studies as part of a 'pre-tender scoping workshop'.

- *Qualified estuarine specialists should be consulted at the inception stage of an Ecological Reserve Determination study (i.e. prior to putting it out to tender) to prepare an inventory of available data and information on a particular estuary, as well as to evaluate the suitability of such data and information for use in the Ecological Reserve determination process. This inventory should be available when preparing specifications for the baseline studies for a particular system, hence eliminating unnecessary expenditure in terms of 're-acquiring' data and information that may already exist.*

  To eliminate unfairness, the DWAF can, for example, use representatives from the organizations it intends to invite to tender to assist in preparing such an inventory as input to the 'pre-tender scoping workshop', mentioned earlier.

- *In many instances the specialist team that designs a long-term monitoring programme may not be responsible for implementation. It is therefore recommended that the long-term monitoring programme includes a detailed map showing the position and coordinates of the selected sampling stations for the selected abiotic and biotic indicators.*

- *The long-term monitoring programme for an estuary should be subject to regular review, e.g. every 5 to 10 years, to continuously assess the relevance of selected monitoring components, as well as optimal use of resources. The review process needs to be conducted by qualified estuarine specialists. This continuous refinement of long-term monitoring programmes is in alignment with the concept of Strategic Adaptive Management.*

- *River inflow (flow gauging), continuous water level recording at the estuary mouth and water quality monitoring of river inflow at the head of estuaries should be undertaken by the Department of Water Affairs and Forestry as part of their national monitoring programme. It is also recommended that the Department initiate long-term monitoring programmes on the sediment dynamics of estuaries, similar to what was undertaken previously by the CSIR on behalf of the Department of Environmental Affairs and Tourism (refer to Appendix A). Even at the Ecological Reserve determination stage (at Intermediate and Comprehensive level) long-term data records are necessary for the above-mentioned parameters to obtain the required confidence. Such data therefore need to be collected on a national scale, through a national data collection programme, to be available when and where an Ecological Reserve determination needs to be conducted.*

- *The Department of Environmental Affairs should re-instate the annual aerial photograph monitoring programme of the South African coast (including estuaries) that was terminated in 1992, as these provide valuable information for both abiotic and biotic assessments in baseline and long-term monitoring programmes.*

Constraints to implementation of resource monitoring programmes:

- *Despite any immediate financial constraints, both baseline studies and long-term monitoring programmes for a particular estuary should be designed in their entirety as part of the Ecological Reserve Determination process. This will provide a focused reference framework within which to launch future data collection or monitoring initiatives in a particular estuary, as and when resources allow. Resources may also become available outside the Department of Water Affairs and Forestry, such as from the Department of Environmental Affairs and Tourism which also has monitoring responsibilities in estuaries.*

- *Ecological Reserve Determinations for estuarine systems of high ecological importance (in a regional, national or global context), that are already affected by developments in their catchment or that are targeted for future development, are carried out at a Comprehensive level as far as possible and that baseline surveys, and subsequent long-term monitoring programmes, be implemented fully. It is also recommended that these systems be identified collaboratively between the Department of Water Affairs and Forestry and the Department of Environmental Affairs and Tourism.*

Data capture and storage:

- *The Department of Water Affairs and Forestry (e.g. through the Directorate: Resource Directed Measures) should establish a dedicated database for the storage of biophysical data collected during the Ecological Reserve Determination process and record the implementation of the RDM process in estuaries. It is also recommended that existing data storage facilities for estuarine data (e.g. that of the CSIR) be expanded rather than re-developing such facilities from scratch.*

  In the interim, it is recommended that the Department of Water Affairs and Forestry require that raw data, collected by consultants during Ecological Reserve Determination studies or during the implementation of long-term monitoring programmes, be submitted to the Department as appendices to the Ecological Reserve Reports. These reports should be stored in a well-organized manner for easy access in future.

- *The Department of Water Affairs and Forestry, as part of the Ecological Reserve Determination process require that voucher specimens of biota collected in a particular system be lodged at a recognised natural history museum.*

- *It is also recommended that the Department approach either the East London Museum or the Natal Museum to set up such a facility for estuarine invertebrates, and the South African Institute for Aquatic Biodiversity to deal with estuarine fishes.*

Communicating information collected in resource monitoring programmes:

- *The Department of Water Affairs and Forestry (Directorate: Resource Directed Measures) should create a website, e.g. 'Ecological Reserve Determinations and Implementation in Estuaries' where Ecological Reserve reports and other related information can be accessed easily. The existence of such a site should be advertise, e.g. on the Department's homepage, the CERM website, at symposia and related publications, e.g. Water SA.*

- *The Department of Water Affairs and Forestry, in collaboration with the Water Research Commission, should also investigate the possibility of extending the River Health Programme to include estuaries in its reporting framework in an appropriate manner. If the monitoring component of the Health Programme could be extended to include estuaries, such an Estuarine Health Programme could even provide some of the data requirements of the Ecological Reserve determination process.*

Key consideration for way forward:

- *The format in which the procedures for (revised) baseline studies and long-term monitoring programmes is presented in this report is specifically selected to facilitate easy incorporation into the existing Ecological Reserve determination methods for estuaries, as published by the Department of Water Affairs and Forestry.*

  As part of the current project, these procedures were only peer reviewed by a limited number of estuarine specialists, due to budgetary constraints. It is therefore recommended that prior to the procedures being incorporated into the official Ecological Reserve determination methods for estuaries, it be sent out for wider comment, e.g. through the Consortium for Estuarine Research and Management (CERM) website.

  It is also important that the request for comments clearly explains the context in which these procedures need to be evaluated, i.e. these procedures provide a list of generic (or minimum) baseline survey and monitoring requirements that will provide acceptable levels of confidence to the Ecological Reserve determination and implementation process. Therefore, these generic baseline and monitoring requirements do not replace the need for detailed research studies to gather a higher level of scientific insight. The latter is of utmost importance to improving knowledge on estuarine systems and should be undertaken, for example, as separate Water Research Commission (as is currently being done through the Consortium of Estuarine Research and Management) or higher degree projects.

SCOPE OF WORK

The CSIR, Environmentek was commissioned by the Water Research Commission to develop Resource Monitoring procedures for estuaries for application in the Ecological Reserve determination and implementation process.

A large component of the Resource Directed Measures methods for estuaries, in particular those addressing the Ecological Reserve had been developed as part of a Department of Water Affairs and Forestry project during 1999-2000. Due to budget constraints, key components such as the design of monitoring procedures to determine resource status and to monitor responses once the Ecological Reserve is implemented were not finalized, hence this project.

The CSIR initially prepared draft monitoring procedures which were then further refined at a workshop attended by a selection of estuarine specialists that have been involved in Ecological Reserve studies on estuaries over the past three years.

The CSIR also used this project as a capacity building opportunity for an intern, Warren Joubert, who has since been appointed as a full staff member at the CSIR. Warren assisted in the review of monitoring programmes on estuaries and was involved in team discussions towards the development of the draft procedures. He also attended the above-mentioned specialist workshop that was held in the Natal Midlands in January 2003. To provide Warren with further exposure to the Ecological Reserve Determination process, this project also provided the opportunity to involve him in a specialist workshop on the Thukela Estuary Intermediate Ecological Reserve Determination currently in progress.

Susan Taljaard and Lara van Niekerk compiled this report with contributions from Piet Huizinga and Warren Joubert.

MARTEN GRüNDLINGH
BUSINESS AREA MANAGER: COASTAL PROCESSES

May 2003
Stellenbosch, South Africa

LIST OF ACRONYMS

GEC	Groot Brak Environmental Committee
CNC	Western Cape Nature Conservation Board
CRUZ	Coastal Research Unit of Zululand, University of Zululand
DEAT	Department of Environment Affairs and Tourism
DWAF	Department of Water Affairs and Forestry
EIA	Environmental Impact Assessment
KZN	Kwazulu-Natal
MCM	Chief Directorate: Marine and Coastal Management of the DEAT
SANP	South African National Parks
UPE	University of Port Elizabeth
UCT	University of Cape Town

TABLE OF CONTENTS

1. INTRODUCTION

1.1 Aim of Project

Approximately 255 functional estuaries, ranging from small temporarily open/closed systems to large permanently open tidal estuaries, are situated along South Africa's 3 000 km coastline. Estuaries form the interface between land and sea and are sensitive to changes in the upstream catchment as well as changes at sea.

Sustainable management of estuaries can only be achieved through a sound understanding of their biophysical process based on appropriate and reliable quantitative data. However, the collection, processing and interpretation of such data are often time consuming and costly, and often require considerable scientific expertise. Presently there is no generally accepted protocol to guide South African authorities in the design and implementation of estuary monitoring programmes. Consequently, monitoring is project specific and discontinuous, plays little part in guiding management decisions and is retarded by a lack of integration between responsible authorities and programmes. This absence in alignment between management requirements and existing monitoring programmes and activities in South African estuaries was highlighted at the recent National Estuaries Workshop held in Port Elizabeth during May 2000 (Boyd *et al.*, 2000).

A large component of the Resource Directed Measures methods for estuaries, in particular those addressing the Ecological Reserve, were developed as part of a Department of Water Affairs and Forestry project in 1999-2000. Due to budget constraints, key components such as the design of monitoring procedures to determine resource status and to monitor responses once the Ecological Reserve is implemented, were not finalized. The aim of this project is to define guidelines and procedures to design resource monitoring programmes for estuaries as part of the Ecological Reserve Determination process for estuaries.

Resource monitoring programmes, in the context of the Ecological Reserve Determination process, can be sub-divided into:

- ***Baseline surveys (or studies)***, the purpose of which is to collect data and information to characterize and understand the ecosystem functioning of a specific system so as to be able to determine Resource Directed Measures such as the Reference Condition, Present Ecological State, Ecological Importance, Ecological Reserve Category and Ecological Specifications (i.e. Resource Quality Objectives for the Biophysical Environment). Baseline data are collected as part of the Ecological Reserve determination process and also provides a benchmark for future monitoring.

- ***Long-term (or compliance) monitoring programmes***, the purpose of which is to assess (or audit) whether the Ecological Specifications (defined as part of the Ecological Reserve determination process) are being complied with after implementation. In addition, these programmes are also used to improve and refine the Ecological Reserve (and associated Ecological Specifications), in the longer-term through an iterative process.

NOTE:

It is important to note the difference between survey and monitoring:

- ***Surveys normally refers to short-term or once-off, intensive investigations on a wide range of parameters to obtain a better understanding of estuarine processes***

- ***Monitoring refers to ongoing data collection of a selection of indicator parameters in order to determine long-term change and trends. Long-term monitoring can be done for several reasons, one of which is for compliance monitoring.***

1.2 Existing Resource Monitoring Programmes undertaken in South African Estuaries

A number of resource monitoring programmes are being undertaken in South African estuaries over recent years, as summarized in Table 1 (refer to Appendix A or further details), of which some have been terminated over the past 2-3 years (see Table 1). However, the number of long-term monitoring programmes, that are still being implemented and that have been running for longer than 5 years, is limited to only a few of South Africa's 255 functional estuaries, as illustrated in Figure 1.

TABLE 1. List of existing monitoring initiatives in South African estuaries

LONG-TERM MONITORING (> 5 years)

Estuary	Organization	Water levels/ Observations	Flow gauging	Sediment	Water Quality	Flora	Inverts	Fish	Birds
Klein	CNC/.MCM/CSIR	x			x				
Bot	CNC/.MCM/CSIR	x			x				
Heuningnes	DWAF/ MCM./CNC	x						x	
Great Brak	DWAF/CSIR	x	x	x	x	x	x		
Swartvlei and Wilderness	IWR/CNC/SANP	x	x	x	x	x		x	x
East Kleinemonde	SAIAB	x						x	
Mkomazi	University of Natal	x	x		x	x	x	x	x
Siyaya	CRUZ			x	x		x	x	x
Mhlathuze	CRUZ	x	x	x	x		x	x	x
Nhlabane	CRUZ	x	x	x	x		x	x	x
St Lucia	KZN Wildlife	x	x		x	x		x	x
Kosi	KZN Wildlife				x?	x		x	

NATIONAL MONITORING OR SURVEY PROGRAMMES

Programme	Organization	Water levels/ Observations	Flow gauging	Sediment	Water Quality	Flora	Inverts	Fish	Birds
Continuous water level recording (Currently implemented in 29 estuaries)	DWAF	x							
Aerial photographs – terminated (Included all estuaries along SA coast)	DEAT/CSIR	x							
Flow gauging stations capturing total runoff of catchment to estuaries	DWAF		x						
Mouth observation program (Currently implemented in 10 estuaries)	CSIR	x							
Topographical surveys – terminated (Included 47 estuaries along SA coast)	DEAT/CSIR			x					
State of Estuaries Reporting – terminated (Included 250 estuaries along SA coast)	DEAT/CSIR			x				x	
Coordinate Water Bird Counts – CWAC (Currently implemented in 24 estuaries)	UCT								x
National Marine and Estuarine Linefish Survey (To include aerial monitoring of all estuaries, ground monitoring of 50 estuaries)	MCM							x	
Botanical importance rating (Included ~70% of estuaries along SA coast)	UPE					x			
National sediment monitoring program (terminated *in situ* monitoring in rivers)	DWAF			x					

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SHORT TERM DATA COLLECTION PROGRAMMES OR SURVEYS (< 5 years)

Name	Organization	Water levels/ Observations	Flow gauging	Sediment	Water Quality	Flora	Inverts	Fish	Birds
Berg Estuary	DWAF/ Anchor Associates	x	x	x	x	x	x	x	x
Sir Lowry's Pass	Cape Metro Council				x				
Eerste	Cape Metro Council				x				
Lourens	Cape Metro Council				x				
Soetwater River	Cape Metro Council				x				
Seekoei	Cape Metro Council				x				
Zandvlei	Cape Metro Council				x				
Silvermine	Cape Metro Council				x				
Diep	Cape Metro Council				x				
Breede (Intermediate RDM)	DWAF	x	x		x	x	x	x	x
Klein Brak and Great Brak	UPE						x		
Swartkops	UPE				x	x	x	x	
Great Fish	SAIAB/UPE				x	x	x	x	
Mpekweni	SAIAB/UPE				x	x	x	x	
Mtati	SAIAB/UPE				x	x	x	x	
Mgwalana	SAIAB/UPE				x	x	x	x	
Bira	SAIAB/UPE				x	x	x	x	
Gcutywa	SAIAB/UPE				x	x	x	x	
Keiskamma	SAIAB/UPE				x	x	x	x	
Thukela (Intermediate RDM)	DWAF	x	x	x	x	x	x	x	x
KZN Estuaries (mouth monitoring)	KZN Wildlife	x							
Durban Bay (harbour)	UN						x		

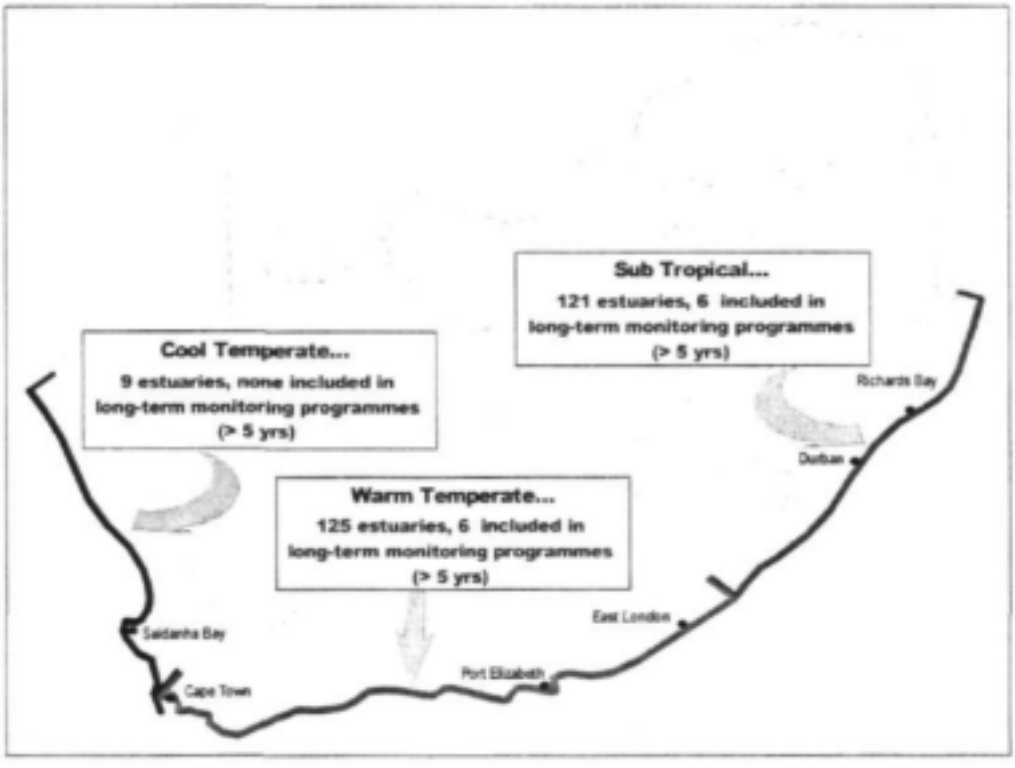

Figure 1. Distribution of existing long-term ecological monitoring programmes implemented in South African estuaries in the Cool Temperate, Warm Temperate and Sub-Tropical biogeographical regions

Currently, there are also a number of other research studies that deal with the development of monitoring initiatives for estuaries, albeit in a different context, such as the *Eastern Cape Estuaries Management: Monitoring Project* commissioned by the Water Research Commission, *South African Integrated Spatial Information System (SA-ISIS)* and the *National Core Set of Environmental Indicators Project* (refer to Appendix A for further details on these projects). The learning and experience gained through the above-mentioned initiatives will be taken into account in the development of monitoring procedures as outlined by this project.

1.3 Legislation Pertaining to Resource Monitoring in Estuaries

The Constitution of South Africa (Act 108 of 1996), in particular the Environmental Right (section 24), states that:

"Everyone has the right

a. to an environment that is not harmful to their health or well-being; and

b. to have the environment protected, for the benefit of present and future generations through reasonable legislative and other measures that –

i. prevent pollution and ecological degradation;

ii. promote conservation; and

iii. secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development'.

This section of the Bill of Rights guarantees the people of South Africa the right to an environment not detrimental to human health or well-being, and specifically imposes a duty on the State to promulgate legislation and take other steps to ensure that the right is upheld and that, among other things, pollution and ecological degradation is prevented.

This section provides a brief overview of the key legislation, whereby authorities are responsible or have the legal mandate to ensure that resource monitoring programmes are implemented, including those on estuaries.

1.3.1 National Water Act 36 of 1998

According to the National Water Act (section 137) the Minister of the *Department of Water Affairs and Forestry* is responsible for establishing a national monitoring system on water resources (which includes estuaries). Such systems must provide for the collection of data and information to assess:

- Quantity of water in the various water resource
- Quality of the water resources
- Use of water resources (i.e. activities)
- Rehabilitation of water resources
- Compliance with resource quality objectives
- Health of aquatic ecosystem
- Atmospheric conditions that may influence water resource (e.g. climate change).

Section 138 of the Act states that the Minister must establish mechanisms and procedures to co-ordinate monitoring after consultation with other organs of state, water management institutions and existing or potential users of water.

Although the National Water Act also does not explicitly require water users to conduct monitoring, there are, however, examples where developers or industry is required to undertake compliance monitoring as part of their license agreement, e.g. Arrabella Country Estate at Bot River Estuary. It has been recommended that this become a compulsory requirement in license agreements pertaining to listed water uses under the National Water Act.

1.3.2 National Environmental Management Act 107 of 1989

Although the National Environmental Management Act does not address monitoring of resources explicitly, it provides for co-operative environmental governance, in general, through the establishment of national environmental management principles, and procedures for their incorporation into decisions affecting the environment. It emphasizes co-operative governance and assistance in ensuring that the environmental right and related rights in the Constitution are protected.

NEMA requires the *Department of Environmental Affairs and Tourism* to be the lead agent in ensuring the effective custodianship of the environment (Smith and Cullinan, 2000).

1.3.3 Environmental Conservation Act 73 of 1989

Although many of the provisions of the Environmental Conservation Act have been repealed by the National Environmental Management Act, the Environmental Impact Assessment (EIA) regulations (implementing sections 21, 22 and 26 of the Act), as well as the regulation on Sensitive Coastal Areas remain in force until they are replaced with new regulations under the National Environmental Management Act. Under the EIA regulations, certain activities require an impact assessment prior to approval. Although the Regulations do not explicitly require environmental management plans (that typically includes long-term monitoring programmes) to form part of such assessments, there are, however, examples where the submission of a management plan (including a long-term monitoring programme) has become an additional condition for approval, e.g. the Thesen Island development on the Knysna Estuary.

1.3.4 Living Marine Resources Act 18 of 1998

The Living Marine Resources Act primarily deals with the protection and allocation of marine living resources and is administered by the *Department of Environmental Affairs and Tourism, Chief Directorate: Marine and Coastal Management.*

Chapter 3 on fisheries planning states that the Minister of environmental Affairs and Tourism is responsible for setting the catch and effort levels for living marine resources. This implies that regular monitoring will have to be done to establish the size of the resource to bases these on. In estuaries living resources, for example, includes fishes and invertebrates. Towards meeting this requirement, the Department of Environmental Affairs and Tourism initiated the National Estuarine Linefish Surveys (refer to Appendix A).

The Act does not require any form of monitoring from permit holders in terms of commercial, subsistence or recreational fishing in estuaries. However, the Minister of the Department of Environmental Affairs and Tourism may appoint any persons of an organ of state to become a fishery control officer or a person, not necessarily from an organ of state, to become a honorary marine conservation officer. Currently the department uses such persons to monitor compliance with permit conditions. Where an incidence of non-compliance is documented by these officers, such information can prove to be a valuable indicator for compliance both in terms of permits and overall strategies and objectives for resource management.

1.3.5 National Environmental Legislation: Coastal Zone Bill

Although still in a draft form, the National Environmental Legislation: Coastal Zone Bill will primarily address the legal mandate of the *Department of Environmental Affairs and Tourism* in the design and implementation of resource monitoring programmes.

In earlier drafts (Draft 2) of the Bill, the establishment of a national coastal monitoring system was explicitly stated as part of the Department's legal mandate, but this was removed in the later versions. The Bill, however, does require that performance indicators be identified to measure progress in terms of the objectives of coastal management programmes on national (section 66), provincial (section 70) and municipal (section 73) levels.

1.3.6 National Environmental Legislation: Biodiversity Bill

Although still in draft form, this Bill's focus is to protect biodiversity and will also be administered by the *Department of Environmental Affairs and Tourism*. Specific actions pertaining to monitoring include:

- Section 41 proposes that the national biodiversity framework must set performance indicators against which progress with the achievement of strategic objectives could be measured as well as to set up mechanisms to monitor and measure such progress.

- Section 44 proposes that a bioregional conservation plan must determine performance indicators to measure progress with the achievement of those objectives and to provide for monitoring the implementation of the plan.

- Section 52 proposes that other conservation plans (established under section 50) must determine performance indicators against which achievement of the objective is to be measured and also that persons, organisations and organs of state must be identified that will be involved in monitoring of the plan.

- Section 63 proposes that the Minister of the Department of Environmental Affairs and Tourism identify the components of biodiversity that are important for biodiversity conservation and the sustainable use of biological resources or which are inadequately conserved or understood. Monitoring mechanisms need to be established for such components. Indicators also need to be set to determine the conservation status of the components and any negative and positive trends affecting the conservation status of the components.

- Section 63(2) proposes that the Minister of the Department of Environmental Affairs and Tourism may require any person, organisation or organ of state involved in managing or monitoringbiodiversity to report regularly to the Minister on the results of such managing or monitoring measured against the predetermined indicators.

The Bill also proposes that, in order to promote biodiversity conservation, the Minister of the Department of Environmental Affairs and Tourism must make such information publicly available by electronic or other means (section 63).

1.3.7 National Environmental Management: Protected Areas Bill

Although also still in draft form, this Bill deals with the establishment, management and control of protected areas with the Department of Environmental Affairs and Tourism as the responsible authority. Specific actions pertaining to monitoring include:

- Section 93 proposes that the contents of a management plan for a protected area must reflect norms and standards that must be met (management objectives) and also include indicators relating to monitoring compliance with those norms and standards.

- Section 95 proposes that the Minister of the Department of Environmental Affairs and Tourism may establish indicators for monitoring performance with regard to the management of national protected areas and of the conservation of biodiversity in those areas, or that a Member of the Executive Council may establish indicators for monitoring performance with regard to the management of provincial and local protected areas and of the conservation of biodiversity in those areas. If the Minister or a Member of the Executive Council so requests, the management authority of a protected area must monitor the area against the selected indicators.

RECOMMENDATIONS:

Due to fragmentation in the management and control of estuaries, resource monitoring programmes are often developed independently, arising from different departmental and legislative requirements. Therefore, to ensure efficient use of resources, both human and financial, and to prevent duplication, it is recommended that resource monitoring programmes within a particular estuary be coordinated, taking into account sampling procedures, as well as spatial and temporal scales. This supports the principle of cooperative governance as required under the National Environmental Management Act and is also recommended in the proposed National Estuarine Management Protocol (Van Niekerk and Taljaard, in press).

Different departmental responsibilities must also be clearly indicated and aligned with the necessary funds and human resources. It is, therefore, also recommended that for a particular estuary:

- ***Specific responsibilities be allocated to specific authorities or institutions within a resource monitoring programme***
- ***The appointed authority or institution have sufficient resources, both human and financial, to execute such monitoring or provide a strategy to obtain such resources.***

2. APPROACH AND KEY CONSIDERATIONS

2.1 Approach

Key to the successful design of resource monitoring programmes is to put forward a conceptual framework of the anticipated abiotic and biotic (biophysical) processes and interactions that take place in a particular estuary, preferably at the inception stage of an Ecological Reserve Determination study. This is referred to as an ecosystem's approach, rather than addressing different biophysical components on an individual basis ('single discipline' approach). An ecosystem's approach is essential to provide resource managers with 'cause and effect chain' type of information required for effective management of estuaries.

It must be recognized that each estuary is somewhat unique in its characteristics. Depending on the complexity of a particular system, the biophysical components that need to be sampled (including the spatial scale and temporal scale at which data need to be acquired) may differ. A conceptual framework of the biophysical processes and interactions relevant to estuaries is illustrated in Figure 2.

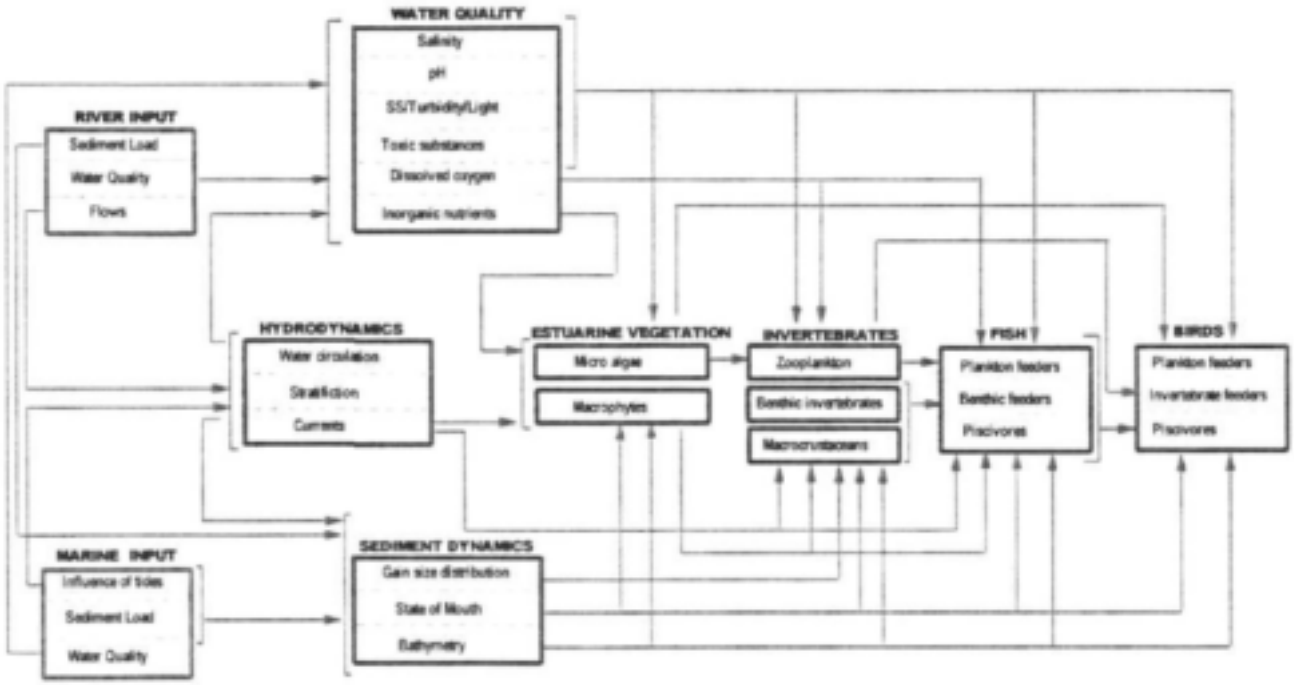

Figure 2. Conceptual framework of the anticipated abiotic and biotic processes and interactions relevant to estuaries

NOTE:

Once a conceptual framework has been drawn up for a particular estuary, it can be used to highlight key abiotic and biotic processes and interactions within that system. This, in turn, provides a visual means of illustrating the complexities in estuarine functioning and to motivate to resource managers the rationale for selecting the abiotic and biotic components to be included in site-specific baseline surveys or long-term monitoring programmes.

To accommodate the high variability in the biophysical functioning of estuaries, the approach in setting procedures for the resource monitoring programmes (as part of the Ecological Reserve determination process) is to provide generic sampling procedures (including recommended spatial and temporal scales) for each abiotic and biotic component, to be applied when a component is selected for inclusion in either baseline studies or the long-term monitoring programme of a particular estuary.

Therefore, although the estuarine specialist team appointed on a particular Ecological Reserve determination study will have some flexibility in customizing the resources monitoring programme, to meet site-specific requirements, this approach will ensure uniformity in the manner in which field data are collected in estuaries as part of the Ecological Reserve determination and implementation process.

RECOMMENDATION:

- ***The format in which the procedures for (revised) baseline studies and long-term monitoring programmes is presented in this report is specifically selected to facilitate easy incorporation into the existing Ecological Reserve determination methods for estuaries, as published by the Department of Water Affairs and Forestry.***

  Due to budgetary constraints, these procedures were only peer reviewed by a limited number of estuarine specialists. It is therefore recommended that prior to the procedures being incorporated into the official Ecological Reserve determination methods for estuaries, it be sent out for wider comment, e.g. through the Consortium for Estuarine Research and Management (CERM) website.

  It is also important that the request for comments clearly explains the context in which these procedures need to be evaluated, i.e. these procedures provide a list of generic (or minimum) baseline survey and monitoring requirements that will provide acceptable levels of confidence to the Ecological Reserve determination and implementation process. Therefore, these generic baseline and monitoring requirements do not replace the need for detailed research studies to gather a higher level of scientific insight. The latter is of utmost importance to improving knowledge on estuarine systems.

2.2 Guidelines for Setting Baseline Studies

The methods for the determination of the Ecological Reserve for estuaries, i.e. *Resource Directed Measures for Protection of Water Resources; Volume 5: Estuarine Component - Version 1.0 (DWAF, 1999)* and subsequent revisions of the methods of which the documentation in currently in preparation (B Weston, DWAF, pers. comm.), already list the requirements for baseline studies for both the Intermediate and Comprehensive level reserve determinations (refer to the sections on Data Organisation). However, these need to be re-assessed to:

- Incorporate the learning gained through Ecological Reserve Determination studies conducted over the past 2-3 years
- Ensure alignment with the procedures for the design of long-term monitoring programmes, to be developed as part of this project
- Allow for integration with other legislative requirements, e.g. resource monitoring under the Living Marine Resources Act 18 of 1998.

The purpose of carrying out baseline studies is to describe the biophysical characteristics of an estuary, and to understand the abiotic and biotic processes and interactions that take place. This understanding should be sufficient to be able to estimate the quantity and quality of river inflow that would be required to maintain a selected ecological category, as described in terms of the ecological specifications. The confidence with which these estimates can be made is strongly correlated with the level of baseline data acquired.

The generic procedures for baseline studies provided for each abiotic and biotic component, and distinguish between Ecological Reserve determinations done on the Comprehensive and Intermediate levels (Chapter 3). In most instances the sampling procedures and spatial scales remain the same for the Intermediate and Comprehensive levels, but for the

Intermediate level temporal scales are often reduced. The logic behind this is that the largest cost incurred is in the mobilisation for field surveys, but once in the field, data should be collected optimally.

Even though the generic procedures recommend spatial scales for different abiotic and biotic components, the estuarine specialist team appointed on a particular Ecological Reserve study needs to ensure that the spatial scales recommended will reflect the anticipated variability within the system. For example, 10 stations on a 70 km long estuary such as the Berg River Estuary may not be sufficient to deliver the required spatial resolution to capture longitudinal variability with reasonable confidence. Statistical methods have been applied elsewhere to determine the level of spatial coverage that would be required to obtain acceptable results (e.g. in the National Marine and Estuarine Linefish Survey of the MCM). Although development of such statistics was not within the scope of this study, it should be considered for future developments.

RECOMMENDATION:

It is recommended that the Department of Water Affairs and Forestry, in collaboration with the Water Research Commission, investigate the use of statistical methods to refine the procedures for setting spatial scales and sample replication in estuarine resource monitoring programmes.

It is envisaged that, in most instances, the entire suite of abiotic and biotic components listed for baseline studies (Chapter 3) will need to be included, taking into account the purpose of the baseline survey, i.e. to describe the biophysical characteristics of an estuary, and to understand the abiotic and biotic processes and interactions. However, it is recognised that, due to the high variability in complexity and functioning of South Africa's estuaries, there will be systems where the baseline studies (required to provide acceptable confidence) will deviate from what is proposed in the generic procedures, either requiring less or more detailed procedures. Therefore, where the estuarine specialist team appointed on a particular Ecological Reserve study deviates from the generic procedures, such deviations must be supported by sound scientific motivations based on their understanding of the complexity of the system and interaction between different abiotic and biotic components.

RECOMMENDATION:

It is recommended that qualified estuarine specialists be consulted at the inception stage of an Ecological Reserve determination study (i.e. prior to putting it out to tender) to prepare a conceptual framework of the anticipated biophysical processes and interactions for that particular estuary and to assist with the specifications for the baseline studies, taking into account budgetary constraints, a reality encountered in most Ecological Reserve studies to date. This will provide a means of leveling the playing field by including detailed baseline requirements as part of the tender document, rather than individual tenders adapting these themselves to accommodate budgetary constraints, hence making it very difficult for the DWAF to compare 'apples-with-apples' in the selection process.

To eliminate unfairness, the DWAF can, for example, use representatives from the organizations it intends to invite to tender to assist in the specification of baseline studies as part of a 'pre-tender scoping workshop'.

Prior to conducting baseline studies, it is important to identify data and information that are already available in the published literature or that have been collected as part of existing monitoring programmes, e.g. those listed in Table 1. It should, however, be noted that the Ecological Reserve determination process requires that data be collected in a manner that provides understanding of linkages between related abiotic and biotic components which is often a short-coming of historical data collection techniques. Therefore, in many instances historical data provide a good description of particular components, but limited understanding on the interaction of these components with related abiotic and biotic components.

It is also important to establish whether historical data are still representative of the present state, particularly in estuaries that have been subjected to anthropogenic influences since the data were collected.

RECOMMENDATION:

It is recommended that qualified estuarine specialists be consulted at the inception stage of an Ecological Reserve Determination study (i.e. prior to putting it out to tender) to prepare an inventory of available data and information on a particular estuary, as well as to evaluate the suitability of such data and information for use in the Ecological Reserve determination process. This inventory should be available when preparing specifications for the baseline studies for a particular system, hence eliminating unnecessary expenditure in terms of 're-acquiring' data and information that may already exist.

To eliminate unfairness, the DWAF can, for example, use representatives from the organizations it intends to invite to tender to assist in preparing such an inventory as input to the 'pre-tender scoping workshop', mentioned earlier.

2.3 Guidelines for Setting Long-term Monitoring Programmes

The purpose of long-term monitoring programmes, in this instance, is to assess (or audit) whether the Ecological Specifications (defined as part of the Ecological Reserve determination process) are being complied with after implementation of the Reserve. In addition, these programmes can also be used to improve and refine the Ecological Reserve measures (including the Ecological Specifications), in the longer-term through an iterative process.

Although baseline studies and long-term monitoring programmes have different purposes, it is extremely important that long-term monitoring programmes follow on from similarly structured baseline studies. In essence, the monitoring activities selected for the long-term monitoring programme should be derived from the monitoring activities conducted as part of the baseline studies, but implemented on less intensive spatial and/or temporal scales.

The baseline studies that are carried out for an Ecological Reserve determination study at Comprehensive level may be considered as the baseline data against which the long-term monitoring is carried out. Therefore, if less than the recommended baseline studies for a comprehensive assessment is carried out, due to budgetary constraints or due to the Ecological Reserve study being carried out at a rapid or intermediate level, then additional 'baseline' work may need to be carried out to produce sufficient baseline data against which future long-term monitoring can take place. In such cases, the additional baseline data may have to be collected over an extended period, even after initial implementation of the Ecological Reserve.

Other criteria that should be considered in the selection and prioritisation of monitoring components or indicators in long-term monitoring programmes, in the context of the Ecological Reserve determination process, are provided below.

A list of abiotic indictors that should always be included in long-term monitoring programmes to allow for proper identification of 'cause and effect' links, in particular links to river inflow and water quality are:

- River inflow (i.e. flow gauging)
- Continuous water level recording at the estuary mouth (recording the state of the mouth, a key driver for most biotic components)
- Water quality of river inflow
- Water quality and flow rate of effluent discharges into the estuary
- Salinity distribution patterns under different river flow ranges.

Aerial photographs, collected on an annual basis, are also considered as key components in the long-term monitoring of estuaries, as these provide useful information on both abiotic and biotic components.

RECOMMENDATION:

It is recommended that river inflow (flow gauging), continuous water level recording at the estuary mouth and water quality monitoring of river inflow at the head of estuaries be undertaken by the Department of Water Affairs and Forestry as part of their national monitoring programme. Also, it is recommended that the Department initiate long-term monitoring programmes on the sediment dynamics of estuaries, similar to that undertaken previously by the CSIR on behalf of the Department of Environmental Affairs and Tourism (refer to Appendix A). Even at the Ecological Reserve determination stage (Intermediate and Comprehensive level), long-term data records are necessary for the above-mentioned parameters (in order to obtain the required confidence). Such data therefore needs to be collected on a national scale, through a national data collection programme, to be available when and where an Ecological Reserve determination needs to be conducted.

It is further recommended that the Department of Environmental Affairs re-institute the annual aerial photograph monitoring programme of the South African coast (including estuaries) that was terminated in1992, as these provide valuable information for both abiotic and biotic assessments.

The inclusion of other abiotic indicators such as sediment characterisation, bathymetric and topographical surveys, water quality (other than salinity) in the estuary and accumulation of toxic substances in sediments will depend on the sensitivity of a particular system to changes in such indicators as well as the level of interaction of such indicators with the selected biotic indicators. Another consideration for inclusion would be any particular abiotic indicator that is on a 'trajectory of change'.

Criteria that should be considered in the selection and prioritisation of biotic indicators for long-term monitoring programmes include:

- Ecological Specifications (i.e. Resource Quality Objectives for Biophysical Environment), specified for a particular estuary as part of the Ecological Reserve Determination process (see note below).

  NOTE:

  Ecological Specifications are clear and measurable specifications of ecological attributes (in the case of estuaries - hydrodynamics, sediment dynamics, water quality and different biotic components) that define a specific ecological reserve category. Although procedures for setting Ecological Specifications for estuaries have not been formulated, it is envisaged that the concept of 'Thresholds of Potential Concern' will be used. Thresholds of potential concern are defined as measurable end points related to specific abiotic or biotic indicators that if reached (or when modelling predicts that such points will be reached) prompts management action. In essence, thresholds of potential concern endpoints should be defined such that they provide early warning signals of potential non-compliance to Ecological Specifications (i.e. not the point of 'no return'). In essence, this concept implies that the indicators (or monitoring activities) selected as part of long-term monitoring programme need to include biotic and abiotic components that are particularly sensitive to ecological changes associated with changes in river inflow.

- The biotic indicators should be particularly sensitive to potential impacts associated with changes in river inflow and water quality, such as state of the mouth, tidal variation, sedimentation/erosion, salinity distribution patterns and deterioration in water quality. For example, in the Great Brak Estuary, benthic invertebrates and salt marsh vegetation were found to be sensitive to inundation of intertidal areas and closure of the mouth (both parameters that are strongly influenced by changes in river inflow).

- Biotic components considered to be on a 'trajectory of change' or that are particularly sensitive to abiotic components that are on a 'trajectory of change', should also be considered for inclusion as indicators in long-term monitoring programmes.

- Biotic components that are of regional or national biodiversity importance are also suitable indicators, particularly when also sensitive to changes in river inflow and water quality. For example, the bird population of the Berg River Estuary, being a Ramsar site, is of high biodiversity importance and should therefore be included in the long-term monitoring programme of that estuary. The biodiversity importance of most South African estuaries has been rated in a document prepared by Turpie *et al.* (2002) and can be used in this regard.

- Biotic indicators should also be representative of the important food chains present in a particular system. This will ensure that monitoring programmes provide resource managers with appropriate data to establish 'cause and effect' links, a key requirement for effective management of estuaries. For example in the Breede River Estuary, fishes were identified as being of high importance; therefore the main food source of the most important fish species, namely the macro-crustaceans (swimming prawn) should also be included, as should the macrophytes (*Phragmites*), being an important habitat for the swimming prawns.

- The selection of biotic indicators should also present a balance between indicators that provides 'early warning' signals and those that reflect longer-term, more cumulative effects. For example, fish are often considered to be useful 'early warning' indicators, while macrophyte distribution patterns are often better indicators of cumulative, longer-term changes in estuaries.

RECOMMENDATION:

In many instances the specialist team that designs a long-term monitoring programme may not be responsible for implementation. It is therefore recommended that the long-term monitoring programmes include a detailed map showing the position and coordinates of the selected sampling stations for the selected abiotic and biotic indicators.

The generic procedures for long-term monitoring programmes, provide guidelines for each abiotic and biotic component in terms of sampling procedures, spatial scales and temporal scales (Chapter 3), should these be selected as indicators for long-term monitoring. In most instances the sampling procedures and spatial scales remain the same as for the baseline studies, but the temporal scales are usually less intense, i.e. long-term monitoring programmes are essentially a 'scaled down' version of the baseline studies.

Initially, long-term monitoring programmes may have to include an extended list of abiotic and biotic indicators, but as the understanding of system response improves, the list of indicators, as well and spatial and temporal scales could be reduced. The scaling down of long-term monitoring programmes should be conducted by qualified estuarine specialists and needs to be accompanied by sound scientific motivation. It is important that long-term monitoring programmes are not scaled down prematurely as it can impact on effective management of estuaries, for example:

- Premature elimination of indicators or reduction of spatial and temporal scales could result in the lack of crucial information required to back-track changes to the actual cause, i.e. understanding of important 'cause and effect ' chains, particularly those linked to changes in river inflow and water quality.

- Long-term monitoring programmes also need to capture variability caused by long-term dry/wet cycles before scaling down, as the response of the system under these long-term climatic cycles can be vastly different, that if not well understood and documented can lead to incorrect management decisions.

RECOMMENDATION:

It is recommended, that the long-term monitoring programme for an estuary be subject to regular review, e.g. every 5 to 10 years, to continuously assess the relevance of selected monitoring components, as well as optimal use of resources. The review process needs to be conducted by qualified estuarine specialists. This continuous refinement of long-term monitoring programmes is in alignment with the concept of Strategic Adaptive Management.

2.4 Constraints on Implementation of Resource Monitoring Programmes

In the event where the recommended baseline studies for a particular Ecological Reserve determination cannot be implemented fully due to, for example budgetary constraints, it must be recognised that the reduced baseline programme will result in poorer understanding of the functioning of the systems in question. This implies that the confidence of the Ecological Reserve determination will be lower (e.g. medium confidence for Intermediate level determination and medium-high confidence for a Comprehensive level determination). This practice holds serious risks if, for example applied in stressed systems where water allocations are already close to the Ecological Reserve.

RECOMMENDATION:

It is recommended that Ecological Reserve Determinations for estuarine systems of high ecological importance (in a regional, national or global context), that are already affected by developments in their catchment or that are targeted for future development, are carried out at a Comprehensive level as far as possible and that baseline surveys, and subsequent long-term monitoring programmes, be implemented fully. It is also recommended that these systems be identified collaboratively between the Department of Water Affairs and Forestry and the Department of Environmental Affairs and Tourism.

Financial constraints can also result in long-term monitoring programmes not being implemented according to the original design. Again this is a risk to estuarine resources, particularly those that are already stressed or where slight changes in river inflow can have marked ecological consequences. One way of accommodating this constraint is to prioritise the selected monitoring components or indicators within a long-term monitoring programme to facilitate incremental implementation as and when resources become available, using the guidelines provided in an earlier section.

RECOMMENDATION:

It is strongly recommended that despite any immediate financial constraints, both baseline studies and long-term monitoring programmes for a particular estuary, be designed as part of the Ecological Reserve Determination process. This will provide a focused reference framework within which to launch future data collection or monitoring initiatives in a particular estuary, as and when resources allow. Resources can, for example, be accessed outside the Department of Water Affairs and Forestry, e.g. from the Department of Environmental Affairs and Tourism which also has monitoring responsibilities in estuaries.

2.5 Capture and Storage of Resource Monitoring Data

Sections 139 and 140 of the National Water Act state that the Minister of Water Affairs and Forestry must establish a national information system regarding water resources. Although the Department of Water Affairs and Forestry has invested in such systems (for example for river and groundwater) these systems do not allow for the type and manner in which biophysical data are collected in estuaries. The CSIR has developed an estuarine database for the capture and storage of abiotic data sets, i.e. sediment, hydrodynamic and water quality data. However, this database currently does not cater for biological data sets, i.e. microalgae, macrophytes, invertebrates, fish and birds.

RECOMMENDATIONS:

It is recommended that the Department of Water Affairs and Forestry (e.g. through the Directorate: Resource Directed Measures) establish a dedicated database for the storage of biophysical data collected during Ecological Reserve Determination processes and their implementation in estuaries. It is also recommended that existing data storage facilities for estuarine data (e.g. that of the CSIR) be expanded rather than re-developing such facilities from scratch.

In the interim, it is recommended that the Department of Water Affairs and Forestry require that raw data, collected by consultants during Ecological Reserve Determination studies or during the implementation of long-term monitoring programmes, be submitted to the Department as appendices to the Ecological Reserve Reports. These reports should be stored in a well-organized manner for easy access in future.

For checking on identification and for future verification of queries regarding the classification of biotic specimens it is also important that voucher specimens collected in a particular system be lodged at a recognised facility, for example:

Macrophytes	*Voucher specimens to be lodged at a recognized herbarium*
Invertebrates	*Voucher specimens to be lodged at a recognised repository. Presently such a facility is not available although the East London Museum, Natal Museum and Cape Town Museum house aquatic invertebrates.*
Fish	*Voucher specimens to be lodged at the South African Institute for Aquatic Biodiversity*

RECOMMENDATIONS:

It is recommended that the Department of Water Affairs and Forestry, as part of the Ecological Reserve Determination process require that voucher specimens of biota collected in a particular system be lodged at recognised repositories.

It is also recommended that the Department approach either the East London Museum or the Natal Museum to set up such a facility for invertebrates.

2.6 Communicating Information collected during Resource Monitoring Programmes

Sections 139 and 140 of the National Water Act (stating that the Minister of the Department of Water Affairs and Forestry must establish a national information system regarding water resources) are also interpreted to include avenues for communicating such information to the wider community. In providing such avenues, the wider community gains access to knowledge and information that will allow them to participate sensibly in estuarine resource management, hence expanding the Strategic Adaptive Management loop.

The Internet is a communication system that is widely applied for such purposes throughout the world. However, the success of using this system depends on a number of factors, such as:

- User-friendliness of the manner in which the information is presented in a website
- Extent to which the community is aware of such a website existing
- Continuous updating of information contained in such a website.

Another avenue that can be used for communicating the resource status of estuaries that is being successfully implemented for rivers is the State-of-River Programme. As part of this programme, reports are prepared on the health of specific rivers, translated into a format easily understood by the wider community. It is envisaged that such a programme can also be successfully launched for estuaries, even as an extension to the River Health Programme.

RECOMMENDATIONS:

It is recommended that the Department of Water Affairs and Forestry (Directorate: Resource Directed Measures) create a website, e.g. 'Ecological Reserve Determinations and Implementation in Estuaries' where Ecological Reserve reports and other related information can be accessed easily. The existence of such a site should be advertised, e.g. on the Department's homepage, the CERM website, at symposia and in related publications, e.g. Water SA.

It is also recommended that the Department of Water Affairs and Forestry, in collaboration with the Water Research Commission, investigate the possibility of extending the River Health Programme to include estuaries in its reporting framework in an appropriate manner. If the monitoring component of the Health Programme could be extended to include estuaries, such an Estuarine Health Programme could provide some of the data requirements of the Ecological Reserve determination process.

3. GENERIC RESOURCE MONITORING PROCEDURES FOR ESTUARIES

This Chapter provides generic procedures for baseline studies and long-term monitoring programmes in estuaries for application in the Ecological Reserve determination and implementation process.

Abiotic components that need to be addressed in the Ecological Reserve determinations for estuaries are:

- Hydrology
- Sediment dynamics
- Hydrodynamics
- Water Quality.

Biotic components that needs to be addressed are:

- Microalgae
- Macrophytes
- Invertebrates (including zooplankton, benthic invertebrates and macrocrustaceans)
- Fish (ichthyofaua)
- Birds (avifauna).

For each of the abiotic and biotic components the following is specified in the procedures:

- Sampling procedures
- Recommended spatial scales, i.e. selection of sampling stations
- Recommended temporal scales, i.e. frequency of sampling.

In most instances the sampling procedures and recommendations on spatial scales remain the same for baseline studies and long-term monitoring programmes. However, there is a distinction is the recommended temporal scale between:

- Baseline studies for Ecological Reserve determination (Intermediate level)
- Baseline studies for Ecological Reserve Determination (Comprehensive level)
- Long-term monitoring programmes

The layout of the manner in which procedures are provided for each component in this chapter is illustrated below:

SAMPLING PROCEDURE	*Description of the sampling (and analytical) procedures that need to be followed for a particular abiotic or biotic component.*	
SPATIAL SCALE	*Recommendation on the manner in which spatial scales (i.e. sampling stations) need to be selected for a particular abiotic or biotic component.*	
TEMPORAL SCALE	INTERMEDIATE LEVEL RESERVE	COMPREHENSIVE LEVEL RESERVE
	Recommended frequency of sampling for an Ecological Reserve determination at Intermediate level.	*Recommended frequency of sampling for an Ecological Reserve determination at Comprehensive level.*
	LONG-TERM MONITORING PROGRAMME (where selected as indicator)	
	Recommended frequency of sampling of a component selected as an indicator for a long-term monitoring programme.	

IMPORTANT NOTES
List of important notes that should be taken into account in baseline studies or long-term monitoring programmes for a particular abiotic or biotic component.

3.1 Hydrology

SAMPLING PROCEDURE	*Simulated runoff data: Data to be simulated for reference condition, present state and a range of future run-off scenarios covering a range of flow reductions from present to worst case.* *Flood hydrographs: To be simulated for the 1:1 to 1:200 year floods for reference condition, present state and a range of future run-off scenarios (usually only required on Comprehensive level).*	
SPATIAL SCALE	*Simulated river runoff: Representative of inflow at head of estuary* *Flood hydrographs: Representative of flow at head of estuary*	
TEMPORAL SCALE	INTERMEDIATE LEVEL RESERVE	COMPREHENSIVE LEVEL RESERVE
	Simulated river runoff: Simulated over a 50-80 year period, provided as average monthly flows (daily flows may at times be required) *Flood hydrographs: Usually not required for Intermediate level reserve*	*Simulated river runoff: Similar to intermediate level reserve* *Flood hydrographs: Provided as hourly flows over the flood period*
	LONG-TERM MONITORING PROGRAMME	
	Not relevant	

3.2 Sediment Dynamics

SAMPLING PROCEDURE	*Sediment grabs: Grab samples should be collected using a Van Veen or a Zabalocki-type Eckman grab (to characterize recent sediment movement) for particle size analyses.* *Sediment cores: Core samples should be collected using a corer (for historical sediment characterization)* *Bathymetric/topographical surveys: Surveys should be conducted using D-GPS and echo-sounding to monitor berm height, mouth sediment dynamics and cross section profiles upstream of the mouth.* *Sediment load at head of estuary (including detritus component – particulate carbon/loss on ignition)*	
SPATIAL SCALE	*Sediment grab samples: Along entire estuary at 500 to 1 000 m intervals* *Sediment cores: Intervals similar to cross-section profiles (see below) where considered appropriate by sediment specialist* *Bathymetric/topographical surveys: Mouth region – Intensive (10 to 50 m interval depending on the size of the estuary and variability in bathymetry); Upstream cross-section profiles along entire estuary at 500 m to 1000 m intervals.* *Sediment load at head of estuary*	
TEMPORAL SCALE	INTERMEDIATE LEVEL RESERVE	COMPREHENSIVE LEVEL RESERVE
	Sediment grabs, Sediment cores, Bathymetric/topographical surveys and Sediment load at head of estuary: Available data, usually these measurements are not required as part of intermediate level reserve.	*Sediment grabs: Seasonal sampling (spring, summer, autumn and winter) for one year.* *Sediment cores: Once-off* *Bathymetric/topographical surveys: Will depend on the time scale of dominant sedimentation/erosion processes in an estuary varying between 1 and 5 year intervals, with a minimum record of about 15 years. Alternatively, numerical models can be used to simulate longer-term processes.* *Sediment load at head of estuary: Daily for a minimum 5 years*

Sediment dynamics continued on next page ...

Sediment dynamics continued ...

	LONG-TERM MONITORING PROGRAMME (where selected as indicator)	
TEMPORAL SCALE	*Bathymetric/topographical surveys and grab samples*	*Every 3-6 years, depending on the time scale of dominant sedimentation/erosion processes in an estuary, as well as after flood events.*
	Sediment loads	*Daily records*

IMPORTANT NOTES: SEDIMENT DYNAMICS

- *Suitable sediment data records cannot be acquired in the short term. Therefore, if sediment processes in estuaries are to be better understood and quantified, long-term programmes will have to be implemented. In this regard it is recommended that the DWAF implement such monitoring activities timeously in South African estuaries, particularly those earmarked for substantial water abstraction in future.*

- *The disturbance of the sediment erosion/deposition equilibrium in an estuary can lead either to siltation, resulting in the estuary becoming shallower, or it can lead to the erosion of important sediment habitats. Under natural conditions many estuaries were probably in a state of long-term equilibrium of sedimentation and erosion. However, this equilibrium can be disturbed because of changes in run-off, especially if the occurrences and magnitudes of major floods are changed.*

- *Floods and, in some cases, high seasonal flows can influence the sediment erosion/deposition equilibrium. Floods can alter important features within an estuary, such as the bathymetry (e.g. channel depth or the size of intertidal areas) and sediment composition (e.g. sand or mud).*

3.3 Hydrodynamics

MONITORING ACTION	*Continuous flow recording of river inflow: A flow gauging station should be installed to measure river inflow.* *Continuous water level recordings: A continuous water level recorder should be installed at the mouth of the estuary.* *Daily observations: Where possible, daily mouth observations should be logged in temporarily open/closed estuaries and particularly in systems with the semi-closed mouth phase. The time at which the observation was made and the state of the tide must also be recorded, ideally at low tide.* *Water levels along estuary: Where a Reserve determination study requires numerical modelling, water levels recordings must also be collected along the length of the estuary, either using continuous water level recorders or water level gauging poles and manual observations.* *Wave conditions: Available data should be accessed, but no measurements are specified as part of a baseline monitoring.* *Aerial photographs: Full colour geo-referenced rectified aerial photographs 1: 5 000 scale covering the entire estuary based on the geographical boundary at low tide in summer i.e. similar to those for macrophyte surveys. Must include the breaker zone near the mouth.*
SPATIAL SCALE	*Continuous flow gauging: Head of estuary* *Continuous water level recording: Mouth area* *Mouth observations: Mouth* *Water levels along estuary: 2-6 stations along estuary* *Aerial photographs: Entire estuary, particularly the mouth area.*

Hydrodynamics continued on next page ...

Hydrodynamics continued ...

	INTERMEDIATE LEVEL RESERVE	COMPREHENSIVE LEVEL RESERVE
TEMPORAL SCALE	*Continuous flow gauging: Minimum of 5 years depending on mouth closure* *Water level recordings and mouth observations: Minimum of 5 years depending on mouth closure* *Water levels along estuary: Manually/digital recorded over one spring tidal cycle and one neap tidal cycle or continuous recordings over two weeks.* *Wave conditions: Available data* *Aerial photographs: Available data*	*Continuous flow gauging: 5-15 years depending on mouth closure* *Water level recordings at mouth and mouth observations: 5-15 years depending on mouth closure* *Water levels along estuary: Similar to intermediate level reserve* *Wave conditions: Similar to intermediate level reserve* *Aerial photographs: Available data, but needs to include one recent photograph representative of present condition.)*
	LONG-TERM MONITORING PROGRAMME	
	Continuous flow recording of river inflow	*Continuous*
	Continuous water level recordings at mouth	*Continuous*
	Aerial photos	*Annually*

IMPORTANT NOTES: HYDRODYNAMICS

- *In requesting continuous flow, the request is not for gauging weirs to be constructed at the top of each estuary as such, but rather that flows be monitored in appropriate ways that will not disturb migration of aquatic biota.*
- *Continuous flow recordings (gauging station) of river inflow at the head of estuaries and continuous water level recording at estuary mouths (and mouth observations) require longer-term data sets and it is therefore necessary to start such baseline monitoring programmes well in advance (at least 5 years) of a Ecological Reserve determination study. In this regard it is recommended that the DWAF implement such monitoring activities timeously in South African estuaries, particularly those earmarked for substantial water abstraction in future.*

3.4 Water (and Sediment) Quality

SAMPLING PROCEDURE	*Water quality of river inflow: System variables (pH, DO, turbidity, suspended solids, TDS and temperature), nutrients (inorganic nitrogen [nitrite, nitrate and ammonia], reactive phosphate and silicate) and toxic substances (where relevant) should be measured.*
	Water quality of the near-shore marine waters: Obtained form available literature.
	Water quality in estuary: The following samples should be collected: • *Salinity and temperature profiles (also required for hydrodynamics)* • *System variables (pH, DO, turbidity, suspended solids)* • *Inorganic nutrients (nitrate/nitrite, ammonia, reactive phosphate and reactive silicate)* *Salinity and temperature data must be collected at 0.5 m depth intervals, while other water quality parameters are collected in surface and bottom waters. At stations deeper than 10 m, a sample at an intermediate depth may also be required (site specific decision).*
	Effluent discharges: Where effluent discharges occur into the estuary, i.e. beyond the head of the estuary, these have to be sampled as well. In addition to flow rate, other parameters to be monitored will depend on the composition of the effluent.
	Toxic substances: Where relevant (e.g. in estuary receiving runoff from urban and industrial areas and contaminated agricultural runoff), sediment samples should be collected and analyzed for toxic substances (i.e. trace metals, petroleum hydrocarbons, herbicides and pesticides). To assist with the interpretation of results, samples should also be analysed for sediment grain size distribution and organic content.

Water quality continued on next page ...

Water quality continued...

SPATIAL SCALE

A sampling station is defined as a location at a specific 'distance from the mouth' that can be sampled at different depth intervals and which is defined by GPS positioning data.

Water quality of river inflow: Head of estuary

Water quality in estuary: Small estuaries (< 5 km long) - Stations distributed geographically along the entire estuary with a minimum of 5 sites. Make sure that all the salinity regimes are covered.

Larger estuaries (> 5 km long) - Stations distributed geographically along the entire estuary at fixed intervals. A rough estimate for setting the distance between stations is to divide the length of the estuary by 10 (i.e. if an estuary is 30 km long, the distance between stations should be about 3 km). Typically a representative number of stations for longer estuaries are between 10 and 15. Make sure that all the salinity regimes are covered.

In systems with large cross sectional areas, sampling stations should also be selected along cross sections. During each sampling survey, water quality samples must also be taken in the river and in the near-shore marine waters (i.e. the water sources).

Effluent discharges: At end of pipe just before entering the estuary.

Toxic substances: A grid of sediment sampling stations to be selected across estuary, specifically targeting depositional areas (characterized by finer sediment grain sizes and/or higher organic content).

TEMPORAL SCALE

INTERMEDIATE LEVEL RESERVE	COMPREHENSIVE LEVEL RESERVE
Water quality of river inflow: At least monthly, minimum of 5-year data record. *Water quality in estuaries: Once during a low flow and a high flow season. For temporarily open/closed systems, a stable closed phase must be sampled as well as a stable open phase.* *Sampling should coincide with microalgae surveys and the invertebrate surveys in year 1.* *Effluent discharges: Should be licensed under the National Water Act where operators are required to monitoring effluent volume and composition. Spatial scale, e.g. daily or weekly will depend on the variability in effluent composition overtime.* *Toxic substances: Once, preferably during the low flow season.*	*Water quality of river inflow: At least monthly, minimum of 5-15 year data record.* *Water quality in estuary: Similar to intermediate level reserve except that sampling should be conducted seasonally, (i.e. during spring, summer, autumn and winter) with river inflow being representative of a particular season.* *In systems where the semi-closed phase or overwash is important, these states need to be sampled. These phases are dynamic and require 3 sub-surveys.* *Sampling should coincide with the microalgae surveys and invertebrate surveys in year 1.* *Effluent discharges: Similar to Intermediate level reserve.* *Toxic substances: Similar to Intermediate level reserve.*

LONG-TERM MONITORING PROGRAMME (where selected as indicator)	
River inflow	*At least monthly*
Effluent discharges	*Should be licensed under the National Water Act where operators are required to monitor effluent volume and composition. Spatial scale, e.g. daily or weekly will depend on the variability in effluent composition overtime.*
Water quality in estuary	*Samples to be collected when related biological sampling surveys (requiring water quality data for interpretation) are conducted.*
Sediment surveys of toxic substances	*Once every 3-6 years*

Water quality continued on next page...

Water quality continued ...

IMPORTANT NOTES: WATER QUALITY

- *The analytical techniques used in the processing of marine and estuarine water quality samples vary greatly form those used in the analysis of fresh water samples. It is therefore crucial that the analyses of water quality samples be conducted by an accredited marine analytical laboratory.*

- *Estuaries receive water from two sources, i.e. the river and sea, each with distinctively different water quality characteristics, particularly in terms of system variables and nutrients. In turn, the water quality characteristics along the length of an estuary depends on the extent of the influences of each of these sources (governed by hydrodynamic processes), as well as biochemical processes (e.g. organic degradation, eutrophication) taking place at that point within the estuary. The influence of biochemical processes is particularly evident in parts of an estuary where residence time of water becomes longer, often observed along the middle reaches of an estuary during the low flow season. It is therefore also crucial that water samples in the two sources, i.e. river and sea.*

- *River water quality requires longer-term data sets and it is therefore necessary to start such baseline monitoring programmes well in advance (at least 5 years). For example, monitoring points at the head of estuaries could be included in the water quality monitoring programme of the DWAF.*

- *At present water quality of near-shore waters is not measured on a routine basis along the SA coast, as is the case for some rivers. Because the seawater quality may show strong seasonal variability, particularly along the SA West coast, a short term monitoring survey may not necessarily be representative. In the short term, data on near-shore seawater quality therefore needs to be derived from available data sources, including the South African Water Quality Guidelines for Coastal Marine Waters. Volume 1: Natural Environment (DWAF, 1995), until such time as routine water quality monitoring programmes are implemented along the SA coast.*

- *For toxic substances (e.g. trace metals and hydrocarbons) it is considered more appropriate to sample environmental components which tend to integrate or accumulate change over time, such as sediments. These surveys need, however, not be done in ALL estuaries, only in systems where river water quality or human activities along the banks of the estuary suggest possible contamination (e.g. industrial effluents or storm water run-off from large urban developments).*

- *For long-term monitoring programmes, water and sediment quality data are particularly important for interpretation of specific biological responses and, therefore must be collected by the relevant biotic components as indicated during their sampling surveys.*

- *Malfunctioning septic tanks, situated in close proximity to the banks of estuaries, may have an influence on water quality in the estuary. However, unlike point source discharges, e.g. effluents from wastewater treatment works, it is often difficult to quantify the inputs from such diffuse sources. Even so, where septic tanks are known to be a problem or potential problem in a particular estuary, inputs need to be taken into account in the water quality assessments.*

3.5 Microalgae

SAMPLING PROCEDURE

Phytoplankton: To estimate phytoplankton biomass, collect duplicate samples for chlorophyll a at the surface and 0.5 m depth intervals. Use a spectrophotometer for sample analysis before and after acidification. Do cell counts (at 400 x magnification) on dominant phytoplankton species to establish species distribution and composition, i.e. green algae, flagellates, dinoflagellates, diatoms and blue-green algae. .

Benthic microalgae: Collect intertidal and subtidal benthic samples for chlorophyll a (biomass) analysis. Collect 5 samples at each station. Analyse samples using a recognised technique, e.g. HPLC.

Record the relative abundance of dominant algal groups, i.e. green algae, dinoflagellates, diatoms and blue-green algae and identify the dominant species.

At each station also measure:

- *Water salinity and inorganic nutrients*
- *Sediment particle size distribution and organic content*
- *Light penetration PAR or Secchi disk).*

SPATIAL SCALE

A sampling station is defined as a location at a specific 'distance from the mouth' that can be sampled at different depth intervals (e.g. in the case of phytoplankton).

As a guideline, the number of stations in a small estuary (< 5 km long) should not be less than 5, distributed along the entire length of the estuary, covering the different salinity zones.

For larger estuaries (> 5 km long), 10 to 15 stations selected geographically along the entire length of the estuary, covering the different salinity zones, can be used as the guideline. Stations should preferably be set at fixed intervals. A rough estimate for setting the distance between stations is to divide the length of the estuary by 10 (i.e. if an estuary is 30 km long, the distance between stations should be about 3 km).

Salinity zones in estuaries typically include:

- *Fresh (representative of river)*
- *0 – 10 ppt*
- *10 – 20 ppt*
- *20 – 35 ppt*

TEMPORAL SCALE

INTERMEDIATE LEVEL RESERVE	COMPREHENSIVE LEVEL RESERVE
Once during a low flow and a high flow season. For temporarily open/closed systems, a stable closed phase must be sampled as well as a stable open phase. *Sampling should also coincide with the water quality survey and the invertebrate surveys in year 1.*	*Similar to intermediate level reserve except that sampling should be conducted seasonally, (i.e. during spring, summer, autumn and winter) for 2 years with river inflow being representative of a particular season.* *In systems where the semi-closed phase or overwash is important, these states need to be sampled. These phases are dynamic and would need to be sampled on 3 occasions.* *Sampling should coincide with the water quality survey and the invertebrate surveys in year 1.*
LONG-TERM MONITORING PROGRAMME (WHEN CONDITION/TREND ASSESSMENT)	
Phytoplankton (water column)	*Two years after implementation conduct a summer and winter survey followed by a summer and winter survey every 3 years thereafter.*
Benthic microalgae	*Two years after implementation conduct a summer and winter survey followed by a summer and winter survey every 3 years thereafter.*

IMPORTANT NOTES: MICROALGAE

- *Water (salinity, temperature, other physico-chemical properties and inorganic nutrients) measurements need to be collected during the microalgae surveys. Combining water and sediment quality surveys on a particular estuary with the microalgae survey does this most cost-effectively.*
- *The temporal scale of the microalgae sampling needs to match that of the invertebrates (zooplankton) to link the response patterns of these biotic components as best as possible.*

3.6 Macrophytes

SAMPLING PROCEDURE

The following information needs to be captured from recent and any available historical aerial photographs and ortho-photographs covering the entire estuary as defined by the geographical boundaries:

- *Number of different habitats (plant community types)*
- *Area covered by each plant habitat*
- *Historical change in area covered by plant habitat*
- *Extent of anthropogenic impacts (agriculture, flood plain development)*

Field data need to be collected for ground truthing of aerial photographs:

- *Number of different plant habitats (plant community types)*
- *Area covered by each plant habitat*
- *Species list for each plant habitat*
- *Extent of anthropogenic impacts such as grazing, trampling, alien vegetation, boating, bait digging*

Permanent transects (sampling stations) need to be set up for long term monitoring of changes in plant habitats:

- *Transects set up along an elevation gradient*
- *Record percentage cover of each plant species in duplicate quadrats (1 m^2) along transects*

Along each transect (minimum of 4) the following data need to be collected:

- *Elevation profile and water level*
- *Water column salinity and turbidity*
- *Sediment salinity, moisture content and sediment composition*

In large supratidal salt marsh areas, boreholes are required to measure depth to water table and ground water salinity.

SPATIAL SCALE

A sampling station is defined as a transect across the estuary (at a specific 'distance from the mouth'), with a number of quadrats arranged along the transect.

Aerial photos: The entire estuary needs to be covered, as defined by the geographical boundaries.

Transects and quadrats: As a guide the larger estuarine plant habitats in a system (e.g. salt marsh) representative of the lower (2 transects) and middle (2 transects) reaches should be covered. Other plant habitats, particularly those sensitive to changes in freshwater inflow, could also be monitored.

TEMPORAL SCALE

INTERMEDIATE LEVEL RESERVE	COMPREHENSIVE LEVEL RESERVE
Once-off survey during summer. For temporarily open/closed systems preferably during the open phase.	*For permanently open systems, once during high flow and once during low flow* *For temporarily open/closed estuaries one survey needs to be conducted in a stable closed phase and one in a stable open phase.*
LONG-TERM MONITORING PROGRAMME (where selected as indicator)	
Aerial photos, transects and quadrats	*Two years after implementation conduct a summer survey, followed by a summer survey every 3 years thereafter (where aerial photographs are available for intermediate years these should also be analyzed). Temporarily open/closed system preferably sampled in stable open phase.*

Macrophytes continued on next page...

Macrophytes continued...

IMPORTANT NOTES: MACROPHYTES

- *There are nine different habitat types recognised for estuaries*, i.e.:*

HABITAT TYPE	*INDICATOR SPECIES*
Open surface water area	*Indicates available habitat for phytoplankton*
Intertidal sand and mudflats	*Indicates available habitat for intertidal benthic microalgae*
Submerged macrophyte beds	*Zostera capensis (eelgrass), Ruppia cirrhosa, Potamogeton pectinatus*
Macroalgae	*Cladophora spp., Enteromorpha spp., Caulerpa filiformis*
Intertidal salt marsh	*Spartina maritima, Sarcocornia perennis, Triglochin spp,*
Supratidal salt marsh	*Sarcocornia pillansii, Sporobolus virginicus*
Reeds and sedges	*Phragmites australis, Schoenoplectus littoralis*
Mangroves	*Avicennia marina, Rhizophora mucronata, Bruguiera gymnorrhiza*
Swamp forest	*Barringtonia racemosa, Hibiscus tiliaceus*

* *These include the microalgal habitats as the area covered by each habitat is used to calculate the overall botanical importance of an estuary.*

3.7 Invertebrates

SAMPLING PROCEDURE

Zooplankton: Collect quantitative samples using a flow meter after dark, preferably during neap tides (mid to high tide) because currents are less strong and zooplankton will be more active in water column. Sampling to be done at mid- water level, i.e. not surface.

Two net trawls (WP 2 – 200 micron mesh), giving replicates (i.e. two samples) at each station. The net should be pulled for 3 minutes per station (10-12 m^3 of water) at 0.15 knots diagonally across the estuary.

Record species and abundance (density per volume) in each trawl and average results for station.

At each station phytoplankton samples (i.e. water column sample) and benthic microalgae samples need to be collected for chlorophyll a analyses.

Benthic invertebrates: Collect (subtidal) samples using a Zabalocki-type Eckman grab sampler with 5-9 randomly placed grabs (replicates) at each station. Collect intertidal samples at spring low tide using a core sampler of minimum 150 mm diameter and 250 mm depth, with 5 replicates at each site along the transect. Put one grab/core sample in a bucket and fill with in situ water. Add a drop of formalin and stir vigorously. Pour off supernatant through a 500 micron sieve. Repeat this process 5 times (minimum). Pour remainder from bucket through a 1 mm sieve. Check form invertebrates on sieve. Repeat with four other grab and core samples.

For intertidal benthic invertebrates which are not well quantified by core sampling (e.g. mud prawns, sand prawns, some crabs), count hole densities of each species in quadrats of minimum area 0.25m^2, with 5 replicates at each station.

The following need to be recorded at each site:

- *Identify fauna to lowest taxon*
- *Record animal density and species abundance (animals per m^2).*
- *Record the presence of Zostera*

At each station, sediment samples need to be collected for particle size distribution (250 ml) and organic content (250 ml). Analyze using standard techniques.

Macrocrustaceans: Quantitative sampling for macrocrustaceans should be conducted during neap tides (mid to high tide), at the same stations used for zooplankton. Use a benthic sled (80 cm x 80 cm, 500 micron mesh) with flow meter to collect sample and tow for about 30 meters diagonally across the estuary. Take 2 samples at each station. Set 2 prawn/crab traps per station overnight (more applicable to sub-tropical areas).

Use appropriate gear to sample shoreline (e.g. marginal vegetation) for size class distribution of dominant organisms in those areas.

Identify fauna to lowest taxon. Record number of species and determine densities.

Invertebrates continued on next page...

Invertebrates continued ...

SPATIAL SCALE

A sampling station is defined as a specific location in the estuary (at a specific 'distance from the mouth') from where a number of replicates are collected.

Sampling stations must be representative of the salinity zones characteristic of a particular estuary, which typically include (these zone should be indicated on a map):

- *Fresh (representative of river)*
- *0 – 10 ppt*
- *10 – 20 ppt*
- *20 – 35 ppt*

Within each salinity zone representative habitats need to be sampled such as:

- *Submerged macrophytes (e.g. Zostera beds)*
- *Soft sediments (sand/muddy sand/fine mud), hard (rocky areas) and organic rich areas.*

Benthic invertebrate stations need to include in addition to the above inter-tidal bird feeding areas.

Where benthic invertebrates are included in long term monitoring programmes, stations need to incorporate areas within the estuary where the habitat types are vulnerable to changes in river inflow.

As a guideline, the number of stations in a small estuary (< 5 km long) should not be less than 5, distributed along the entire length of the estuary, covering the salinity zones and habitat types as described above. Small systems with high habitat diversity may require more stations (in estuaries where the salinity regime is uniform, the selection of stations should focus on different habitat types).

For larger estuaries (> 5 km long), 10 to 15 stations selected geographically along the entire length of the estuary, covering the salinity zones and habitat types as described above, can be used as the guideline (although this may vary depending on habitat diversity of a system). Stations should preferably be set at fixed intervals or positions. A rough estimate for setting the distance between stations is to divide the length of the estuary by 10 (i.e. if an estuary is 30 km long, the distance between stations should be about 3 km).

In systems with large cross sectional areas (e.g. estuarine bays), sampling stations should also be selected along cross sections.

TEMPORAL SCALE

INTERMEDIATE LEVEL RESERVE	COMPREHENSIVE LEVEL RESERVE
Zooplankton, benthic invertebrates and macrocrustaceans: One survey in summer/spring and 1 survey in winter each year for 2 years. It is important that, at the time of sampling, the state of the estuary, as represented by the extent of saline intrusion and the state of the mouth, must be representative of that particular season. *For temporarily open/closed estuaries one survey needs to be conducted in a stable closed phase and one in a stable open phase.*	*Zooplankton, benthic invertebrates and macrocrustaceans: To be conducted in four seasons over 2 years (i.e. in spring, summer, autumn and winter in each year). At the time of sampling, the state of the estuary, as represented by the extent of saline intrusion and the state of the mouth must be representative of that particular season.* *For temporarily open/closed estuaries at least one survey must be conducted in a stable closed phase and at least two surveys in the stable open phase.*

LONG-TERM MONITORING PROGRAMME (where selected as indicator)	
Zooplankton	*Two years after implementation conduct a summer and winter survey followed by a summer and winter survey every 3 years thereafter.*
Benthic invertebrates	*Two years after implementation conduct a summer and winter survey followed by a summer and winter survey every 3 years thereafter.*
Macrocrustaceans	*Two years after implementation conduct a summer and winter survey followed by a summer and winter survey every 3 years thereafter.*

Invertebrates continued on next page ...

Invertebrates continued...

IMPORTANT NOTES: INVERTEBRATES

- *Because of the high variability in invertebrates in response to flow it is important to sample over two years to obtain the required confidence level (medium for Intermediate level and high for Comprehensive level).*
- *Total lack of information on invertebrates in most of South Africa's estuarine systems is the reason from the greater intensity (temporal scale) of sampling for this component to get the required confidence. There is also a rapid change in community composition and abundance over time (weeks to months). Sampling is even more intensive for zooplankton because of their rapid response over time.*
- *As far as possible, the invertebrate and macrophyte sampling stations should be matched to be able to link habitats with invertebrate characteristics.*
- *Water (salinity, temperature, pH, dissolved oxygen & turbidity) and sediment quality (sediment grain size and organic content) measurements need to also be collected during the invertebrate surveys. Combining water and sediment quality surveys on a particular estuary with the invertebrate surveys does this most cost-effectively.*
- *For invertebrate surveys, 7 sediment grain size categories should be used, ranging from mud to very coarse sand. Each category relates to a particular size diameter in the following manner:*
  >2 mm: > very coarse sand; 2 - 1 mm: very coarse sand; 1 - 0.5 mm: coarse sand; 0.5 – 0.25 mm: medium sand; 0.25 – 0.125 mm: fine sand; 0.125 – 0.0625 mm: very fine sand; <0.0625 mm: mud (silt and clay)
- *The percentage organic content of sediments can roughly be classified as:*
  <0.5%: Very low; 0.5 – 2%: Low; 1 – 2%: Moderately low; 2 –4%: Medium; > 4%: High

3.8 Fish (Ichthyofauna)

SAMPLING PROCEDURE

Conduct fish surveys using gear appropriate to the habitat of a particular estuary, but with seine nets and gill nets as primary gear.

Seine nets: 30 m x 2 m x 15 mm multifilament bar mesh in the wings and a 5 mm bar mesh in the purse.

Seine nets should be 30 m long by 2 m depth. The cod end (bag, purse) and the wings 5 m either side of it should be 5 mm bar whereas the remaining 15 m of each wing can be 15 mm bar mesh. This is required to adequately sample estuarine and 'faster moving' marine species. The net should be weighted such that it sinks below the surface when set in water deeper than 2 m (i.e. the distance between the lead and cork lines). A light net makes it more difficult to obtain a representative sample from weed and sandy areas, e.g. flatfish species tend to burrow in the sand and escape under a light seine.

Gill nets: Monofilament gill nets should comprise at least 3 different mesh sizes within the range 40-150 mm stretch mesh. Monofilament gill nets should comprise at least 4 nets (or panels) of which one net comprises 44, 48, 51 and 54 mm mesh, plus 3 more nets in the 75-150 mm stretched mesh range (e.g. 75, 100 and 145 mm stretched mesh).

Other sampling methods that may be used where primary gears are not appropriate, include:

- *Scoop nets (e.g. in extensive submerged macrophyte beds)*
- *Otter trawls (e.g. in deep channel area)*
- *Cast nets (e.g. in inaccessible areas).*

N.B. Where historic fish data for a particular estuary have been collected, using mesh sizes that differ from the above, it is recommended that previous net dimensions be used.

At each sampling station the following data need to be recorded:

- *Species lists*
- *Number of each species*
- *Size frequency distributions in total length*

Fish continued on next page...

Fish continued...

SPATIAL SCALE

A sampling station is defined as a specific location in the estuary (at a specific 'distance from the mouth') from where fish samples are collected using appropriate sampling gear (see above).

Sampling stations must be representative of the salinity zones characteristic of a particular estuary, typically (these zone should be indicated on a map):

- *Fresh (representative of river)*
- *0 – 10 ppt*
- *10 – 20 ppt*
- *20 – 30 ppt*
- *30 –35 ppt (at least one station should be in this range). It has been found that this salinity range supports a substantially different species composition than that found, for example in the range 20-30 ppt (S Lamberth, MCM and P Cowley, SAIAB, pers. comm.)*

Within each salinity zone, representative habitats need to be sampled such as:

- *Submerged macrophytes (e.g. Zostera beds)*
- *Sandy/muddy/rocky areas (representing different food sources)*

As a guideline, the number of seine net stations in a small estuary (< 5 km long) should not be less than 5, distributed along the entire length of the estuary, covering the salinity zones and habitat types as described above. Small systems with high habitat diversity may require more stations. Gill net samples do not need to be in the same quantity as seine samples. In small estuaries these nets could be used in the mouth, middle and upper reaches.

For larger estuaries (> 5 km long), 10 to 15 seine net stations selected geographically along the entire length of the estuary, covering the salinity zones and habitat types as described above, can be used as the guideline (although this may vary depending on habitat diversity of a system). Stations should preferably be set at fixed intervals. A rough estimate for setting the distance between stations is to divide the length of the estuary by 10 (i.e. if an estuary is 30 km long, the distance between stations should be about 3 km). For larger estuaries gill nets can be used at every 2-3 seine net sites. For example, the Breede River Estuary was sampled at the mouth and thereafter every 5 km upstream, approximately 9 gill net sites over 40 km.

TEMPORAL SCALE

INTERMEDIATE LEVEL RESERVE	COMPREHENSIVE LEVEL RESERVE
One survey in summer/spring and 1 survey in winter/autumn to sample the spectrum of species in the system. It is important that, at the time of sampling, the state of the estuary, as represented by the extent of saline intrusion and the state of the mouth must be representative of that particular season. *For temporarily open/closed estuaries one survey needs to be conducted in a stable closed phase and one in a stable open phase.*	*Seasonally over 1 year, i.e. in spring, summer, autumn and winter. The temporal scale needs to address recruitment patterns as well as species distribution within habitats in different seasons. Also, at the time of sampling, the state of the estuary, as represented by the extent of saline intrusion and the state of the mouth must be representative of that particular season.* *For temporarily open/closed estuaries at least one survey must be conducted in a stable closed phase.*

LONG-TERM MONITORING PROGRAMME (where selected as indicator)

Permanently open estuaries: Two years after implementation conduct as a summer and winter survey, followed by a summer and winter survey every 3 years thereafter.

For temporarily open/ closed estuaries, summer and winter surveys to be conducted within a 3-year period to ensure that conditions representative of stable open and closed phases are captured.

Sampling should be done immediately after any fish kill, followed by another 1-2 months after the event. This should be budgeted for in a contingency fund.

Fish continued on next page...

Fish continued...

IMPORTANT NOTES: FISH

- *Gill nets are extremely valuable in determining the seasonal changes in the along-stream distribution of the adults of large fish species. For example, it was found that a 44, 48, 51 and 54 mm mesh sizes were needed to obtain a representative sample of the different mullet species in the southwestern Cape. The 44 mm mesh catch tends to be dominated by Liza dumerilii, the 48 mm by L. richardsonii and the 51 and 54 by L. tricuspidens, Myxus capensis and Mugil cephalus. (Note: Monofilament nylon nets should be used, not woven nylon nets, as the latter have a completely different capture efficiency).*

- *Non-destructive sampling should be practiced where possible. The survival rate of larger fish is much greater if they are removed from a gill net by cutting the mesh (easily repaired afterwards) whereas most seined fish can be measured and released alive. If there are abundant fish in a sample, 100 individuals of a species should be measured, the rest counted and released. However, it must be accepted that some fish, especially clupeids, die very easily.*

- *The primary goal of fish sampling is to obtain species and size composition of the fish present in the system.*

- *Gill nets are necessary to sample those fast swimming species and larger individuals that are not captured in the seine nets.*

- *Monofilament gill nets of various mesh sizes can, for example be purchased from Laaiplek Handelshuis and ALNET (Pty) Ltd.*

- *Water quality measurement (salinity, temperature and other physico-chemical properties) need to be collected during the fish surveys. Combining water quality surveys on a particular estuary with the fish surveys does this most cost-effectively.*

- *Fish are more responsive to flow changes, than for example estuarine invertebrates or vegetation, making these good indicator species.*

- *In temporarily open/closed estuaries not all pre-selected sites may be assessable with the same gear during the various sampling trips. This would especially be the case for sites selected on habitat variability, e.g. protective backwater areas. This is an acceptable practice, as long as representative sites are monitored in the same salinity regime to allow for extrapolation.*

- *The advantages of using fish as indicators include (Whitfield and Elliot, 2002):*

  - *Fish are present in all aquatic systems*
  - *Life-history and environmental response information is available for most species*
  - *Relatively easy to identify and samples can be processed in the field, with the fishes being returned to the water (non-destructive sampling)*
  - *Communities usually include a range of species that represent a variety of trophic levels*
  - *Fish are relatively long-lived and therefore provide a integrative record of environmental stress*
  - *Fish contain many life forms and functional guilds and are likely to cover a number of components of aquatic ecosystems affected by change*
  - *Both sedentary and mobile and thus will reflect localized stressors as well as provide a broader assessment of effects*
  - *Acute toxicity and stress effects can be evaluated in the laboratory*
  - *High public awareness value, i.e. general public relate more to information on fish than on invertebrates or plants;*
  - *Societal costs of environmental degradation (e.g. cost-benefit analyses) are more readily determined in terms of the economic, aesthetic and conservation values attached to fishes.*

- *Difficulties associated with using fish as indicators include (Whitfield and Elliot 2002) include:*

  - *Selective nature of sampling gear for certain habitats and sizes and species of fishes*
  - *Mobility of fishes on seasonal time scales can lead to sampling bias*
  - *Fishes may be relatively tolerant to substances chemically harmful to other life forms*
  - *Can swim away from a disturbances, thus avoiding localized exposure to pollutants or adverse environmental conditions*
  - *Estuarine environments that have been physically altered by humans may still contain diverse fish assemblages.*

3.9 Birds (Avifauna)

SAMPLING PROCEDURE

Undertake full bird counts of all water-associated birds, recording the following information:

- *First, divide the estuary into counting sections on the basis of habitat type (e.g. sandy intertidal, muddy intertidal, mangroves, Zostera beds, salt marsh) and record on a map.*
- *For each counting section and for all estuary, provide:*
  - *Species list*
  - *Number of birds of each species (at low tide)*
  - *State of the habitat at the time of observation (or photo of site)*
  - *Levels of human disturbance at time of counting*
- *Identify key areas for feeding, roosting and breeding on the estuary and adjacent floodplain*
- *Identify and count high tide aggregations of feeding or roosting birds as far as possible*
- *Identify breeding areas and count breeding aggregations as far as possible.*

SPATIAL SCALE

The area covered must include the entire estuary and its floodplain, incorporating all habitats used by water-associated birds for feeding, breeding or roosting.

The upper boundary of the study area is the same as that for the overall study, i.e. the upper geographical boundary of the estuary.

The seaward boundary, which is regularly crossed by seabird species such as cormorants, gulls and terns, is most difficult to define. As a guideline, it should include the full tidal delta area and sand bars up to the back line of breakers outside the estuary mouth.

The sensible lateral extension would be different for each estuary, and may include rocky bars, etc. Thus it is important to furnish a map of the area counted. Any major bird roost in close proximity to the estuary should be counted and mapped.

TEMPORAL SCALE

INTERMEDIATE LEVEL RESERVE	COMPREHENSIVE LEVEL RESERVE
One summer month count when the tide in the estuary is at its lowest. In the case of temporarily open/closed estuaries this must be conducted when the mouth is open. However, in estuaries with a high variability in avifauna, three summer and two winter counts over one year may be required to obtain a medium confidence.	*Birds to be counted every month for one year. Alternatively conduct three summer month counts (September, December and March) and two winter month count (Jun and July) each year over two years. In the case of temporarily open/closed estuaries, at least one count must be done in summer when the mouth is open, in addition to fulfilling the above requirements.*

LONG-TERM MONITORING PROGRAMME (where selected as indicator)

Conduct a summer and a winter survey every year.

IMPORTANT NOTES: BIRDS

- *Where bird sampling is done according to sections, the section or station number need to be labeled as 'distance from mouth'.*

- *Ideally, the summer count should be in a consistent month, with the same month being used for the monitoring programme. Thus, unless there is a problem with mouth closure, the summer count should always be in February or March, and never after the end of March. Numbers of birds in an estuary change markedly throughout the year, with summer numbers often continuing to increase from spring right up until the end of March, after which there is a dramatic drop in early April following the departure of long-distance Palearctic migrants. Counting birds earlier than February would not only potentially lead to an underestimate of maximum bird numbers, but would be compromised in quality by presence of summer holiday-makers. Human disturbance on estuaries is known to have a significant impact on numbers of birds counted on estuaries.*

- *Bird numbers fluctuate cyclically, in fact often with a 3-year periodicity. If you count every 2 years you will completely lose this pattern, which will make interpretation of trends very difficult indeed. Therefore, in the long-term monitoring programme birds should be sampled every year.*

Birds continued on next page ...

Birds continued...

IMPORTANT NOTES: BIRDS

- *To investigate major food sources of key piscivorous, invertebrate and macrophyte feeders stomach content can be used, but this requires specialised equipment and expertise. Besides, estuarine birds are highly adaptive feeders, and describing the diet at one point in time (from a limited sample) may drive one to a rather simplistic and erroneous conclusion about the impacts of changes in the food base. Any trained ornithologist would be able to use available understanding on bird diets and behavioural ecology, coupled with an understanding of their food base, to predict what will happen, with no less certainty than if you went out and stomach-pumped a limited sample of birds.*

- *The Coordinated Waterbird Counts (CWAC) monitors South Africa's waterbird populations and the conditions of the wetlands which are important for waterbirds. This is being done by means of a programme of regular mid-summer and mid-winter censuses at a large number of South African wetlands and estuaries, at regular six-monthly intervals. CWAC currently monitors over 350 wetlands around the country. For a reserve determination it is important top check the availability of CWAC data on a specific estuary. Where available, CWAC data can be acquired at a cost of between R10 000-15 000 per system (allow for this in the budget) (http://web.uct.ac.za/depts/stats/adu/p_cwac.htm)*

- *It is recommended that the Directorate: Resource Directed Measures provide CWAC with a list of priority estuaries, and in this way those estuaries could be considered for inclusion in their monitoring network.*

- *Although the selection of components in long-term monitoring programmes will be selected on a site specific level, birds are likely to be important indicators in the following instances:*

  - *Large permanently open estuaries*
  - *Estuarine lakes*
  - *Estuarine bays*
  - *If there are a number of rare and/or endangered species (diversity and/or density)*
  - *Estuaries known to be utilized during migration*

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APPENDIX A

REVIEW OF RESOURCE MONITORING PROGRAMMES IN SOUTH AFRICAN ESTUARIES

Prepared by

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TABLE OF CONTENTS

1. INTRODUCTION

The great value of estuaries is reflected in the vast amount of goods and services that these sensitive ecosystems provide. Some of the goods and services provided by estuaries relate to their role in sustaining the functioning of the larger ecosystems (Costanza *et al.*, 1997; Mander *et al.* 2001; Mander, 2001), such as:

CATEGORY	*GOODS AND SERVICES*	*EXAMPLES OF OPPORTUNITIES & ACTIVITIES*
Ecological	*Biological Control*	*Maintaining the balance/diversity of plants/ animals*
	Refugia/Migratory Corridors	*Fish and crustacean nurseries and roost for migratory birds*
	Sediment supply	*Creation and maintenance of beaches, sand bars and sand banks.*
	Erosion control	*Prevention of soil loss by estuary vegetation, and by capturing soil in reed beds and mangroves.*
	Soil formation	*Accumulation of sediment and organic material on floodplains and in mangroves.*
	Nutrient supply and cycling	*Nutrient supply, nitrogen fixation and nutrient cycling through food chains.*
	Genetic Resources	*Genes for mariculture, ornamental species and fibre.*
	Disturbance regulation	*Flood control, drought recovery and refuges from natural and human induced catastrophic events (e.g. oil spills).*
Subsistence	*Collection of living resources for food*	*Line fishing, inter-tidal collecting, beach and seine netting*
	Raw material for subsistence use (e.g. building material)	*Harvesting of craftwork and house-building materials.*
Recreational & Tourism	*Nature appreciation*	*Providing access to estuaries and associated wildlife for viewing and walking.*
	Scenic views	*Resort, residential houses, housing complexes and offices with scenic views, increasing turnover of properties with seaview*
	Culture	*Aesthetic, educational, research, spiritual, intrinsic and scientific values of estuary ecosystems.*
	Sports fishing	*Estuary flyfishing, estuary and inshore conventional fishing*
	Water sports	*Water sports: swimming, sailing, canoeing, skiing and kayaking*
Commercial and Industrial	*Waste treatment*	*Breaking down of waste and detoxifying pollution.*
	Water supply and regulation	*Water supply to marine environment and water for mariculture.*
	Mariculture (e.g. oysters, bait, etc.)	*Production (natural and cultivated) of fish, crustaceans and worms.*
	Commercial food production	*Fishing*
	Raw material for commercial use	*Diamond and titanium mining*
	Transport services	*Ports, harbours, marinas and skiboat launching sites*

Notwithstanding, all of the above, estuaries are also expected to sustain their scenic beauty to support services such as tourism, bird watching and nature appreciation.

The major threats to the sustainability of the goods and services provided by estuaries (some of which are affected by other 'goods and services' themselves) can be subdivided into the following categories:

- Land-use/infrastructure development which lead to modification and destruction of habitat
- Unsustainable use of living resources

- Water quantity
- Water quality
- Climate and other environmental changes

Specific activities relevant to each of the above are listed below:

MAJOR THREATS	*SPECIFIC ACTIVITIES*
Land-use/Infrastructure	*Low lying developments* *Mariculture alien introduction* *Inappropriate mouth breaching practices* *Channel modification* *Structures, e.g. marinas, bridges, jetties* *Dredging* *Mining (sand, diamond, heavy minerals)* *Exceedance of carrying capacity i.t.o. boating, bathers etc.* *Uncontrolled/inappropriate developments along estuaries, including housing, paths, roads (formal and informal)*
Exploitation of living resources	*Commercial:* - *Net fishing (e.g. gill nets, beach seine nets and fyke nets)* - *Linefish* - *Collection of shell fish, red bait and other invertebrate species (e.g. bait)* - *Mariculture (including the use of genetically modified organisms)* - *Fishing harbours* - *Commercial fishing activities (e.g. landing, transportation, delivery and processing, aquarium trade, curio trade, traditional medicinal, medical research)*
	Subsistence: - *Net fishing (e.g. beach seine nets, gill nets, set nets, drift nets and stake nets)* - *Traditional fish traps* - *Linefish* - *Collection of shell fish, red bait and other invertebrate species (e.g. bait)* - *Aquatic plants (e.g. mangroves for building material)*
	Recreation: - *Cast net fishing* - *Linefish* - *Collection of shell fish, red bait and other invertebrate species (e.g. bait)* - *Hobby aquarium collection (e.g. exploitation of seahorses and pipefish)*
	Biological pest control
	Ballast water
Water quantity	*Water abstraction* *Water demand of alien vegetation* *Water demand of forestry* *Modification of flows*
Water quality	*Industrial effluents, including cooling water discharges* *Sewage effluents* *Storm water runoff* *Bad catchment practices, e.g. erosion, fertilizers, pesticides, etc.* *Solid waste dumps near estuaries, e.g. littering and seepage* *Septic and conservancy tank seepage* *Littering* *Mariculture waste products* *Pollution related to shipping activities in harbours*
Climate and other environmental changes	*Sea level rise*

Therefore, in the estuarine environment a variety of activities occur, some of which demand a 'good quality' estuary, while others have a tendency to 'deteriorate quality'. To manage this conflict situation, knowledge of the following aspects, amongst others, is required:

- character and functioning of the natural systems
- links between threats and their impact on the character and functioning of estuaries
- decision-making process involved in the selection of appropriate management actions to mitigate.

Underpinning the successful management of the above is data and information, which, in many instances can only be obtained through the design and implementation of monitoring programmes.

Monitoring programmes for activities or developments are often developed independently from different departmental and legislative requirements, despite potential overlap in their focus area. Furthermore, these can also overlap with baseline monitoring programmes undertaken, for example in the State of the Environment reporting. Therefore, to ensure efficient use of resources, both human and financial, and prevent duplication, monitoring initiatives within a particular estuary should be coordinated, taking into account aspects such as monitoring sites, monitoring frequency and monitoring parameters. It, therefore, is recommended that for a particular estuary:

- Monitoring initiatives be coordinated and that specific responsibilities be allocated to specific authorities or institutions.
- The appointed authority or institution have sufficient resources, both human and financial, to execute such monitoring or provide a strategy to obtain such resources.
- That scientifically defensible data and information on the functioning of estuarine ecosystems be collected so that the links between major threats and associated impacts can be established.

2. LOCAL MONITORING PROJECTS IN SOUTH AFRICA

2.1 Klein River Estuary (MCM, CSIR and Western Cape Nature Conservation)

2.1.1 Water levels, berm height and rainfall

The Western Cape Nature Conservation Board is the responsible authority for the Klein Estuary, near Hermanus. In the case of the Klein they have to practise artificial breaching due to approved low-lying developments on the flood plain. The system needs to be artificially breached at the lowest point on the mouth sandbar when the water reaches a level of about 2.6 m MSL.

Monitoring technique: With the assistance of Mr E Lucas, an Honorary Nature Conservation Officer, the water levels of the Klein River estuary are monitored regularly. These visual observations of the water levels are then used in conjunction with data collected by means of a continuous water level recorder (Department of Water Affairs and Forestry) to assist in the estuary mouth management. Mr Lucas also assists in monitoring the sand berm's height at the mouth and identifying the lowest area on the berm appropriate for breaching.

Mr Lucas has established an informal rainfall monitoring network, by which rainfall figures in the upper catchment are used as an early warning signal for expected increases in runoff to the estuary. This information is then used to assist in mouth management e.g. whether the estuary needs to be breached or not.

Spatial scale: Water levels are visually observed and continuously recorded in the middle regions of the estuary. Berm heights are recorded in the mouth area. Rainfall data is gathered from outlying farms in the area.

Temporal scale: Water levels are continuously recorded throughout the year, with daily visual observations contributing insights during critical periods of high water levels. Berm heights are only recorded during critical periods when the risk of flooding becomes significant.

2.1.2 Salinity

The CSIR, in conjunction with Western Cape Nature Conservation Board, have been regularly monitoring the changes in salinity in the estuary to establish general trends and gain an understanding of the hydrodynamics of the system.

Monitoring technique: Salinities are measured *in situ* (Valeport salinity - conductivity - temperature - depth meter) at 0.5 m intervals.

Spatial scale: Salinity measurements are taken longitudinally from the mouth of the estuary to the Stanford Bridge, at 1.0 to 2.0 km intervals.

Temporal scale: Salinity measurements are taken at monthly intervals, in order to establish long-term trends.

2.1.3 Fish

Since 2001, MCM have been monitoring the fish in the Klein Estuary on a monthly basis to establish trends, verify its status as an important nursery area and to gather information on the health of the system.

Monitoring technique: The fish are sampled using a 30 m x 2.0 m x 15 mm bar mesh seine and gill nets. Each gill net has a range of mesh sizes comprising 44 mm, 48 mm, 51 mm, 54 mm, 64 mm, 100 mm and 145 mm stretched mesh monofilament panels, 30 m in length and 2m deep. Netting is carried out during daylight hours. Seine netting is limited to shallow (<1.5 m deep), unobstructed areas with gently sloping banks whereas gill netting is used to sample the deeper (>1 m) open and mid-channel waters. The gill nets were set for a minimum of one hour at each sampling site and checked regularly to prevent undue fish mortalities.

All fish in each haul are identified and counted. A sub-sample of a maximum of 100 of each species are measured to the nearest mm total length (TL) and returned alive to the system. A sub-sample of 30 mullet is retained for biological analyses.

Spatial scale: A number of sites in various habitats (e.g. sandy bottom, submerge macrophytes) are monitored in both the estuary and river to establish preferences in term of habitat or salinities ranges.

Temporal scale: Fish surveys are taken at monthly intervals, in order to establish long-term trends. After the initial three-year intense data collection period, the monitoring frequency will be scaled down to quarterly.

Discussion

The monitoring projects that the Western Cape Nature Conservation Board have in estuaries work effectively, for they are not time consuming and the individuals involved are enthusiastic. The community involvement has been long-term and to a large extent self motivated.

2.2 Bot River Estuary (MCM, CSIR and Western Cape Nature Conservation)

2.2.1 Water levels

A continuous water level recorder (maintained by the DWAF) has been monitoring the water level of the estuary since 1979. This is one of the longest continuous records of its kind available in the country.

2.2.2 Salinity

Western Cape Nature Conservation Board has been monitoring the salinities of the Bot Estuary on a monthly basis for a number of years since the 1980s. When salinities in the estuary fall below 10 ppt the monitoring frequency escalates to every two weeks, with weekly measurements taken when it nears the critical limit of 6 ppt. Research in the past has indicated that at salinity values below 6 ppt fish kills tend to occur in the system.

2.2.3 Birds

Monitoring technique: Coordinated Waterbird Counts (CWAC) are regularly done on the system.

Spatial scale: The counts are conducted over the entire system, from the mouth to the bridge crossing the estuary about 6.0 km upstream.

Temporal scale: The bird counts are conducted twice a year on the entire system.

2.2.4 Fish

Since 2001 the Chief directorate: Marine and Coastal Management (MCM) of the Department of Environmental Affairs and Tourism (DEAT) has been monitoring the fish in the Bot Estuary on a monthly basis to establish trends, verify its status as an important nursery area and to gather information on the health of the system.

Monitoring technique: The fish are sampled using a 30 m x 2.0 m x 15 mm bar mesh seine and gill nets. Each gill net has a range of mesh sizes comprising 44 mm, 48 mm, 51 mm, 54 mm, 64 mm, 100 mm and 145 mm stretched mesh monofilament panels, 30 m in length and 2m deep. Netting is carried out during daylight hours. Seine netting is limited to shallow (<1.5 m deep), unobstructed areas with gently sloping banks whereas gill netting is used to sample the deeper (>1 m) open and mid-channel waters. The gill nets were set for a minimum of one hour at each sampling site and checked regularly to prevent undue fish mortalities.

All fish in each haul are identified and counted. A sub-sample of a maximum of 100 of each species are measured to the nearest mm total length (TL) and returned alive to the system. A sub-sample of 30 mullet is retained for biological analyses.

Spatial scale: A number of sites in various habitats (e.g. sandy bottom, submerge macrophytes) are monitored in both the estuary and river to establish preferences in term of habitat or salinities ranges.

Temporal scale: Fish surveys are taken at monthly intervals, in order to establish long-term trends. After the initial three-year intense data collection period, the monitoring frequency will be scaled down to quarterly.

2.3 Heuningnes Estuary (MCM and Western Cape Nature Conservation)

2.3.1 Water levels

A continuous water level recorder (maintained by the DWAF) monitors the water level in the estuary.

2.3.2 Fish

Monitoring technique: At the Heuningnes Estuary, the Western Cape Nature Conservation Board has been assisting MCM since 1995 in the distribution and collection of catch cards to determine the fish catch and effort in the system. Data such as fish species targeted, catch sizes, bait used, whether the fish was released or not, are regularly collected and assists greatly in determining the fishing pressures on the system. The data can also be used to deduce the presence or absence of certain key species and give an indication of size class distributions. Absolute numbers of fishers are known as all entering the estuary are recorded at the gate of the De Mond Reserve. There are also data available from a two-year (1997-1999) bimonthly sampling programme conducted on the estuary.

Spatial scale: The data are collected on a variable spatial scale because it depends on the position of the angler catching the fish. Therefore fishing areas with easy access have higher catch rates than sections that are more difficult to reach.

Temporal scale: The data are collected on a variable temporal scale depending on the fishing intensity (e.g. more anglers over holidays and less during winter) and the diligence of the personnel manning the gate of the reserve.

Discussion

For a catch card monitoring system to work as effectively as it does at the Heuningnes Estuary you need to have limited access and good control, or the data becomes very unreliable. For some isolated systems like the Tyolomna Estuary this might work very well but not for an estuary with multiple access points (Mr S. Lamberth, MCM, pers. comm.).

Good indicators of fishing effort in estuaries include the following information:

- Number of people fishing
- Number of people collecting bait
- Number of boats on system
- Number of people in boats

At some stage, a trained person (preferably a scientist or technician) should then randomly verify what people are catching and what size the fish are.

2.4 Groot Brak Monitoring Programme (PetroSA, formerly Mossgas)

2.4.1 Background

A unique management and monitoring programme has been undertaken at the Great Brak Estuary near George. A major dam, the Wolwedans Dam was constructed between 1988 and 1990 and serious concerns existed on the effect of the dam, and especially the reduction in freshwater flow, on the estuary.

Comprehensive initial investigations were undertaken during the construction of the dam to develop a detailed understanding of the biophysical processes in the estuary and to predict the possible effects of the dam. Investigations were also undertaken on the sociological perceptions and concerns of the effects of the dam on the estuary. The first

version of a management plan was developed for the estuary and it was recognised that an ongoing programme was required to monitor the effects of the dam and also the effectiveness of the management plan.

Valuable experience was obtained from the monitoring programme and the understanding of the dynamics of the estuary was considerably improved. Based on this, major modifications were made to the management plan.

With the construction of the Wolwedans Dam, a steering committee, the Great Brak River Environmental Committee (GEC) was established by the then Department of Water Affairs with the specific aim of investigating the effect of the dam on the Great Brak Estuary. The GEC also had to establish an effective estuarine management plan for the optimal use of the water allocated to the estuary to maintain the current environmental status.

Under the guidance of the GEC an interdisciplinary study was completed, prior to the commissioning of the dam in1990, in which the effect of the Wolwedans dam on estuarine dynamics, water quality, estuarine ecology and the socio-economic aspects was investigated. The study concluded that the reduction of river flow to the estuary, because of the Wolwedans Dam, might have different effects on the estuary. For example, it could cause the mouth to close more frequently if no effective management plan was implemented. The potential effects of such conditions on the physical dynamics, water quality and ecology of the estuary were also highlighted.

To minimize negative impacts on the estuary and to monitor progress, a management plan, including a monitoring programme was implemented. This monitoring programme was initiated in 1990 and the results were used to review and improve the management plan.

2.4.2 Monitoring Programme

The purpose of the programme was to monitor the condition of the estuary and the effectiveness of the Management Plan. The funding available for the monitoring was limited and the programme therefore also needed to be cost effective.

At an early stage it was concluded that the health of the estuary was determined by the physical and water quality conditions and that the biotic responds to these conditions. Changes in the health of the biota can be assessed against a continuous record of the physical and water quality conditions in the estuary.

During the initial investigations it was decided to concentrate on the salt marsh vegetation and the benthic invertebrates to monitor the ecological health of the estuary. It was decided not to include estuarine fish and birds, because of their high mobility.

Below is an overview of the work undertaken as part of the monitoring programme for the main components:

- Hydro- and sediment dynamics
- Ecology, including botany and invertebrates
- Water quality
- Socio-perceptions

Further details of the monitoring undertaken for each component are listed and briefly described below.

Hydro-and sediment dynamics

The physical conditions are driven by the river flow and by interaction with the sea. Continuous records of these two aspects are therefore required. Continuous river flow data is obtained from a flow gauging station below the Wolwedans Dam. Interaction with the sea takes place when the mouth is open and normal tidal variations occur in the estuary. A crucial record on the interaction with the sea is obtained from a water level recorder installed at the railway bridge in the estuary. The mouth is open when the water level recordings show tidal variations and it is normally closed when these variations are absent. There are exceptions to this rule and it is therefore also important that these recordings are complemented with direct observations of the mouth as well.

Concerns in the short term are related to open and closed mouth conditions, while concerns in the long term are related to the possibility of ongoing sedimentation in the estuary. At the Great Brak Estuary this was monitored by topographical surveys of the estuary at regular intervals.

Monitoring technique: Continuous monitoring:

- Water level recordings in the estuary at the railway bridge (Department of Water Affairs and Forestry [DWAF])
- Recording of river flow into the estuary (DWAF)
- Ad hoc monitoring of mouth conditions (CSIR co-operating with local community)
- Evaluation of mouth breachings (CSIR).

Topographical surveys and bathymetrical surveys

Monitoring technique: The mouth surveys are done using a 'wading survey' technique, which is performed by using standard line surveying techniques. A survey team member transverses the survey lines holding a rod supporting a surveying prism, stopping at appropriate intervals to allow an instrument operator to read and record the distance and horizontal and vertical angles. The wading survey is continued seaward into the water until the rod holder can no longer stand steady with the survey rod. The land section is done preferably at low tide so that readings extend as far seaward as possible. The electronic surveying instrument provides distance measurement accuracies of 5 mm. The angle measurements were done with an electronic single second theodolite.

Surveying of cross sections in estuaries by standard land surveying techniques is time consuming and expensive. For this reason an alternative method, using a ski boat and echo sounder has been developed, allowing reasonably accurate survey of the cross sections below the water level to be undertaken within a short time at much reduced costs.

A boat mounted digital echo sounder and a differential geographical position fixing systems (GPS) is used. At the time of the survey, the water level is also recorded at the mouth so as to correct the data to MSL Although the survey by ski boat and echo sounder covers only the deeper parts of the estuary which are accessible by boat, these are usually the main areas where changes in sedimentation and erosion takes place.

The vertical accuracy of the depths measured with the echo sounder are within 0.10 m, provided that bottom material is hard enough to provide a proper echo. Vertical inaccuracies are also introduced by the reduction of the echo sounder reading to a depth referred to MSL. This, in turn, depends on the accuracy of the water level readings taken from the gauge plate, which is of the order of 0.01 m, as well as the accuracy with which the actual water level at the echo sounder position can be corrected based on the gauge plate readings. For this reason, accuracies in readings close to the location of the gauge plate will be in the order of 0.02 m, while at greater distances the accuracy will be of the order of 0.1 m, depending on the accuracy with which the phase differences of tidal variation can be determined. These errors will be minimal at small tidal variations and for this reason these types of surveys are generally undertaken during *neap tides*. The total degree of inaccuracy for these surveys is therefore estimated at 0.1 m near the gauge plate and 0.2 m further away from the gauge plate.

Spatial scale: Topographical surveys of mouth area and bathymetrical surveys of cross-sections, about every 1.0 km upstream of the estuary to the full extend of tidal variation were regularly conducted by professional surveyors from the CSIR.

Temporal scale: Topographical surveys of mouth:

- December 1988 (baseline survey)
- July 1989
- June 1990
- June 1991
- March 1992
- September 1992
- October 1992
- July 1993
- July 1993 (after release)
- January 1995

- January 1996
- December 1996
- March 1999
- March 2000
- April 2001 (DWAF)

Bathymetrical surveys of cross-sections upstream in estuary (by professional surveyors of the CSIR)

- December 1988 (baseline survey)
- July 1993

Estuarine vegetation

Monitoring technique: For vegetation the mean cover values were determined for each species at the quadrat positions along two transect lines. Duplicate 1 m^2 quadrats were assessed for vegetation percentage cover at each position.

Spatial scale: Two transects covering most of the environmental and phytosociological variation within the lower reaches of the Great Brak Estuary was used to assess the state of the communities of salt marsh vegetation.

Temporal scale: The baseline surveys were undertaken in January 1989 and the results from later surveys were compared with those of the baseline surveys.

Surveys of estuarine vegetation were conducted on:

- January 1989 (baseline survey)
- February 1991
- February 1992
- April 1999

Estuarine invertebrates

Monitoring technique: Assessments of the status of the three common benthic macrofaunal species in the lower estuary were carried out by means of burrow counts along transects and in the open water sections of the lower estuary. After ascertaining that live animals were present, burrow openings were counted in areas of 0,1 m^2 (from a wire quadrat thrown randomly ten times at each site). Densities of the sand prawn *Callianassa kraussi*, the mud prawn *Upogebia africana* and marsh crab *Sesarma catenata* were thus obtained and the data for recent surveys compared graphically with previous survey data.

In addition crabs were caught manually at each transect. These were sexed and carapace widths were measured to provide some indication of population structure. The method of collecting crabs by hand probably biasses the samples in favour of crabs greater than about 8 mm carapace width. Smaller specimens, being more cryptic in the salt marsh vegetation, tend to be missed in favour of the more visual sub-adults and adults.

Spatial scale: Two of transects covering most of the environmental and phytosociological variation within the lower reaches of the Great Brak Estuary were used to assess the state of the benthic macrofauna community.

Temporal scale: The baseline surveys were undertaken in January 1989 and the results from later surveys were compared with those of the baseline surveys. Additional surveys on the same transects were undertaken by Professor Wooldridge of the University of Port Elizabeth (UPE) as part of his research programme.

Surveys of invertebrates (normally by specialists of the CSIR) as part of the monitoring programme on

- January 1989 (baseline survey)
- February 1991
- February 1992
- January 1994
- May 1994 (UPE)
- August 1994 (UPE)

- May 1995 (UPE)
- September 1995 (UPE)
- October 1996
- October 1997
- April 1999.

Water quality

Monitoring technique: Longitudinal water quality samples were collected. Salinity and temperature profiles were measured at 0.5 m intervals, while other water quality parameters (pH, dissolved oxygen and inorganic nutrients) were measure in surface and bottom waters.

Spatial scale: Sampling stations were located along the entire estuary at approximately 200-500 m intervals.

Temporal scale: Water Quality Surveys were conducted by specialists of the CSIR on:

- November 1988 (baseline survey)
- February 1991
- January 1992
- February 1993
- July 1993 (during release)
- January 1994
- February 1998.

Socio-perceptions

Monitoring technique: In order to capture resident's and visitor's perception and concerns regarding the current and future state of the Great Brak River Estuary, as well as their perceptions regarding the effectiveness of the Estuary Management Plan in mitigating the potential negative impacts associated with the construction of the Wolwedans Dam, a questionnaire-based survey was conducted amongst residents and visitors to Great Brak River. In addition, a number of interviews were conducted with representatives of key stakeholder groups to obtain additional background information.

The questionnaire included a combination of fixed-choice and open-ended questions to determine:

- The profile of residents and visitors
- The recreational activities associated with the estuary
- Preferences for open or closed mouth conditions
- Current problems with the state of the estuary
- Perceptions of the current state of the estuary
- Concerns about the future state of the estuary
- The effectiveness of the estuary management plan in mitigating the negative impacts of the Wolwedans dam;
- The effectiveness of the DWAF, the Great Brak River Municipality, PetroSA (formerly Mossgas) and the CSIR in terms of implementing the estuary management plan; and
- The effectiveness of these implementing agents in communicating decisions relating to the management of the dam and the estuary to residents and regular holidaymakers.

Questionnaires were distributed in both English and Afrikaans.

Spatial scale: The Great Brak River area was broken down into a number of different target areas. These areas were selected on the basis that they are all, to a greater or lesser extent, impacted on by the condition of the estuary and the effectiveness of the Estuary Management Plan. Approximate estimates for the number of houses in these areas are included below:

Great Brak River Town:	250 houses
Greenhaven:	900 houses
The Island:	80 houses

Hersham:	180-200 houses
Southern Cross:	200 houses.

In addition, the Pine Creek Caravan Site includes a number of permanent residents who stay in Plettenberg houses and 150 caravans over the Christmas and New Year period.

Temporal scale: Socio-perception Surveys were conducted three times by specialists of the University of Cape Town or the CSIR on:

- 1989 (initial investigation)
- 1993/94
- December 2001.

Efforts were also made to keep the community continuously informed on the results from the monitoring programme and the public also had the opportunity to comment and to convey their concerns.

Discussion

Considerable success was achieved with the monitoring programme at the Great Brak Estuary. The results proved to be useful in monitoring the biophysical condition of the estuary and were frequently used to improve the Management Plan for the system. The results from the socio-perception surveys also provided useful information on the perceptions and concerns of the local community on the condition of the estuary.

This was the first time that such a monitoring programme was undertaken in South Africa to monitor the effects of reduction in freshwater flow on an estuary or river. The experience gained provides useful information for this project.

Important conclusions are:

- The monitoring programme was initially comprehensive with surveys undertaken at relatively short intervals. The programme was later refined and became more focused with larger time intervals between surveys.

- Most of the monitoring work was undertaken by specialists or professionally qualified people. There was limited scope for involving non-qualified people in the monitoring process.

- The physical dynamics and water quality conditions drive the ecological processes in an estuary. Some aspects such as river flow and tidal conditions need to be monitored continuously, while others such as sedimentation need to be monitored at regular intervals.

- Daily mouth observations at different river flow and tidal conditions are essential for complementing the information obtained from continuous water level monitoring. Only then can a proper understanding of the dynamics of an estuary mouth be obtained.

- Gauging of river flow and recording of water level variations need to be undertaken in a professional way by a competent organization. The expertise required is available in the Hydrological section of the DWAF. This department is therefore best suited to continue undertaking this work at Great Brak and to extent it to other estuaries.

- Large differences exist between estuaries on the flow required to maintain open mouth conditions and other physical processes. It is therefore dangerous to use information obtained for one estuary to draw conclusions on the flow requirements of another estuary. Specific monitoring is required for each estuary.

- Reasonably good results were obtained for the ecological condition of the Great Brak Estuary by concentrating on salt marsh vegetation and benthic invertebrates in the estuary. However, the need to include other components such as fish and birds should be re-assessed.

- The focusing of the surveys on salt marsh vegetation and benthic invertebrates at two fixed transects was effective in the measurement of changes between the different surveys. However, less intensive but wider monitoring over a larger area is also required to obtain information on the condition of the whole estuary.

- Frequent interaction with the local community is essential to allow them to comment and to obtain information on their concerns. This should be seen as an essential component of any monitoring programme.

- Human perceptions are often the cause of concerns amongst the community. Problems can, however, only be quantified if reliable monitoring data is collected. Such data can confirm whether a real problem exists or not.

2.5 Swartvlei and Wilderness Estuaries (South African National Parks)

South African National Parks at Rondevlei Research Station have been involved in the monitoring of the Swartvlei and Wilderness estuaries for nearly 10 years (Ian Russel, South African National Parks, pers. comm.). The following components are being monitored on an ongoing basis:

- *Hydrodynamics:* Continuous water level and inflow data (DWAF), limited mouth observations
- *Water Quality:* Quarterly sampling of salinity, temperature, turbidity, ph, in the past limited oxygen and nutrient samples were also collected
- *Sediment:* In the past regulars, every 3 – 4 years, transects were measured in the in mouth to estimate sediment movement, this is currently only done for events, e.g. storms of floods, some limited observations on wave highest.
- *Vegetation:* Submerged vegetation surveyed every 2nd year to evaluate biomass and species composition, riparian vegetation was surveyed as a once-off in 1997 to compare with earlier 1995 work.
- *Fish:* Once-off comprehensive survey in all the lakes using gill and seine nets. Currently the survey is only repeated in areas were there is drastic change in for example salinities.
- *Birds:* Twice a year in winter and summer.

2.6 East Keinemonde Fish (South African Institute for Aquatic Biodiversity)

Dr P Cowley initiated a monitoring programme on the East Kleinemonde Estuary in 1993. The project focus was initially to gather data for his PhD thesis, but after completion of the thesis field monitoring was continued in a reduced format. The main aim of the study was to examine the fish species composition and quantify the contributions made by the different taxa to the estuary (Cowley and Whitfield, 2001; Cowley & Whitfield 2002).

2.6.2 Mouth observations

Daily mouth observations are made at the East Kleinemonde, categorizing the state of the estuary mouth as: closed, overwash (by springtides or storm events) or open. Observations are also made on the extent of the interaction with the marine environment, e.g. whether only a trickle of water is running out (i.e. semi-closed) or whether the mouth is fully open. These mouth observations have lately been expanded to include the West Kleinmonde Estuary.

2.6.3 Temperature and Salinity

Monitoring technique: Salinity and temperature data was collected at twice weekly intervals during the first two years of the study, after which it was reduced to monthly measurements.

Spatial scale: Water temperatures (surface and bottom) were recorded in the middle reaches of the estuary for January 1994 to December 1995. Surface salinities were measured fortnightly (March 1994 to March 1996) in the middle reaches, and from July 1994 to March 1996 an additional two sites were include from the lower and upper reaches.

Temporal scale: Water temperatures (surface and bottom) were recorded once a week over a period of two years (January 1994 to December 1995). Surface salinities were measured fortnightly.

2.6.4 Fish Surveys

Monitoring technique: A variety of gear types where used, including small and large mesh seine nets and a fleet of gill nets. Different gear was used to target specific groups and/ or size ranges of fishes. The large seine net was laid in a semi-circle from the bank by motorised boat and then hauled in by three or four people, ensuring that the foot rope (lead line) was dragged along the bottom. All fish captured were identified and measured to the nearest standard length (SL) before being returned to the water alive. The small mesh seine sampling method was similar, except that due to the large number of fish captured, fish were preserved in formalin and identified at the laboratory, with the exception of larger individuals which were measured in the field. Seine netting was conducted during daylight hours.

Monofilament gill nets were used to sample larger fish of both marine spawning and freshwater species, as members of both groups are known to actively avoid seine nets. The nets were 10 m in length and 2 m in depth consisting of three equal length sections of 45 mm, 75 mm, and 100 mm stretch meshes. Generally two nets were used in each reach (upper, middle and lower). Gill nets were deployed in the evening and lifted the following morning. All fish captured were identified and measured to the nearest mm in standard length. Three seine net samples are conducted in each region, using two different nets of different mesh sizes (a 5 mm mesh size net of 30 m long and a 15 mm mesh size net of 50 m long). Fish sampled in the large mesh seine net are identified, measured and released back into the estuary whereas the fish captured in the small mesh seine net are preserved for later identification and measuring in the laboratory. The target groups and size classes (mm standard length) of different gear types are listed below:

GEAR TYPE	*STRECH MESH SIZE*	*TARGET GROUP*	*TARGET SIZE CLASSES*
Small mesh seine (30m x 2m)	*5 mm*	*Estuarine spawning species and smaller marine spawning species*	*All size classes excluding very small individuals*
Large mesh seine (50m x 2m)	*15 mm*	*Marine spawning species and fresh water species*	*All size classes excluding very small individuals (<40 mm SL)*
Gill nets (10 m x 2 m)	*45, 75 and 100 mm*	*Marine spawning species and fresh water species*	*Larger individuals (<100 mm SL)*

Spatial scale: The estuary is subdivided into four basic regions, mouth, lower, middle and upper. The East Kleinemonde data has shown that the fish fauna of the mouth area has a distinctly different structure from the rest of the estuary and therefore is seen as separate from the lower reaches. Due to fluctuations in water depth during the study period, sampling stations were not fixed but were selected according to where nets could be laid. Sampling was conducted in a variety of littoral habitats (i.e. sandy, muddy and vegetated areas).

Temporal scale: During the firsts three years of the programme sampling was done every month, after which it was reduced to twice a year (summer and winter).

2.7 Mkomazi Estuary (Marine and Estuarine Research)

2.7.1 Vegetation

Monitoring technique: Phytoplankton is measured in the water column as *chlorophyll a* using fluorometry.

Spatial scale: There are six sites in total along the length of the Mkomazi Estuary, of which just the lower three sites are sampled for phytoplankton.

Temporal scale: The estuary is sampled annually in August during the low flow period. The sampling might be conducted earlier if river inflow is low in a specific year.

2.7.2 Invertebrates

Monitoring technique: Zooplankton night sampling is done using a 500 micron mesh net towed by boat. Hyperbenthos is sampled using a benthic frame net also towed by boat. Zoobenthos is sampled by using a Zabalocki–type Eckman grab, with 5 replicates per site.

Spatial scale: The Mkomazi Estuary is monitored at six sites along the length of the system.

Temporal scale: The estuary is sampled annually in August during the low flow period. The sampling might be conducted earlier if river inflow is low in a specific year.

2.7.3 Fish

Monitoring technique: The fish of the estuaries were sampled using a 30 m x 1.7 m x 15 mm bar mesh seine net fitted with a 5 mm bar mesh purse and, where possible, a fleet of gill nets. Each gill net had a range of mesh sizes and comprised three 45 mm, 75 mm and 100 mm stretch mesh monofilament panels and was either 10 m or 20 m in length and 1.7 m deep.

Spatial scale: Fish are monitored at 3 - 4 sites in the estuary, depending on the water levels in the system.

Temporal scale: The estuary is sampled annually in August during the low flow period. The sampling might be conducted earlier if river inflow is low in a specific year.

2.7.4 Birds

Monitoring technique: Birds are counted and the maximum number at any one time recorded.

Spatial scale: Birds are recorded over the entire estuary.

Temporal scale: The estuary is sampled annually in August during the low flow period. The sampling might be conducted earlier if river inflow is low in a specific year.

2.8 Mhlathuze, Nhlabane and Siyaya Benthic Invertebrates and Fish (CRUZ)

During the past decade the Coastal Research Unit of Zululand (CRUZ) has been sampling the Mhlathuze, Nhlabane, Siyaya estuaries for benthic invertebrates, macrocrustaceans, fishes, water quality and sediment quality.

Monitoring technique: Five benthic invertebrate samples are collected by means of a grab at each site and analysed down to the species level where possible, otherwise to taxa level, to determine species composition and densities. Swimming prawns are sampled using baited traps. At the larger Mhlathuze estuary a beam trawl is used.

Fish sampling involves gill nets (50 mm, 75 mm and 100 mm mesh sizes) and the use of large and small purse seine nets of 1mm mesh. Fish larvae are also being monitored at Siyaya and Nhlabane and a two year study was completed at Mhlathuze (Prof D Cyrus and Ms F McKay, CRUZ, pers. comm.).

Sediment sampling is conducted using grab and core samples and processed for grain size and organic content.

A comprehensive range of 25 water quality parameters are collected, including salinity, temperature, oxygen, nitrate, nitrate, bacteriological counts, chlorophyll-a , nutrients, cathodes, antinodes, and toxins.

Spatial scale: The sampling is done at a number of predetermined sites, varying from 13 - 14 in the Mhlathuze, six sites at Nhlabane and four to five sites at Siyaya estuaries. Sampling is done along the length of the systems and is representative of the various habitat types found in the different estuaries.

Temporal scale: CRUZ has been sampling the Nhlabane and Siyaya quarterly since 1992. In 1994 the sampling was scaled up to include the more comprehensive water quality parameters, sediment analysis and hyperbenthos. The quarterly sampling of the Mhlathuze commenced in 1996.

Discussion

The data collected on Mhlathuze and Nhlabane estuaries have proven to be very useful in previous reserve determinations. For example the benthic invertebrate data was used to evaluate the impact of droughts (mouth closure during the 1993-1995 drought) on the benthic communities and to establish how resilient the communities are in recovering from such an event. The benthic invertebrate data collected at the Mhlathuze estuary was also used to establish the impact of dredging activities at Richards Bay Harbour and the impact on the benthic invertebrate community of the sediment plume entering the estuary.

Details on CRUZ monitoring programme in Mhlathuze Estuary (Fiona MacKay, CRUZ, pers. comm.)

	Data	No of sites	Seasons	Years	Method of Collection	Method of Analysis	Data Available
Abiotic	Sediment						
	Grain Size Distribution	7 (11)	Summer Autumn Winter Spring	1996 to 1999 (1999-2002)	Vertical core through each zoobenthic sample (Zabalocki type Eckman grab)	Settling tube. Earlier data analysed by wet sieving	% Gravel, Very Coarse Sand, Coarse Sand, Medium Sand, Fine Sand, Very Fine Sand, Mud (ø <-1 to >+4) median phi value, mean phi value, mean grain size (in mm), Sorting coefficient, Skewness
	Organic Content	7 (11)	Summer Autumn Winter Spring	1996 to 1999 (1999-2002)	See above	Incineration at 600°C for 8 hours. Pre- and post sample weights	% Combustible organic content
	Water						
	Physico-Chemistry	7 (11)	Summer Autumn Winter Spring	1996 to 1999 (1999-2002)	Hydrolab Water Quality probe Datasonde 3	Auto results (Hydrolab Water Quality probe Datasonde 3)	Depth, Temperature (°C), Salinity, TDS, Conductivity (mS cm), pH, Oxygen (% dissolved and mg/l)
	Water Quality	5	Summer Autumn Winter Spring	1996-2002	Hydrobics collecting bottle or by hand	Mhlathuze Water analytical laboratories	NO_3, NO_2, NH_4, T-PO_4, SR-PO_4 TSS, ($CaCO_3$), (all mg/l) Cha ug/l
	Bacteriology	5	Summer Autumn Winter Spring	1996-2002	By hand	Mhlathuze Water analytical laboratories	Total coliforms per 100 ml, Heterotrophic plate counts per 1 ml, Faecal coliforms per 100 ml
Biotic	Zoobenthos	7 (11)	Summer Autumn Winter Spring	1996 to 1999 (1999-2002	Zabalocki-type Eckman grab (5 replicates per site)	Microscope. Sorting, identification to species level, count per replicate	Abundance as density (no. per m^2)
	Macrocrustacea	2	Summer Autumn Winter Spring	1992-2002	Baited Prawn traps Seine nets, Beam trawls 1996-2000	Sorting, identification to species level, count per trap. Sorting, identification to species level	CPUE per site (no. of traps, time out and no. individuals) Density per m^2
	Ichthyofauna	3 Gill nets 2 small seine 2 large/medium seine	Summer Autumn Winter Spring	1996-2002	Small seine nets (10m, 1mm mesh), medium seine nets (40m), large seine nets (60m) 51 mm Gill nets (30 & 60 m) 75 mm Gill nets (30 & 60 m) 100 mm Gill nets (30 & 60 m)	Sorting, identification to species level, count per net. Conversion to CPUE	CPUE per site (type and length of net, no. of hauls and no. individuals)

Details on CRUZ monitoring programme in Siyaya Estuary (Fiona MacKay, CRUZ, pers. comm.)

	Data	No of sites	Seasons	Years	Method of Collection	Method of Analysis	Data Available
Abiotic	Sediment						
	Grain Size Distribution	5	Summer Autumn Winter Spring	1992 to 2002	Vertical core through each zoobenthic sample (Zabalocki type Eckman grab)	Settling tube. Earlier data analysed by wet sieving	% Gravel, Very Coarse Sand, Coarse Sand, Medium Sand, Fine Sand, Very Fine Sand, Mud (ϕ <-1 to >+4) median phi value, mean phi value, mean grain size (in mm), Sorting coefficient, Skewness
	Organic Content	5	Summer Autumn Winter Spring	1992 to 2002	See above	Incineration at 600-C for 8 hours. Pre- and post sample weights	% Combustible organic content
	WATER						
	Physico-Chemistry	5	Summer Autumn Winter Spring	1992 to 2002	Hydrolab Water Quality probe Datasonde 3	Auto results (Hydrolab Water Quality probe Datasonde 3)	Depth, Temperature (-C), Salinity, TDS, Conductivity (mS.cm), pH, Oxygen (% dissolved and mg/l)
	Water Quality	5	Summer Autumn Winter Spring	1995-2002	Hydrobios collecting bottle or by hand	Mhlathuze Water analytical laboratories	Cl, NO_2, NO_3, NH_4, COD, SO_4, F, T-PO_4, SR-PO_4, TSS, T-alk ($CaCO_3$), Ca, Na, Mg, K, SiO_2, (all mg/l) Chla ug/l
	Bacteriology	5	Summer Autumn Winter Spring	1995-2002	By hand	Mhlathuze Water analytical laboratories	Total coliforms per 100 ml, Heterotrophic plate counts per 1 ml, Faecal coliforms per 100 ml
Biotic	Zoobenthos	5	Summer Autumn Winter Spring	1992-2002	Zabalocki –type Eckman grab (5 replicates per site)	Microscope, Sorting, identification to species level, count per replicate	Abundance as density (no. per m^2)
	Macrocrustacea	3	Summer Autumn Winter Spring	1992-2002	Baited Prawn traps Seine nets	Sorting, identification to species level, count per trap.	CPUE per site (no. of traps, time out and no. individuals)
	Ichthyofauna	2 Gill nets 3 small seine 3 large/medium seine	Summer Autumn Winter Spring	1992-2002	Small seine nets (10m, 1mm mesh), medium seine nets (40m), large seine nets (60m) 51 mm Gill nets (30 & 60 m) 75 mm Gill nets (30 & 60 m) 100 mm Gill nets (30 & 60 m)	Sorting, identification to species level, count per net. Conversion to CPUE	CPUE per site (type and length of net, no. of hauls and no. individuals)

Details on CRUZ monitoring programme in Nhlabane Estuary (Fiona MacKay, CRUZ, pers. comm.)

	Data	No of sites	Seasons	Years	Method of Collection	Method of Analysis	Data Available
Abiotic	Sediment						
	Grain Size Distribution	6	Summer Autumn Winter Spring	1992 to 2002	Vertical core through each zoobenthic sample (Zabalocki type Eckman grab)	Settling tube. Earlier data analysed by wet sieving	% Gravel, Very Coarse Sand, Coarse Sand, Medium Sand, Fine Sand, Very Fine Sand, Mud (ø <-1 to >+4) median phi value, mean phi value, mean grain size (in mm), Sorting coefficient, Skewness
	Organic Content	6	Summer Autumn Winter Spring	1992 to 2002	See above	Incineration at 600°C for 8 hours. Pre- and post sample weights	% Combustible organic content
	Water						
	Physico-Chemistry	3	Summer Autumn Winter Spring	1992 to 2002	Hydroleb Water Quality probe Datasonde 3	Auto results (Hydrolab Water Quality probe Datasonde 3)	Depth, Temperature (°C), Salinity, TDS, Conductivity (mS.cm), *p*H, Oxygen (% dissolved and mg/l)
	Water Quality	3	Summer Autumn Winter Spring	1998-2002	Hydrobios collecting bottle or by hand	Mhlathuze Water analytical laboratories	NO_2, NO_3, NH_4, T-PO_4, SR-PO_4, TSS, ($CaCO_3$), (all mg/l) Cha ug/l
	Bacteriology	3	Summer Autumn Winter Spring	1998-2002	By hand	Mhlathuze Water analytical laboratories	Total coliforms per 100 ml, Heterotrophic plate counts per 1 ml, Faecal coliforms per 100 ml
Biotic	Zoobenthos	6	Summer Autumn Winter Spring	1992-2002	Zabalocki –type Eckman grab (5 replicates per site)	Microscope, Sorting, identification to species level, count per replicate	Abundance as density (no. per m^2)
	Macrocrustacea	2	Summer Autumn Winter Spring	1992-2002	Baited Prawn traps Seine nets. Hyperbenthic trawls 1998-2002	Sorting, identification to species level, count per trap. Sorting, identification to species level	CPUE per site (no. of traps, time out and no. individuals) Density per m^3
	Ichthyofauna	2 Gill nets 3 small seine 3 large/medium seine	Summer Autumn Winter Spring	1992-2002	Small seine nets (10m, 1mm mesh), medium seine nets (40m). large seine nets (60m) 51 mm Gill nets (30 & 60 m) 75 mm Gill nets (30 & 60 m) 100 mm Gill nets (30 & 60 m)	Sorting, identification to species level, count per net. Conversion to CPUE	CPUE per site (type and length of net, no. of hauls and no. individuals)

2.9 St Lucia Monitoring Programme (KZN Wildlife)

A diversity of data and information are continually being collected by KZN Wildlife at St Lucia. The purpose of the data collection may be for long-term monitoring, or for specific research projects. Normally, the results accumulate and are analysed in detail at the end of a project cycle, but often the managers need more frequent feedback. Therefore, KZN Wildlife produces a quarterly report to provide a brief overview of the state of the system and to maintain a record of what has happened at St Lucia. The focus of the quarterly report is Lake St Lucia and anything in the surrounds that directly influences the lake.

2.9.1 Rainfall, salinity and water levels

KZN Wildlife monitors a number of physical variables at St Lucia. A record of rainfall in the St Lucia area is kept to establish trends in both the short and long-term, such as the duration of droughts (Figure 1). Continuous water level recorders monitor the water levels in the system at various stations in the lake (Figure 2). Salinities are also frequently measured throughout the St Lucia lake system and correlated with rainfall (Figure 3). Regular observations are made on mouth position and depth of the combined St Lucia and Umfolozi mouths (Figure 4). Miscellaneous observations are also made on variables such as bank erosion and sand bar overtopping by waves.

Figure 1: Rainfall - Charter's Creek

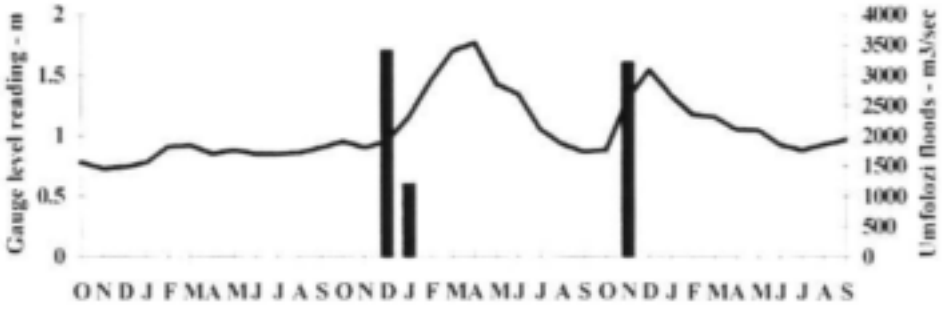

Figure 2: Lake level at Charter's Creek (Oct 1998 - May 2000)

Figure 3: Salinity - Charter's Creek (South Lake)

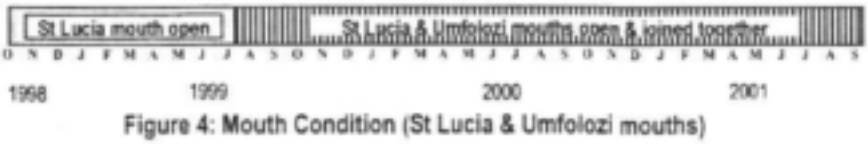

Figure 4: Mouth Condition (St Lucia & Umfolozi mouths)

2.9.2 Vegetation

The distribution of freshwater vegetation, e.g. *Potamogeton pectinatus*, in the lake is monitored as these plants give a good indication of average salinities in the system. Observations are also made on the health of the mangroves in the estuary.

2.9.3 Fish

KZN Wildlife monitor fish species, using standardised gill nets. The objective is to provide low-level long-term monitoring of changes in fish species composition (and hence of fish trophic level composition), of relative abundance of various species and the size composition of the species. All live undamaged fish are returned to the water. Fish measurements recorded are the mean total length (the mean of all the total lengths of the fish from tip of mouth to end tip of caudal fin). Results include a list of the species caught, and the depth, salinity and water temperature at which they where caught.

Analysis is also made of the boat angling effort in the lake for every quarter and angler-return cards (four stations) are collected to establish the most abundant species caught in the system (Figure 5).

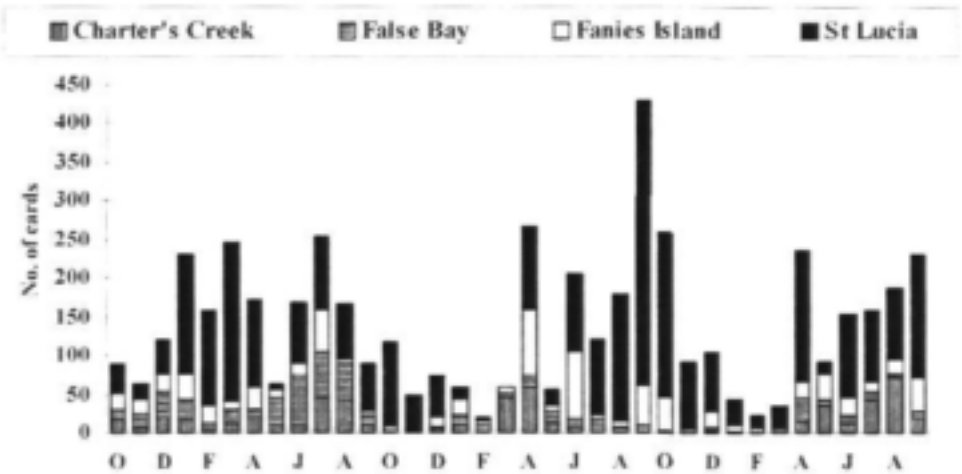

Figure 5: Number of light tackle boat catch return cards submitted between October 1998 and September 2001

2.9.4 Birds

Coordinated Waterbird Counts (CWAC) are done at St Lucia on a quarterly basis (Figure 6). The bird counts are sometimes influenced by low lake levels which make some parts of the lake inaccessible for boating.

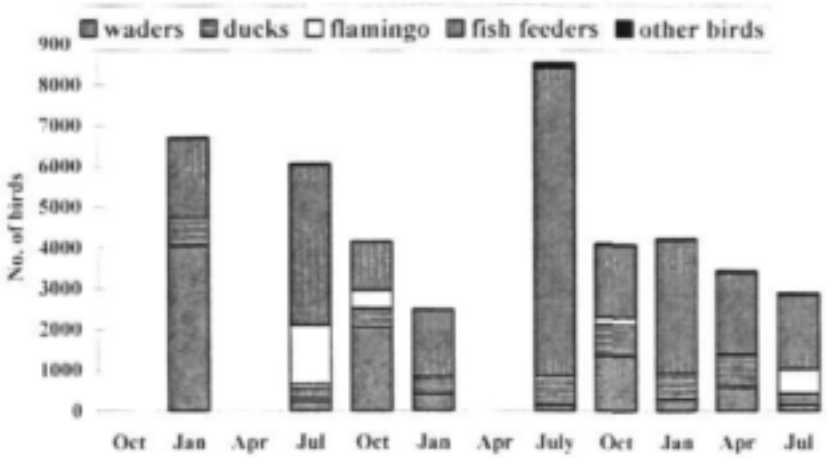

Figure 6: Bird composition between October 1998 and July 2001

2.9.5 Compliance

A compliance record is kept of recorded illegal gill netting, listing the place and weight of fish confiscated by KZN Wildlife staff.

The Marine and Coastal Management Subsistence Committee has recommended that there should be no small-scale commercial gill-netting in any Kwazulu-Natal estuary and that the current subsistence gill netting permits will be phased out over 4 years. Of concern is the growing illegal gill netting that has been detected in recent years.

2.10 Kosi Bay (KZN Wildlife)

2.10.1 Physio-chemical data

Some physical data are collected at Kosi Bay. There are two permanent continuous water level recorders (currently operational) being manned and monitored by DWAF. Weather data are collected on a daily basis, e.g. rainfall, wind and temperature. Salinity data are collected in the main lake on an *ad hoc* basis, depending on the degree of expected change, e.g. after a rainfall event.

2.10.2 Resource utilization

Monitoring technique: A team of trained local people carried out daily monitoring of resource utilisation in the areas north of Nhlange Lake. The team principally consists of women and two supervisors. They report to a conservation officer stationed in the area. In other words, resource users were employed to monitor their off-take themselves.

The monitoring team's duty was to intercept all users and obtain harvesting data from them. The monitor recorded information from the harvester such as what was done with the resource and details on the material collected. Data sheets were checked by supervisors and submitted for entry and analysis on computer. Initially the catch of all fish-traps was monitored, but later, due to financial constraints, only a known proportion was covered and a total catch estimated. This technique was later used for other resources with a minimum of one year complete monitoring.

Random counts of the number of people collecting resources and their harvest were made as a check on the procedure and compared with the estimates.

Spatial scale: People access the lake system along a number of paths, running from residential areas to the waterside. During periods of intensive monitoring employees were stationed on these paths.

Temporal scale: Monitoring is primarily done on springtides and during that period carried out on a daily basis, i.e. monitored for 50% of the time. This is due to the fact that the programmes focus is mainly on the fish traps, which only operate during springtides (Dr S. Kyle, pers. comp).

Discussion

By these methods it was possible to obtain "best estimates" for the amount of utilization and the economic value of most of the resources and the number of users. The estimates are not absolutely correct, but provide the best figures obtainable within the financial and other constraints (Kyle, 1995).

Currently the resources utilisation monitoring is funded through the Living Marine Resources Fund and therefore only focuses on:

- Fish (e.g. fish-traps, recreational angling, traditional spearing, subsistence angling, gill netting and illegal methods)
- Invertebrates (e.g. small crabs, sand prawns, other invertebrates)
- Sedges and reeds (e.g. *Juncus kraussi, Phragmites* spp.)

Initially the programme was internally funded by KZN Wildlife, but this has since ceased. No new monitoring data have been collected since 1996 on the following aspects (Dr R. Kyle, KZN Wildlife, pers. comm):

- Firewood
- Traditional medicines
- Wild fruit and wine making
- Wild honey
- Fish trap and house building material
- Grazing of cattle and goats
- Illegal hunting
- Ecotourism
- Cultural and Religious activities.

3. NATIONAL MONITORING AND SURVEY PROGRAMMES

3.1 Water level recorders (primarily DWAF)

The importance of data collected from water level recorders to improve the understanding of the functioning of specific estuaries has been highlighted on several occasions. Examples are the water level recordings collected in the Great Brak, Thukela, Wilderness, Berg and Palmiet Estuarine Flow Requirement (EFR) and Reserve studies.

A recorder in an estuary near its mouth can provide the following information:

- An accurate historical record of open and closed mouth conditions, indicated by the presence or not of tidal variations on the recordings. If additional river flow data are also available, the river flow required to maintain an open mouth, can be estimated accurately (Figure 7).
- The heights of the water levels at low tide give an indication of the depths in the mouth and also whether and to what extent siltation might be occurring.
- The heights of water levels during major floods and the shape of the recorded flood hydrographs give invaluable information on such floods, for example for the determination of 1:50 year flood levels.
- Water level recordings for specific shorter periods of days and weeks can be very important for the calibration of a numerical model (e.g. Mike 11) of an estuary. Such models can then be used for further investigations on salinities and river floods.

The monitoring of long term trends are normally more important than the measuring of short term phenomena and the risks involved in a slight reduction in the reliability of the recorders is therefore not as important as is the case in the gauging of river flow, normally undertaken by the DWAF.

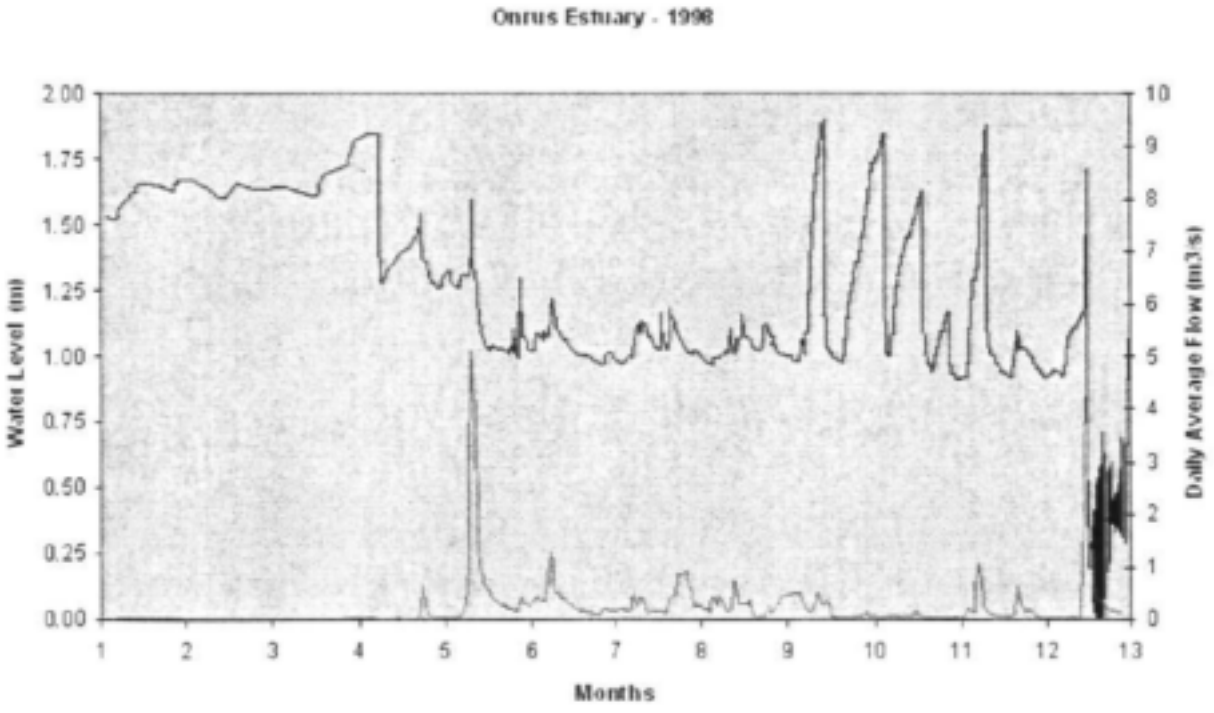

Figure 7: Continuous water level recording and river inflow data collected by DWAF at the Onrus Estuary

Discussion

In summary, a continuous recording of water level variations are probably the single most important parameter that can be used to monitor and verify the physical conditions of an estuary.

Such water level recordings are essential for providing information on the functioning of estuaries, e.g. required for investigations by the DWAF to investigate the impacts of future dams and/or to estimate the flow requirements of an estuary.

Having the DWAF install, calibrate and service the water recorders has the advantage of standardising the data and ensuring that it is of the highest possible accuracy. Furthermore, if the data is then incorporated into the national database for gauging weirs in South Africa, it is accessible to everybody and assured of long-term availability. In the case of data being stored in databases at a municipality, university or other organisation there is a greater possibly of data being lost if the individual in charge of the data set should leave.

Water level recorders currently operational in South African estuaries are:

- Orange
- Olifants
- Wadriftsoutpan
- Berg
- Zandvlei (Cape Metropolitan Council)
- Lourens
- Palmiet
- Kleinmond
- Bot
- Klein
- Onrus
- Heiningnes
- Breede
- Goukou (previous Kafferkuils)
- Wilderness
- Hartenbos
- Klein Brak
- Groot Brak
- Touws
- Swartvlei
- Goukamma (DWAF in progress of installing recorder)
- Knysna
- Keurbooms
- Tsitsikamma
- Swartkops (Municipality/ DWAF to install 2 recorders)
- Umkomaas
- Thukela
- Nhlabane (RBM)
- St Lucia

Currently less than 10% of South Africa's estuaries, of which the majority are in the Western Cape, have permanent water level recorders installed. It is therefore strongly recommended that this practise be expanded to more systems along the South African coastline.

3.2 Aerial Photography of South African coastline (CSIR and DEAT)

One of the most valuable tools in estuarine research and management is aerial photograph analysis. If a photographic record exists of an estuary over time, this can be used to establish the following:

- Behavior of the estuary mouth under different flow conditions
- Impact of major floods on the estuary
- Sedimentation rates and areas of high sediment deposition
- Changes in estuarine vegetation e.g. due to human encroachment or invasive aliens in the floodplain
- Impact of infrastructure development e.g. jetties, bridges, mouth stabilization

In the past the DEAT and the CSIR had regular aerial surveys done of the South African coastline and estuaries. In the case of the larger estuaries such as the Berg or Breede, the flight path covered the estuary to the head of tidal variation.

Listed below is a summary of aerial surveys in South Africa:

DATE	AREA	FUNDED	NEGATIVES	TYPE
1935 -....	Various photos of SA Coastline	Trig Survey	Trig Survey	Black/White
1981	Estuaries of Cape	CSIR	Univ of Natal	
February 1987	Olifants to Kei mouth (excluding Ciskei)	DEAT	DEAT	Colour
April 1988	Orange to Olifants, Olifants to Cape Piont, False Bay, Arniston Block, Gourits to Groot Brak (Mosselbay)	DEAT	DEAT	Colour
February 1989	Koeëlbaai to Arniston	CSIR	CSIR	Colour
February 1990	Waenhuiskrans to Arniston	CSIR	CSIR	Colour
March 1990	Krom to Kabeljous	CSIR	CSIR	Colour
April 1990	Natal	CSIR	J Amstrong	Colour
May 1990	Blouberg to Kei	CSIR	CSIR	Colour
May 1991	Orange to False Bay Hermanus, Struisbaai, Potberg, Keurbooms	CSIR	CSIR	Colour
December-January 1993	Natal Coast	CSIR	CSIR	Colour
January 1993	Transkei	CSIR	CSIR	Colour
March 1993	Melkbos to Swartkops	CSIR	CSIR	Colour
October 1993	Chamais Bay to Port Nolloth	CSIR	CSIR	Colour
January 94	Durban Bluff	Durban Corporation	J Amstrong	Colour
October 1993	Diep River	CSIR	CSIR	Colour
July 1996	Outeniqua: Danabaai to Groot (Wes)	DEAT	CSIR	Colour

Discussion

Unfortunately, 1996 was the last year such aerial photography was undertaken and this represents a major gap in our understanding of the current health of many of the estuaries along the South African coast. At the rate that coastal development is progressing, an up-to-date visual record is crucial for strategic coastal zone planning and estuarine management.

It is therefore strongly recommended that national aerial photography surveys be instituted again. The required specifications for such surveys are:

- Done annually
- Scale 1:5 000
- Digital format
- Geo-referenced
- Colour
- Vertical (not oblique because that distorts observations)
- Up to the head of larger estuarine systems

It is further recommended that the digital data be made available to all coastal and estuarine managers and researchers free of charge, since this primary data is of tremendous value to a diversity of disciplines and authorities.

3.3 Topographical and Bathymetric Monitoring and Survey Programme (CSIR and DEAT)

In order to quantify the problem of sedimentation in estuaries, the DEAT commissioned the CSIR to design and implement a monitoring programme in 1985 (Van Niekerk *et. al.*, 2000). Initially 20 estuaries from the Orange River on the west coast to the Quinera along the east coast were selected, based on certain criteria. In the 1990s, it became obvious that specific information from each important estuary is required, because sedimentation processes and long-term equilibrium between sedimentation and erosion are different for each estuary. The number of estuaries included in the previous programme was therefore gradually increased to 47. Thus, valuable data was collected, which has been used for example, in assessing the freshwater requirements of estuaries.

The programme commenced in 1985 and ended in 1999. The main objectives of this monitoring programme are as follows:

- to collect baseline information essential for the understanding of the physical functioning of estuaries
- to provide long-term ongoing information on the physical changes of estuary mouths
- to monitor medium to long-term changes on erosion and sedimentation in estuaries.

The monitoring programme typically includes:

- a topographical survey of the mouth area
- cross section profiles along the length of estuaries.
- grain size distribution measurements (usually at the mouth)

The Monitoring programme was implemented in the following estuaries:

ESTUARY	MOUTH SURVEYS	CROSS SECTIONS
Orange	1987, 1988, 1990	
Olifants	1987, 1988, 1989,1991, 1997, 1999	1994, 1997
Great Berg	1986, 1986, 1988,1990, 1990, 1997, 1999	1994, 1997
Diep	1986, 1987, 1988,1990, 1991, 1997, 1999	
Palmiet	1986, 1986, 1987, 1988, 1989, 1990, 1992, 1994, 1995, 1997, 1999, 1999	
Bot	1997, 1999, 1999	
Klein	1986, 1987, 1988,1989, 1991, 1992, 1994, 1996, 1996, 1997, 1998, 1998, 1999	
Uilkraals	1997, 1999	1999
Heuningnes	1986, 1988, 1989, 1991, 1992, 1996	1996
Breede	1996	1996
Duiwenshoks	1986, 1988, 1988,1989, 1990, 1992, 1996, 1996	1996, 1996
Goukou (previously Kafferkuils)	1986, 1988, 1988,1989, 1990, 1992, 1993,1996	1996, 1996
Gouritz	1986, 1986, 1988, 1988,1989, 1991, 1992, 1993,1996	1996
Hartenbos	1984, 1986, 1986, 1988, 1988,1989, 1990, 1991, 1992, 1993, 1996	1996, 1996
Klein Brak	1986, 1988, 1988,1989, 1991, 1992, 1993,1996	1996, 1996
Great Brak	1988, 1989, 1990, 1991, 1992, 1993, 1995, 1996, 1996	1998
Keurbooms	1986, 1987, 1988, 1989, 1990, 1991, 1992, 1993,1996, 1997	1998
Kromme	1990, 1991, 1992, 1993,1996	1998, 1996
Seekoei	1986, 1988, 1988, 1989, 1991, 1992, 1993,1996, 1996	1986, 1996, 1996
Gamtoos	1996	1996
Swartkops	1998	1998
Sundays	1998	1998
Bushmans	1988, 1988, 1990, 1992, 1996, 1999	1996
Kariega	1994, 1995, 1999	1999
Kowie		1998
Weskleinemonde	1986, 1988, 1988, 1991, 1992, 1996, 1999	1986, 1996, 1999
Great Fish	1994, 1995, 1999	1994, 1995, 1999
Keiskamma	1996	1996
Tyolomnqa	1998	1998
Ncera	1998	1998
Qinira	1986, 1988, 1988, 1990, 1992, 1993, 1995, 1999	1996, 1999
Nahoon	1986, 1988, 1988, 1990, 1992, 1993, 1996, 1999	1996, 1999
Gqunube	1986, 1988, 1988, 1990, 1992, 1993, 1995, 1996, 1999	1996
Kwelera	1998	1998
Bulura	1998	1998
Cefane	1998	1998

ESTUARY	MOUTH SURVEYS	CROSS SECTIONS
Quko	1998	
Great Kei	1996	1996
Qora	1998	1998
Mbashe	1998	1998
Umtata	1996	1996
Mdumbi	1998	1998
Mngazana	1998	1998
Mngazi	1998	1998
Msikaba	1998	1998
Mtentu	1998	1998

3.3.1 Mouth surveys

Trigonometrical beacons were used as survey control points. The co-ordinates used in the survey were based on the South African Survey Grid (Gauss Conform Projection) and the heights are reduced to Mean Sea Level (MSL) as the elevation level. The co-ordinates of the survey stations were determined using the Blunt resection method and by theodolite traversing using a Nikon Total Station D500.

The mouth surveys (Figure 8) were done using a 'wading survey' technique, which was performed by using standard line surveying techniques. A survey team member transversed the survey lines holding a rod supporting a surveying prism, stopping at appropriate intervals to allow an instrument operator to read and record the distance and horizontal and vertical angles. The wading survey was continued seaward into the water until the rod holder could no longer stand steady with the survey rod. The water? section was done preferably at low tide so that readings extend as far seaward as possible. The electronic surveying instrument provided distance measurement accuracies of 5 mm. The angle measurements were done with an electronic single second theodolite.

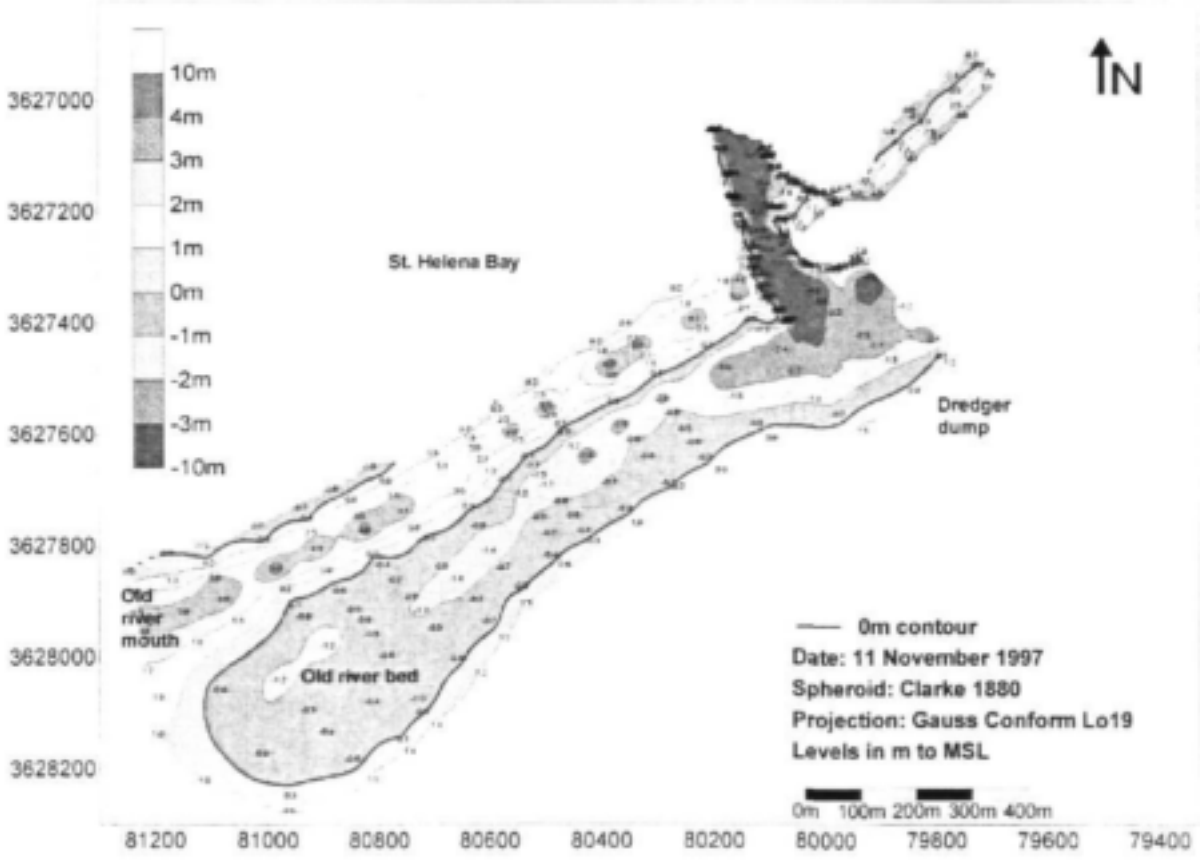

Figure 8: Mouth Survey of the Berg River Estuary, 11 November 1997

3.3.2 Cross sections

Surveying of cross sections in estuaries by standard land surveying techniques is time consuming and expensive. For this reason an alternative method, using a ski boat and echo sounder was developed, allowing reasonably accurate survey of the cross sections below the water level to be undertaken within a short time at much reduced costs (Figure 9).

A boat mounted digital echo sounder and a laser rangefinder was used. The rangefinder was used to determine the positions of the soundings (usually recorded as *distance [in m] from left bank*) across a section. The position of each cross section is usually verified using differential position fixing systems (GPS). At the time of the survey, the water level is also recorded at the mouth to correct the data to mean sea level.
Although the survey by ski boat and echo sounder covers only the deeper parts of the estuary which are accessible by boat, these are usually the main areas where changes in sedimentation and erosion takes place.

The vertical accuracy of the depths measured with the echo sounder was within 0.10 m, provided that bottom material is hard enough to provide a proper echo. Vertical inaccuracies were also introduced by the reduction of the echo sounder reading to a depth referred to MSL. This, in turn, depended on the accuracy of the water level readings taken from the gauge plate, which is of the order of 0.01 m, as well as the accuracy with which the actual water level at the echo sounder position can be corrected based on the gauge plate readings. For this reason, accuracies in readings close to the location of the gauge plate will be in the order of 0.02 m, while at greater distances the accuracy will be of the order of 0.1 m, depending on the accuracy with which the phase differences of tidal variation can be determined. These errors were minimal at small tidal variations and for this reason this type of surveys were generally undertaken during *neap tides*. The total degree of inaccuracy for these surveys was therefore estimated at 0.1 m near the gauge plate and 0.2 m further away from the gauge plate.

The position of each cross section was normally pre-determined on an ortho-photo map. The cross section was then surveyed in the field at the approximate location.

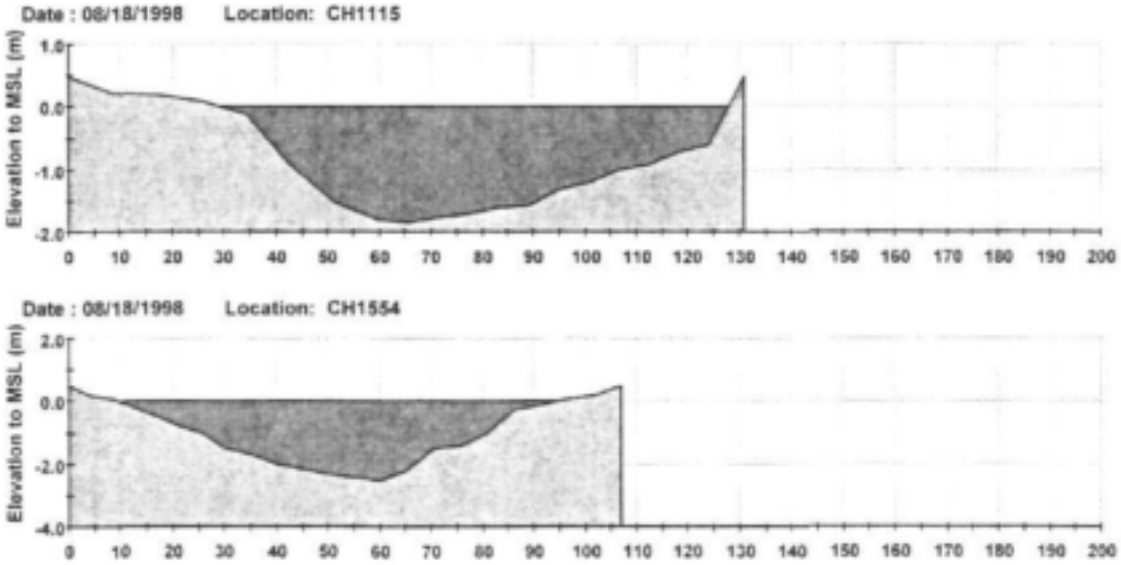

Figure 9: Cross sections of the Qora Estuary (1998)

3.3.3 Grain size analysis

Sediment samples, for grain size analyses, were usually collected at the estuary mouth during mouth surveys and analysed using a settling tube.

Discussion

The topographical and bathymetry data collected in these surveys have proven to be extremely useful in Estuarine Flow Requirement and Reserve studies (e.g. Mtata, Mngazi, Breede). Often this would be the only available physical data on an estuary and its responses to larger floods. Numerical modelling would also be impossible without this type of data.

It is recommended that the monitoring programme be re-implemented with the following provisions:

- KwaZulu-Natal estuaries should be added to the programme to ensure a national overview.
- Each estuary should be surveyed once every 3 years. This is the optimum frequency to ensure sufficient and meaningful information, while also taking into account financial resources.
- The monitoring programme should be kept flexible in order to undertake extra surveys after major floods have occurred in some areas. These surveys would then be substituted for some of the other scheduled surveys (for other estuaries where floods did not take place).

- The extension of the older topographical surveys from mouth surveys to surveys including upstream cross-sections was successful and should be continued. Recent developments, especially based on the higher accuracy of Differential-GPS survey technologies, now make it possible to further improve the accuracy of the survey results (enabling much better interpretation of differences/changes). Differential-GPS also has the additional advantage that it automatically compensates for depth changes due to tidal variation and weather conditions.

- Salinity and temperature profiles upstream in estuaries should be measured when possible in conjunction with the bathymetric surveys. This will provide valuable data that can be used to improve the understanding of the interaction between river flow, salinity distributions, water quality and ecology of these estuaries.

- The low level monitoring of open or closed mouth conditions of relevant estuaries should be re-implemented.

3.4 Geomorphology, Fish, Water Quality and Aesthetics of South African Estuaries (CSIR and DEAT)

As part of a national program to assess the state of South Africa's estuarine environment, basic surveys were conducted on these systems during the period 1992 to 1999. These included fish, water quality, and geomorphological and aesthetic observations. Some 67% of South Africa's 'estuaries' have been surveyed to date. This baseline data was analysed and synthesised to render it understandable to the non-specialist but at a sufficiently high level to inform potential end users of the state of South Africa's estuaries.

The objectives of the study were (i) to conduct multidisciplinary basic surveys of South Africa's estuaries using a consistent protocol for sampling and analysis and (ii) to compile these data in such a form that the status of estuaries could be ascertained at regional and individual levels.

The research was based on seven years of intensive field sampling during which some 250 estuaries were visited between the Orange (Gariep) and Kosi Bay. At each estuary a suite of geomorphological, ichthyological, water chemistry and aesthetic measurements were made in a consistent manner. These data are recorded on a CSIR database. In addition, preliminary reports on the status of each individual system were compiled on a regional basis at the conclusion of each year's fieldwork. These reports (Cooper *et al.*, 1993, Harrison *et al.*, 1994, 1995, 1996, 1997, 1998) each deal with about 50 estuaries that were sampled each year and contain further information on individual systems as well as a preliminary index assessment of the status of each system. A summary report which condenses the findings of previous reports, and attempts to take a national perspective on estuarine status and variability, takes account of biogeographic constraints and utilises the full dataset available in an attempt to address the status of South African estuaries (Harrison *et. al.*, 2000).

3.4.1 Geomorphological classification

A conceptual classification of the geomorphic variability among South Africa's estuaries has been produced. Several systems particularly on the west coast were not considered estuaries either due to their small size, their ephemeral nature, or because they were essentially isolated. Six basic estuary types were identified. These were divided into

normally open and normally closed systems. Two types of normally closed estuaries were identified. These were systems where the water level was typically perched above sea level and those where the water level was approximately at sea level. In this report, however, the normally closed estuaries were sub-divided into small, medium, and large systems based on surface area. The normally open systems were divided into barred and non-barred estuaries. Two types of permanently open barred estuaries were recognised: river-dominated and tide-dominated systems. In the report the two types of normally open barred estuaries were not identified but were sub-divided into small and medium to large systems based on their mean annual runoff.

3.4.2 Fish

Based on the fish data and the geomorphological classification, the three biogeographic regions that characterise the coastline were identified and delineated. These were the cool-temperate region from the Gariep (Orange River) Estuary to Cape Agulhas, the warm-temperate region from Cape Agulhas to and including the MdumbiEstuary, and the subtropical region from the Lwandilana Estuary to Kosi Bay.

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

Specimens collected by seine netting were, where possible, identified in the field, measured to the nearest mm standard length (SL), using a measuring board, and returned alive to the system. A minimum of 25 specimens of the abundant species as well as those specimens that could not be identified in the field were placed in labelled plastic bags and preserved in 10% formalin for transport to the laboratory. Specimens collected in the gill nets were identified, measured to the nearest mm SL and weighed in the field.

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

Aspects of the fish community structure of each geomorphic estuary type were investigated and each estuary type appeared to contain fairly distinctive fish assemblages although some overlap did exist. The fish community structure (species richness, composition and relative abundance) of each estuary type within each biogeographic region was described and this was used as a reference against which each estuary could be assessed.

In terms of their species richness, composition and relative abundance, two systems (8%) in the cool-temperate region had low ratings. Ten estuaries (42%) were rated as moderate and the remaining 12 systems (50%) had a good overall rating. Of a total of 119 estuaries analysed in the warm-temperate region, nine (8%) had a relatively poor overall rating, 35 (29%) were rated moderate and the remaining 75 (63%) had a good overall rating. In the subtropical region, three estuaries (5%) were rated poor, 23 (36%) had a moderate overall rating and the remaining 37 (59%) had a good rating.

3.4.3 Water Quality

The results of the water quality surveys were summarised into an estuarine water quality index (WQI) to provide a 'snapshot' of the average water quality of South Africa's estuaries. Six indicators of estuarine water quality were chosen and these were divided into three categories: suitability for aquatic life (dissolved oxygen, oxygen absorbed, ammonia), suitability for human contact (faecal coliform), and trophic status (nitrate nitrogen, ortho-phosphate). The effect of including/removing chlorophyll-*a* in the water quality index was also tested. The results indicated that the exclusion of chlorophyll had no significant effect on the relative index ranking for the estuaries tested. The sensitivity of the index to

various aggregation formulas was also tested. Alternative formulations did not significantly alter the relative ranking of the estuaries tested. Using the eWQI values, five water quality classes were identified. Approximately 74% of all the systems sampled were classified in a "Fair" or better condition. The remaining 26% were classed as "Poor" or "Very Poor". Systems on the south and south-east coasts had the best overall water quality with a preponderance of estuaries classed as "Good" or "Very Good". Estuaries on the Transkei and KwaZulu-Natal had a relatively high proportion of systems in "Poor" condition.

3.4.4 Aesthetic observations

Aesthetic observations on each estuary were divided into 14 weighted categories: floodplain land use, shoreline status, estuary surrounds, bridges, dams and weirs, mouth stabilisation, litter and rubble, human use, algal growth, turbidity, odour, air pollution, noise, and invasive and exotic vegetation. The aesthetic state of each estuary was assessed according to the type and degree of impairment to each category. Overall, 251 systems were assessed and 18 (7%) had relatively poor aesthetic ratings, 88 (35%) were regarded as moderate while the remaining 145 (58%) were rated relatively good aesthetically.

Discussion

The results of this study provide a useful summary of the status of South Africa's estuaries. However, there exists a need to make all of the basic data, as well as various forms of summarised data, available to interested parties from scientists to managers and even the general public. Furthermore, much of the baseline data collected during these surveys has not been fully analysed. The assessment of the fish fauna was only based on a few components of the fish community. Other aspects of community structure such as biomass composition, life-history styles and trophic structure should be investigated. In terms of water quality, a physical water quality impairment category, involving such indicators as temperature, salinity, pH, and turbidity should be explored. Also, water quality rating curves for different estuary types should be investigated.

There are also some obvious significant gaps in the database. A number of estuaries, particularly in the Transkei, have not been sampled and these gaps need to be filled. The geomorphological classification is based only on available data and additional information is required to improve its resolution, for example data on mouth condition and tidal prisms. The fish community structure is based on a comprehensive sampling programme at each site. It is, however, recognised that these one-off sampling exercises may yield anomalous results under certain circumstances (recent floods, breaches, etc). This is an unavoidable constraint, imposed by sampling many systems in a short period. The water quality data were collected at an instant in time and may therefore not be representative of long-term conditions, or of episodic events in estuaries. Again, this is an unavoidable effect of large spatial scale sampling.

Long-term data sets are also required to establish the range of the natural variation between and within estuaries on a seasonal basis. This would provide a better understanding of how estuaries of various types function, a critical requirement for effectively managing coastal issues such as artificial breaching, estuarine water requirements, eutrophication of estuaries, and biological functioning.

In each instance, the information presented provides a baseline against which to monitor change and to assess future trends. In every instance, more detailed information is held by the authors in a raw data form.

There is also a lack of a cohesive plan for temporal monitoring of key systems. Investigations into other estuarine components (e.g. hydrology, sediment biogeochemistry, vegetation, zooplankton, zoobenthos, birds, habitat assessment, catchment land-use) should also be undertaken to ensure a more complete appraisal of the ecological integrity of the nation's estuarine resource.

3.5 Coordinated Waterbird Counts in South Africa (CWAC) (Avian Demography Unit – UCT)

The Coordinated Waterbird Counts (CWAC) was launched in 1992. The objective of CWAC is to monitor South Africa's waterbird populations and the conditions of the wetlands which are important for waterbirds. This is being done by means of a programme of regular mid-summer and mid-winter censuses at a large number of South African wetlands and estuaries, at regular six-monthly intervals. CWAC currently monitors over 350 wetlands around the country.

This project was initiated by the then Ramsar Working Group of the Department of Environmental Affairs and Tourism in part-fulfilment of South Africa's commitment to the Ramsar Convention. CWAC also contributes its data to the African Waterbird Census, a programme coordinated by Wetlands International and based at the African headquarters of Wetlands International in Senegal.

In 1999, the *TOTAL CWAC Report* (Taylor *et. al.* 1999) was published. It provides a useful summary of all counts made between the start of the project and 1997.

Sites registered with CWAC have their waterbirds censused every six months, in midsummer and midwinter. The permissible periods are mid-January to mid-February, and July, respectively. Where ideally all counts should be carried out on the same day, in practice it is necessary to provide a wider time period to accommodate volunteers and organizations. Originally summer counts where conducted in January, but the slightly later period was instituted to avoid disruptive summer holidays. Monthly counts are conducted at a few sites to get details on seasonality.

Methods of counting are standardize for a particular site in terms of area covered and manner in which counters are deployed. This is a not possible between sites, for at some sites censuses are done by observers on foot, while others are done by boat or motorcar. Counters are provided with information sheets, which advise on how to count efficiently and avoid double-counting and misidentification.

In the case of sites affected by tidal fluctuations, it is recommended that counts be consistently conducted at low tide when the mud banks are exposed and waders are feeding. Observers are also requested to monitor their sites by fixed-point photography at two-year intervals. This is to establish long-term variability in physical changes at wetlands.

Counts are submitted on a standard form, which also requests details on weather and threats currently having an impact on the wetland and birds. This is then directly entered into the computer. Feed back on each seasonal count are provided by means of a newsletter which is distributed shortly before the next count, together with a computer output of previous count and a blank form.

Estuaries included in the CWAC counts are:

- Orange Estuary
- Olifants Estuary
- Berg Estuary
- Jakkalsvlei Estuary
- Verlorenvlei Estuary
- Zandvlei Estuary
- Wildevoelvlei Estuary
- Kleinmond Estuary
- Bot Estuary
- Heuningness Estuary
- Wilderness Estuary
- Knysna Estuary
- Keurbooms Estuary
- Kabeljous Estuary
- Seekoei Estuary
- Swartkops Estuary
- Great Fish Estuary
- Mlalazi Estuary
- Umgeni Estuary
- Umvoti Estuary
- Thukela Estuary
- Richards Bay
- Mfolozi mouth area
- St Lucia Estuary

Discussion

Comparison of counts from different wetlands gives an indication of seasonal movements and the relative importance of sites for the conservation of different species.

CWAC counts are being done on about 7% of South Africa's estuaries and have successfully been used in various estuarine studies (e.g. Swartkops, Olifants and Bot). The data collected are of high standard as the observers are dedicated birdwatchers and it would be an impossible task to collect this valuable data with professionals alone (Dr J Turpie, pers. comm.). It is therefore recommended that where possible the monitoring system be expanded to other estuaries in the country.

The following two photographs were taken of the Bot/Kleinmond Estuary using the fixed-point technique and demonstrate how the condition of the wetland, and habitat change, can help draw conclusions about waterbird abundance and estuarine conditions in general at a site. Note how full the estuary was in February 2000 compared to 1996 (Figure 10). This practise should be encouraged when monitoring an estuary.

Figure 10: View looking west towards Kleinmond from Sonesta (Source: CWAC volunteer, Mariana Delport)

3.6 The Botanical Importance Rating (BIR) Index

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 Water Research Commission projects. The first study (Coetzee *et al.* 1996, 1997) rated the botanical importance of 33 Cape estuaries according to the area covered by the plant community types, their condition, the number of plant community types and the association between the plants and the estuary. The second study (Colloty *et al.* 2001, Colloty *et al.* 2002) developed the botanical importance rating further and applied it the former Ciskei and Transkei regions of the Eastern Cape Province.

Botanical surveys were conducted in 92 estuaries found in the former Transkei and Ciskei region (September 1997-July 1998). Data available for each estuary included:

- once-off measurements 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 area contained and summarized in a database available from the Department of Botany, University of Port Elizabeth. These data were then used to determine:

Botanical importance of an estuary that 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 11). The botanical importance scores were calculated for all Ciskei / Transkei estuaries and for 87 other South African estuaries.

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 (Figure 11). Overall habitat integrity scores were calculated for 129 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.

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 (Colloty *et al.* 2000), 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.

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.

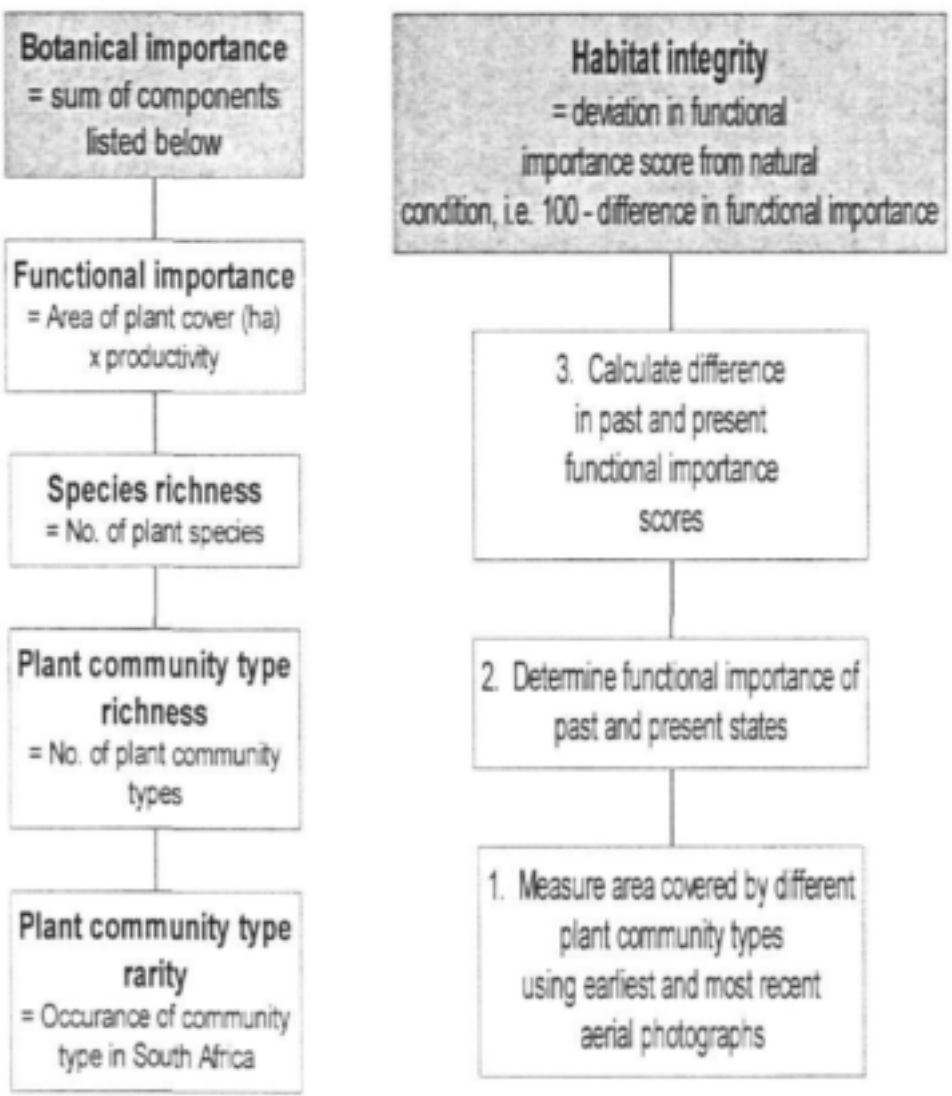

Figure 11: **Flow chart depicting the components of the botanical importance rating and habitat integrity index (Colloty *et al.* 2001).**

3.7 National Marine and Estuarine Linefish Survey (MCM)

The first National Linefish Survey evaluating participation in, and management of, the South African line fishery was a three-year project completed in 1996. It provided invaluable information on catch, effort and the socio-economics of the fishers involved. It also highlighted the importance of the line fishery with an estimated value of R 2.2 billion per annum.

A five-day workshop was convened in 2002 at which linefish researchers, managers and fishers throughout SA gave input into the design the next National Linefish Survey so that survey methods, questionnaires and data analysis could be standardized. The workshop recommended that the National Linefish Survey be repeated every 5 years. It was also decided that the next survey should entail two years of sampling. The survey is due to start in 2003 (Mr S. Lamberth, MCM, pers. comm.).

At the third Southern African Marine Linefish Symposium held at Arniston, 28 April – 1 May 1999, the lack of estuarine linefish data was highlighted as a major gap in the knowledge base. The National Linefish Survey will therefore explicitly include the collection of data on catch, effort, participation and socio-economics of estuarine fisheries. Monthly aerial surveys, for the two year period, will cover the entire coastline, including all estuaries, whereas a minimum 50 estuaries will be surveyed by ground personnel to monitor exploitation of estuarine and estuarine dependant fish and invertebrate species. These personnel will also be responsible for interviewing recreational, commercial and subsistence fishers. The estuaries to be surveyed include the top 50 on the priority list but the final selection still needs to be decided on a regional basis.

3.8 Sediment Monitoring (DWAF)

Early attempts to quantify the sediment loads of southern African rivers were prompted mainly by the potential threat that sediment posed to reservoirs. Ad hoc river sampling was initiated in 1919 and regular sampling programmes (daily sampling) were initiated at a number of stations during 1928 – 1929. Most of the original sampling data collected up to 1970 have unfortunately been lost.

Through the years the emphasis in monitoring of sediment loads has shifted from daily stream sampling to regular resurveying (every 10 years) of existing reservoirs to record sediment accumulation rates (Rooseboom, 1992).

3.8.1 Sampling technique (1929 –1971)

The person taking the sample was instructed to daily (at 8h00) take a bottle, submerge it 1 ft (300 mm) below the surface and allow fill up. After all 14 bottles in the crate were full, the crates were railed to Pretoria for analyses. Following a period of rest during which the sediment was allowed to settle out, the majority of the water in the sample was decanted. The remaining water would then be driven off by heating. Up to 1971 grain size analyses were performed by sieve above 0.03 mm and by means of the hydrometer method for smaller particles.

When the settling velocities of particles being transported are small, relative to the shear velocities of the stream, sediment concentrations tend to vary only slightly across the stream. Sediment particles carried by southern African rivers at the points where stream sampling was taken, tend to be small, with a large proportion < 0.2 mm in diameter. Because of this, it is possible to convert the recorded bottle concentrations into mean concentrations for the total stream sections by applying correction factors (Rooseboom, 1992).

3.8.2 Sampling technique (1971-....)

Although bottle samples are still being taken mainly for water quality monitoring, it has been accepted that suspended sediment sampling should be performed by pumping samples from appropriate sampling points in the stream. A reasonable database exists of sediment yields for higher sediment yield areas of South Africa. It is therefore unlikely that extensive long-term stream sampling monitoring will be required in future. It would be of greater value however to institute short term measuring programmes in order to determine the relative yields from different sub-catchments. Electronic sedimentation scales and other modern equipment are now available to simplify grain size analyses and concentration determinations for large numbers of samples. Laboratory processing of samples has therefore become less cumbersome.

Reservoir basins are being resurveyed on a regular basis by DWAF with modern depth sounding and positioning instruments. This is a very efficient manner to determine average sediment loads and yields (Rooseboom, 1992).

Discussion

It is recommended that the practice of collecting sediment samples in rivers be re-established in rivers upstream from estuaries in order to quantify the sediment loads reaching these systems. For example, historic data collected in the Thukela river were invaluable in quantify the sediment to the estuary downstream from the dams. These insights could not be derived from depth soundings and sedimentations rates in the reservoirs.

3.9 Eastern Cape Estuaries Management: Monitoring Project (UPE and CSIR)

The objective of the project is to develop, document and test a monitoring protocol appropriate for Eastern Cape estuaries within the framework of national and provincial estuary management policies and legislation. The monitoring protocol should be designed so that it presents practical methodologies that can be adopted by different levels of local and provincial government as well as semi-government and community organisations (Taljaard and McGwynne, in press).

The monitoring protocol will use environmental variables or parameters to measure change in physical, chemical, biological and socio-economic aspects. The selection of these variables will be guided by an identification of the factors that pose the greatest threats to the estuarine environment, taking into account the experience and needs of management and interested and affected parties.

3.9.1 Selection of Preliminary List of Indicators

The preliminary list of indicators for inclusion in the monitoring protocol for Eastern Cape estuaries, a workshop was held in Port Elizabeth on 23 August 2001 which included participants from:

- Scientific community
- Eastern Cape Provincial authorities dealing with the management of estuaries
- Representatives from Eastern Cape local nature conservation groups.

Estuarine managers from the provincial and local authorities were requested to identify their needs in terms of the control and management of estuaries.

Some of the key points that were highlighted included:

- **Thresholds**. In terms of allowable developments and carrying capacities (e.g. humans, boats, jetties, living resources), in many instances these are not available and, due to a lack of scientifically defensible information, are difficult to set.

- The **lack of resources** (human and financial) to implement the monitoring protocols (e.g. DEAT does not have the capacity to undertake such monitoring) was identified as a concern.

- **Justice system not working** – before monitoring can be instituted proper policing needs to be ensured. Without this one can monitor, but no action can be taken, or where taken will not address the problem.

- **Education** (at all levels) with regard to estuary function and management is a priority.

- **Data management**: There is need to ensure a coordinated management of data and the dissemination to the appropriate persons/decision making bodies. Too much data is lying around idle and not being used as a frame on which to hang decisions reached, or is simply not reaching the appropriate managers (e.g. research information needs to be shared with managers). Possibly an indicator should be developed to track data management, data dissemination and associated action.

From the above a preliminary generic set of environmental indicators for Eastern Cape estuaries where develop focussing on the following aspects (Dr L McGwynne, pers. comm.):

- Hydrodynamic and sedimentary processes
- Water quality
- Plants, animals and habitats
- Human population
- Control of human activities
- Planning and development
- Law enforcement
- Cooperative governance and co-management
- Estuary management
- Economic contribution of estuarine resources
- Basic human needs.

Discussion

The monitoring program is designed for local and provincial government personnel working where possible with special interest groups or estuary forums. The selection of indicators has been geared towards users with limited expertise, limited time and limited budgets i.e. it has not been designed for scientists although the outcome can contribute to research projects (Dr L McGwynne, pers. comm.).

The monitoring program value lies in (i) highlighting trends, (ii) documenting the variability inherent in estuarine systems that is important for the interpretation of trends, (iii) generating hypotheses on ecological and other relationships that can be tested by scientific investigation, (iv) identifying (or red flagging) issues/elements that can limit progress towards achieving specific objectives and need further investigation and (v) a limited degree of compliance monitoring to measure adherence to specified conditions/targets.

Some of the limitations of the programme are: (i) it is not equipped to answer specific questions, e.g. the impacts of a development on water quality or biota (ii) the project focuses on community participation in monitoring and therefore oversimplifies from a Reserve determination perspective, (iii) managers confronted with the extended list for the first time often felt overwhelmed with the detailed requirements.

At the Swartkops Estuary, one of the pilot sites the project, it was felt to be more beneficial to first consolidate existing monitoring projects and then broaden the scope to include a more extended list. For example, at the Swartkops Estuary the following parameters are already being monitored:

- Partial measurement of river runoff to the estuary
- Number of bags of litter collected on a monthly basis
- Water Quality (*E. coli* counts)
- CWAC bird counts twice a year
- Some information on number of boats, anglers, bait collectors and permit holders on estuary.
- Some information on compliance (e.g. number of fines and arrests in terms of the Marine Living Resources Act 18 of 1998)

3.10 National Core Set of Environmental Indicators (DEAT)

The project output consists of a series of 8 specialist reports produced as part of Phase 3 of the National Environmental Indicators Programme. This Programme was initiated by the South African national Department of Environmental Affairs and Tourism (DEAT) to develop national environmental indicators for State of the Environment (SoE) reporting in South Africa.

In the first phase, approximately 330 SoE indicators related to the marine and coastal environment were identified from a review of both national and international SoE Reports. National reports included the South African National SoE Report,

the Cape Town SoE Report, and the Durban SoE Report, as well as information from the South African Integrated Spatial Information System (SA-ISIS) Programme. An international perspective was gained from SoE Reports from countries such as Australia, Canada, China, India, Japan, the Mediterranean, New Zealand, Norway, the United Kingdom, the United States, and the Western Indian Ocean, as well as the Commission for Sustainable Development (CSD) and the Organisation for Economic Co-operation and Development (OECD).

In assessing this list of indicators, they were first grouped into broad categories based on a common theme. The indicators within each grouping were then further divided into sub-categories according to common indicator measures. Within each sub-group, issues and pressures relevant to the South African marine and coastal zone were identified and the appropriate preliminary indicators selected.

The second phase comprised the identification of priorities relating to the coastal and marine environment as outlined in South Africa's environmental legislation and policies. The third phase involved a stakeholder workshop where key issues relating to the coastal and marine environment were identified and in the final phase core indicators were identified for the coastal and marine environment.

The National core indicators selected for the marine, coastal and estuarine environment are listed below (Harrison *et. al.*, in press):

NUMBER	*INDICATOR NAME*
MC01	*Catches and Maximum Sustainable Yield per fishery sector*
MC02	*Distribution and abundance of resource species*
MC03	*Catch per unit effort per fishery sector*
MC04	*Commercial fishing rights supporting SMME development*
MC05	*Estuarine Health Index (State of South African Estuaries (DWAF/DEAT))*
MC06	*Pollutant loading entering the seas from land based sources*
MC07	*Blue Flag beaches*
MC08	*Concentrations of heavy metals in sediments or biological tissues (e.g. Mussel Watch)*
MC09	*Oil pollution accidents along the coast*
MC10	*Land cover change in the coastal zone*
MC11	*Population density change in the coastal zone*

Discussion

In the final selection of national indicators, some indicators very relevant to estuarine monitoring were discarded due to data availability and cost of data collection. Examples of these indicators discarded during the second and third phase of the study are:

- Number of alien species per taxonomic group
- Reduction in freshwater inflows to coastal rivers and estuaries
- Coastal mining activities
- Ship traffic in coastal waters (proxy for 'litter from sea' and 'oils spills')
- Sea-level rise (result of global warming)
- Number of endemic species per taxonomic group
- Threatened and extinct species
- Frequency of algal blooms and dominant species of algae
- Pathogenic contamination of coastal waters
- Litter & debris in the coastal zone
- Erosion setback lines (e.g. management response to changes in sea level)
- Municipal/Provincial waste management expenditure
- Extent of conserved areas (e.g. MPA)
- Budgetary allocation for education and awareness programmes
- Budgetary allocation to environmental research
- Multilateral environmental agreements
- Budgetary allocation to natural resource management
- Number of operational environmental monitoring programmes.

3.11 South African Integrated Spatial Information System (SA-ISIS) Programme

One of the most recent indicator developments in South Africa was undertaken by the South African Integrated Spatial Information System (SA-ISIS) Programme funded by the Innovation Fund. SA-ISIS is a multi-partner, integrative initiative led by three principle groups, i.e. ARC Institute for Soil, Climate and Water; CSIR and the University of Pretoria. The aim of SA-ISIS is to assist government in wise decision-making (*assumed to be both management and policy development*) and to bring information about our rich natural resource base to society at large. Within SA-ISIS three initiatives are identified: SA-ISIS Agriculture, SA-ISIS Biodiversity and SA-ISIS Coastal and Marine.

As part of SA-ISIS (Coastal and Marine), State of Environment (SoE) indicators are being developed for the following components of the coastal zone:

- Terrestrial zone (from the spring high water mark to 10 km inland)
- Estuaries (no definition provided)
- Shoreline (from the spring high water mark to the surf back line)
- Inshore zone (from the surf back line to the 50 m depth contour on the continental shelf)
- Offshore zone (from the 50 m depth contour to the Exclusive Economic Zone [EEZ] 200 nm [360 km]).

A core team of experts were tasked to select a set of SoE indicators for each of the coastal zones identified above. Existing initiatives on the development and implementation of SoE indicators (both national and international) had to be reviewed and this, together with expert knowledge on the South African situation, was used to derive set of indicators. A selected group of estuarine, marine and coastal scientists peer reviewed the list of indicators for each of the zones in workshop forums.

The indicators are selected to fit the Pressure-State-Response framework. The indicators at this stage are still at a preliminary stage of development and are subject to further review and modification. Approximately 100 indicators have been identified for the different coastal zones and these are presented below:

ISSUE	*PRESSURE*	*INDICATOR*
Physical dynamics	*Anthropogenic activities such as water abstraction and inappropriate agricultural practices in river catchments that alter the freshwater inflow patterns and sediment inputs to estuaries*	*Record of freshwater inflow*
		Longitudinal salinity distribution patterns
		State of the mouth primarily through visual observations
		Sedimentation in the mouth as measured by berm wall height or topographical surveys of the mouth area
		Long-term sedimentation processes through cross section profiling at pre-selected sites along the estuary
Water and sediment quality	*Deterioration in aesthetic value*	*Secchi disc depth*
		Record of sightings of floating objects, surface contaminants and where possible the source.
	Eutrophication and anoxic conditions as a result of nutrient input from sewage and agricultural runoff	*Record of location and frequency of occurrence of fish and invertebrate mortalities*
		Record of location of areas in estuaries with bad smells
		Dissolved oxygen concentrations
		Record of location and frequency of occurrence of microalgal blooms
		Dissolved nutrient concentrations
	Chemical pollution as a result of industrial and urban (storm water) development	*Trace metal concentrations in sediments*
	Health risk to recreational users of estuaries	*Microbiological (e.g. E. coli) counts*
Habitat quality	*Changes in plant communities owing to anthropogenic influences*	*Plant habitat area*
		Macro- and micro algal blooms
		Nuisance (alien) vascular plant species
	Changes in animal	*Invertebrates*

ISSUE	PRESSURE	INDICATOR
	communities owing to anthropogenic influences	*Fish*
		Birds
Integrated Management	*Population density and utilisation in and around estuaries*	*Location and number of peoples and settlements associated with estuaries*
	Flood plain development	*Number and type of flood plain developments*
	Catchment development	*Types of land uses in river and stream catchments for estuaries and lagoons*
	Lack of integrative management	*Number and nature of catchment management programmes in coastal river and stream catchments*
		Number and nature of formally implemented estuarine management programmes
		Degree of integration between authorities with jurisdiction over different parts of an estuary
		Nature and extent of Marine Protected Areas/Sensitive Areas

4. SHORT TERM DATA COLLECTION PROGRAMMES OR SURVEYS (< 5 YEARS)

4.1 Great Berg Estuary (Anchor Associates, Cape Town and DWAF)

In 1993 an EFR done on the Great Berg Estuary concluded that the Skuifraam dam would have a measurable impact on the estuary and serious concerns were expressed in terms of the confidence in prediction due to the complicity of the estuary. It was therefore recommended that a baseline monitoring programme of five years be conducted on the estuary, before the construction of the Skuifraam Dam. In 2002 DWAF funded a 3-year programme to collect data on the Great Berg Estuary. The following components are currently being monitored in the estuary:

- Hydrodynamics (continuous water level and river inflow data)
- Sediment Dynamics (once of detailed survey of 40 transects, thereafter 15 transects repeated annually)
- Water Quality (seasonal sampling at 25 stations of salinity, temperature, oxygen)
- Vegetation (once-off detailed mapping of riparian vegetation, thereafter annual survey of transects in transitional zones)
- Invertebrates (first year an winter and summer survey of inter-tidal and sub-tidal invertebrates, thereafter sampling only done in summer)
- Fish (first year an winter and summer survey along the length of the system for 40 sites, up to 65 km upstream, thereafter only a summer survey)
- Birds (CWAC counts for winter and summer every year).

4.2 Water Quality Monitoring of Cape Town Estuaries (Cape Metropolitan Council)

Monitoring technique: Cape Metropolitan Council monitors the water quality of a number of urban estuaries in the vicinity of the metropole. The following standard water quality constituents are measured on a monthly basis: pH, Conductivity (mS/m), Suspended solids (mg/l), Chemical oxygen demand (mg/l), NO_3-N (mg/l), NO_2-N (mg/l), Total NH_4-N (mg/l), PO_4-P (mg/l), SiO_4-Si (mg/l), Faecal coliforms (counts/100 ml) and Faecal streptococci (counts/100 ml).

The estuaries monitored by the Cape Metropolitan Council are:

ESTUARY	*DETAIL*
Sir Lowry's Pass River	*Listed WQ constituents are measured once a month. The monitoring started April/May 2002.*
Eerste	*Listed WQ constituents are measured once a week near Macassar outlet. CWAC bird counts twice a year. Monthly bird counts by representatives of CMC (23 months of data available). Biological monitoring of invertebrates was done twice at of eight stations, but suspended after nothing was found*
Lourens	*Listed WQ constituents are measured once a month at the bridge for the last 2 years.*
Soetwater River	*Listed WQ constituents once a month are measured near Greenways. The monitoring started April/May 2002.*
Seekoei	*Listed WQ constituents are measured once a month at four stations in the vlei. Chlorophyll A is also measured. If algal counts are very high, toxicity test are done.*
Zandvlei	*Listed WQ constituents are measured once a month. Salinities are measured twice a month. Measurements are done at the surface and bottom waters at 14 stations in the estuary. Chlorophyll A is also measured. If algal counts are very high, toxicity test are done. CWAC bird counts twice a year.*
Silvermine	*Listed WQ constituents are measured once a month.*
Diep	*Listed WQ constituents are measured at three stations in the estuary (at mouth, near bridge, and one in-between the mouth and the bridge) once a month.*

Discussion

The monitoring data gathered are used to assess the water quality conditions of the estuaries within the metropole's boundaries. The data collected are summarized and compared to establish trends and the effectiveness of management strategies. The primary focus of the monitoring programme is on human health and therefore results are assessed in that context.

The data can also be used in the wider sense, for example, the False Bay Water Quality Review Study which reviewed the sources and loads of nutrients, heavy metals and other hazardous substances being discharged to False Bay. The assessment included inputs from rivers, storm water runoff, treated wastewater, ground water, air pollution as well as harbour and shipping activities. The study made recommendations on the research needs for False Bay (Taljaard *et. al.*, 2000).

Due to legal requirements and budgetary constraints CMC only monitor the water quality of the estuaries within its boundaries. There is a need to expand this monitoring programme to include some biological monitoring (e.g. Diep Estuary), but there are no future plans to do so (Dr D van Driel, Cape Metropolitan Council, pers. comm.).

4.3 Klein Brak and Groot Brak Estuaries Mud Prawn Monitoring (UPE)

The projects aim was to make a direct comparison between the prawn populations of the Klein Brak and Groot Brak estuaries. The research hypothesis was that the Klein Brak Estuary would have a more stable prawn population, as it was permanently open estuary, than the Groot Brak, which was a temporarily open/closed estuary.

Monitoring technique: Two basic techniques were used to monitor the prawn populations (*Upogebia africana*), namely borrow counts and prawn pumping. After ascertaining that live animals were present, burrow openings were counted in areas of 0,1 m^2 (from a wire quadrat thrown randomly). There were about 70 – 100 replicate counts done in the two study areas. A prawn pump was used randomly over the study areas to get size class distribution.

Spatial scale: The study focused on the muddy, lower intertidal reaches of the Klein and Groot Brak estuaries. In the Klein Brak Estuary it comprised an area of about 200 to 300 m below the N2 bridge while in the Groot Brak the study site was about 500-600 m as it included areas around the island.

Temporal scale: The monitoring was conducted from 1993 to 1996. It was repeated twice a year, once in March (i.e. the end of the breading season) and again in August (i.e. the start of the breeding season).

Discussion:

The study showed that, as was hypothesised, that while the Klein Brak prawn densities stayed stable, the prawn densities of the Groot Brak Estuary increased after the dam construction. The monitoring programme also showed that a grid reference system worked better than a transect system for prawn monitoring, as it allowed for small localised changes in sediment composition to be incorporated in the results (Prof T Wooldridge, UPE, pers. comm.).

4.4 Eastern Cape Monitoring of Copepods (UPE)

Recent research in the estuaries of the Eastern Cape (e.g. Nahoon, Kromme, Swartkops, Mkazana) indicated promising results in the use of endemic copepods as indicators of change in freshwater inflow. The procedure focuses on three endemic, easily identifiable species that can be used to indicate change in an estuary. One of the species is very sensitive to change in fresh water inflow and would reduce in numbers or disappear during high runoff event, while the other two species would increase during period of reduced freshwater inflow. The copepods are also good indicators of nutrient input, food accessibility and phytoplankton. The combination of the three species therefore gives a holistic picture with regard to changes in the water column habitat. Counts varying between hundreds to lower thousands indicate low biomass, where counts of ten thousands to a hundred thousand indicate high biomass.

The use of these three indicator species would allow for limited time in the field and laboratory in comparison with the normal intense fieldwork and analysis that is associated with invertrebrate analyses (Prof T Wooldridge, UPE, pers. comm.).

4.5 Eastern Cape Estuaries (South African Institute for Aquatic Biodiversity and UPE)

After a lack in baseline information in smaller estuaries along the Eastern Cape was identified, nine estuaries were surveyed between the Klein Plamiet and the Keiskamma. The project was originally intended as a long-term monitoring project. The estuaries were compared in terms of aquatic vegetation, invertebrates and fish. The ideal plan would be to repeat the survey for each system every three years.

The fish study compared the species composition, relative abundance, richness and diversity, longitudinal distribution and length frequency data for the fish communities, whereas the invertebrate study compared species composition, relative abundance and distribution patterns in the different estuaries. Macrophytic plant communities were mapped and microalgal parameters in each estuary were documented. A study of the physical characteristics in each system was also carried out (Vorwerk *et al.*, 2001).

4.5.1 Physico-chemical sampling

Monitoring technique: Temperature, salinity and turbidity were recorded at 1 m intervals in the water column

Spatial scale: Five sites up the length of each estuary were selected, with one site occurring in each of the following reaches: mouth, lower, middle, upper and head reaches.

Temporal scale: Sampling was conducted during early mornings and mid afternoons in winter and summer, to obtain measurements during the coolest and warmest period of the day.

4.5.2 Sediment sampling

Monitoring technique: Sediment samples were analysed in terms of organic content and particle size distribution. The samples were classified as gravel (>2 mm), coarse sand (2-0.5 mm), fine sand (0.5-0.063 mm), silt (<0.063 mm) or a combination of these categories.

Spatial scale: Five sites up the length of each estuary were sampled, with one site occurring in each of the following reaches: mouth, lower, middle, upper and head reaches.

Temporal scale: A single summer survey was undertaken.

4.5.3 Fish sampling

Monitoring technique: A range of gear types where used, including small and large mesh seine nets and a fleet of gill nets. Different gear was used to target specific groups and/ or size ranges of fishes. After identification fish were assigned to estuarine association categories according to Whitfield (1998).

The number of large mesh seine hauls varied in each system, depending on the estuary size and decline in the collection rate of new species. In all estuaries littoral habitats were sampled. The net was laid in a semi-circle from the bank by motorised boat and then hauled in by three or four people. All fish captured were identified and measured to the nearest standard length (SL) before being returned to the water alive. The small mesh seine sampling method was similar, except that due to the large number of small fish captured, fish were preserved in formalin and identified at the laboratory.

Monofilament gill nets were used to sample larger fish of both marine spawning and freshwater species, as members of both groups are known to actively avoid seine nets. The nets were 10 m in length and 2 m in depth, consisting of three equal length sections of 45 mm, 75 mm, and 100 mm stretch meshes. Generally two nets were used in each reach (upper, middle and lower). No gill nets were set in smaller systems. Gill nets were deployed in the evening and lifted the following morning. All fish captured were identified and measured to the nearest mm in standard length. The target groups and size classes (mm standard length) of different gear types are listed below (Vorwerk *et al.* 2001):

GEAR TYPE	STRECH MESH SIZE	TARGET GROUP	TARGET SIZE CLASSES
Small mesh seine (30m x 2m)	*10 mm*	*Estuarine spawning species*	*All size classes excluding very small individuals (<10 mm SL)*
Large mesh seine (50m x 2m)	*30 mm*	*Marine spawning species and fresh water species*	*All size classes excluding very small individuals (<40 mm SL)*
Gill nets (10 m x 2 m)	*4.5, 7.5 and 10.0 mm*	*Marine spawning species and fresh water species*	*Larger individuals (<100 mm SL)*

Spatial scale: Five sites up the length of each estuary were sampled, with one site occurring in each of the following reaches: mouth, lower, middle, upper and head reaches.

Temporal scale: Fish were sampled bi-annually, during June or July (winter) and January or February (summer), on one or 2-3 consecutive days, depending on the size of the estuary.

4.5.4 Invertebrate sampling

Invertebrates (zooplankton and macrocrustacea) were surveyed between 2 and 7 times for the various estuaries.

Monitoring technique: Using a Van Veen-type grab, with 9 replicates per station.

Spatial scale: Sampling was done along the length of the estuaries, in all the salinity regimes from saline to fresh.

Temporal scale: Summer and winter surveys at each estuary, with some repeat surveys at some.

4.5.5 Vegetation sampling

The vegetation of the various systems was sampled as a once-off survey for the PhD thesis of Dr B Colloty (University of Port Elizabeth).

4.6 Natal Estuaries Mouth Monitoring (KZN Wildlife)

KwaZulu-Natal Wildlife (KZN Wildlife) has instituted a monitoring programme on KwaZulu-Natal estuary mouth conditions.

Monitoring technique: Visual observations are made by compliance officers during their daily duties. While patrolling the estuaries along the KwaZulu-Natal coastline they are required to note the mouth status of the estuaries they visit during the day. The data is then forwarded to a central point and collated.

Spatial scale: The observations are made at the mouth of the estuaries.

Temporal scale: The visual observations are made on a weekly basis.

Discussion

The data set is very valuable as for many small Natal estuaries this is the only record of open or closed mouth conditions. The mouth observations can be used to establish broad trends in estuarine responses to rainfall/runoff and its related impact on the associated biota e.g. migration patterns.

Unfortunately, the data is only collected on a weekly basis and the visual observation not restricted to a specific tide. This makes correlating the estuary mouth condition to specific river base flows difficult. The net result of a reserve study based on this information would normally yield a broad flow range to allow for tidal and temporal differences in observations.

4.7 Durban Harbour Sand Prawn Monitoring (Marine and Estuarine Research)

In order to establish differences between open and restricted/closed areas in the sand prawn *Callianassa kraussi* population of Durban Harbour, Marine and Estuarine Research have been monitoring changes in population dynamics for the last five years.

Monitoring technique: A prawn pump is used to collect the samples, which were then analysed to establish the impact of bait collecting on size distributions, community structure and prawn densities. Unfortunately, it was discovered that during the night even the closed areas where heavily poached and therefore could not serve as a true reference condition.

Spatial scale: Monitoring was done in open and restricted/closed areas.

Temporal scale: The monitoring used to be done on a monthly basis for the past five years. Recently the frequency of monitoring has been scaled down to quarterly.

4.8 Durban Bay (Marine and Estuarine Research)

4.8.1 Invertebrates

Monitoring technique: Zooplankton night sampling is done using a 500 micron mesh net towed by boat. Hyperbenthos is sampled using a benthic frame net also towed by boat. Zoobenthos is sampled by using a Zabalocki–type Eckman grab, with 5 replicates per site.

Spatial scale: The Mkomazi Estuary is monitored at six sites along the length of the system.

Temporal scale: The estuary is sampled annually in August during the low flow period. The sampling might be conducted earlier if river inflow is low in a specific year.

4.8.2 Fish

Monitoring technique: The fish of the estuaries are sampled using a 30 m x 1.7 m x 15 mm bar mesh seine net fitted with a 5 mm bar mesh purse and, where possible, a fleet of gill nets. Each gill net had a range of mesh sizes and comprised three 45 mm, 75 mm and 100 mm stretch mesh monofilament panels and was either 10 m or 20 m in length and 1.7 m deep.

Spatial scale: Fish are monitored at 3 - 4 sites in the estuary, depending on the water levels in the system.

Temporal scale: The estuary is sampled annually in August during the low flow period. The sampling might be conducted earlier if river inflow is low in a specific year.

5. INTERNATIONAL PERSPECTIVE

Global monitoring programs were viewed and there is a wealth of information readily available on the web and published in journals. Even though some overseas environmental organizations are at the forefront of research in this area, it is not necessarily applicable to the South African situation mainly because of differences in estuary size. Smaller estuaries respond differently to various stresses than larger estuaries so monitoring needs are likely to differ. Some problems might overlap with the SA situation and therefore we should not totally discard overseas methods and experience. Also, funding opportunities are not as readily available in South Africa as overseas, so we have to concentrate on the indicators that are economically viable and that can still be used as representative of a group of indicators.

What follows is a summary of some international monitoring programmes.

5.1 The Chesapeake Bay Monitoring Programme

The Chesapeake Bay Monitoring Programme (www.chesapeakebay.net) started in 1984 by the Chesapeake Bay Executive Council and is an EPA /state cooperative effort. The first agreement, creating the Bay Program was signed in 1983. A second was signed in 1987 and amended in 1992. Finally, the Chesapeake 2000 agreement guides the Bay Program partnership efforts to the year 2010.

The goal of the Chesapeake Bay Monitoring Program is to assist in the development and implementation of management policies to protect and restore the economic and recreational value of Chesapeake Bay. A long term monitoring program was designed by the Department of Natural Resources to provide State managers and policy makers with accurate, timely and comprehensive information about the Bay's existing condition and how it is responding to management initiatives

Monitoring was divided into groups, i.e. physical, chemical (including a full suite of nutrients), sediment chemistry and exchanges, ecosystem processes, assessment of phyto- and zooplankton, SAV, benthic invertebrates, key rate processes and resident fish communities.

Key problem areas include:

- Characterizing existing conditions
- Processes affecting Bay water quality
- Linkages between water quality and living resources

Water, habitat and biological measurements are taken in a coordinated fashion, in most cases at the same times and places to enhance understanding of linkages between monitored parameters. Other considerations in site selection included habitats such as base spawning areas and availability of historical data. Bay-wide perspective was applied to evaluate the effectiveness pollution control measures and to identify regions in need of action as well as a better understanding of the fate of pollutant inputs.

Interpreting and presentation of results are done in several ways in the Chesapeake Bay Monitoring Program depending on specific management questions. Status or characterisation was conducted by fixed station observations. Each salinity zone has a baseline on which to score water quality at each station and is then compared to the most current three-year record.

Mathematical modelling used to project water quality responses uses monitoring data. A three-dimensional Bay and Tributary Water Quality time-variable model is currently under review for predictive purposes.

Considering the size of the Chesapeake Bay estuary (2522.4 miles^2), it is not comparable with any estuary in SA. However, it can be useful to consider some of their approaches when designing a monitoring program.

A survey was done from 1976 to 1983 directed by EPA and its findings were that:

- Bay grasses (submerged aquatic vegetation - SAV) had declined.
- Oyster spat set had declined.
- Landings of freshwater-spawning fish had decreased.
- Levels of nutrients were increasing in many areas.
- The amount of summer Bay water showing low (or no) dissolved oxygen had increased significantly.
- High levels of heavy metals and toxic organic compounds had accumulated in Bay water and sediments

5.2 The Derwent Estuary Programme (DEP)

The Derwent Estuary Programme (www.derwentriver.tas.gov.au) was established in 1999 with the goal of monitoring the environmental resources of the Derwent Estuary. It is a joint State, Local and Commonwealth Government project using a strategic coordinated planning approach across all levels of government, industry and community.

Issues that affect the estuary in particular are:

- Heavy metal contamination
- Introduced marine pests
- Loss of habitat and species
- Intermittent faecal contamination of recreational waters
- Elevated nutrient concentrations
- Environmental flows and barriers
- Foreshore issues.

The first aim was to develop a coordinated environmental management strategy. Effective natural resource management is an on-going and reliable source of environmental data.

Monitoring activities carried out during 2000 included the following:

- weekly recreational water quality testing during summer months
- quarterly water quality monitoring for a wider range of indicators
- annual survey of mercury in flathead and heavy metals in shellfish
- baseline survey of estuarine habitat types and distribution
- baseline survey of estuarine sediment quality.

During 2000, a detailed baseline survey of estuarine habitats was conducted by the Tasmanian Aquaculture and Fisheries Institute at the University of Tasmania. The type and distribution of sub-tidal habitats between Iron Pot and New Norfolk were identified through a combination of field mapping using echo-sounders, grab sampling and video assessment, and digitising habitat boundaries from aerial photographs.

In parallel with the habitat mapping, a detailed survey of sediment quality (redox, grain size, organic content and heavy metals) was completed, consisting of 123 short cores from all parts of the estuary. Results indicate that the majority of Derwent estuary sediments are very fine-grained, organic-rich and contain high levels of heavy metals.

Sediment quality, toxicity testing, biological surveys (e.g. fish, macroinvertebrates and wetlands), nutrient cycling, biogeochemical processes and modelling are also some of the indicators monitored for estuary risk assessment.

6. LESSONS FROM EXISTING RESOURCE MONITORING PROGRAMMES

- At present there are very few long-term monitoring programmes running in South Africa.

- A crucial and relatively inexpensive form of monitoring is aerial surveys of all South African estuaries. Aerial photographs have proven themselves to be invaluable in terms of establishing trends in mouth behaviour, scouring during flood events, sedimentation rates, change in vegetation cover, encroachment by human settlement and impact of agricultural activities on an estuary. It is therefore strongly recommended that the aerial surveys on a national scale be resumed and repeated annually.

- The longest running form of monitoring, pertaining to estuaries, is the collecting of river runoff data. Unfortunately, in the case of estuaries, the last part of the river system, runoff data seldom captures the total runoff from the entire catchment as the main purpose of a gauging weir is normally to establish viable sources for future abstraction or probable dam sites. Runoff gauging weirs also have a negative impact as they stop fish and invertebrate migration upstream and should therefore be installed with caution.

- In a select few estuaries (e.g. Klein and Bot), continuous water level recorders have been installed for nearly 20 years. Unfortunately, less than 10% of South Africa's estuaries have a continuous water level recorder installed. It cannot be stressed enough that this is the single most important monitoring parameter that can be measured in an estuary. From this data many other results can be inferred if nothing else is available, e.g. migration patterns of biota or the health of salt marshes. It is also relatively inexpensive to collect if converted to a digital format, and can be used as an early warning system where needed.

- Mouth observation by community members (Groot Brak and Klein estauries) has proven to be invaluable in understanding the dynamics of estuarine systems. Unfortunately, where no water level data are available to back up observations, it should preferably be done on a daily basis, to be of real assistance in Reserve studies (in order to establish trends between river inflow and mouth conditions).

- In the case of the Groot Brak Monitoring project, estuarine vegetation (salt marshes) and invertebrates (marsh crabs and prawns) have proven to be very good indicators of estuarine health. In the case of the invertebrates it is recommended that the survey technique be expanded from a stationary transect system to a grid reference system, since benthic invertebrates are more mobile than first assumed and this would allow for migration up and down the estuary (Prof. T. Wooldridge, UPE, pers. comm.).

- Fish and birds are good indicators of changes in freshwater inflow, human disturbances and over-exploitation and should be included to assess the overall health of a system. If the temporal and spatially intervals at which fish monitoring are conducted, are well spaced and the monitoring is coupled to water quality measurements (especially salinity), fish data are representative of estuarine health on a comparative basis, even though the individuals are highly mobile (e.g. Breede Reserve study).

- The National Marine and Estuarine Linefish Survey (every 5 years), which will include estuaries, will give a good indication of exploitation pressures on estuarine associated fishes and help to establish to what degree the current health status of the fish in an estuary are not related to water quality and quantity aspects.

- Similarly, CWAC bird counts have proven to be valuable sources of data in estuarine flow requirement studies (e.g. Swartkops and Bot) and should be encouraged in more estuarine systems.

- Before establishing a monitoring programme in a system, it is worth the effort to verify with the different local authorities what is currently being monitored in and around an estuary and try to build on present monitoring programmes to save resources (as was the case for the Swartkops Estuary).

- The proposed National Estuarine Management Protocol calls for the coordination of monitoring activities relating to a specific estuary, both in terms of baseline and compliance monitoring. It also requires the allocation of responsibility to different local authorities for monitoring in its Estuarine Management Plan so to ensure that resources (financial and human) be allocated to monitoring.

Other related WRC reports available:

Prioritization of South African Estuaries based on their potential importance to estuarine-associated fish species

Maree RC • Whitfield AK • Quinn NW

The National Water Act of 1998 ensures that estuaries are regarded as a water resource, and are therefore subject to legislation regarding water resources. Consequently, the monitoring of estuarine water quality and quantity is important to maintain a desired level of structure and function within an aquatic ecosystem. Because biological communities are regarded as an integral component of the estuarine water resource, the prioritization of potential conservation areas are often necessary for the successful determination of aquatic reserve sites. This exercise, referred to as the 'Fish Importance Rating' (FIR), aims to prioritize South African estuaries in terms of their importance to estuarine-associated fish species. The FIR complements similar procedures undertaken for botanical and waterbird communities.

The FIR is based on a scoring system of seven criteria that are considered to reflect the importance of estuaries to estuarine-associated ichthyofauna. Scores are allocated to criteria, where factors that influence the estuarine fish community positively are allocated higher scores than those that influence fish communities negatively. Allocated scores within each criterion are subjected to various weighing factors, after which the products are added to generate a fish-based estuarine hierarchy.

This prioritization exercise presents a ranking of South African estuarine systems based on their importance to estuarine-associated fish species, and aims to facilitate the identification of South African estuaries with a high conservation priority, by placing all South African systems in a regional and national context.

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