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REPUBLIC OF SOUTH AFRICA

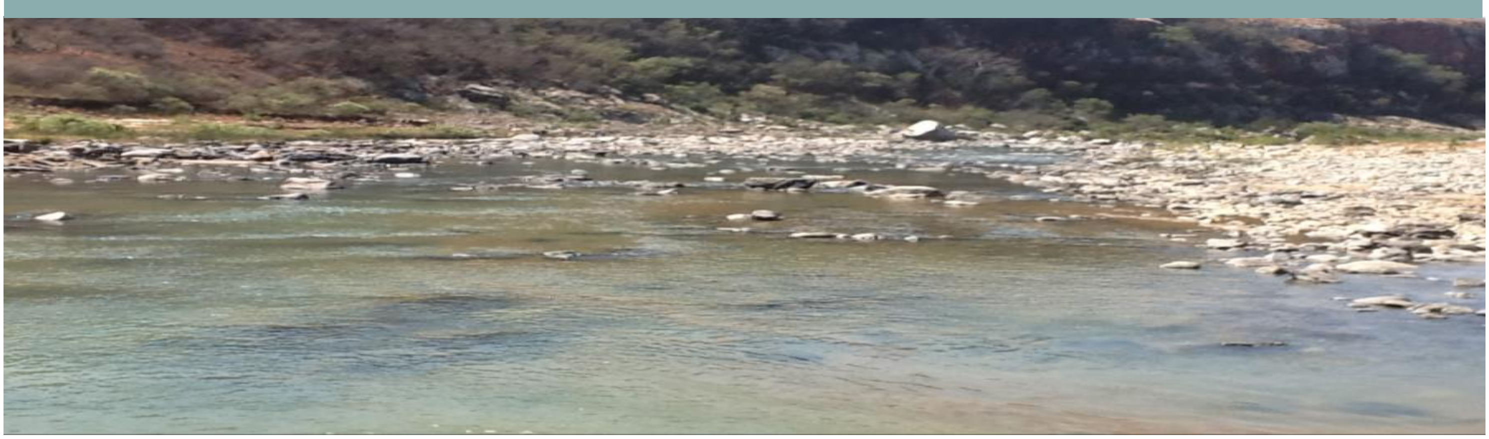
RESERVE DETERMINATION STUDIES FOR SELECTED SURFACE WATER, GROUNDWATER, ESTUARIES AND WETLANDS IN THE USUTU/MHLATUZE WATER MANAGEMENT AREA
WP 10544

MLALAZI ESTUARY RAPID EWR

FINAL

SEPTEMBER 2015

Report No. RDM/WMA6/CON/COMP/1313



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DEPARTMENT OF WATER & SANITATION

CHIEF DIRECTORATE: WATER ECOSYSTEMS

CONTRACT NO. WP 10544

RESERVE DETERMINATION STUDIES FOR SELECTED SURFACE WATER, GROUNDWATER, ESTUARIES AND WETLANDS IN THE USUTU/MHLATUZE WATER MANAGEMENT AREA:

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Report Title: Rapid Environmental Water Requirements (EWR) Determination of the Mlalazi Estuary.

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EXECUTIVE SUMMARY

Introduction

The mouth of the Mlalazi Estuary is approximately 105 km north east of Durban and 56 km south of Richards Bay. The Mlalazi Estuary mouth closes for about 4% of the time, i.e. it is a "temporarily open/closed" estuary (Ezemvelo KZN Wildlife weekly mouth observation database).

For the purposes of this EWR study, the geographical boundaries of the estuary were defined as follows:

Downstream boundary:	Estuary mouth 28°56'43.60"S 31°49'7.43"E
Upstream boundary:	Left tributary: 28°55'50.71"S 31°42'32.15"E Centre tributary: 28°55'9.89"S 31°42'21.14"E Right tributary: 28°54'15.91"S 31°46'8.54"E
Lateral boundaries:	5 m contour above mean sea level (a.m.s.l.) along each bank

Geographical boundaries of the Mlalazi Estuary based on the Estuary Functional Zone.

Present Ecological Status

The Mlalazi Estuary in its Present State is estimated to be 80% similar to the Natural Condition, which translates into a Present Ecological Status (PES) of a B Category. This is mostly attributed to the following factors:

- *Reduction in river flow, especially baseflows that maintain the salinity regime in the system;*
- *Recreational activities (e.g. boat launching) in the lower reaches affecting birds abundance;*

- *Over exploitation of living resources (e.g. poaching and line fishing);*
- *Agricultural activities in the Estuary Functional Zone causing loss of estuarine habitat; and*
- *Past disposed spoil from dredging in the 1960's as well as berm construction near the mouth.*

The overall current Estuarine Health Score as well as the score with non-flow related pressures removed is given in Table 5.1 below.

Estuarine Health Score for the Mlalazi Estuary.

Variable	Estuarine health score		
	Overall	**Excluding non-flow related pressures**	**Conf**
Hydrology	61	70	L
Hydrodynamics and mouth condition	97	97	L
Water quality	80	83	L
Physical habitat alteration	89	95	M
Habitat health score	**82**	**88**	**L**
Microalgae	80	81	L
Macrophytes	70	97	M
Invertebrates	80	84	L
Fish	75	88	M
Birds	80	96	L
Biotic health score	**77**	**87**	**L**
ESTUARY HEALTH SCORE	**80**	**88**	**L**
PRESENT ECOLOGICAL STATUS (PES)	**B**	**A/B**	**L**
OVERALL CONFIDENCE	**L**	**L**	**L**

Relative contribution of flow and non-flow related impacts on health

Estimates of the contribution of non-flow related impacts on the level of degradation of each component led to an increase in the health score from a PES of 80 to 88, which would raise the health score to an A/B Category. This suggests that non-flow related impacts have played some role in the degradation of the estuary to a B, but that some flow-related impacts are also driving degradation.

Non-flow related impacts that need to be addressed include, habitat loss to sugar farming within the estuary functional zone (5m mean sea level contour) and the vegetation integrity of those areas along with potential water quality problems associated with the Mtunzini WWTW and the Aquaculture Kob Farm. Historical dredging and berm construction were also identified as important factors currently influencing ecological health of the system.

Overall Confidence

Confidence levels for three of the four abiotic components were rated as Low. Only two of the five biotic components had enough data to yield Medium Confidence assessments. The overall confidence assessment for this study is LOW.

Estuary Importance

The Estuary Importance Score (EIS) takes size, the rarity of the estuary type within its biographical zone, habitat, biodiversity and functional importance of the estuary into account. Biodiversity importance, in turn is based on the assessment of the importance of the estuary for plants, invertebrates, fish and birds, using rarity indices. Estuary Importance was rated at 85, indicating that the estuary is rated as "Highly Important".

Estuarine Importance of the Mlalazi Estuary.

Criterion	Weight	Score
Estuary Size	15	90
Zonal Rarity Type	10	30
Habitat Diversity	25	90
Biodiversity Importance	25	96
Functional Importance	25	90
Estuary Importance Score		**85**

The Functional Importance of the Estuary is also very high. It serves an important nursery function for marine-living fish and invertebrates, is an important movement corridor for invertebrates and fish breeding in the sea, contributes to detritus, nutrients and sediments to the sea and plays some role as a migratory stopover for coastal seabirds.

Recommended Ecological Category

The Recommended Ecological Category (REC) represents the level of protection assigned to an estuary. The Present Ecological State (PES) sets the minimum REC. The degree to which the REC needs to be elevated above the PES depends on the level of importance and level of protection or desired protection of a particular estuary. The PES for the Mlalazi Estuary is a B and the Estuary is rated as "Highly Important" from a biodiversity perspective.

The Mlalazi Estuary also forms part of the core set of priority estuaries in need of protection to achieve biodiversity targets in the National Estuaries Biodiversity Plan for the National Biodiversity Assessment (Turpie et al., 2012c). The NBA 2011 (Van Niekerk and Turpie 2012) recommended that the minimum Category for the Mlalazi be a A, that the system be granted full no-take protection, and that 75 % of the estuary margin be undeveloped.

Taking into account the current conditions (PES = B), the reversibility of the impacts, the ecological importance and the conservation requirements of the Mlalazi Estuary, the REC for the system is an A Category. However at the workshop it was found that the "Best Attainable State" for the estuary was an A/B (±3 points from the category boundary.

Estuary protection status and importance, and the basis for assigning a Recommended Ecological Category.

Protection status and importance	REC	Policy basis
Protected area	A or BAS*	Protected and desired protected areas should be restored to and maintained in the best possible state of health
Desired Protected Area		
Highly important	PES + 1, min B	Highly important estuaries should be in an A or B category
Important	PES + 1, min C	Important estuaries should be in an A, B or C category
Of low to average importance	PES, min D	Estuaries to remain in a D category

* BAS = Best Attainable State

Based on this study, the above National Biodiversity Plan targets and the reversibility of current impacts, the Recommended Ecological Category for the Mlalazi Estuary is an A/B Category.

Ecological Categories associated with scenarios

The fowling ecological scenarios were evaluated as part of this study:

Scenarios	Description	MAR (X10^6 m^3)	% Remaining
Reference	Natural Flow	164.31	100
Present	Present day	124.57	76
Scenario 1	Scenario 1 is the same as present day except it includes an additional demand which is approximately 10% of the present day MAR (13 Mm^3) supplied by the upstream dam which has an increased capacity of 15 Mm^3.	112.46	68
Scenario 2	Present day reduced by 10% through abstraction from lower reaches of river	111.89	68
Scenario 3	Present day reduced by 20% through abstraction from lower reaches of the river.	102.93	63
Scenario 4	Scenario 4 is the same as Scenario 3 except an additional demand of 10% MAR is taken out the upstream catchment from a dam with a capacity of 20 Mm^3 (over and above the 20% demand taken directly from the river).	86.74	53

The individual Estuarine Health Index (EHI) scores, as well as the corresponding ecological category under different scenarios are provided below. The estuary is currently in a B Category. Under Scenario 1 the Mlalazi Estuary will decline slightly in health, as a result of more closed mouth conditions, but is expected to just remain in a B Category. While, under Scenarios 2, 3 and 4 the estuary will deteriorate further in health by about 12%, 8% and 7% respectively as a result of increase closed mouth conditions.

EHI score and corresponding Ecological Categories under the different runoff scenarios.

	Weight	Present	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Confidence
Hydrology	25	61	51	38	34	23	L
Hydrodynamics and mouth condition	25	97	97	65	47	41	L
Water quality	25	80	84	79	78	77	L
Physical habitat alteration	25	89	74	81	78	58	M
Habitat health score		**82**	**76**	**66**	**59**	**49**	**L**
Microalgae	20	80	87	72	64	58	L
Macrophytes	20	70	65	50	45	45	M
Invertebrates	20	80	80	70	65	60	L
Fish	20	75	70	55	45	35	M
Birds	20	80	75	60	45	40	L
Biotic health score		**77**	**75**	**61**	**53**	**48**	**L**
ESTUARY HEALTH SCORE		**80**	**76**	**64**	**56**	**49**	**L**
ECOLOGICAL CATEGORY		**B**	**B**	**C**	**D**	**D**	**L**

For the Mlalazi Estuary, none of the scenarios achieved the REC of an A/B Category. Therefore Scenario 1 in conjunction with a number of management interventions is the recommended ecological flow scenario. The following management interventions are required to achieve the Mlalazi REC:

- *Hydrological information is required on causes of baseflow declines. Due to this study only being conducted at a Rapid level there is a need to verify the baseflows and to look at how these can be protected, i.e. no futher decrease in flow.*
- *To ensure the future water quality of the system, introduce compliance monitoring of effluent water from both the Mtunzini WWTW (which is apparently due to be doubled in size) and the Aquaculture Kob Farm.*
- *Increase baseflows to the estuary by 10 to 20% to ensure that mouth closure does not occur.*
- *Create interventions within the riparian buffer zone that would improve the nutrient status and help with sedimentation issues.*
- *Undertake restoration of the Mlalazi Flood Plain up to the 5m a.m.s.l. contour and reduce agriculture impacts in the supratidal area of the system.*
- *Curb Illegal gill netting of targeted species, as well as illegal seine & cast netting. This has an impact on the nursery function and impacts on prawns which form part of the bycatch.*
- *Remove the migration barrier (dumped rocks at vehicle crossing) which is situated some 14 km upstream of the estuary.*
- *Curb recreational activities in the lower reaches through zonation and improved compliance.*

The nearby Tronox Mine has been looking for wetland offsets, this might be an opportunity to establish something that could have the potential to contribute to the baseflow. This could include the purchase of 'offset' land in the supra tidal zone of the Mlalazi Estuary and possibly the diversion of process runoff water, originating from the Mhlathuze catchment, out of the Siyaya catchment and into the Mlalazi catchment.

Key findings of the study are summarised in the appendixes to the main report;

- *Appendix A Mlalazi Estuary Mouth State*
- *Appendix B Mlalazi Estuary water level and salinity measurements used to derive the abiotic states*
- *Appendix C Data available on the Mlalazi Estuary used for the study*
- *Appendix D Specialist report Microalgae*
- *Appendix E Specialist report Macrophytes*
- *Appendix F Specialist report Zooplankton*
- *Appendix G Specialist report Macrobenthos*
- *Appendix H Specialist report Macrocrustacea*
- *Appendix I Specialist report Fish*
- *Appendix J Specialist report Birds*

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ABBREVIATIONS AND ACRONYMS

m a.m.s.l.	meters above mean sea level
BAS	Best Attainable State
CD	Chief Directorate
CSIR	Centre of Scientific and Industrial Research
DEA	O&C Department of Environmental Affairs: Oceans and Coast
DIN	Dissolved Inorganic Nitrogen
DIP	Dissolved Inorganic Phosphate
DO	Dissolved Oxygen
DRP	Dissolved Reactive Phosphate
DRS	Dissolved Reactive Silicate
DWA	Department of Water Affairs
DWS	Department of Water Affairs and Sanitation
EHI	Estuarine Health Index
EIS	Estuarine Importance Score
EKZNW	Ezemvelo KZN Wildlife
ERC	Ecological Reserve Category
EWR	Ecological Water Requirement
H	High
L	Low
M	Medium
MAR	Mean Annual Runoff
MCM	Million Cubic Metres
MCM/a	Million Cubic Metres per annum
MPB	Microphytobenthos
MSL	Mean Sea Level
NMMU	Nelson Mandela Metropolitan University
NWA	National Water Act (1998)
P	Present
PES	Present Ecological Status
ppt	Parts per thousand
psu	Practical Salinity Units
R	Reference
RDM	Resource Directed Measures
REC	Recommended Ecological Category
REI	River Estuary Interface
RQO	Resource Quality Objectives
SA	South Africa
SDF	Standard Design Flood
VL	Very low
WMA	Water Management Area

GLOSSARY OF TERMS

Ecological Category	Defines the ecological condition of a river in terms of the deviation of biophysical components from the reference condition. There are six Ecological Categories that range from A (natural) to F (critically modified).
EcoClassification	The determination and categorisation of the Present Ecological Status or various biophysical attributes of rivers relative to the natural and/or reference condition.
EcoStatus	The totality of features and characteristics of the river and its riparian areas that bear upon its ability to support an appropriate natural flora and fauna and its capacity to provide a variety of goods and services.
Ecological Water Requirements	The pattern (magnitude, timing and duration) and quality of flow needed to maintain an aquatic ecosystem in a particular condition (Ecological Category).
Ecological Reserve	The quantity and quality of water required to satisfy basic human needs by securing a basic water supply and in order to ensure ecologically sustainable development and use of water resources, as prescribed in the NWA.
EcoSpecs	Clear and measurable specifications of ecological attributes (e.g. water quality, flow, biological integrity) that defines the Ecological Category.
Present Ecological Status	The degree to which ecological conditions have been modified from reference conditions, based on water quality, biota and habitat information that is scored on a six point scale from A (natural) to F (critically modified).
Reference conditions	Natural ecological conditions prior to anthropogenic disturbance.

1 INTRODUCTION

1.1 Background to the Study

The Chief Directorate: Resource Directed Measures issued an open tender invitation for the "Appointment of a Professional Service Provider to undertake Reserve Determinations for selected Surface water, Groundwater, Estuaries and Wetlands in the Usutu to Mhlatuze Basins". The focus on this area was a result of the high conservation status and importance of various water resources in the basin and the significant development pressures in the area affecting the availability of water.

Preliminary Reserve determinations are required to assist the Department of Water and Sanitation (DWA) in making informed decisions regarding the authorisations of future water use and the magnitude of the impacts of the proposed developments on the water resources in the WMA, and to provide the input data for Classification of the area's water resources, and eventual gazetting of the Reserve (DWAF1999).

DWA appointed Tlou Consulting to undertake the project in July 2013.

1.1.1 Study objectives

The objectives of the study are to:

- determine the Ecological Reserve (DWAF 1999), at various levels of detail, for the Nyoni, Amatikulu, Mlalazi, Mhlatuze, Mfolozi, Nyalazi, Hluhluwe, Mzinene, Mkuze, Assegaai and Pongola Rivers;
- determine the Ecological Reserve, at an Intermediate level for the Pongola floodplain;
- determine the Ecological Reserve, at an Intermediate level for the St Lucia/Mfolozi, Estuary System;
- determine the Ecological Reserve, at a Rapid level for the Mlalazi Estuary;
- determine the Ecological Reserve, at a Rapid level for the Amatikulu-Nyoni Estuary;
- determine the Ecological Reserve, at an Intermediate level for Lake Sibaya;
- determine the Ecological Reserve, at a Rapid level for Kosi Lake and Estuary;
- classify the causal links between water supply and condition of key wetlands
- incorporate existing EWR assessments on the Mhlatuze (river and estuary) and Nhlabane (lake and estuary) into study outputs;
- determine the groundwater contribution to the Ecological Reserve, with particular reference to the wetlands;
- determine the Basic Human Needs Reserve for the Usutu/Mhlatuze WMA;
- outline the socio-economic water use in the Usutu/Mhlatuze WMA;
- build the capacity of team members and stakeholders with respect to EWR determinations and the ecological Reserve.

1.2 This report

This report details the processes and outcome of a Rapid Environmental Water Requirements (EWR) Determination for the Mlalazi Estuary.

1.3 Ecological water requirement method for estuaries

Methods to determine the environmental flow requirement of estuaries were established soon after the promulgation of the NWA in 1998. The so-called "Preliminary Reserve Method" involves setting a Recommended Ecological Category (i.e. desired state), recommended Ecological Reserve (i.e. flow allocation to achieve the desired state) and recommended Resource Quality Objectives for a resource on the basis of its present health status and its ecological importance. The method follows a generic methodology that can be carried out at different levels of effort (e.g. rapid, intermediate or comprehensive). The official method for estuaries (Version 2) is documented in DWAF (2008). In 2013, a Version 3 of the method was published as part of a Water Research Commission study (Turpie *et al.* 2012a). At the start of this project it was decided that Version 2 would be used in the study (DWAF 2008).

The generic steps of the official "Ecological Reserve Method" for estuaries were applied as follows:

Step 1: Initiate study defining the study area, project team and level of study (confirmed in the **inception report** of this study)

Step 2: Delineate the geographical boundaries of the resource units (confirmed in the **delineation report** of this study)

Step 3a: Determine the **Present Ecological Status** (PES) of resource health (water quantity, water quality, habitat and biota) assessed in terms of the degree of similarity to the reference condition (referring to natural, unimpacted characteristics of a water resource, and must represent a stable baseline based on expert judgement in conjunction with local knowledge and historical data). An Estuarine Health Index (EHI) is used to evaluate the current condition of the estuary (Table 1.1).

In the case of this assessment the EHI scoring of the various variables is based on a review of historical data, as well as data collected during a field monitoring programme in 2013 (refer to Appendices for specialist reports).

The estuarine health score is translated into one of six ecological classes provide below in Table 1.2.

Table 1.1 Estuarine Health Index (EHI) scoring system.

VARIABLE	SCORE	WEIGHT	WEIGHTED SCORE
Hydrology	…	25	…
Hydrodynamics and mouth condition	…	25	…
Water quality	…	25	…
Physical habitat alteration	…	25	…
Habitat health score			**…**
Microalgae	…	20	…
Macrophytes	…	20	…
Invertebrates	…	20	…
Fish	…	20	…
Birds	…	20	…
Biotic health score			**…**
Estuary Health Score Mean (Habitat health, Biological health)			**…**

Table 1.2 Translation of EHI scores into ecological classes.

EHI SCORE	PES	GENERAL DESCRIPTION
91 – 100	A	Unmodified, or approximates natural condition; the natural abiotic template should not be modified. The characteristics of the resource should be determined by unmodifed natural disturbance regimes. There should be no human induced risks to the abiotic and biotic maintenance of the resource. The supply capacity of the resource will not be used
76 – 90	B	Largely natural with few modifications. A small change in natural habitats and biota may have taken place, but the ecosystem functions are essentially unchanged. Only a small risk of modifying the natural abiotic template and exceeding the resource base should not be allowed. Although the risk to the well-being and survival of especially intolerant biota (depending on the nature of the disturbance) at a very limited number of localities may be slightly higher than expected under natural conditions, the resilience and adaptability of biota must not be compromised. The impact of acute disturbances must be totally mitigated by the presence of sufficient refuge areas.
61 – 75	C	Moderately modified. A loss and change of natural habitat and biota have occurred, but the basic ecosystem functions are still predominantly unchanged. A moderate risk of modifying the abiotic template and exceeding the resource base may be allowed. Risks to the wellbeing and survival of intolerant biota (depending on the nature of the disturbance) may generally be increased with some reduction of resilience and adaptability at a small number of localities. However, the impact of local and acute disturbances must at least partly be mitigated by the presence of sufficient refuge areas.
41 – 60	D	Largely modified. A large loss of natural habitat, biota and basic ecosystem functions has occurred. Large risk of modifying the abiotic template and exceeding the resource base may be allowed. Risk to the well-being and survival of intolerant biota depending on (the nature of the disturbance) may be allowed to generally increase substantially with resulting low abundances and frequency of occurrence, and a reduction of resilience and adaptability at a large number of localities. However, the associated increase in the abundance of tolerant species must not be allowed to assume pest proportions. The impact of local and acute disturbances must at least to some extent be mitigated by refuge areas.
21 – 40	E	Seriously modified. The loss of natural habitat, biota and basic ecosystem functions is extensive
0 – 20	F	Critically modified. Modifications have reached a critical level and the lotic system has been modified completely with an almost complete loss of natural habitat and biota. In the worst instances the basic ecosystem functions have been destroyed and the changes are irreversible

Step 3b: Determine the **Estuary Importance Score (EIS)** that takes the size, the rarity of the estuary type within its biographical zone, habitat, biodiversity and functional importance of the estuary into account (Table 1.3 and 1.4).

Table 1.3 Estuary Importance scoring system.

Criterion	Score	Weight	Weighted Score
Estuary Size	…	15	**…**
Zonal Rarity Type	…	10	**…**
Habitat Diversity	…	25	**…**
Biodiversity Importance	…	25	**…**
Functional Importance	…	25	**…**
Weighted Estuary Importance Score			**…**

Table 1.4 Estuarine Importance rating system.

EIS	Importance rating
81 – 100	Highly important
61 – 80	Important
0 – 60	Of low to average importance

Step 3c: Set the **Recommended Ecological Category (REC)** which is derived from the PES and EIS (or the protection status allocated to a specific estuary) following the guidelines listed in Table 1.5.

Table 1.5 Guidelines to assign REC based on protection status and importance and PES of an estuary.

Protection Status and Importance	REC	Policy basis
Protected area	A or BAS*	Protected and desired protected areas should be restored to and maintained in the best possible state of health
Desired Protected Area (based on complementarity)		
Highly important	PES + 1, min B	Highly important estuaries should be in an A or B category
Important	PES + 1, min C	Important estuaries should be in an A, B or C category
Of low to average importance	PES, min D	The remaining estuaries can be allowed to remain in a D category

* BAS = Best Attainable State

An estuary cannot be allocated an REC below a category "D". Therefore systems with a PES in categories 'E' or 'F' needs to be managed towards achieving at least a REC of "D".

Step 4: **Quantify the ecological consequences of various runoff scenarios** (including proposed operational scenarios) where the predicted future condition of the estuary is assessed under each scenario. As with the determination of the PES, the EHI is used to assess the predicted condition in terms of the degree of similarity to the reference condition.

Step 5: Quantify the (recommended) **Ecological Water Requirements**, which represent the lowest flow scenario that will maintain the resource in the REC.

Step 6: Estimate (recommended) **Resource Quality Objectives (Ecological Specification)** for the recommended REC, as well as future **monitoring requirements** to improve the confidence of the EWR.

1.4 Definition of confidence levels

The level of available historical data in combination with the level of effort expended during the assessment determines the level of confidence of the study. Three levels of study have been recognised in the past in terms of the effort expended during the assessment – rapid, intermediate and comprehensive. The brief for the current study was to undertake a Rapid Assessment of the Mlalazi Estuary. One field trip was budgeted for and this was undertaken during May 2013. In terms of abiotic data several historical sets of Water Quality, Sediment Grain Size, Organic Content and Physico-chemical data were available. Apart from the fish and benthic invertebrates almost no historical biotic data was available. No long-term river inflow data was available to be able to benchmark abiotic processes for which there was also almost no data. As a result the confidence of the study is low. This is a situation that can only be remedied with some comprehensive and long term data collection on the system. Criteria for the confidence limits attached to statements in this study are:

Confidence level	Situation	Expressed as percentage
Low	Limited data available	<40% certainty
Medium	Reasonable data available	40 – 80% certainty
High	Good data available	> 80% certainty

1.5 Assumptions and limitations for this study

The following assumptions and limitations should be taken into account:

- The accuracy and confidence of an Estuarine Ecological Water Requirements study is strongly dependent on the quality of the hydrology. The overall confidence in the hydrology supplied to the estuarine study team is of a Low Level (<40%), with a particular concern regarding the accuracy of the simulated base flows during the low flow period into the estuary.
- While the biotic data collected allowed the EWR process to be undertaken, the lack of data meant that the confidence in the assessment of most of these components was at a Low Level.

1.6 Structure of this report

The report is structured as follows:

Chapter 1 Provides an overview of EWR methods and confidence of the study.

Chapter 2 Summarises important background information related to the hydrological characteristics, catchment characteristics and land-use, as well as human pressures affecting the estuary.

Chapter 3 Defines the geographical boundaries of the study area, as well as the zoning and typical abiotic states adopted for this estuary.

Chapter 4 Provides a baseline ecological and health assessment of the estuary. It describes each of the abiotic and biotic aspects of the estuary, from hydrology to birds, describing an understanding of the present situation and estimation of the reference condition. The health state of each component is computed using the Estuary Health Index (EHI).

Chapter 5 Describes the overall state of health (or Present Ecological Status) of the estuary. It also summarises the overall confidence of the study and the degree to which non-flow factors have contributed to the degradation of the system.

Chapter 6 Combines the EHI score with the Estuarine Importance Score (EIS) for the system to determine the Recommended Ecological Category.

Chapter 7 Describes the ecological consequences of various future flow scenarios, and determines the Ecological Category for each of these using the EHI.

Chapter 8 Concludes with the recommendations on the ecological water requirements for the estuary, as well as recommended resource quality objectives (ecological specifications). Finally, monitoring requirements to improve the confidence of the EWR assessment is recommended.

2 BACKGROUND INFORMATION

2.1 Hydrological characteristics

The Mlalazi catchment is estimated at 420 to 507 km^2. The Mlalazi river length is about a 40 to 68 km. The natural MAR is of the order of 127.93 Million m^3.

2.2 Catchment characteristics and land-use

Table Mountain Sandstone and Archaean granites dominate the catchment. Formations of Ecca and cretaceous deposits (sand stone and shale) occur in the environs of the estuary.

While sugarcane farming and forestry activities are practised in the surrounding catchment area, most is restricted to the lower reaches of the Mlalazi River, with a large part of the estuarine area up to the 5 m contour under cane. There is also some exotic afforestation on the north side within the area below the 5 m contour which has been present since before 1937. Some 75% of the Mlalazi catchment falls within tribal land (Begg 1978), with sections in the lower reaches of the Mlalazi river being under small scale ('block') sugarcane growing, undertaken by the rural community.

A large part of the estuary itself falls within the protected area of the Mlalazi Nature Reserve managed by Ezemvelo KZN Wildlife (EKZNW) and there is little development inside the reserve. However effluent discharges from both the Mtunzini Municipal Waste Water Treatment Works and the Mtunzini Aquaculture Projects Kob Farm (located on the western banks of Zone B) flow through parts of the reserve and into the estuary. Both are considered to have significant effects on the Mlalazi Estuary. The Kob Farm, which is situated on the flood plain of the Mlalazi estuary, started operations in 2006. It was operated initially as a Prawn Farm, from 1993 until closure in 2004 (Evans 2009), during which time it also disposed its effluent water into the Mlalazi estuary. Discharges from both the WWTW and the Fish Farm have a potential to increase the levels of nutrients and toxic chemicals in the estuary, particularly during floods and during very low flow periods.

In the 1960's extensive dredging, apparently due to mouth closures (R.H.Taylor *pers comm.*), was undertaken along the greater length of the estuary (Begg, 1978). Hemens *et al.* (1971) reported that the dredging was undertaken by the Reclamation Unit of Provincial Building Services and was underway by 1965 with spoil being deposited in the *Phragmites* swamp in the central part of the estuary. To a large degree the system appears to have reset itself after this anthropogenic event except in the areas where the spoil was dumped in the upper part of Zone A, Zone B and Zone C (see Figure 3.2). There has been loss of supratidal habitat, as a result of its elevation due to the dredging, as well as due to sugar farming and its associated drainage canal.

2.3 Human activities affecting the estuary (Pressures)

Table 2.1 provides a summary of significant flow related pressures on the Mlalazi Estuary, while Table 2.2 summarises key non-flow related pressures.

Table 2.1 Pressures related to flow modification.

ACTIVITY	PRESENT	DESCRIPTION OF IMPACT
Water abstraction and dams (including farm dams)	✓	Mostly small farm dams. There is also abstraction from weirs on the Ntuze tributary of the Mlalazi.
Augmentation/Inter-basin transfer schemes		A pipeline brings water into the catchment from the Mhlathuze river. This feeds directly in to a reservoir at Mtunizini. Return flow of water used by the town must enter the estuary via the ground water.

Table 2.2 Pressures, other than modification of river inflow presently affecting estuary.

ACTIVITY	PRESENT	DESCRIPTION OF IMPACT
Agricultural and pastoral run-off containing fertilisers, pesticides and herbicides	✓	There are sugarcane lands in the floodplain and runoff occurs via a number of canals excavated to drain fields.
Mtunzini Municipal WWTW	✓	The sewage works (WWTW) is located in Zone B of the estuary. There is evidence of accumulated nutrients in the canal draining the treatment works into the estuary.
Mariculture	✓	Formerly a prawn farm which now cultures kob discharges effluent via a stream next to the launch site at Zone B. Biological effect of the effluent are apparent but there appears to be historical effects of the prawn farm on water quality. It is unknown what the risks of parasites and pathogens & genetic contamination are for the wild stock.
Bridge(s)	✓	There are three bridges situated about halfway up the system.
Artificial breaching	✓	This does take place on occasion.
Bank stabilisation and destabilisation	✓	Bank is stabilised at picnic site in Zone B limiting intertidal habitats There is also a berm near the mouth and in many places there are berms formed from the dumping of dredger spoil in the 1960's.
Low-lying developments	✓	Sugar cane fields & Kob farm.
Migration barrier in river		There is a road crossing/drift in upper part of estuary about 14km from the mouth which acts as a migration barrier. The two weirs on the Ntuze stream also form migration barriers.
Recreational fishing	✓	Present in the estuary but not intensive
Commercial/Subsistence fishing (e.g. gillnet fishery)	✓	Recreational boat fishing
Illegal fishing (Poaching)	✓	Quite heavy, consists of gill netting targeted species, as well as seine & cast netting. Impact on the nursery function. In addition prawn bycatch impacts on that component of the biota.
Translocated or alien fauna and flora	✓	The aquatic snail *Tarebia granifera* has been translocated into the system. In addition the alien tree *Casuarina equisetifolia* was planted in the 1950's to stabilise the mobile sands at the mouth of the estuary.
Recreational disturbance of waterbirds	✓	Disturbances by boating at the intertidal areas adjacent to the launch and picnic site.

3 DELINEATION OF ESTUARY

3.1 Geographical boundaries

The mouth of the Mlalazi Estuary is approximately 105 km north east of Durban and 56 km south of Richards Bay. The Mlalazi Estuary estuary mouth closes for about 4% of the time, i.e. it is a "*temporarily open/closed*" estuary.

For the purposes of this EWR study, the geographical boundaries of the estuary are defined as follows:

Downstream boundary:	Estuary mouth 28°56'43.60"S 31°49'7.43"E
Upstream boundary:	Left tributary: 28°55'50.71"S 31°42'32.15"E Centre tributary: 28°55'9.89"S 31°42'21.14"E Right tributary: 28°54'15.91"S 31°46'8.54"E
Lateral boundaries:	5 m contour above mean sea level (a.m.s.l.) along each bank

Figure 3.1 Geographical boundaries of the Mlalazi Estuary based on the Estuary Functional Zone.

3.2 Zonation of the Mlalazi Estuary

For the purposes of this study, the Mlalazi Estuary is sub-divided into four distinct zones, primarily based on bathymetry and sediment characteristics (Figure 3.2).

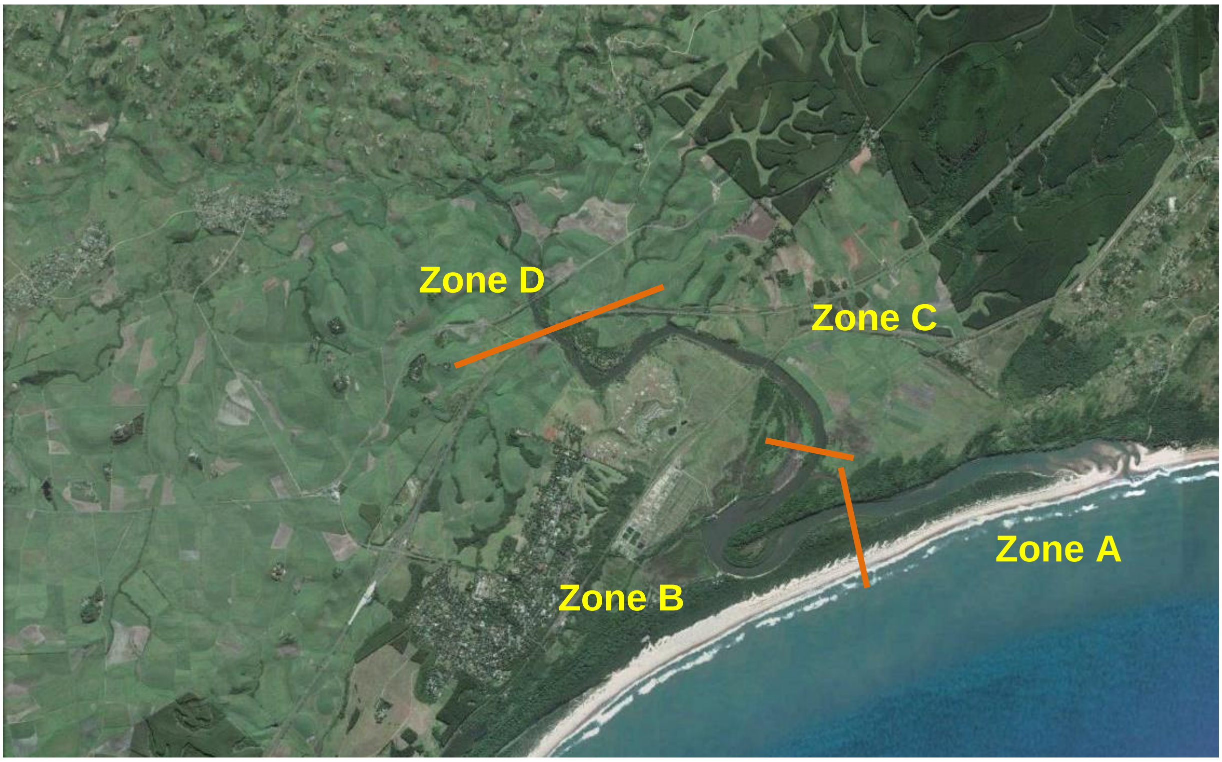


Figure 3.2 Zonation of the Mlalazi Estuary.

Table 3.1 below lists some of the key features of the Mlalazi Estuary zonation that are used to determine the weighting of scores.

Table 3.1 Key features of the Mlalazi Estuary zonation.

	Zone A: Lower	Zone B: Middle	Zone C: Upper	Zone D: Riverine
Area (ha)	63	50	33	15
Maximum depth (When open)	-1.0 to -2.0	-1.0 to -2.0	-1.0 to -2.5	1.0
Relative %	40	30	20	10

3.3 Typical abiotic states

Based on available literature, a number of characteristic 'states' can be identified for the Mlalazi Estuary, related to mouth condition, tidal exchange, salinity distribution and water quality. These are primarily determined by river inflow patterns. The different states are listed in Table 3.2.

Table 3.2 Summary of the abiotic states that can occur in the Mlalazi Estuary.

State	Flow range (m^3/s)	Description
State 1: Closed	< 0.25	The estuary mouth is closed for days to weeks. Zones A, B, and C are well mixed and salinity is brackish throughout. Zones A, B and C have salinity of about 25 (Lower), 25 (Middle) and 20 (Upper) respectively, Zone D (Riveriner) backfloods with saline water of about 15 into the riverine section.
State 2: Open marine	0.25 – 1.0	The system shows a marine influence due to reduced freshwater inflow and open mouth state. Zones A (Lower), B (Middle) and C (Upper) have salinity of about 35, 25 and 20 respectively, Zone D is 10.
State 3: Open stratified	1.0 – 15.0	The system is open and strongly stratified in Zone B and C due to increased flow. Zones A is about 30. In Zone B surface waters are about 10 and bottom waters 25, while in Zone C surface waters is about 5 and bottom waters 10. Zone D is fresh.
State 4: Freshwater dominated	> 15.0	All zones are fresh, with some tidal pumping on high tides into Zone A (Lower).

The transition between the different states will not be instantaneous, but will take place gradually.

To assess the occurrence and duration of the different abiotic states selected for the estuary during the different scenarios, a number of techniques were used:

- Colour coding (indicated above) was used to visually highlight the occurrence of the various abiotic states between different scenarios.
- Summary tables of the occurrence of different flows at increments of 10%iles are listed separately to provide an overview.

A summary of the typical physical and water quality characteristics of different abiotic states in the Mlalazi Estuary is provided in Chapter 4.

4 ECOLOGICAL BASELINE AND HEALTH ASSESSMENT

4.1 Hydrology

4.1.1 Baseline description

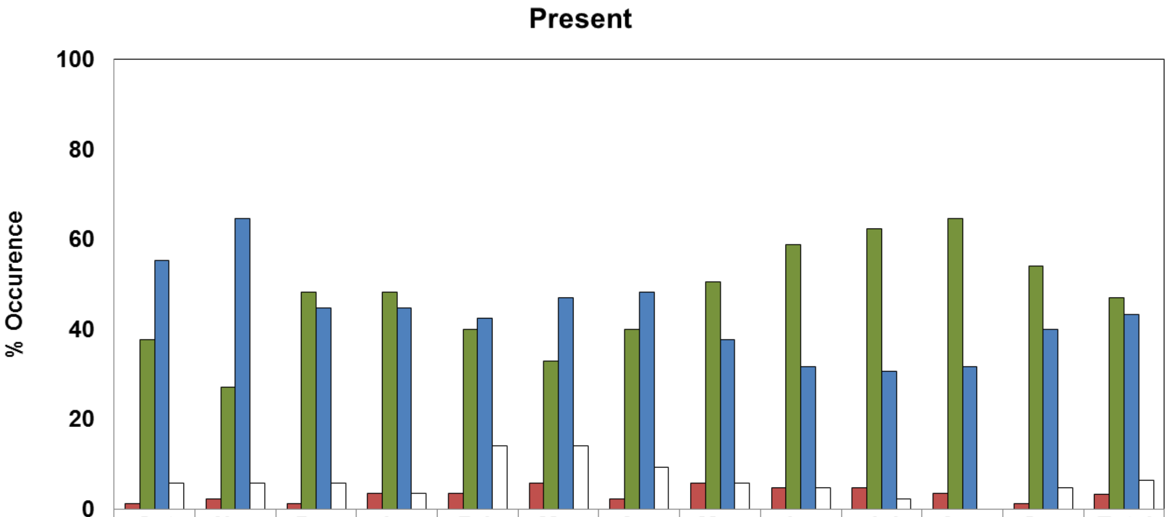
According to the hydrological data provided for this study, the present day MAR into the Mlalazi Estuary is 124.57 Million m^3. This is a decrease of 24% compared to the natural MAR of 164.31 Million m^3. The occurrences of flow distributions (mean monthly flows in m^3/s) for the Present State and Reference Condition of the Mlalazi Estuary, derived from the 85-year simulated data set, are provided in Table 4.1 and Table 4.2. A graphic representation of the occurrence of the various abiotic states is presented in Figure 4.1 and 4.2. The full 85-year series of simulated monthly runoff data for the present state and Reference Condition is provided in Table 4.3 and 4.4.

Table 4.1 A summary of the monthly flow (in m^3/s) distribution under the Present State.

%ile	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
99.9	35.8	31.0	42.8	54.0	67.1	103.9	41.6	45.3	31.9	41.6	14.2	94.2
99	29.8	27.5	32.2	25.3	58.8	50.4	35.1	26.9	27.1	29.9	13.3	36.4
90	10.2	12.0	10.9	9.1	19.2	18.6	14.2	8.1	6.9	5.4	4.4	5.4
80	5.9	5.9	4.7	5.3	12.2	10.5	5.6	5.0	1.9	1.5	1.5	2.4
70	4.3	4.9	2.1	3.7	5.6	5.9	3.6	1.6	1.2	1.1	1.0	1.3
60	2.8	3.2	1.5	1.5	2.8	4.3	2.0	1.2	0.8	0.8	0.8	1.1
50	1.5	1.9	1.0	0.9	1.6	2.2	1.2	0.8	0.7	0.7	0.7	0.9
40	1.0	1.2	0.8	0.6	0.9	1.1	0.9	0.7	0.6	0.6	0.6	0.7
30	0.8	1.0	0.6	0.5	0.6	0.7	0.6	0.5	0.5	0.5	0.5	0.6
20	0.6	0.8	0.5	0.4	0.4	0.5	0.4	0.4	0.4	0.4	0.4	0.5
10	0.4	0.6	0.4	0.4	0.3	0.4	0.3	0.3	0.3	0.3	0.3	0.4
1	0.3	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3
0.1	0.2	0.2	0.2	0.2	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2

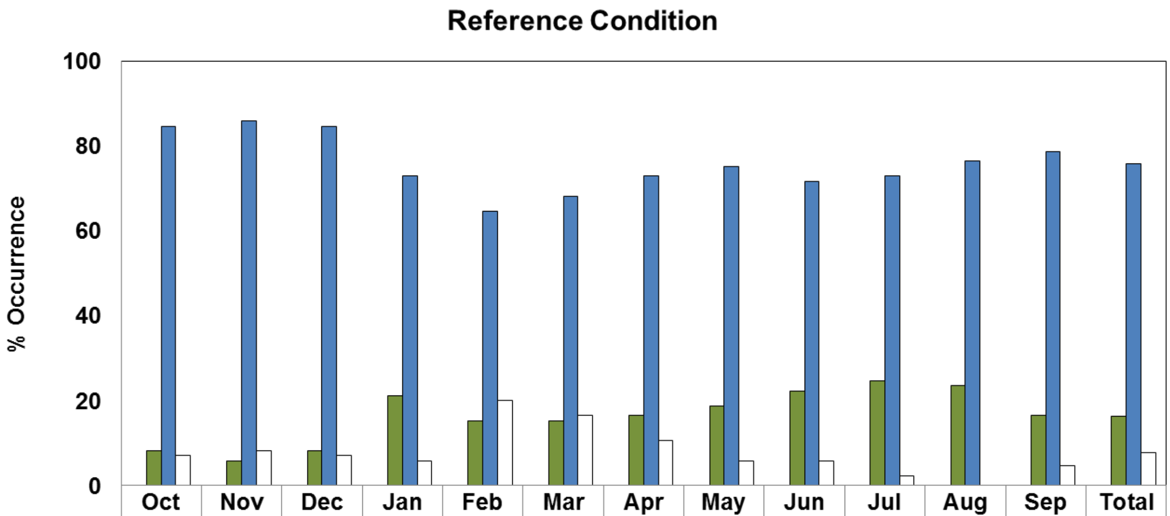
Table 4.2 A summary of the monthly flow (in m^3/s) distribution under the Reference State.

%ile	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
99.9	36.5	33.4	44.4	55.7	68.2	104.1	42.2	46.1	33.5	42.9	14.6	93.9
99	32.2	29.0	33.7	26.9	60.0	51.4	36.6	28.6	28.1	33.9	14.1	37.6
90	12.7	13.5	12.8	11.6	21.6	21.1	15.3	9.5	8.4	7.0	7.1	7.2
80	8.2	8.1	5.9	7.9	14.2	12.1	7.2	6.2	4.6	2.9	2.7	4.2
70	6.4	6.8	3.6	5.6	8.1	8.1	5.0	3.5	2.6	2.2	2.1	2.9
60	4.6	4.7	2.6	3.3	4.7	6.5	3.5	2.2	1.9	1.7	1.9	2.5
50	3.0	3.6	2.1	2.1	3.2	3.6	2.7	1.7	1.5	1.5	1.7	1.9
40	2.4	2.8	1.8	1.5	2.2	2.4	1.9	1.4	1.3	1.3	1.4	1.6
30	1.7	2.3	1.5	1.2	1.4	1.5	1.3	1.1	1.2	1.1	1.2	1.4
20	1.4	1.8	1.2	1.0	1.1	1.2	1.1	1.0	1.0	0.9	1.0	1.1
10	1.2	1.4	1.0	0.9	0.9	0.9	0.9	0.8	0.8	0.7	0.7	0.9
1	0.7	0.6	0.7	0.5	0.5	0.6	0.5	0.6	0.5	0.5	0.6	0.7
0.1	0.6	0.6	0.6	0.4	0.5	0.6	0.5	0.5	0.5	0.5	0.6	0.6



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
State 1	1	2	1	4	4	6	2	6	5	5	4	1	3
State 2	38	27	48	48	40	33	40	51	59	62	65	54	47
State 3	55	65	45	45	42	47	48	38	32	31	32	40	43
State 4	6	6	6	4	14	14	9	6	5	2	0	5	6

Figure 4.1 Graphic presentation of the occurrence of the various abiotic states under the Present State.



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
State 1	0	0	0	0	0	0	0	0	0	0	0	0	0
State 2	8	6	8	21	15	15	16	19	22	25	24	16	16
State 3	85	86	85	73	65	68	73	75	72	73	76	79	76
State 4	7	8	7	6	20	16	11	6	6	2	0	5	8

Figure 4.2 Graphic presentation of the occurrence of the various abiotic states under the Reference Condition.

Table 4.3 Mlalazi Estuary Present State simulated monthly flows (in m³/s).

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1920	1.16	0.79	2.03	1.43	0.63	3.37	2.09	1.02	0.65	0.45	0.33	1.28
1921	5.55	26.77	16.62	2.99	0.33	0.41	0.44	0.56	0.69	0.47	0.72	0.70
1922	2.82	7.53	2.47	11.57	4.66	0.42	0.30	0.24	0.22	0.24	0.23	0.22
1923	0.20	0.24	0.46	0.39	0.54	1.40	1.09	0.77	0.72	0.71	0.67	2.49
1924	1.69	12.36	11.14	4.76	16.97	109.79	42.30	16.66	5.57	1.33	0.97	1.10
1925	4.38	2.30	0.82	0.45	0.36	4.09	1.91	0.52	0.59	0.55	0.42	0.58
1926	1.84	1.46	1.31	0.96	0.95	10.46	3.91	0.72	0.62	0.73	0.74	0.68
1927	0.85	0.63	0.56	1.88	2.96	1.32	0.90	1.71	1.25	0.72	0.63	0.49
1928	0.50	0.37	0.27	1.33	0.85	26.17	9.75	1.16	1.55	1.40	1.87	3.48
1929	3.44	1.75	0.60	11.61	4.62	0.43	0.51	0.45	0.66	0.83	1.01	2.31
1930	1.39	1.01	0.90	0.44	0.41	0.43	0.54	0.42	0.41	0.48	0.40	0.39
1931	0.50	0.61	0.62	0.45	40.31	18.94	26.11	20.45	5.17	0.81	0.47	0.39
1932	0.55	0.91	2.14	1.37	1.13	0.77	0.51	0.31	0.25	0.27	0.35	0.38
1933	0.43	0.68	1.87	6.35	7.33	2.37	2.03	3.18	5.10	5.20	2.58	1.11
1934	0.72	0.73	11.56	4.26	0.81	0.67	0.61	4.15	32.49	10.83	6.31	2.67
1935	0.64	0.36	0.24	0.53	13.56	5.91	1.19	11.72	4.79	1.08	0.70	0.78
1936	1.89	17.65	5.59	0.46	5.96	4.76	1.94	0.75	0.61	0.65	0.76	0.67
1937	0.52	1.10	9.97	3.92	10.17	3.21	0.44	0.41	0.76	6.76	3.18	0.96
1938	0.87	0.57	0.66	0.54	16.27	10.35	2.50	7.18	3.35	1.77	1.28	13.07
1939	4.73	11.35	3.89	0.53	0.28	1.56	1.42	23.00	26.08	6.52	1.29	1.14
1940	0.93	12.51	6.89	1.39	0.38	0.40	0.46	0.36	0.41	0.42	0.37	0.48
1941	0.44	1.05	0.82	5.23	2.18	7.36	3.25	1.22	1.29	1.06	1.00	1.24
1942	1.08	4.98	16.16	5.13	0.68	17.99	27.98	7.62	0.97	5.80	9.21	3.22
1943	7.18	3.89	1.18	0.37	0.61	1.40	0.95	0.49	7.72	4.27	1.40	16.05
1944	5.91	3.80	1.52	0.38	3.05	20.92	7.30	0.65	0.44	0.31	0.31	0.27
1945	0.31	0.25	0.35	0.57	0.57	0.67	1.08	0.85	0.60	0.34	0.31	0.29
1946	0.45	0.42	0.44	0.42	7.08	7.87	3.65	1.31	1.21	1.83	1.43	1.31
1947	1.17	2.48	1.46	1.00	1.66	1.16	1.12	0.78	0.46	0.28	0.27	0.34
1948	0.42	0.57	0.42	0.36	1.43	0.97	15.68	5.46	0.84	0.65	0.52	0.61
1949	4.04	2.60	14.11	5.09	3.13	2.21	1.18	0.83	0.81	0.62	0.54	0.38
1950	0.32	0.21	0.37	0.40	0.34	0.44	0.44	0.41	0.49	0.60	6.89	4.31
1951	5.34	1.89	0.54	0.44	0.40	0.36	0.43	1.28	1.08	0.95	0.72	0.43
1952	0.29	0.45	0.55	0.45	0.53	0.70	0.50	0.39	0.32	0.31	0.32	0.67
1953	1.91	13.16	4.62	0.81	12.72	4.45	4.16	8.48	3.45	1.10	0.79	5.47
1954	25.99	8.75	0.44	1.74	1.19	13.85	5.48	1.20	0.82	0.48	0.50	0.78
1955	4.64	6.50	2.31	0.38	20.98	16.40	4.00	0.89	1.31	1.05	1.09	2.69
1956	1.70	1.26	30.00	12.60	7.20	4.45	14.83	5.04	0.73	0.78	0.95	19.36
1957	24.89	6.98	0.87	17.83	14.50	2.70	3.94	1.74	0.71	0.71	0.58	2.72
1958	2.29	1.12	0.65	0.60	0.43	0.22	0.16	0.35	0.42	0.34	0.57	1.33
1959	5.63	2.46	1.22	0.57	4.15	3.67	13.21	5.03	1.16	0.73	0.61	0.73
1960	0.75	21.62	44.00	13.25	10.33	3.59	19.17	6.68	11.00	5.09	1.34	1.28
1961	5.97	5.36	1.58	0.65	0.47	0.77	1.16	1.00	0.67	0.46	0.58	0.63
1962	1.05	4.70	2.03	1.66	1.15	5.50	4.14	1.22	16.66	42.88	13.10	0.69
1963	0.75	1.13	0.81	5.71	2.58	0.62	2.27	1.20	0.53	0.58	0.62	0.55
1964	7.13	3.25	0.88	0.38	0.27	0.20	0.28	0.40	1.70	1.28	5.15	5.35
1965	14.04	5.08	0.55	4.00	2.30	0.56	0.44	0.45	0.58	0.50	0.74	1.10
1966	0.91	0.69	0.42	0.55	0.97	12.59	33.78	10.01	0.72	0.70	0.78	0.56
1967	0.72	1.60	0.73	0.40	1.58	4.37	1.82	0.43	0.46	0.41	0.75	1.14
1968	1.38	1.42	2.14	0.81	0.26	24.67	11.00	3.29	1.66	0.83	0.48	0.71
1969	7.32	3.08	0.60	0.38	0.36	0.35	0.41	1.44	1.18	0.66	0.46	0.60
1970	11.10	9.46	2.18	0.78	2.05	5.90	6.03	47.30	16.38	7.02	2.99	1.18
1971	8.28	3.38	0.84	2.99	36.09	11.91	1.48	10.34	4.42	1.36	0.88	0.50
1972	0.46	0.71	1.09	0.90	1.00	0.74	1.77	1.17	0.63	0.47	6.91	24.14
1973	7.64	2.01	1.11	7.31	3.19	0.69	0.60	1.63	1.40	0.94	0.68	0.42
1974	0.30	1.10	0.93	5.37	21.19	6.43	1.03	0.76	0.58	0.51	0.52	8.84
1975	3.70	1.20	2.05	19.23	12.13	39.14	23.03	5.11	1.28	0.80	0.91	0.84
1976	4.05	3.12	8.23	5.95	57.04	27.17	3.94	0.50	0.35	0.32	0.46	1.70
1977	1.45	1.20	1.03	14.28	5.83	1.59	8.98	3.33	0.84	0.96	1.19	1.40
1978	12.71	5.06	0.60	0.38	0.30	0.22	0.33	1.01	1.02	0.83	0.84	2.19
1979	1.52	1.43	1.09	0.72	0.46	0.26	0.25	0.23	0.26	0.24	0.27	6.94
1980	2.90	0.83	0.45	1.78	2.74	1.08	0.71	15.27	7.98	1.71	1.95	9.04
1981	4.82	6.94	2.34	0.49	0.45	1.31	1.05	0.82	0.59	0.40	0.28	0.35
1982	0.88	0.81	0.38	0.23	0.25	0.19	0.20	0.22	0.29	0.47	2.82	1.50
1983	2.88	14.26	4.89	57.14	67.98	17.61	6.81	2.43	0.95	12.35	7.60	1.82
1984	0.85	1.03	0.89	5.56	37.33	11.02	0.36	0.22	0.41	0.81	0.78	0.88
1985	28.55	10.27	0.54	0.38	0.41	0.50	0.75	0.49	0.52	0.38	0.31	0.42
1986	0.62	0.67	5.88	10.27	3.22	4.82	2.22	0.71	14.36	5.53	14.29	100.58
1987	36.46	3.39	1.19	0.41	12.75	18.96	5.55	0.54	0.65	0.70	0.71	0.86
1988	5.32	5.79	19.73	6.37	13.28	4.29	0.44	0.45	0.60	0.74	0.53	0.71
1989	1.11	31.36	10.58	0.69	0.63	6.26	2.92	0.92	0.57	0.33	2.33	1.46
1990	8.74	3.46	1.78	2.55	15.77	21.31	6.08	6.19	2.92	1.14	0.98	0.88
1991	1.15	0.94	0.50	0.24	0.13	0.23	0.30	0.22	0.19	0.18	0.21	0.28
1992	0.32	0.85	0.64	0.45	0.48	0.41	0.34	0.26	0.24	0.21	0.31	0.53
1993	14.51	5.80	0.99	1.18	0.68	0.47	0.37	0.28	0.27	0.28	0.51	0.61
1994	6.23	2.95	0.57	0.16	0.22	5.75	23.23	7.58	8.62	3.64	1.09	0.62
1995	1.01	4.97	11.73	7.39	20.76	10.55	2.29	0.75	0.52	3.28	1.75	0.57
1996	0.68	0.80	0.44	4.30	2.29	0.63	0.72	0.96	1.23	1.21	0.93	1.33
1997	3.04	19.54	6.16	0.30	0.45	0.34	0.37	0.31	0.24	0.30	0.28	0.38
1998	0.59	0.93	0.70	1.76	20.87	6.53	0.58	0.44	0.39	0.54	0.77	1.17
1999	15.85	5.73	0.66	0.57	0.68	0.63	0.65	0.83	0.67	0.40	0.26	0.28
2000	0.31	3.62	1.72	1.18	1.24	0.69	0.59	0.46	0.34	0.28	0.22	0.39
2001	2.72	5.11	4.14	4.87	2.06	0.68	0.55	0.33	0.39	27.42	10.83	1.49
2002	0.94	1.05	0.68	0.39	0.43	0.27	0.34	0.37	0.86	1.02	0.69	0.78
2003	0.71	0.74	0.40	0.59	7.75	5.47	1.76	0.59	0.34	0.59	0.69	0.86
2004	0.71	1.77	0.79	0.47	0.75	1.82	0.91	0.39	0.47	0.40	0.31	0.28

Table 4.4 Mlalazi Estuary Reference Condition simulated monthly flows (in m^3/s).

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1920	5.05	2.27	4.34	3.10	1.27	6.87	3.78	1.71	1.13	0.71	0.62	3.54
1921	7.87	28.06	17.81	3.80	0.64	1.06	1.16	1.35	1.57	1.08	1.67	1.63
1922	5.80	9.59	3.36	14.60	6.46	0.86	0.68	0.62	0.55	0.62	0.67	0.58
1923	0.56	0.65	1.43	1.09	1.29	3.40	2.70	1.77	1.66	1.46	1.38	5.17
1924	3.42	13.66	12.66	6.49	18.47	110.00	42.88	17.38	6.61	2.68	1.99	2.43
1925	6.02	3.60	1.54	0.98	0.89	8.60	4.00	0.98	1.31	1.36	0.99	1.42
1926	4.35	3.14	2.49	1.92	2.00	13.18	5.43	1.40	1.39	1.64	1.72	1.47
1927	1.93	1.46	1.20	4.17	5.57	2.50	1.81	3.41	2.44	1.33	1.27	1.13
1928	1.18	0.95	0.67	4.01	2.34	29.82	11.90	1.91	3.02	2.87	3.15	4.57
1929	4.57	2.85	1.21	15.11	6.62	0.91	1.20	1.21	1.64	1.99	2.27	4.59
1930	2.72	1.99	1.86	1.02	0.94	1.21	1.47	1.08	0.98	1.26	1.05	0.96
1931	1.39	1.52	1.47	1.12	45.25	21.15	27.06	21.17	6.32	1.42	0.89	0.92
1932	1.39	2.37	4.11	2.64	2.36	1.62	1.05	0.71	0.60	0.69	1.03	1.11
1933	1.19	2.17	3.82	8.89	9.55	3.65	3.63	4.29	6.08	6.14	3.71	2.01
1934	1.37	1.59	14.66	6.00	1.66	1.54	1.40	7.51	34.06	11.98	7.22	3.53
1935	1.19	0.86	0.63	2.41	17.79	8.15	2.08	13.78	6.46	1.99	1.33	1.63
1936	3.88	19.14	6.52	0.91	10.42	7.21	3.16	1.44	1.11	1.50	1.75	1.53
1937	1.21	2.90	12.89	5.61	12.13	4.27	0.86	1.08	1.95	10.16	5.32	1.84
1938	1.71	1.25	1.40	1.40	20.65	12.72	3.52	9.16	4.95	3.07	2.34	14.15
1939	5.88	13.15	5.04	1.08	0.73	4.76	3.37	24.85	27.01	7.62	2.53	2.28
1940	1.78	14.62	8.84	2.24	0.85	1.05	1.33	0.92	1.06	1.22	0.99	1.31
1941	1.23	2.99	2.07	8.50	3.83	10.41	5.14	2.24	2.53	2.07	1.97	2.51
1942	2.13	6.98	17.63	6.12	1.38	21.35	29.74	8.74	1.89	7.75	10.27	4.19
1943	8.89	5.57	2.22	0.83	1.73	3.17	2.00	1.03	11.42	6.21	2.42	17.21
1944	7.33	5.31	2.33	0.84	7.34	23.18	8.43	1.27	0.96	0.78	0.83	0.76
1945	0.86	0.75	0.92	1.91	1.54	2.15	2.44	1.77	1.17	0.74	0.71	0.78
1946	1.27	1.14	1.06	1.11	12.29	10.49	5.00	2.30	2.36	3.16	2.63	2.53
1947	2.27	3.96	2.57	2.21	3.09	2.29	2.29	1.57	0.88	0.63	0.66	0.93
1948	1.26	1.64	1.08	0.85	3.91	2.34	18.79	7.10	1.39	1.37	1.11	1.37
1949	7.24	4.66	15.48	6.25	5.53	3.94	2.26	1.62	1.67	1.31	1.16	0.96
1950	0.82	0.59	0.93	1.19	0.87	1.16	1.24	1.00	1.27	1.49	10.96	6.37
1951	6.54	2.69	1.05	1.21	1.01	0.94	1.17	3.51	2.51	1.98	1.54	0.88
1952	0.68	1.20	1.47	1.15	1.33	1.65	1.25	0.87	0.75	0.74	0.84	2.16
1953	4.08	15.37	5.91	1.53	15.87	6.19	6.08	9.66	4.70	2.04	1.43	7.61
1954	27.08	9.68	1.10	4.32	2.73	16.56	7.37	2.27	1.54	0.94	1.08	1.88
1955	7.75	8.50	3.35	0.89	25.67	18.63	5.04	1.73	2.91	2.20	2.25	3.92
1956	2.91	2.54	31.47	14.17	9.01	6.10	15.90	6.08	1.29	1.70	2.11	21.56
1957	26.01	8.06	1.80	20.49	16.68	3.63	7.07	3.24	1.27	1.54	1.32	5.77
1958	4.17	2.01	1.27	1.39	1.09	0.56	0.46	1.04	1.33	0.86	1.96	3.53
1959	8.15	3.87	2.58	1.32	8.19	5.98	14.36	6.40	2.07	1.33	1.28	1.64
1960	1.74	24.63	45.62	14.46	12.18	4.80	21.06	8.11	12.37	6.34	2.37	2.61
1961	7.34	6.91	2.44	1.34	1.18	2.43	2.84	2.11	1.30	0.94	1.39	1.57
1962	2.80	7.41	3.38	3.18	2.31	8.09	5.98	1.99	18.68	43.88	14.04	1.53
1963	1.65	2.46	1.66	8.76	4.29	1.26	5.10	2.57	0.95	1.29	1.52	1.28
1964	10.76	5.41	1.72	0.84	0.65	0.59	0.78	1.19	5.12	3.25	7.03	6.69
1965	14.87	6.23	1.09	7.65	4.51	1.15	0.89	1.18	1.47	1.28	1.83	2.53
1966	1.99	1.44	0.97	1.31	2.65	15.69	35.35	10.96	1.37	1.50	1.79	1.21
1967	1.68	3.54	1.64	0.89	3.96	7.12	3.04	0.81	1.00	1.10	1.93	2.52
1968	2.91	2.89	3.91	1.64	0.59	29.76	13.55	4.35	2.62	1.52	0.93	1.57
1969	10.15	4.72	1.16	0.92	0.95	0.99	1.16	4.02	2.74	1.28	0.98	1.39
1970	14.53	11.62	3.02	2.12	3.80	7.98	7.75	48.09	17.33	8.39	4.15	2.36
1971	9.48	4.43	1.64	5.65	38.00	13.31	2.89	11.64	5.89	2.55	1.60	0.93
1972	1.03	1.74	2.81	2.08	2.33	1.64	3.43	2.36	1.19	0.96	10.26	25.72
1973	8.71	3.63	2.06	9.92	4.83	1.42	1.35	3.67	2.95	1.84	1.31	0.91
1974	0.75	3.27	2.27	8.37	23.18	7.63	1.96	1.58	1.18	1.11	1.27	12.53
1975	5.90	2.24	3.64	20.77	13.81	40.21	23.91	6.21	2.07	1.50	1.96	1.82
1976	6.55	4.92	9.80	7.81	58.24	28.04	4.83	0.94	0.81	0.83	1.24	4.49
1977	3.26	2.37	2.06	16.41	7.51	3.05	10.78	4.48	1.54	2.06	2.52	2.90
1978	14.00	6.43	1.21	0.86	0.84	0.63	0.93	3.47	2.75	1.73	1.78	4.44
1979	3.02	2.76	2.14	1.48	1.04	0.64	0.66	0.66	0.70	0.69	0.74	12.97
1980	5.40	1.52	1.02	4.22	5.34	2.09	1.41	18.11	9.61	2.61	3.17	9.92
1981	5.90	8.33	3.19	1.04	1.20	3.24	2.42	1.73	1.24	0.85	0.71	0.92
1982	3.00	2.11	0.82	0.57	0.68	0.59	0.55	0.62	0.82	1.50	7.53	3.92
1983	4.54	15.63	6.00	58.92	69.10	18.69	8.31	3.41	1.86	14.03	8.86	2.65
1984	1.67	2.20	1.88	8.48	39.21	11.93	1.06	0.53	1.20	2.34	1.89	2.02
1985	31.35	11.90	1.20	0.92	1.16	1.40	1.87	1.21	1.16	1.01	0.77	1.15
1986	1.72	1.63	9.73	12.66	4.21	8.42	4.06	1.34	16.83	7.43	14.68	100.18
1987	36.95	4.78	2.26	0.93	17.21	21.08	6.55	1.02	1.48	1.67	1.63	1.93
1988	8.25	7.90	21.02	7.40	16.47	5.91	0.88	1.07	1.50	1.77	1.30	1.65
1989	2.92	33.83	12.02	1.49	1.37	9.99	5.01	1.75	1.07	0.73	5.88	3.36
1990	10.44	4.70	3.49	4.45	17.45	22.51	7.12	8.56	4.53	2.18	1.95	1.73
1991	2.62	2.00	1.03	0.60	0.45	0.60	0.95	0.65	0.49	0.49	0.62	0.85
1992	0.99	3.07	1.85	1.00	1.19	1.06	0.81	0.60	0.56	0.53	0.82	1.55
1993	20.17	8.06	2.05	2.43	1.41	0.98	0.91	0.63	0.63	0.73	1.58	1.74
1994	10.28	5.10	1.15	0.38	0.50	11.82	25.96	8.74	9.64	4.91	2.01	1.11
1995	2.52	7.39	13.41	9.21	22.28	11.97	3.31	1.44	1.06	6.43	3.46	1.02
1996	1.47	1.87	1.02	8.51	4.58	1.28	1.55	2.13	2.69	2.40	1.80	2.74
1997	4.68	20.78	7.07	0.65	1.22	0.99	0.94	0.86	0.62	0.79	0.88	1.06
1998	1.89	2.48	1.74	3.42	23.50	7.88	1.03	1.00	0.96	1.34	1.87	3.07
1999	18.23	7.11	1.31	1.37	1.63	1.53	1.54	1.89	1.52	0.87	0.60	0.70
2000	0.91	8.55	3.83	2.59	2.86	1.49	1.20	1.09	0.78	0.65	0.59	1.06
2001	7.18	7.77	5.78	6.66	3.21	1.38	1.22	0.76	0.95	32.01	13.02	2.81
2002	1.81	2.33	1.46	0.85	1.10	0.74	0.83	1.09	3.16	2.61	1.41	1.69
2003	1.62	1.57	0.94	1.83	11.62	7.70	2.75	1.09	0.69	1.40	1.78	1.94
2004	1.64	3.76	1.78	0.98	1.86	3.56	1.88	0.78	1.11	1.06	0.75	0.69

4.1.2 Low flows

Seasonal base flows are very similar to that of the Reference Conditions (Table 4.5), thereby maintaining open mouth conditions and ingress of salinity into the middle and upper reaches of the estuary. Overall base flows have been reduced by about 58% to the estuary.

Table 4.5 Summary of the change in low flow conditions to the Mlalazi Estuary from the Reference Condition to the Present State.

Percentile	Monthly flow (m^3/s)		% Remaining
	Natural	Present	
30%ile	1.3	0.6	44.6
20%ile	1.1	0.5	41.7
10%ile	0.9	0.4	41.1
% Similarity in low flows			**42.5**

Confidence: Low

4.1.3 Flood regime

To provide an indication of the change in flood regime from the Reference Condition to the Present State the twenty highest simulated monthly flow volumes were compared for the 85-year period (summarised Table 4.6). The analysis of the simulated monthly flow data indicate that under Reference Conditions floods were about 12 % higher than at present, depending on the size class.

Table 4.6 Summary of the ten highest simulated monthly volumes to the Mlalazi Estuary under Reference Condition and Present State.

Date	Monthly Volume (x10^6 m^3/month)		% Remaining
	Natural	Present	
Mar-25	294.63	294.05	99.8
Sep-87	259.67	260.71	100.4
Feb-84	168.65	165.92	98.4
Jan-84	157.82	153.05	97.0
Feb-77	142.15	139.22	97.9
May-71	128.81	126.68	98.3
Dec-60	122.2	117.85	96.4
Jul-63	117.53	114.85	97.7
Apr-25	111.15	109.65	98.7
Feb-32	110.45	98.39	89.1
Mar-76	107.71	104.83	97.3
Oct-87	98.98	97.65	98.7
Feb-85	95.71	91.11	95.2
Feb-72	92.74	88.09	95.0
Apr-67	91.64	87.55	95.5
Jun-35	88.28	84.21	95.4
Nov-89	87.7	81.28	92.7
Jul-02	85.74	73.44	85.7
Dec-56	84.28	80.35	95.3
Oct-85	83.96	76.48	91.1
% Similarity in floods			**87.8**

Confidence: Low

4.1.4 Hydrological health

Table 4.7 provides a summary of the hydrological health of the Mlalazi Estuary.

Table 4.7 Calculation of the hydrological health score.

Variable	Summary of change	Score	Conf
a.% Similarity in period of low flows	Overall a 57% reduction in base flows to the estuary	43	L
b.% Similarity in mean annual frequency of floods	The simulated monthly flow data indicate that under Reference Conditions floods were 12 % higher than at present.	88	L
Hydrology score		**61**	**L**

4.2 Physical habitat

4.2.1 Baseline description

Begg (1978) indicated that the sediment distribution in the Mlalazi Estuary is determined by the system's geomorphology (size and shape) and current velocities (river inflow and tidal). Soft muds dominated in permanently submerged or inter-tidal areas where flow velocities were low. Where velocities were higher, the substrate became more sandy in nature. Muds tend to form hard clay beds in the supra-tidal and flood plain areas where inundation occurs less regularly. Rocky outcrops occur as low reefs about 200m above the railway bridge. Particle size and chemical analyses undertaken in 1971 indicate that in some places the muds were associated with fine organic sediments that were anaerobic and contained high sulphide concentrations (Begg 1978). Some variability was observed before and after floods, with less muds and fine organics occurring in the systems after floods.

Recent sediment surveys conducted in May 2013 show that medium size sandy substrate dominate the lower reaches (Zone A) of the system, with areas of high muds occurring in some parts. The middle reaches (Zone B) are dominated by muds and fine sands, while the upper reaches (Zone C) vary between course to medium sands and muds, depending on the channel configuration. The riverine section (Zone D) is dominated by course to very coarse grain sands. The limited core data available show a tendency towards a finer subsurface substrate, which confirms Begg's (1978) findings that the system can vary somewhat depending on how much time has lapsed since the last flood as finer sediments are relatively easily washed out during high flow events. During this survey the % organic material varied between 0.01 and 4.89% (unpublished CRUZ data).

Table 4.8 Mlalazi Estuary grain size data for May 1913 (unpublished CRUZ data).

	Zone D	Zone C		Zone B	Zone A		Zone C	Zone B	Zone A	
Sample	**A**	**1**	**2**	**4**	**6**	**7**	**Core 2**	**Core 4**	**Core 6**	**Core 7**
%Gravel	17.75	2.26	0.74	0.07	0.00	0.03	0.18	2.82	0.07	0.00
%vcs	34.42	7.08	3.25	0.15	0.18	0.55	1.65	5.71	0.32	0.05
%cs	**37.33**	10.32	30.04	0.93	1.64	16.95	13.39	11.19	22.33	1.40
%ms	9.33	16.42	**54.79**	18.09	**50.27**	**68.47**	**26.96**	31.19	**71.96**	42.47
%fs	0.98	22.52	8.80	28.41	8.82	12.45	**27.65**	**32.12**	3.51	**44.32**
%vfs	0.00	1.43	0.56	11.78	1.54	0.58	9.57	8.76	0.35	3.08
%mud	0.19	**39.98**	1.83	**40.56**	37.55	0.97	20.61	8.20	1.45	8.69
Mean (phi)	-0.12	2.65	1.23	3.13	2.69	1.43	2.49	1.87	1.27	2.13
Mean (mm)	1.09	0.16	0.43	0.11	0.16	0.37	0.18	0.27	0.42	0.23
Median (phi)	-0.06	2.72	1.21	2.89	1.97	1.38	2.22	1.98	1.26	2.08
Median (mm)	1.04	0.15	0.43	0.13	0.25	0.38	0.21	0.25	0.42	0.24
Sorting	1.00	1.80	0.66	1.18	1.33	0.54	1.46	1.30	0.45	0.73
Skewness	-1.14	-3.18	0.06	2.06	7.11	0.27	2.79	-0.50	0.07	2.56
% Organics	0.01	**4.89**	0.10	1.90	1.46	0.14	0.60	0.06	0.10	0.11

Under the Reference Condition there would have been less sediments coming from the catchment. Poor land-use practises (e.g. sugar cane farming up to the river's edge) are at present leading to more sediment, especially finer fractions, entering the system (Begg 1978).

In addition to changes in substrate composition, some intertidal habitat has also been lost due to inappropriate bank protection in the lower reaches (Zone A). The hardening of the estuary banks leads to an increase in wave/tidal/flow energy and a related erosion of intertidal habitat as it prevents a gentle slope from forming.

Figure 4.3 Loss of intertidal habitat in the Mlalazi Estuary due to bank protection (Photos: P Huizinga).

A key issue of concern was the establishment of a mangrove stand in a historic part of the "bend" in Zone B. While some concerns have been raised that this mangrove patch is an indicator of sedimentation in the system, it should be noted that mangroves also respond to changes in tidal levels (e.g. as a consequences of the 1965 channel dredging or the stabilisation of the inlet in the 1970s). In addition it should also be noted that siltation of old estuary channels is a natural process and not necessarily an indicator of sedimentation. However it should be noted that Begg (1978) recorded that during the dredging process, dredge spoil was deposited in the *Phragmites* swamp at the end of the bend, i.e. there is some uncertainty around the localised impacts of old dredge operations in the Mlalazi Estuary and the related disposal of such spoil. The dredging during the 1960's was done in response to the farmers' concerns about the increasing frequencies of mouth closure. This enabled the mouth to stay open for a much greater proportion of the time, creating a habitat that was suitable for mangroves to survive in.

Figure 4.4 Localised colonisation of intertidal areas by mangroves, total area in Zones A, B & C is 40 ha.

4.2.2 Physical habitat health

Table 4.9 provides a summary of the hydrological health of the Mlalazi Estuary.

Table 4.9 Calculation of the physical habitat score and adjusted score (net of non-flow impacts).

Variable		Score	Motivation	Conf.
1. Resemblance of intertidal sediment structure and distribution to Reference condition				
1a	% Similarity in intertidal area exposed	85	Sedimentation processes are similar to Reference Conditions, but there is some loss of intertidal habitat due to deposition and infilling of the intertidal habitat. During States 1 there is also less exposed intertidal habitat to increased mouth closure and greater mouth restriction. There have also been losses of the upper intertidal habitat due to draining and planting to sugar. This has been mainly on the north bank downstream of the railway bridge.	M
1b	% Similarity in sand fraction relative to total sand and mud	90	Information is lacking on changes in % similarity in sand fraction relative to total sand and mud, but the score of 90 is based on an increase in clay and silt fractions experienced in similar systems, especially in Zone B, C and D.	M
2	% Similarity in subtidal components: depth, bed or channel morphology	90	There has been some infilling of sub-tidal areas as a result increased sediment yield from the catchment. The 12% loss of floods would also impact on the sediment deposition/scouring process leading to some infilling.	M
	Physical habitat score	**89**		**M**

Anthropogenic influence:			
Percentage of overall change in intertidal and supratidal habitat caused by **anthropogenic** activity as opposed to modifications to water flow into estuary	60	Poor agricultural practises and developments in the catchment are causing degradation and changes in sedimentation- this is especially relevant.	M
Percentage of overall change in subtidal habitat caused by **anthropogenic** modifications (e.g. bridges, weirs, bulkheads, training walls, jetties, marinas) rather than modifications to water flow into estuary	40	Poor agricultural practises and developments in the catchment are causing degradation and changes in sedimentation.	M

[1] $Score = \frac{(\min(a\ to\ d) + mean(a\ to\ d))}{2}$

4.3 Hydrodynamics

4.3.1 Baseline description

The Mlalazi Estuary lies deflected behind a 3.5 km long north extending sandbar. The origin of this sand is largely contributed to the Tugela and wave energy. The greater part of this sandbar is colonised by dune forest and forms a stable spit.

The Mlalazi mouth is dynamic, showing some variation in its configuration over time. An analyse of historical aerial photographs and recent satellite imagery (Figure 4.5 and Figure 4.11) of the mouth shows that at times the mouth position can vary by almost 1 km in a North-South direction. Under these conditions the remnant channel forms a blind inlet north of the present mouth.

Begg (1978) recorded that granite boulders were laid down in the mouth region in 1962, at the foot of the dunes on the west bank, to prevent erosion into the estuary. By the addition of sand bags and dolosse over time this structure acted as a “training berm” to direct the flood water away from the dunes. This was to prevent dune slumping and possibly assist in maintaining an open mouth state. It was partially destroyed by floods in May 1971.

According to Begg (1978) the Mlalazi mouth remained permanently open between 1952 and 1987. He states that before 1952 mouth closure was a regular event and that as far back as 1912 farmers used to open the mouth to prevent the flooding of sugar cane.

The Ezemvelo KZN Wildlife weekly mouth observation database shows that the Mlalazi Estuary was open for about 96% of the time during the period 1993 to 2013. The record also shows that the system is closed for weeks at a time. Historical data indicate that under the hydraulic constraint of the estuary mouth, low neap tide levels are lower than the spring tide (the reverse of what occurs at sea) (Begg 1978). This was because the volume of water which enters the estuary on a spring high tide does not have to time to escape before the next tide starts rising. The tidal data pattern is less clear in recent data sets (DWS tidal recorder W1T001) collated over the past year, but could just be a reflection of the fact that the mouth was relatively open during the observation period showing lower tides on the spring tides.

After floods, which can scour the mouth wide open, this effect is expected to be reversed with low tide levels being the lowest during spring tides. A tidal variation of 0.9 m has been recorded at the bend. Tidal variation has also been noted at the railway bridge. Recent satellite imagery also shows a severely constrained mouth at times (e.g. June 2006 and July 2010).

Figure 4.5 Historical image of the Mlalazi Estuary showing an open mouth – 1937.

Figure 4.6 Historical image of the Mlalazi Estuary showing an open mouth – 1957.

Figure 4.7 Historical image of the Mlalazi Estuary showing an open mouth – 1961.

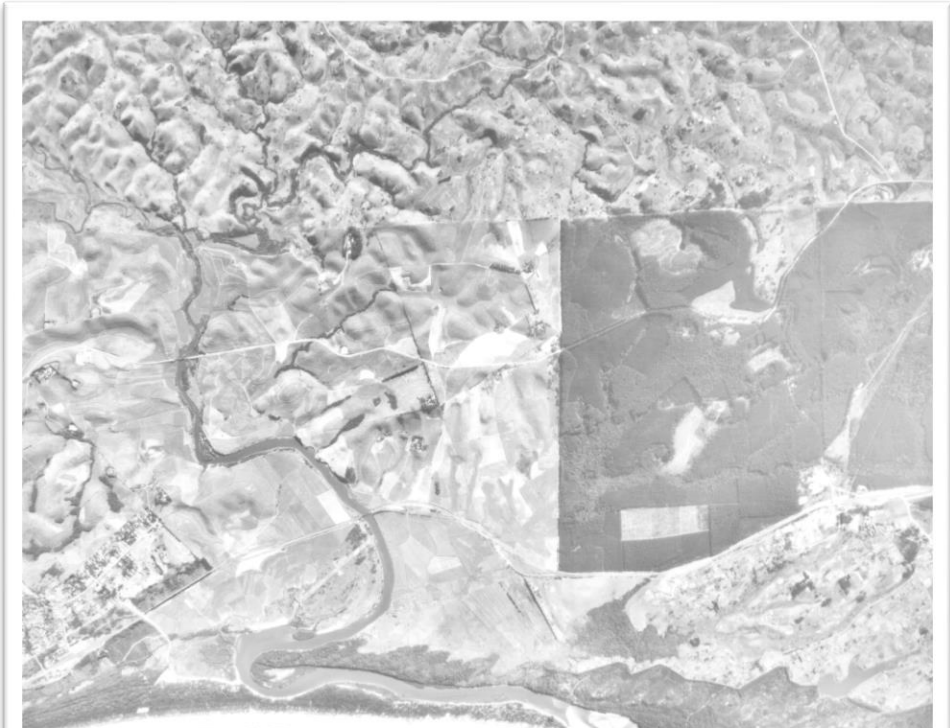


Figure 4.8 Historical image of the Mlalazi Estuary showing an open mouth – 1975.

Figure 4.9 Satellite image of the Mlalazi Estuary – 2 June 2006 (Google Earth).

Figure 4.10 Satellite image of the Mlalazi Estuary - 22 July 2010 (Google Earth).

Figure 4.11 Satellite image of the Mlalazi Estuary – 3 May 2014 (Google Earth).

Table 4.10 provides a summary of the hydrodynamics characteristics associated the typical abiotic states occurring in the Mlalazi Estuary.

Table 4.10 Summary of the abiotic states, and associated hydrodynamic characteristics.

PARAMETER	State 1: Closed, brackish	State 2: Open, gradient	State 3: Open, stratified	State 4: Open, fresh
Flow range (m^3/s)	<0.25	0.25 – 1.0	1.0 – 15.0	>15.0
Mouth condition	Closed	Open	Open	Open
Water level (m to MSL)	1.5 – 2.0 (can reach ~3 m MSL if closed for extended periods)	1.5	1.5	1.5, but can increase significantly during floods to 3 m MSL
Inundation	Yes, back flooding during closed state	N/A	N/A	Yes, during floods
Tidal range (m)	0	0.3 – 1.0	0.3 – 1.5	2.0 m, but suppressed during floods
Dominant circulation process	Wind	Tides	Tides and river	River
Retention	Weeks to months	2 – 3 weeks	1 - 2 weeks	< 1 day

4.3.2 Hydrodynamic health

Table 4.11 provides a summary of the hydrodynamic health of the Mlalazi Estuary.

Table 4.11 Calculation of the hydrodynamics score.

Variable	Summary of change	Score	Conf
Hydrodynamics and mouth conditions score	Mouth closure occurs for about 3-4% of the time under the Present State, while under the Reference Condition it used occur very seldom.	97	L
Hydrodynamic score		**97**	**L**

4.4 Water quality

4.4.1 Baseline description

Table 4.12 presents a summary of the water quality characteristics for the various states, in each of the four zones. This summary is derived from available information on the estuary. Water Quality stations are depicted in Figure 4.12.

Figure 4.12 Water Quality sampling sites.

4.4.2 Salinity

While a large number of salinity observations are available for the Mlalazi, only a subset of these observations cover the whole estuary, i.e. from the mouth to the top (Zone A to D). In addition it should be noted that only surface and bottom observations are available, which means that very little information is available on the stratification of the system. This study draws from monthly data collected between August 1999 to July 2000 and in September 2012 (See Appendix B for data).

Measurements taken during low flow periods, indicative of open marine conditions (State 2), show that the Mlalazi Estuary is between 35 and 30 in Zone A, 30 and 25 in Zone B and 25 and 20 in Zone C (Figure 4.13). The salinity profile is well mixed throughout.

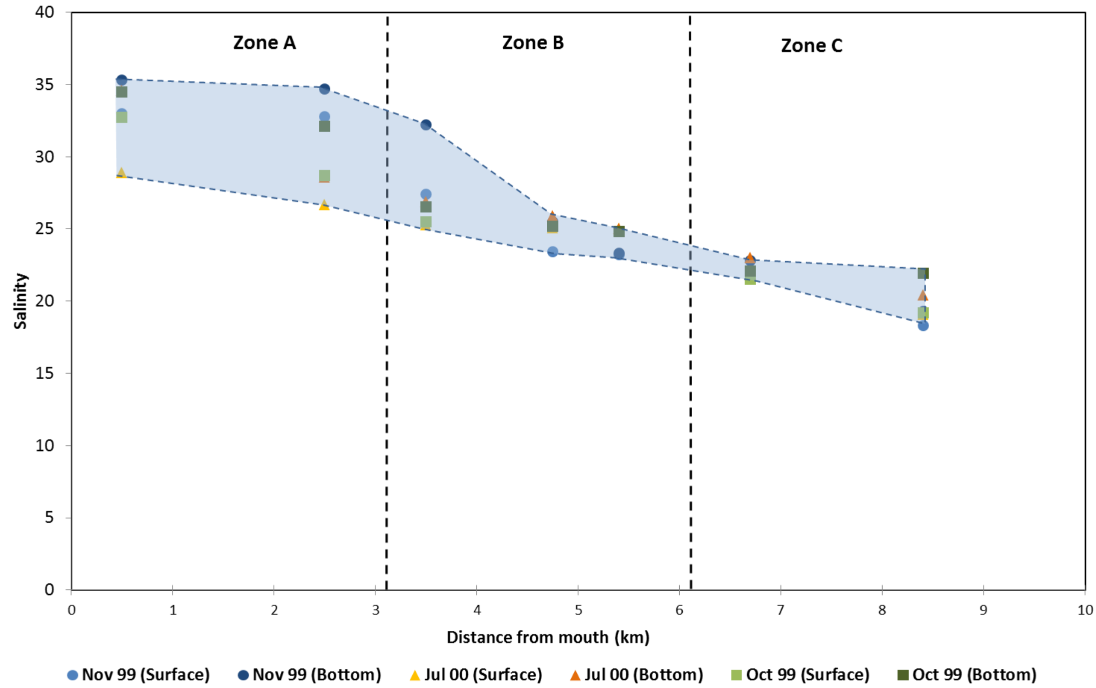


Figure 4.13 Salinity measurements indicative of an open marine state (State 2).

As river inflow increases the surface and bottom waters of the Mlalazi Estuary start to stratify significantly (Figure 4.14). Under these intermediate flow conditions salinity in Zone A vary between 25 to 15 on the surface, and 30 and 35 on the bottom. Zone B surface salinity varies between 15 and 5, with bottom waters between 15 and 30. In Zone C surface salinity varies between 10 and 1, while bottom waters vary between 20 and 5.

Measurements taken during high flows, indicative of open freshwater dominated conditions (State 4), show that the Mlalazi Estuary is fresh throughout with only pockets of marine water sitting in deeper areas (Figure 4.15).

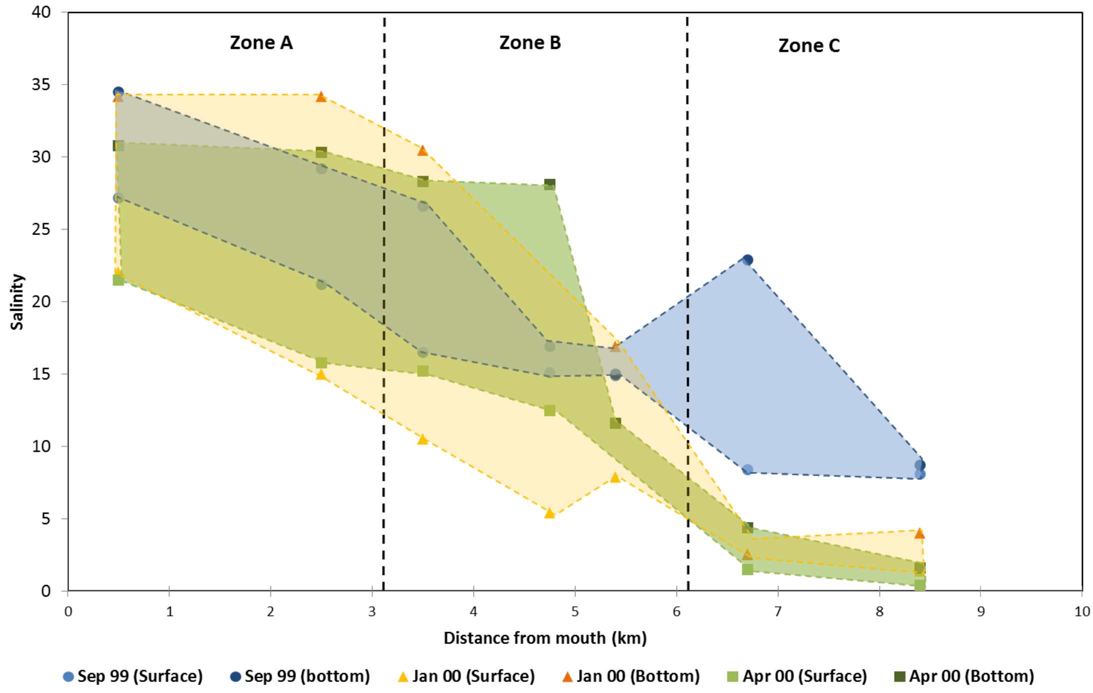


Figure 4.14 Salinity measurements indicative of an open stratified state (State 3).

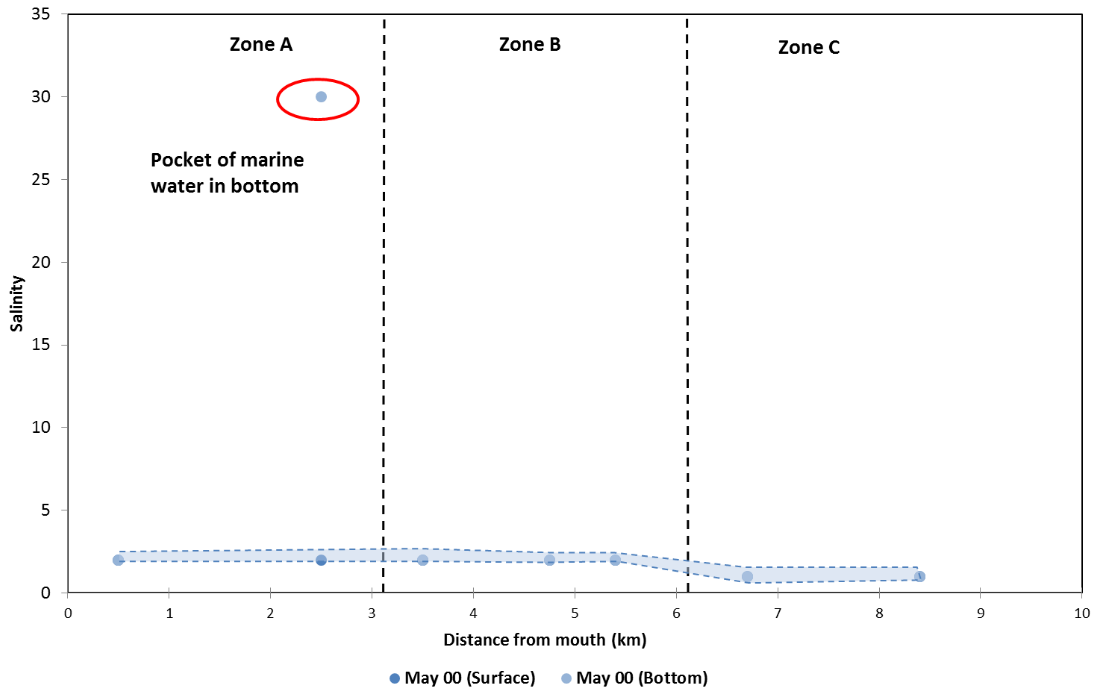


Figure 4.15 Salinity measurements indicative of a freshwater dominated state (State 4).

Table 4.12 Summary of water quality characteristics of different abiotic states in the Mlalazi Estuary (differences in state between reference condition and present state and future scenarios – due to anthropogenic influences other than flow - are indicated) (R = Reference, P = Present, T = Top, B = Bottom, O = Open & C = Closed).

Parameter	State 1: Closed Mouth	State 2: Open, Gradient	State 3: Open, Stratified	State 4: Open, Freshwater dominated
Salinity	25 25 20 15	35 25 20 10	25 10 5 0 30 20 10	5 0 0 0
Temperature (ºC)	Summer 24.0 - 29.5 Winter 18.0 - 21.5	Summer 24.0 - 29.5 Winter 18.0 - 21.5	Summer 24.0 - 29.5 Winter 18.0 - 21.5	Summer 24.0 - 29.5 Winter 18.0 - 21.5
pH	6.5 - 8.8	6.5 - 8.8	6.5 - 8.8	6.5 - 8.8
DO (mg/l)	R 8 8 8 8 PO 7 7 7 6 PC 6 4 4 6	R 8 8 8 8 P 8 7 7 7	R 8 8 8 8 PT 8 6.5 6 8 PB 7 6 5	R 8 8 8 8 P 7 6 7 7
Turbidity (NTU)	10 10 10 10	8 10 10 15	P 10 12 15 20 T 11 15 17	20 30 30 30

NOTE: For the purposes of this assessment the estuary was sub-divided into four zones representing from left to right: Zone A (lower), Zone B (middle), Zone C (upper) and Zone D (Riverine). Stratification in State 3 is denoted by a further subdivision of surface and bottom waters in Zones A to C.

Table 4.12 continued:

Parameter	State 1: Closed Mouth	State 2: Open, Gradient	State 3: Open, Stratified	State 4: Open, Freshwater dominated
DIN (µg/l)	R: 50, 50, 50, 50 P: 150, 170, 180, 200	R: 50, 50, 50, 50 P: 80, 120, 150, 180	R: 50, 50, 50, 50 PT: 80, 100, 130, 200 PB: 70, 90, 120	R: 50, 50, 50, 50 P: 200, 350, 250, 290
DIP (µg/l)	R: 10, 10, 10, 10 P: 30, 30, 30, 30	R: 10, 10, 10, 10 P: 20, 30, 30, 30	R: 10, 10 / *9*, 10 / *9*, 10 P: 30 / 20, 30 / 28, 40 / 35, 50	R: 10, 10, 10, 10 P: 70, 130, 90, 110
DRS (µg/l)	1000, 1000, 1500, 1800	200, 1000, 1500, 1800	500, 1000, 1500, 2000	2000, 3500, 3500, 3500

NOTE: For the purposes of this assessment the estuary was sub-divided into four zones representing from left to right: Zone A (lower), Zone B (middle), Zone C (upper) and Zone D (Riverine). Stratification in State 3 is denoted by a further subdivision of surface and bottom waters in Zones A to C.

A summary of the water quality characteristics under the various flow scenarios are provided for each zone in Table 4.13.

Table 4.13 Summary of average changes in water quality from Reference Condition to Present State within each of the various.

Parameter	Summary of change	Zone	Reference	Present
Salinity	Due to decrease in the base flows to the system (i.e. an increase in the occurrence of monthly flows below 1 m^3/s)	Lower Sur	25	28
		Lower Bot	29	31
		Middle Sur	12	17
		Middle Bot	19	21
		Upper Sur	7	12
		Upper Bot	11	14
		Riverine	2	6
`	Increases due to anthropogenic inputs from fertilisers and contribution by prawn and later fish farm.	Lower	50	80
		Middle Sur	50	100
		Middle Bot	50	90
		Upper Sur	50	120
		Upper Bot	50	100
		Riverine	50	200
DIP (µg/ℓ)	Slight increases due to agricultural activity	Lower	10	30
		Middle Sur	10	30
		Middle Bot	10	28
		Upper Sur	10	40
		Upper Bot	10	35
		Riverine	10	50
Turbidity (NTU)	Increases due to sedimentation	Lower	5	8
		Middle Sur	7	10
		Middle Bot	7	12
		Upper Sur	7	15
		Upper Bot	7	17
		Riverine	10	20
DO (µg/ℓ)	Decreases due to decrease base flow and higher nutrient accumulation	Lower	9	8
		Middle Sur	8	6.5
		Middle Bot	8	6
		Upper Sur	8	6
		Upper Bot	8	5
		Riverine	8	7
Toxic substances	Toxic substances present in water and fine sediment due to human activities			

4.4.3 Water quality health

The similarity in each parameter (e.g. dissolved oxygen) to reference condition was scored as follows:

- Define **zones** along the length of the estuary **(Z)** (i.e. Zones A, B, C and D)
- **Volume fraction** of each zone **(V)** (i.e. Lower = 0.40; Middle = 0.30; Upper = 0.20, Riverine = 0.10)
- Different **abiotic states (S)** (i.e. States 1 to 3)
- Define the **flow scenarios** (i.e. Reference, Present, Future scenarios)
- Determine the **% occurrence** of abiotic states for each scenario
- Define **WQ concentration range (C)** (e.g. 6 mg/l; 4 mg/l; 2 mg/l)

Similarity between Present State, or any Future Scenarios, relative to the Reference Condition was calculated as follows:

- Calculate Average concentration for each Zone for Reference and Present/Future Scenarios, respectively:
- Average Conc (Z_A) = [({∑% occurrence of states in C_1}*C_1)+({∑% occurrence of states in C_2}*C_2)+({∑% occurrence of states in C_n}*C_n)] divided by 100
- Calculate similarity between Average Conc's Reference and Present/Future Scenario for each Zone using the Czekanowski's similarity index: ∑(min(ref,pres)/(∑ref + ∑pres)/2
- For the final scores, a weighted average of the similarity scores of different zones was computed using the volume fractions.

Table 4.14 Summary of changes and calculation of the Water Quality health score.

Variable		Summary of change	Score	Conf
1	**Salinity**			
	Similarity in salinity	Slight increase in salinity in Zone A.	87	L
2	**General water quality in estuary**			
a	DIN and DIP concentrations	Increases due to agricultural fertilisers	85	L
b	Turbidity (transparency)	Increases due to sedimentation	85	L
c	Dissolved oxygen (mg/l)	Decrease	80	L
d	Toxic substances	Slight increase due to diffuse contamination	90	L
Water quality health score[1]				
% of impact non-flow related			**80**	**L**
Adjusted score			**83**	

[1] $\text{Score} = (0.6 * \text{S} + 0.4 * (\min(\text{a to d}))$

4.5 Microalgae

4.5.1 Overview

The microalgae component comprises the autotrophic microorganisms, i.e. those that contain chlorophyll and, as a result, are able to convert sunlight into living material. In this capacity they are at the base of the food chain and responsible for most of the food consumed by the primary consumers. This is especially important in that they provide the food resources for the juvenile fish and benthic microorganisms, including those that, in the adult form, are found in the sea and play an important role in the South African economy.

i) *Main grouping and baseline description*

They are grouped into two main types, the planktonic and the benthic. The planktonic group are the phytoplankton (plants in the water column) while the benthic group comprises the microphytobenthos (small plants found mostly attached to sediment particles (mud, sand, gravel, rocks). The true phytoplankton usually have flagellae which enable them to maintain a position in the water column, while the microphytobenthos are not flagellated and are therefore unable to maintain a position in the water column.

These organisms are greatly influenced by the amount of water flowing through the estuary as well as the way it passes through the estuary, i.e. they are sensitive to the hydrology and the hydrodynamic flows. The amount of water in the system and the continuity of flow determine the volume available and thus the absolute maximum amount of material available, while the hydrodynamic factor influences the stability of the system and especially the microphytobenthos (MPB). Estuaries with a large MAR are open more often, are usually larger and therefore are in the open mouth state for longer than those with a smaller MAR. Estuaries with a large MAR tend to be less sensitive to flow variation than do those with a small MAR. The importance of the hydrodynamic flow is that the flooding regime influences the state of the mouth, (open or closed- faunal recruitment or not).

The MPB are very important both when they are attached to sediment particles but also when they are attached to submerged or emergent plants (epiphytes), thus the status of the macrophyte community also impacts on the state of the microalgal community and whether or not the juvenile fish have an available food source in a protected environment, i.e. they have a measure of protection plus a source of food in amongst the living plant material.

Microalgae respond to the nutrient status of the water column. Under reference conditions, the nitrogen and phosphorus contents are usually low, but might occasionally be raised by an abundance of large terrestrial animal excreta. Thus the reference condition is considered to be one of low nutrient status to which the microalgae respond by having a high diversity of species. Where pollution raises the nutrient levels, the biomass rises but the species diversity is lowered, but only under extreme conditions.

The flagellate components of the microalgal community are able to maintain themselves in the water column using their flagellae and they are usually numerically dominant when counts are made. They are made up of both autotrophic and heterotrophic organisms, the latter being consumers rather than photosynthetically productive. Despite this, they are still components that are ingested and are therefore part of the food available to larger consumers and especially fish.

The cyanophytes (blue-green microalgae) are a group of non-flagellated photosynthetic bacteria that can make up a large component of both the planktonic and benthic microalgal community. They can be important in that under certain conditions (including anaerobic) they can utilise gasses such as hydrogen sulphide in order to grow. Some species are able to fix nitrogen and can become important under conditions where the water column is oligotrophic. Certain species of cyanophytes can produce toxins that are able to be harmful if present in high concentration.

The green microalgae are a very diverse group that can be present in estuary waters in fairly high proportions. They are included mostly in the flagellated group and because of the flagellum they are able to maintain their presence within the water column rather than sink to the sediment surface as do the diatoms. The phytoplankton are more sensitive to extreme floods than are the MPB which are only lost from the system under very strong flooding conditions. All records appear to show that the microalgae are a very resilient group of organisms.

Under reference conditions, the flagellate community would be relatively small while under polluted conditions the heterotrophic component of the flagellate community would be expected to be high because of a high organic component in the water.

ii) Description of factors influencing microalgae

Abiotic and biotic factors affecting the various microalgae groupings are given in Table 4.15 while Table 4.16 details the responses of the microalgae to the different abiotic states.

Table 4.15 Effect of abiotic characteristics and processes, as well as other biotic components (variables) on various groupings of Microalgae.

Variable	Grouping	
	Phytoplankton	**Microphytobenthos (MPB)**
Open water area	Proportional reduction with loss of open water area	Proportional reduction with loss of open water area
Salinity	Very little effect when > 5 psu. When < 5 psu there can be a few freshwater species present. Very seldom that freshwater diatoms appear in an estuary sample	Very little salinity effect with estuary MPB. This was established during a prolonged survey at St. Lucia where salinity rose from normal to ~150 psu.
Mouth condition	Mouth open - Biomass maximum at ~15psu. That area known as the REI (river estuary interface) Vertical and lateral salinity gradients	Mouth never closed - MPB elevated at low flows as a result of diatom settling.
Water flow rate	Under water high flow rates most of the microalgae are suspended in the water column.	Many diatoms that are commonly benthic (epipelic) are found in the water column. This is especially the case where the fine sediment fraction is suspended due to turbulence.
Water retention time	Phytoplankton biomass elevated at long retention time with diatoms on the sediment.	MPB biomass elevated at long retention time.
Floods	Only temporary reduction in phytoplankton biomass as a result of flooding. Consumer population also reduced - therefore little effect	Only temporary reduction in MPB biomass as a result of flooding. Consumer population also reduced - therefore little effect.
Turbidity	Because high turbidity occurs at the time of flooding there is very little effect on phytoplankton	Possible small reduction in MPB productivity.
Water quality	Low nutrient content - maximum species diversity. Diversity decreases at high nutrient levels.	No evidence of a species change at high nutrient levels
Toxins	Literature indicates that there is an unspecified adverse effect with certain toxins	No information
Macrophyte community structure	Diatom phytoplankton exchange onto and off submerged aquatic surfaces.	MPB high with high density of rooted aquatic macrophytes. Food availability to juvenile fauna increases - also security.
Oxygen levels	No effect on phytoplankton	No effect on MPB

Table 4.16 Summary of Microalgae responses to different abiotic states.

State	Response
State 1: Closed mouth	The effect is to separate the phytoplankton and MPB more than under flowing conditions. MPB has a higher value than normal. If DIN/DIP elevated then MPB is even higher than normal.
State 2: Open, Gradient	The REI is maximal in 15psu zone. Good mixing of MPB and PP.
State 3: Open, Stratified	The REI is absent because the fresh water is flowing over the saline water. Sharper difference in microalgal biomass between surface and deeper water.
State 4: Open, Freshwater dominated	No REI. Biomass lower because the time for biomass to develop is reduced.

iii) Reference condition

A summary of the relative changes in the Microalgae from the Reference Condition to the Present State is given in Table 4.17.

Table 4.17 Summary of relative changes in Microalgae from Reference Condition to Present State.

Key drivers	Change
Loss of water flow	Change in mouth state alters the ratio between PP and MPB
Increase in DIN/DIP	Results in a higher biomass in all areas and may bring about changes in the relative abundance of the pp groups. Not likely to change the MPB species assemblage.
Loss of intertidal area	Greatest effect on the MPB. Thick lawns of diatoms colonise the intertidal zone. These are large cells that provide good food sources for juveniles
TOTAL CHANGE	**20% change of functionality**

4.5.2 Microalgae health

The microalgae component health score under the Present State is provided on Table 4.18.

Table 4.18 Microalgae component health score.

Variable	Summary of change	Score	Conf
1. Species richness	Likely increase in heterophytes and drop in PP diversity	90	L
2. Abundance	Increased abundance due to higher DIP/DIN	80	M
3. Community composition	Some change ratios – more heterophytes with some green microalgae	95	L
Biotic component health score		**80**	**L**
% of impact non-flow related		5	M
Adjusted score		**81**	**L**

4.6 Macrophytes

4.6.1 Overview

i) Main grouping and baseline description

Macrophytes have two important characteristics:

(i) they cannot move once established (except as propagules) – and so environmental conditions for the life span of the plant must remain within the envelope that that particular species can tolerate; and

(2) compared with many of the estuarine biota, they have long life-spans – ranging from several months to decades (depending on the species).

So, with the above understanding one must realise that plants require stability in conditions, and that absence of a plant may indicate extreme conditions (for that plant) may have occurred a long while previously.

<u>**Main groups:**</u>

Mangroves

Under the reference condition there were few or no mangroves in the Mlalazi Estuary (Macnae, 1963; Hill, 1966). This indicates that there may have been more frequent and more prolonged mouth closures than the hydrology simulations for the period 1920 to 2004 show. These closures would have been associated with significant back-flooding which would have killed mangrove seedlings.

Submerged water plants

Due to fast flows during floods and few sites where flows are minimal, there are almost no submerged macrophytes in the system. Only *Zostera* is present – and this is in small quantities and only at specific times after a period of stable salinities in the marine range. No *Stuckenia* or *Ruppia* have been found recently or reported in the past

Intertidal species (emergent plants)

Reeds are abundant – but not *Schoenoplectus*. This indicates not much groundwater seepage into the lateral margins of the estuary.

Intertidal - Succulent salt marsh

This habitat is characterised by the succulent plant *Schoenoplectus* natalensis. This short-lived plant relies on saline mud flats. This habitat was virtually exterminated by the dredging which created berms, that prevented tidal inundation, but which was restored in the 1990s by EKZNW, who breached the dredged berm.

Intertidal – *Juncus kraussii*

A long-lived resilient plant. In places the *Juncus* is being shaded out by *Phragmites*.

Infratidal – saline lawns.

This is the estuarine floodplain, which is flooded with saline water at irregular intervals (during extremely high tides) and on mouth closure. Large areas of this habitat have been lost to sugar cultivation.

Freshwater swamp forest

This vegetation type is not closely associated with the estuary and is usually unaffected by changes in estuary conditions. Some of this vegetation may be affected to some extent by prolonged flooding.

Overview of conditions

It seems as if the estuary had already been quite severely affected by change by 1937 (as is evident from the first aerial photos). At this stage large areas of the supratidal habitat had been lost – due to draining and sugar planting. It is likely that significant sedimentation from the farms would have occurred. The lack of mangroves indicates mouth closure conditions were a key driver preventing their establishment and growth.

A major change occurred in the 1960s when extensive dredging was carried out. Since then mouth closures have been minimal – and the mouth has usually been artificially breached within weeks of closure. This has enabled mangroves to colonise and grow – now forming 40 ha of habitat.

Table 4.19 Macrophyte habitats and functional groups recorded in the estuary (spp. examples in italics).

Habitat Type	Area (ha)	Indicator species/comments
Open surface water area	140	Habitat available for phytoplankton
Intertidal sand and mudflats.	45	Habitat available for benthic microalgae (Included intertidal rocks)
Submerged macrophyte beds	0	Zostera capensis (in very low quantities). No *Stuckenia pectinatus* or *Ruppia cirrhosa*
Macroalgae	0	Charophytes, Enteromorpha, algae on pneumatophores
Intertidal salt marsh Succulent salt marsh Intertidal salt marsh Juncus salt marsh	11	(Succulent salt marsh) *Sarcocornia natalensis*, *Triglochin striatus*
	31	(*Juncus* salt marsh) *Juncus kraussii, Phragmites australis, Acrostichum aureum, Diplachne fusca*
Supratidal: Salt marsh (shoreline and saline lawns) Floodplain	568	*Sporobolus virginicus, Paspalum vaginatum, Canavalia rosea, Diplachne fusca. Imperator cylindrica, Hemarthria altissima, Stenotaphrum secundatum.* Much of this category has been converted to sugarcane farms
Reeds and sedges	43	*Phragmites australis, Schoenoplectus scirpioides*.
Mangroves	40	*Avicennia marina, Rhizophora mucronata, Bruguiera gymnorrhiza*
Swamp forest /Riparian forest	104	*Barringtonia racemosa, Hibiscus tiliaceus, Ficus trichopoda, Voacanga thouarsii, Rauvolfia cafra.*
Transformed	61	Fish farm, Road and rail (areas where soil has been reworked)
Thicket	77	*Acacia/Ekebergia/Schinus/Melia*
Total area	1119	

ii) Description of factors influencing macrophytes

The main factors are:

Water levels and flooding regime

This is especially important for mangroves, infratidal and intertidal habitats. It has different dimensions – the amount of flooding that occurs (water elevation), the duration of the flooding and the salinity of the flood waters. Flooding can be in the form of river floods, tidal flooding or back-flooding when the mouth has closed and water levels slowly build up.

Water salinity

Each estuarine plant species has a salinity range it can tolerate. Below or above this, it dies.

Mouth conditions

This manifests itself as changes in water levels and as salinity

Stability of the substratum

This related to the ability of the plant to remain anchored. Very unstable substrata are not colonised. In places plants are lost due to erosion.

Plant nutrients

At the scale we work, and increase of these is most evident in the fast-growing reeds and grasses.

Harvesting, grazing and fire

Some plants are affected by removal of biomass. There is an indication that this is the case with harvested *Juncus kraussii*. Reeds are susceptible to grazing following fire. Mangroves are particularly sensitive to fire when reedbeds are burnt adjacent to mangrove stands. Freshwater swamp forest is killed by fire. Chopping of trees and creation of swamp gardens reduces swamp forest.

Other factors

These include current flows and turbidity which affect submerged macrophytes.

Stability of environmental conditions

As macrophyte plants may be relatively long-lived, they do require a certain degree of stability.

Abiotic and biotic factors affecting the various macrophyte groupings are given in Table 4.20 while Table 4.21 details the responses of the macrophytes to the different abiotic states.

Table 4.20 Effect of abiotic characteristics and processes, as well as other biotic components (variables) on various groupings of Macrophytes.

Variable	Grouping		
	Reeds and sedges	Swamp forest	Mangroves
Mouth conditions	Less closure and less backing up of water – for shorter times now promotes mangroves growth.		
Retention times of water masses	Not important as such – but rather as the water levels, salinity and stability of conditions.		
Flow velocities (e.g. tidal velocities or river inflow velocities)	Fast flows limit submerged macrophyte growth (combined with sediment instability).		
Total volume and/or estimated volume of different salinity ranges	Volume is important as a feature of tidal prism as well as river flood effects on water levels. Salinity is important as the range and stability within a range.		
Floods	These affect water flow speed (making it difficult for submerged plants to remain anchored. Also affects the erosion of banks and mangrove margins. Floods also alter turbidity, salinity and short-term water levels. Flood routing patterns were altered by the railway bridge.		
Elevated water levels – Back-flooding	Can kill mangroves if they are submerged for prolonged periods. *Avicennia* more susceptible than *Bruguiera*. Blockage of drainage channels can flood freshwater swamp forests and kill some of the trees in them.		
Salinity	This is needed to be fairly stable .		
Turbidity	Has some effect on submerged plants – not the other macrophyte plants		
Dissolved oxygen	Changes do not affect the plants – unless they lead to total anoxia from eutrophication		
Nutrients	Will promote growth – especially of reeds and saline grasses		
Sediment characteristics (including sedimentation)	The main relevance is the instability of bottom sediments during floods – which affects colonisation of submerged macrophytes. It is likely that the sediments of the system have always been fairly mobile.		
Other biotic components	Harvesting of *Juncus*		

Table 4.21 Summary of Macrophyte responses to different abiotic states.

State	Response
State 1: Closed mouth	Kills mangroves and *Zostera* if prolonged and water is elevated for some time
State 2: Open, Gradient	Little difference for macrophytes between stages 2 and 3.
State 3: Open, Stratified	Little difference for macrophytes between stages 2 and 3.
State 4: Open, Freshwater dominated	Speed of flows possibly precludes most of the colonisation potential for submerged macrophytes

iii) Reference condition

No (or very few?) mangroves were present at that stage.

There was much more supratidal area – consisting of *Juncus* and saline lawns and reeds. These were the main differences when compared to reference state.

Zostera was possibly present – but it cannot be confirmed.

A summary of the relative changes in the Macrophytes from the Reference Condition to the Present State is given in Table 4.22.

Table 4.22 Summary of relative changes in Macrophytes from Reference Condition to Present state.

Key drivers	Change
Mouth closure regime changed	Mangroves able to colonise
Deeper water now	Fewer possibilities for submerged macrophytes
Loss of infratidal floodplain	Reduced infratidal salt marsh (*Juncus*, saline lawns, *Phragmites*)
Altered fire regime	Pushes reeds to saline lawn
TOTAL CHANGE	**The overwhelming change is that there are now large areas of mangroves. There is also less infratidal area due to drainage for sugar cane farming**

4.6.2 Macrophyte health

The Macrophyte component health score under the Present State is provided in Table 4.23.

Table 4.23 Macrophyte component health score.

Variable	Summary of change	Score	Conf
1. Species richness	Increased with mangroves (altered from reference - so scores lower even although we tend to value mangroves highly) **NB:** More species now than Reference condition	90	H
2. Abundance	Loss of supratidal areas	70	M
3. Community composition	Assume much the same – except for the mangrove communities	80	M
Biotic component health score		**70**	**M**
% of impact non-flow related		90	M
Adjusted score		97	M

4.7 Invertebrates

4.7.1 Overview

i) Main grouping and baseline description

a) Zooplankton

No previous data on the zooplankton community structure has been published. The present assessment is based on one sampling session at six sampling sites during May 2013. Sampling for this study occurred during autumn and densities of many of the zooplankton species would be lower than during summer, approaching winter levels. The results indicate a normal mesozooplankton community for KwaZulu-Natal estuaries associated with a salinity gradient along its main axis. As with most estuaries calanoid copepods were numerically dominant. The zooplankton community composition reflected the axial salinity gradient of the estuary with coastal marine taxa recorded in the lower reaches of the estuary and a gradual decrease in abundance of estuarine copepods towards the mouth. At the upper site the zooplankton was dominated by the estuarine calanoid copepods *Acartiella natalensis* and *Pseudodiaptomus* spp. The latter genus was represented by two species, *P. stuhlmanni* and *P. hessei*. Zoeae of the mud crab *Paratylodiplax blephariskios* were recorded at most of the sampling sites except for the uppermost site; numbers increased towards the lower estuary and dominated the zooplankton at the mouth sampling site. This crab species has an obligatory marine phase as part of its life cycle and rely on open mouth conditions for survival.

b) Macrobenthos

Information on the macrobenthos of the system is limited to a thesis and some CRUZ research reports. The present assessment is based on one sampling session at 8 sampling sites during May 2013. A total of 33 subtidal macrobenthic taxa were recorded in the Mlalazi Estuary. The subtidal benthos was numerically dominated by the polychaetes, notably *Prionospio sexoculata*, *Dendronereis keiskamma* and *Desdemona ornata*, also the tanaid *Apseudes digitalis* and Tubificidae oligochaetes. Highest densities were recorded in the soft muddy substrate at Site 4, where highest densities of the mud crab, *Paratylodiplax blephariskios* and oligocheates were recorded. The number of taxa per site ranged from 10-18. The fact that the highest number of taxa per site was 18, yet 33 taxa were recorded in total, is indicative that there was considerable variation is species composition between sites. The number of taxa per site were considerably lower compared to that recorded during previous sampling periods, but the average benthic densities were comparable and even higher at certain sites. A shift in the benthic community from 1989 from an amphipod dominated to a completely polychaete dominated community was noted. By and large, the subtidal macrobentos was quite typical for a stable permanently open system characterised by relatively high salinities. The intertidal benthic community was dominated by the polychaetes *D. arborifera* and *P. sexoculata*, the gastropod *Assimnea ovata* and the Tubificidae oligochaetes. These four taxa comprised 88% of the intertidal organisms recorded.

c) Macrocrustaceans

There is no information in the literature on the macrocrustacea of the Mlalazi Estuary**.** Eight prawn species were recorded in seine nets and beam trawls which is lower than the 12 and 13 species recorded in the Amatikulu-Nyoni (this project) and Mfolozi estuaries. This is due to the almost complete absence of freshwater species from the system, with the exception of *Macrobrachium equidens*, which was recorded only in low densities. The low number of freshwater species in the system is an indication that the system is probably not preferred habitat for freshwater species, probably due to the relatively high salinities in the system most of the time. This will become even more so if the salinity increases in future. The prawn community was completely dominated by marine spawning prawns (families Penaeidae and Sergestidae), notably the small sergestid *Acetes erythraeus* (45%) and the penaeids *Fenneropenaeus indicus* (28%) and *Metapenaeus monoceros (22%).* These three species comprised 94.5% of the prawns recorded in the system. The dominance of *A. erythraeus* is typical, as these prawns often dominate the prawn community in muddy mangrove estuaries, and they are seasonally very abundant in in mangrove lined muddy channels. Five of the seven penaeid prawn species known to occur along the KwaZulu-Natal coastline were recorded during this study. The penaeid *M. monoceros* was abundant throughout the system, while *F. indicus* was most abundant at Site 5. *Metapenaeus monoceros* was the only prawn recorded in the upper reaches at Sites 1A and 1, confirming the idea that this species is capable of penetrating the upper, low salinity reaches of estuaries. The abundance of *F. indicus* (50%) is very similar to that recorded in the Amatikulu-Nyoni Estuary (59%) (this project) and the Mfolozi-Msunduzi estuarine system (57%)**,** but *M. Monoceros* was more abundant than in these systems.

Table 4.24 Invertebrate groupings and their defining features and typical/dominant species.

a) Zooplankton

Main groupings	Defining features and typical/dominant species
Estuarine resident	*Pseudodiaptomus spp, Acartiella natalensis*,
Estuarine dependent marine	Prawn and crab larvae relying on connection to the sea or river.
Marine	Calanids, paracalanids, chaetognaths
Freshwater	Freshwater cyclopoids

b) Macrobenthos

Main groupings	Defining features and typical/dominant species
Estuarine resident	All but the mud crab
Estuarine dependent marine	Mud crab, *Paratylodiplax blephariskios*
Marine	
Freshwater	None

c) Macrocrustaceans

Main groupings	Defining features and typical/dominant species
Estuarine resident	None
Estuarine dependent marine	The prawns are dominated by estuarine dependent marine species, with 7 of the 8 species falling in this category. Dominated by *Acetes erythraeus, Fenneropenaeus indicus* and *Metapenaeus monoceros*
Marine	
Freshwater	*Macrobrachium equidens*

ii) Description of factors influencing invertebrates

a) Zooplankton

Distribution and abundance of zooplankton in estuaries may be influenced by a variety of factors, including salinity, hydrodynamic stability, nutrients and seasonal environmental changes. The Mlalazi system has a normal salinity gradient along the main axis of the estuary, driving much of the spatial distribution patterns of the zooplankton community, with marine taxa near the mouth, estuarine species along most of the estuary and some freshwater representation in the upper reaches. Moderate increases in nutrient inputs into the system should generally be beneficial for zooplankton production; however the zooplankton densities collected during autumn did not suggest any nutrient enrichment. Unstable water column conditions such as strong flows during flooding will decrease the zooplankton densities; however, substantial river flows keep the estuary mouth open, which is essential for the migration of species between the estuary and the adjacent coastal environment.

The crab *Paratylodiplax blephariskios*, e.g., rely on an open connection to the sea to complete its life cycle through migration of its planktonic larvae.

b) Macrobenthos

The distribution of macrobenthos in estuaries is influenced by a variety of factors, of which sediment composition and distribution and salinity can be regarded as the most important. The estuary varies in sediment distribution, with the middle reaches being very muddy, the upper reaches being sandy mud, while the mouth varies between sandy and muddy. The species composition in the middle reaches is typified by organisms found in very fine muddy sediment, i.e. *Paratylodiplax blephariskios,* where this crab occured in high densities and dominated the densities and biomass. Low densities were recorded in the marine sands at the mouth, which is typical of the tidal system. The estuary displays a strong salinity gradient, although salinities are high throughout, with the upper reaches only showing salinities below 5 under high flow conditions. The muddy sands found at Sites 2 and 5 typically show a diverse macrobenthic community with high densities.

c) Macrocrustaceans

Estuarine prawns communities are dependent on a number of factors during their stay in estuaries. These are salinity, access to the marine environment and mouth condition, shelter and nutrients in the form of detritus. For penaeid prawn larvae that recruit into estuaries, salinity is one of the most important environmental factors affecting their growth and survival. In contrast to adults, postlarvae of most penaeids can survive relatively low estuarine salinities (i.e. 8-10) as they osmoregulate well at lower salinities, generally preferring salinities between 10-20, with survival impeded below a salinity of 5. Recruitment of penaeid postlarvae into estuaries usually peaks during late spring and summer, with subadults emigrating back to sea in late summer and early autumn. Access to the marine environment during the periods of recruitment is therefore a determining factor affecting the survival of postlarvae when their migrate into estuaries. Prolonged flooding conditions in summer which result in low salinities can be detrimental to prawn development as larvae are pushed out to sea prematurely by the low salinities. *Macrobrachium* larvae require brackish water for successful development, with most species requiring salinities of around 8 and cannot develop in high salinities. The range of salinities in the system appear not to be conducive to *Macrobrachium* development, which explain the low species number and low abundance of freshwater prawns and specifically *Macrobrachium* in the system. It is also noteworthy that no estuarine resident prawns species were recorded, probably also due to the high salinities. This is specifically the case with *Palaemon concinnus,* a resident estuarine species usually present in east coast estuaries, which is restricted to low salinity regions in the freshwater head-regions of estuaries and can complete its entire life cycle within the upper estuarine environment.

Abiotic and biotic factors affecting the various invertebrate groupings are given in Table 4.25 while Table 4.26 details the responses of the invertebrates to the different abiotic states.

Table 4.25 Effect of abiotic characteristics and processes, as well as other biotic components (variables) on various groupings of Invertebrates.

a) Zooplankton

Variable	Grouping			
	Estuarine resident	Estuarine dependent marine	Marine	Freshwater
Mouth condition: Mouth closure	Extended periods of mouth closure will lead to fresher conditions and will affect the abundance of the calanoid *Acartiella natalensis* but not necessarily that of the *Pseudodiaptomus spp. Extended mouth closure will also prevent the migration of larval stages relying on an open connection with the sea to complete their life cycles.*	Mouth closure will prevent any exchange of marine zooplankton between the estuary and the coastal marine environment e.g. *Paratylodiplax blephariskios*.		Mouth closure resulting in long term freshwater conditions will enhance the production of freshwater taxa such as cladocerans and freshwater cyclopoids.
Salinity	Low salinities will affect the abundance of the calanoid *Acartiella natalensis* and to a lesser extent that of *Pseudodiaptomus spp.*		Elevated salinities, around seawater levels will support marine taxa and therefore also a more diverse, but less abundant zooplankton community	Freshwater taxa will only be supported at very low salinities.
Dissolved oxygen	Low oxygen levels will reduce zooplankton densities.		Low oxygen levels will reduce zooplankton densities.	Low oxygen levels will reduce zooplankton densities.
River flow	Strong, sustained river flows creates unstable water column conditions and will reduce the abundance of typical estuarine calanoid copepods.	Strong, sustained river flows will prevent marine taxa from migrating into the estuary.		Strong, sustained river flows will wash more freshwater taxa into the estuary, but will not lead to any stable freshwater community. Substantial river flows during summer to autumn will be beneficial for the release of *Macrobrachium* larvae.

b) Macrobenthos

Variable	Grouping			
	Estuarine resident	Estuarine dependent marine	Marine	Freshwater
Mouth condition: Mouth closure	Extended periods of mouth closure will cause salinities drop and become more uniform throughout. This is not detrimental to most euryhaline taxa, but may affect taxa that prefer higher salinities	Closure of the mouth will disrupt recruitment of marine taxa into the system, and these will also be affected by the lower salinities		Mouth closure will benefit taxa that inhabit the low salinity heads of estuaries and will allow them to expand their distribution lower down into the system, replacing taxa that prefer higher salinities
Salinity	Prolonged low salinities will affect the abundance and distribution of estuarine species. At present, salinities are high most of the time, favouring taxa that prefer high salinities		Few estuarine benthic taxa can withstand prolonged salinities approaching marine levels and will be affected. It will however curb the expansion of the invasive snail *Tarebia granifera*	Most benthic taxa will disappear under freshwater conditions due to osmotic stress, with freshwater taxa such as *Tarebia granifera* being able to expand its distribution
Dissolved oxygen	Estuarine benthic taxa are generally sensitive to reduced oxygen levels. Low oxygen levels will reduce benthic densities.		Estuarine benthic taxa are generally sensitive to reduced oxygen levels. Low oxygen levels will reduce benthic densities	Estuarine benthic taxa are generally sensitive to reduced oxygen levels. Low oxygen levels will reduce benthic densities
River flow	Strong river flows in summer create low salinity conditions and will wash epibenthic taxa such as *Apseudes digitalis* out to sea, while burrowing taxa being less affected.	Strong flows maintain the estuarine mouth open for longer, which favours marine taxa as it ensures recruitment through an open mouth, and also creates a stronger salinity cue out in the open sea.		Prolonged strong flows create lower salinity conditions, which will benefit freshwater taxa.

c) Macrocrustaceans

Variable	Grouping			
	Estuarine resident	Estuarine dependent marine	Marine	Freshwater
Mouth condition: Mouth closure	Closed mouth conditions benefit estuarine species as it generally creates more uniform conditions throughout the system and allows these species to expand into the upper and lower reaches	Migration of prawns and crabs rely on an open mouth to allow access to the estuarine nursery area. An open mouth also creates a salinity gradient and more variable salinities, thus increasing the chances of these species finding the "right" salinities. Mouth closure in early summer will prevent recruitment as survival of the larvae is dependent on access to the estuarine habitat. Mouth closure will also reduce salinities, with the danger that salinities will be too low throughout the system.		Larval development of *Macrobrachium* prawns depends on access to brackish waters. Closed mouth conditions will benefit their distribution as salinities in the lower reaches will become more suitable. Under open mouth tidal conditions freshwater prawns will be absent from the lower reaches.
Salinity	Larval development requires brackish water, with most Penaeid species requiring salinities of around 8-20. Freshwater species require lower salinities. Salinities below 5 will affect larval development of all species.		Marine prawns in the system will be favoured under open mouth conditions due to generally higher salinities, but freshwater prawns not. Freshwater prawns will be restricted to the upper reaches and will perish if salinities rises.	*Macrobrachium* larvae require brackish water for successful development, with most species requiring salinities of around 8. The current range of salinities in the system appear to be too high for *Macrobrachium* development, explaining the low *Macrobrachium* numbers. *Caridina* prawns needs freshwater conditions for development
Dissolved oxygen	Macrocrustaceans are generally sensitive to reduced oxygen levels and their survival will be affected <3mg/l		Macrocrustaceans are generally sensitive to reduced oxygen levels and their survival will be affected <3mg/l	Macrocrustaceans are generally sensitive to reduced oxygen levels and their survival will be affected <3mg/l
River flow	River flow is important due to its effect on mouth status and salinities, but strong flows will wash epibenthic prawns out of the system	Strong river flows will create low salinity conditions down the entire system, except for a small and very steep salinity gradient at the mouth. This will push developing Penaeid prawn larvae and sub-adults out to sea, prematurely, as they cannot withstand such low salinities. It will however create more suitable conditions for freshwater prawns		Strong river flows will create more suitable conditions for freshwater prawns throughout the system, allowing them to expand into the middle and lower reaches

Table 4.26 Summary of Invertebrate responses to different abiotic states.

a) Zooplankton

State	Response
State 1: Closed mouth	The migration of taxa between the estuary and sea will be prevented; this may lead to the demise of species such as *Paratylodiplax blephariskios.* Based on salinity information supplied in Table 3.2 the estuarine zooplankton community would not be substantially affected. Coastal marine species will not enter the estuary, leading to a decline in zooplankton diversity in the lower estuary.
State 2: Open, Gradient	Normal estuarine zooplankton will dominate. Marine taxa will occur in the lower reaches. Migration between estuary and the adjacent marine and freshwater environments will occur, e.g., crab and prawn larvae will be able to complete their life cycles.
State 3: Open, Stratified	Normal estuarine zooplankton will dominate. Marine taxa will occur in the lower reaches. Migration between estuary and the adjacent marine and freshwater environments will occur, e.g., crab and prawn larvae will be able to complete their life cycles. Freshwater zooplankton in upper reaches.
State 4: Open, Freshwater dominated	Unstable conditions created by strong freshwater flows will prevent the establishment of a stable zooplankton community.

b) Macrobenthos

State	Response
State 1: Closed mouth	If the mouth remains closed, the system will freshen and taxa that tolerate lower salinities such as *Corophium triaenonyx* and *Grandidierella lignorum* will benefit and become more abundant. Estuarine resident taxa will proliferate, while freshwater and marine taxa numbers will diminish. Lack of recruitment will affect taxa with a marine-linked life cycle such as *Paratylodiplax blephariskios*
State 2: Open, Gradient	Open tidal conditions create variable salinities and a normal salinity gradient, with taxa being afforded the opportunity to inhabit areas with more favourable salinities. This will create a more diverse macrobenthic community. Marine taxa will dominate the mouth area while estuarine taxa will be favoured..
State 3: Open, Stratified	Open tidal conditions create variable salinities and a normal salinity gradient, with taxa being afforded to opportunity to inhabitat areas with more favourable salinities. This will create a more diverse macrobenthic community. Marine taxa will dominate the mouth area while estuarine taxa will be favoured..
State 4: Open, Freshwater dominated	This will alter the current situation, with the system becoming freshwater dominated. Open freshwater dominated conditions generally favour freshwater taxa and many estuarine taxa will disappear from the system.

c) Macrocrustaceans

State	Response
State 1: Closed mouth	Closed mouth conditions favour freshwater and estuarine resident prawn species as the generally low salinities will create suitable nursery habitat in the most of the system. Such conditions will however be extremely detrimental to marine prawns and crabs as their larvae will not be able to recruit into the system and the salinities will often be too low for successful larval development. However, closed mouth conditions under low flow winter conditions create very stable conditions in the estuary and as long as salinities do not drop too low, will be favourable for these prawns.
State 2: Open, Gradient	An open mouth will allow recruitment of marine prawns and create variable salinity conditions in the system, which will favour marine prawns. Under these conditions, marine prawns will dominate the lower and middle reaches, while freshwater prawns will be able to colonize the upper reaches, if salinities do mot remain too high.
State 3: Open, Stratified	An open mouth will allow recruitment of marine prawns and create variable salinity conditions in the system, which will favour marine prawns. Under these conditions, marine prawns will dominate the lower and middle reaches, while freshwater prawns will be able to colonize the upper reaches, if salinities do mot remain too high
State 4: Open, Freshwater dominated	Open, fresh conditions will favour estuarine resident and freshwater prawns, as it gives them access to larger areas in the system. These conditions are detrimental to marine prawns as they are generally restricted to the saline lower reaches around the mouth, with most larvae being pushed out to sea by the low salinities

iii) Reference condition

a) Zooplankton

Much of the state of the major drivers under the reference condition that may influence the abundance, distribution and composition of the zooplankton community seem to be not too different from that of the present condition. The only factors that could have had an influence would be the time and duration of mouth closure episodes and the flow velocities. An increase in open mouth duration during the reference condition would have been beneficial for the estuarine zooplankton taxa if a normal salinity gradient along the axis of the estuary was maintained and the water column not too unstable (too strong flows). It would also have allowed migration of taxa between the estuary and the sea.

b) Macrobenthos

The estuary is regarded as a permanently open system, although it does close on occasion. As stated above, the current conditions in terms of mouth condition and hydrodynamics is deemed to be not much different from the reference condition. At present the mouth closes from time to time, but under reference conditions it probably remained open most of the time. This means that a typical salinity gradient would have been in place for longer, resulting in a more diverse macrobenthic community.

c) Macrocrustaceans

The system supports a diverse penaied prawn community comparable to other systems along the Zululand coastline. As such, the current species composition is probably quite close to what would have been found under reference conditions, although the low diversity of freshwater species is believed to be quite variable and is dependent on salinity conditions. The longer open-mouth periods would however have resulted in better recruitment of marine prawns and the defined salinity gradient under tidal open conditions would have benefitted development of these species. With the mouth closing more frequently under present conditions, estuarine and freshwater prawns are favoured.

A summary of the relative changes in the Invertebrates from the Reference Condition to the Present State is given in Table 4.27.

Table 4.27 Summary of relative changes in Invertebrates from Reference Condition to Present State.

a) Zooplankton

Key drivers	Change
Extended mouth closure	Decrease in exchange of taxa between sea and estuary. May have been more beneficial for estuarine resident species in terms of more stable water column.
Decreased flow velocities	Decreased velocities would be slightly better for zooplankton as long as mouth remains open.

b) Macrobenthos

Key drivers	Change
More frequent mouth closure	Estuarine taxa with lower salinity preference will be favoured.
Change in salinity	Estuarine taxa with lower salinity preference will be favoured.
Alien invasive	Lower salinities favour *Tarebia granifera*, the alien invasive snail, which will gradually expand its current limited distribution.

c) Macrocrustaceans

Key drivers	Change
More frequent mouth closure	Will benefit freshwater prawn species, due to lower salinities in the middle and upper reaches, but will be detrimental to the dominant marine prawn as well as mangrove crab species. Will cause a major shift in species composition.
Nutrient loading	Affect water quality and habitat quality for developing prawn larvae.

4.7.2 Invertebrate health

i) Zooplankton

For this type of estuary the zooplankton community seems quite healthy at the present state and although there is no historical data to compare with, it is probably not much different from the reference state.

ii) Macrobenthos

The macrobenthic numbers of taxa were lower than expected, compared to previous sampling years, and although the system is regarded as of generally good health, should be carefully monitored. At present, the influence of the invasive gastropod, *Tarebia granifera*, in the intertidal habitat is largely controlled through the high salinities, but more prolonged periods of mouth closure will change this.

iii) Macrocrustaceans

Although there is no historical data with which to compare the macrocrustacean numbers, the system supported a diverse marine prawn community. The species composition and the numbers of the dominant prawn species are comparable to that found in other systems along the coastline, so the prawn community appears to be relatively healthy. The low numbers of freshwater and estuarine prawns is a reflection of the prevailing open mouth and high salinity conditions in the system.

The Invertebrate component health score under the Present State is given on Table 4.28.

Table 4.28 Invertebrate component health score.

a) Zooplankton

Variable	Summary of change	Score	Conf
1. Species richness	Only one sample and no historical data to compare with, however, given these limitations it seems to compare favourable to zooplankton richness recorded in other east coast estuaries.	98	M
2. Abundance	Only one sample and no historical data to compare with. Not as abundant as some other local systems.	98	M
3. Community composition	Only one sample and no historical data to compare with. Composition as would be expected for this type of estuary.	98	M
Biotic component health score		**98**	**M**
% of impact non-flow related		0	M
Adjusted score		98	M

b) Macrobenthos

Variable	Summary of change	Score	Conf
1. Species richness	Lower than previous sampling years	80	M
2. Abundance	Similar to previous sample years	90	M
3. Community composition	Slightly modified, probably due to higher salinities	85	M
Biotic component health score		**85**	**M**
% of impact non-flow related		30	M
Adjusted score		86	M

c) Macrocrustaceans

Variable	Summary of change	Score	Conf
1. Species richness	No historical data, dominance of marine species, very low freshwater species numbers	80	M
2. Abundance	Marine species dominant	80	M
3. Community composition	No way to relate to historical composition	80	M
Biotic component health score		**80**	**M**
% of impact non-flow related		30	M
Adjusted score		86	M

d) Invertebrates (Lowest Scores)

Variable	Summary of change	Score	Conf
1. Species richness		80	L
2. Abundance		80	L
3. Community composition		80	L
Biotic component health score		**80**	**L**
% of impact non-flow related		20	L
Adjusted score		84	L

4.8 Fish

4.8.1 Overview

i) Main grouping and baseline description

A total of 90 fish species have been recorded from the Mlalazi Estuary based on detailed monthly records from 1981-82 and 1989-90 (CRUZ) and a once-off sampling in May 2013 (this project). The fauna utilizing the system can be divided into five categories based on their life cycle traits (Whitfield, 1994 & 1998). These categories, their definitions, species number and percentage contribution and examples of each are listed in Table 4.29. From this it is clear that the dominant group are the Euryhaline marine species which breed at sea but with juveniles that show varying degrees of dependence on estuaries. They made up 48% of the species recorded. The dominance of this group, in terms of frequency of occurrence, number of species and relative abundance, indicates the importance of this estuary as a nursery habitat for these marine species. Marine species not dependent on estuaries comprised 40%, reflecting the dominance of an open stratified system, while Estuarine Residents only made up 8%. If one looks at the 2013 data only, there is an even greater percentage of estuarine dependant marine species present (62%), with the marine species only contributing 18% and estuarine residents 17% (Table 4.29). These latter results might indicate that more recently the Mlalazi may have moved from an open gradient system towards a more open stratified system.

In terms of feeding guilds the species recorded in the Mlalazi Estuary are representative of four major feeding groups, detrivores, zooplanktivores, zoobenthivores and piscivores, indicating the availability of prey for all groups within the system.

Table 4.29 The major life cycle categories of Fish utilising the Mlalazi Estuary based on Whitfield (1998) and the number & percentage contribution of species from each category recorded in the estuary (n = 90 species).

	All Data		2013-05		
Category	**Number**	**%**	**Number**	**%**	**Defining features and typical/dominant species**
I	**7**	**8**	**7**	**16**	**Estuarine species which breed in estuaries:**
	5		5		I a Resident species which have not been recorded spawning in marine or freshwater environments (*Ambassis ambassis & Eleotris fusca)*.
	2		2		I b Resident species which have been recorded spawning in marine or freshwater environments (*Ambassis natalensis & Glossogobius callidus)*.
II	**43**	**48**	**27**	**62**	**Euryhaline marine species which breed at sea but with juveniles that show varying degrees of dependence on estuaries:**
	14		9		IIa Juveniles dependent on estuaries as nursery areas (*Acanthopagrus vagus & Liza macrolepis)*.
	15		11		IIb Juveniles occur mainly in estuaries but are also found at sea (*Caranx sexfasciatus & Gerres methueni)*.
	14		9		IIc Juveniles occur in estuaries but are usually more abundant at sea (*Platycephalus indicus & Solea bleekeri)*.
III	**36**	**40**	**8**	**18**	**Marine species which occur in estuaries in small numbers but are not dependent on these systems** (*Amblyrhynchotes honckenii & Epinephalus malabaricus).*
IV	**2**	**2**	**1**	**2**	**Euryhaline freshwater species. Includes some species which may breed in both freshwater and estuarine environments (***Oreochromis mossambicus* & *Glossogobius giuris***).**
V	**2**	**2**	**1**	**2**	**Obligate catadromous species which use estuaries as transit routes between the marine and freshwater environments:**
	0		0		Va Obligate catadromous species which require a freshwater phase for their development (*Anguilla mossambica)*.
	2		1		Vb Facultative catadromous species which do not require a freshwater phase for their development (*Myxus capensis)*.
Species	**90**		**44**		

ii) Description of factors influencing fish

Abiotic and biotic factors affecting the various fish groupings are given in Table 4.30 while Table 4.31 details the responses of the invertebrates to the different abiotic states.

Table 4.30 Effect of abiotic characteristics and processes, as well as other biotic components (variables) on various groupings of Fish.

<table>
<tr><th rowspan="2">Variable</th><th colspan="4">Grouping</th></tr>
<tr><th>Estuarine resident</th><th>Estuarine dependent marine</th><th>Marine</th><th>Freshwater</th></tr>
<tr><td>Mouth condition: Mouth closure</td><td>Most resident species proliferate under closed mouth conditions.</td><td colspan="2">Recruitment of marine spawning fish is reduced by mouth closure. However, short periods of closure may benefit the estuarine dependant fishes that are already in the system. Extended mouth closure results in declines of both Category II and III species.</td><td>Increase in abundance with lower salinities through both recruitment from the freshwater reaches and breeding in the system.</td></tr>
<tr><td>Salinity</td><td colspan="2">Estuarine and estuarine dependant marine species are tolerant of a wide range of salinities, from almost fresh to that of seawater. The only impact of salinity on this group is that the species will distribute themselves across the estuarine gradient according to salinity preference.</td><td>This group inhabits waters with near marine salinities and become stresses when these drop below 20.</td><td>Other than Oreochromis mossambicus, which can breed in high salinities, most species in this group avoid salinities >5.</td></tr>
<tr><td>Dissolved oxygen</td><td colspan="2">Most resident and estuarine dependant marine species become stressed when oxygen drops below 4 mg/l[1].</td><td>Little tolerance to low oxygen levels.</td><td>Some species tolerant of low oxygen but responses variable.</td></tr>
<tr><td>River flow</td><td>During high flow periods these species may be washed out to sea but most return once the flood waters recede.</td><td colspan="2">Also susceptible to being washed out to sea with flood waters but soon recruit back as the flood front recedes.</td><td>Very high water levels coupled with floodplain inundation may promote spawning in this group. Individuals that are washed out to sea suffer from osmoregulatory shock and die.</td></tr>
</table>

Table 4.31 Summary of Fish responses to different abiotic states.

State	Response
State 1: Closed mouth	Closure of the mouth during the spawning months effectively reduces the recruitment cues which lead fish to the system. Some washover recruitment may occur but this is limited. This leads to a decline of the estuarine dependant marine and catadromous species.
State 2: Open, Gradient	This state provides good conditions within the estuary for marine and estuarine dependant marine fishes as recruitment is not interrupted due to the open mouth. Estuarine species may be excluded to a greater extent.
State 3: Open, Stratified	This state provides good conditions within the estuary for estuarine dependant and estuarine fishes as recruitment is not interrupted due to the open mouth. Marine species may be more restricted to the lower reached.
State 4: Open, Freshwater dominated	The offshore plume is developed to its full potential, acting as a strong recruitment cue for estuarine dependant marine as well as catadromous species. Marine species occur in reduced numbers and many estuarine dependant marine species may be restricted to the lower reaches of the system or may only use it on a tidal basis. Freshwater species may occur along the full length of the estuary and right down to the mouth, however these are limited to only a few taxa.

iii) Reference condition

Under the reference condition the Mlalazi was very much an open gradient type system with mouth closure almost never occurring. The fish fauna would have been much as it is now, possibly with slightly greater species diversity, with greater fish densities and a larger marine component. Based on the macrophyte Reference Condition assessment, that *Zostera* would probably have been present, it can be concluded that this would have resulted in the estuary playing an even greater role, as a nursery for juvenile estuarine dependant marine fish, than it does now.

A summary of the relative changes in the Fish from the Reference Condition to the Present State is given in Table 4.32.

Table 4.32 Summary of relative changes in Fish from Reference Condition to Present State.

Key drivers	Change
Salinity gradients (estuarine state)	The Open Gradient & Stratified tidal states would have been more dominant resulting in the estuarine conditions been more dominant throughout the year, this has been reduced to some extent in the Present State but is still of significance.
Connectivity with tidal fresh waters	Pattern and frequency of connectivity appears to be much the same in the Present State as it was in the Reference Condition. However the Open Gradient tidal state was completely dominant.
Nursery habitat	Key nursery area for estuarine dependant marine species which has been reduced to some extent in the Present State but is still of significance.

4.8.2 Fish health

The Fish component health score under the Present State is given on Table 4.33.

Table 4.33 Fish component health score.

Variable	Summary of change	Score	Conf
1. Species richness	A similar number of species use the estuary as would have under the Reference Condition.	90	M
2. Abundance	There is probably a reduction in the abundance of species using the estuary due to increases in mouth closure as well as reduced extent of *Zostera* bed.	75	M
3. Community composition	Community composition remains similar to the Reference Condition with the exception that a few estuarine dependant marine species and marine stragglers could well have been lost. The have possibly been replaced by estuarine species.	75	M
Biotic component health score		**75**	**M**
% of impact non-flow related		50	M
Adjusted score		88*	M

* The Adjusted score is derived from an estimate of the fish component health score if the non-flow related impacts such as gill net poaching and illegal fishing etc., were to be removed.

4.9 Birds

4.9.1 Overview

Apart from a comprehensive checklist for the Mlalazi Nature Reserve produced by Ezemvelo KZN Wildlife (EKZNW) and bird records by month for the Quarter Degree grid square in which the reserve falls (Cyrus & Robson, 1980) there were no detailed counts relating to the avifauna of this Mlalazi Estuary.

i) Main grouping and baseline description

A bird count of the entire estuarine area was undertaken in May 2013 with 19 species comprising 48 individuals being recorded. The EKZNW checklist for the Mlalazi Nature Reserve and records by Cyrus & Robson (1980) comprise some 68 species.

The waterbird guilds and their defining features are listed on Table 4.34.

Table 4.34 Waterbird feeding guilds and their defining features and typical/dominant species.

Main foraging guilds	Defining features and typical/dominant species
Swimming piscivores	Open deeper water swimming species which catches its prey underwater. This group includes Reed & White-breasted Cormorant & African Dater. They may be found along the entire length of the estuary. It is possible that small numbers of Cape Cormorant may also utilize the estuary during the winter-spring period.
Aerial piscivores	Plunge diving species which catch their prey in the shallows or in open water. This group includes the Fish Eagle, Osprey, Pied, Giant & Malachite Kingfishers as well as Common & Swift Terns. The estuary is used by several tern species as a roosting site when they are not feeding offshore.
Large wading piscivores	Prey capture is undertaken by stealth wading in the shallows, intertidal areas and on the edges of the *Phragmites* beds. These species are characteristic of wetland shorelines and have the ability to move into inundated areas to hunt. The extent of this is determined by size and leg length of the species. This group includes the Grey Heron, Little, Yellow-billed & Great Egret.
Small wading invertebrate feeders	Mainly forage in the intertidal sand- and mud-flats for macrobenthic invertebrates but also exploit shallow inter-tidal areas. This group includes the Greenshank, Wood & Common Sandpiper, Common Whimbrel and Little Stint which are all migratory Palaearctic waders that visit the estuary during the summer months. Most are wholly reliant on these habitats for feeding during the non-breeding season. Also present occasionally are a number of other wading birds including Black-winged Stilt and Water Thick-knee.
Swimming herbivorous waterfowl	These species tend to use the open water areas for feeding or the shoreline and small tidally exposed sandbank islands for roosting. The occurrence of this group in estuaries is to a large extent determined by the salinity regime of the system as higher salinities tend to restrict the growth of submerged vegetation thus reducing the food supply for these herbivores. This group includes White-faced & Yellow-billed Duck and Egyptian & Spur-winged Goose.
Carnivorous and scavenging gulls	Scavengers, with a substantial range of foraging strategies, feeding on a wide range of both live and dead vertebrate and invertebrate. The estuary is also used by individuals of the same species as a roosting site, along with the terns, when they are not feeding offshore. The primary species in this group are the Grey-headed and Kelp Gull.

ii) Description of factors influencing birds

Table 4.35 below lists the effects of various abiotic and biotic factors on the different waterbird feeding guilds present at the Mlalazi Estuary, while Table 4.36 provides a summary of the birds responses to the different abiotic states.

Table 4.35 Effect of abiotic characteristics and processes, as well as other biotic components (variables) on various Bird groupings (generalist gulls excluded from consideration due to overall resilience, unpredictability and adaptability).

Variable	Grouping			
	Swimming & large wading piscivores	**Aerial piscivores**	**Swimming herbivorous waterfowl**	**Small wading invertebrate feeders**
Mouth condition	Open mouth increases the diversity and density of fish which are their prey item. An indirect affect relating to water level can be positive when extensive back-flooding accompanies mouth closure.		Has an indirect effect through its influence on macrophytes. May be positive when extensive back-flooding accompanies mouth closure.	A closed mouth situation has a negative effect on the intertidal sand banks of the lower and to some extent middle estuary in that it results in reduces foraging habitat. Can also affect roosting terns and gulls.
Salinity	Affects species composition and densities of fish present in the estuary		Prefer lower salinities	Some Palearctic waders are dependent on estuarine conditions
Turbidity	Increases may negatively affect the efficiency of foraging activities		Negatively affects submerged aquatic macrophytes, such as *Zostera,* which they are associated with.	Increases may impact on benthic macroinvertebrates and affect efficiency of foraging activities
Intertidal area	Indirectly, affects species composition and densities of fish present in the estuary	Indirectly, affects species composition and densities of fish present in the estuary. Also shallow water at high tide is valuable as a foraging area	This may only be important to the group if it results in the exposure of *Zostera* at low tide. Suitable roosting sites also exposed at low tide.	This is a critically important habitat for waders which rely almost exclusively on intertidal areas for feeding.
Sediment characteristics (including sedimentation)	Indirectly, through its influence on the species composition of the fish fauna		May enhance macrophyte growth, especially *Phragmites*	Influences foraging activity dependant of preferred prey, most waders prefer medium to fine sand whilst a few prefer course sand or mud. Smothering of benthic macroinvertebrates through sediment movement can severely affect this guild
Primary productivity	Indirectly, through its influence on food supply			
Submerged macrophytes abundance	Indirectly, through its influence the species composition of the fish fauna (food & cover)		Has a positive effect on herbivorous waterfowl who forage in these areas	Indirectly, if it affects the benthic macroinvertebrates
Abundance of reeds and sedges	Indirectly, through its influence on the species composition of the fish fauna (food & cover). Also encroaches on the availability of roosting habitats for terns and gulls		Has a positive effect on herbivorous waterfowl who forage in these areas	Direct affect through the encroachment of macrophytes at the expense of the open habitats required by the waders
Abundance of zooplankton	Indirectly, through its influence on the species composition of the fish fauna		May have a positive effect on some omnivorous species	
Benthic invertebrate abundance	Indirectly, through its influence on the species composition of the fish fauna			Primary food source for invertebrate feeding waders. Influences foraging activity dependant of preferred prey
Fish biomass	Increasing numbers of small to medium sized fish in the system will result in an increase in the number of avian piscivores			Indirectly, of fish compete for benthic macroinvertebrates

Table 4.36 Summary of Bird responses to different abiotic states.

<table>
<tr><th>State</th><th>Response</th></tr>
<tr><td>State 1: Closed mouth</td><td>The closed mouth state results in deeper water conditions which increases the habitat for swimming and aerial piscivores. Any resultant back flooding onto the flood-plain would increase the habitat for wading piscivores and herbivorous waterfowl and probably for water birds overall. The lack of tidal conditions results in reduced feeding habitat for many of the key invertebrate-feeding waders. In addition there will be a reduction in the number of exposed sandbanks that are suitable as roosting sites for the water birds in general.</td></tr>
<tr><td>State 2: Open, Gradient</td><td rowspan="2">Under these states the system will offer a number of areas of intertidal sand- and mud-flats which are the key habitat for the important invertebrate-feeding waders. In addition additional suitable roosting sites become available to all waterbirds.</td></tr>
<tr><td>State 3: Open, Stratified</td></tr>
<tr><td>State 4: Open, Freshwater dominated</td><td>Under this state the system is probably least productive from a water bird prospective. Intertidal areas are reduced and salinities decline reducing available habitats and piscivorous prey which are associated with more saline waters.</td></tr>
</table>

iii) Reference condition

The bird fauna under the Reference Condition would have been fairly similar to the Present State as there has been limited change in the percentage of time the system was closed and the percentage it was in the freshwater state. The two open states which dominated would have had similar positive influences on the bird fauna irrespective of their percentage contribution.

Table 4.37 provides a summary of the relative changes in the birds from the Reference Condition to the Present State.

Table 4.37 Summary of relative changes in Birds from Reference Condition to Present State.

Key drivers	Change
Disturbances along the shoreline and at the mouth	Precludes large numbers of roosting terns and gulls and also disturbs waders feeding in the intertidal area.
Agriculture and other anthropogenic modifications in the floodplain	Whilst the south bank is still intact and under conservation, large parts of the northern part of the flood plain have been impacted by sugar cane cultivation causing some reduction in the estuarine area.
Angling	Increased disturbance along the shoreline, potential reduction in available food and an increased danger of entanglement to water birds from discarded tackle.
Poaching	Reduction in food availability and increased danger of entanglement in gill nets.

4.9.2 Bird health

The Bird component health score under the Present State is given in Table 4.38.

Table 4.38 Bird component health score

Variable	Summary of change	Score	Conf
1. Species richness	It is likely that the majority of species present under the Reference Condition still occur.	90	M
2. Abundance	It is likely that some losses have occurred due to increased disturbance at the mouth, on the water body and along the shoreline which may have reduced the estuaries suitability as a foraging area and roost for large numbers of gulls and terns. Angling and poaching activities reduce abundance present.	80	L
3. Community composition	The basic structure of the water bird community is probably still intact but disturbances at the mouth, on the water body and along the shoreline will have resulted in some reduction in the number of coastal and intertidal species.	80	L
Biotic component health score		**90**	**L**
% of impact non-flow related		80	L
Adjusted score		96	L

5 PRESENT ECOLOGICAL STATUS

5.1 Overall Estuarine Health Index Score

The Mlalazi Estuary in its Present State is estimated to be 80% similar to the Natural Condition, which translates into a Present Ecological Status (PES) of a B Category. This is mostly attributed to the following factors:

- Reduction in river flow, especially baseflows that maintain the salinity regime in the system;
- Recreational activities (e.g. boat launching) in the lower reaches affecting birds abundance;
- Over exploitation of living resources (e.g. poaching and line fishing);
- Agricultural activities in the Estuary Functional Zone causing loss of estuarine habitat; and
- Past disposed spoil from dredging in the 1960's as well as berm construction near the mouth.

The overall current Estuarine Health Score as well as the score with non-flow related pressures removed is given on Table 5.1 below.

Table 5.1 Estuarine Health Score (EHI) for the Mlalazi Estuary.

Variable	Estuarine health score		
	Overall	Excluding non-flow related pressures	Conf
Hydrology	61	70	L
Hydrodynamics and mouth condition	97	97	L
Water quality	80	83	L
Physical habitat alteration	89	95	M
Habitat health score	**82**	**88**	**L**
Microalgae	80	81	L
Macrophytes	70	97	M
Invertebrates	80	84	L
Fish	75	88	M
Birds	80	96	L
Biotic health score	**77**	**87**	**L**
ESTUARY HEALTH SCORE	**80**	**88**	**L**
PRESENT ECOLOGICAL STATUS (PES)	**B**	**A/B**	**L**
OVERALL CONFIDENCE	**L**	**L**	**L**

5.2 Relative contribution of flow and non-flow related impacts on Estuarine Health

Estimates of the contribution of non-flow related impacts on the level of degradation of each component led to an increase in the health score from a PES of 80 to 88 (Table 5.1), which would raise the health score to an A/B Category (±3 points from the category boundary). This suggests that non-flow related impacts have played some role in the degradation of the estuary to a B, but that some flow-related impacts are also driving degradation.

Of the non-flow related impacts, habitat loss to sugar farming within the 5m contour and the vegetation integrity of those areas along with potential water quality problems associated with the Mtunzini WWTW; the Aquaculture Kob Farm and historical dredging and berm construction were identified as important factors currently influencing ecological health of the system. A full list of items that could improve estuarine health is given under Section 7.5 Ecological Categories associated with scenarios.

The following is important to note:

Potential Impacts of Mariculture

The National Biodiversity Assessment: 2011 (Driver *et. al.,* 2012) identified Mariculture as an emerging pressure in the marine and coastal environment. It is stated that although mariculture can sometimes provide options for easing pressure on over-exploited marine resources, it can also have serious negative impacts if not appropriately undertaken and managed, for example causing declines in water quality through nutrient enrichment and pollution, incubation of parasites and pathogens which may then transfer to wild stocks, introduction and spread of invasive alien species, and degradation of marine habitats.

5.3 Overall Confidence

Confidence levels for three of the four abiotic components were rated as Low. Only two of the five biotic components had enough data to yield Medium Confidence assessments. The overall confidence assessment for this study is LOW.

6 THE RECOMMENDED ECOLOGICAL CATEGORY

6.1 Conservation Importance

The Estuary Importance Score (EIS) takes size, the rarity of the estuary type within its biographical zone, habitat, biodiversity and functional importance of the estuary into account (Table 6.1). Biodiversity importance, in turn, is based on the assessment of the importance of the estuary for plants, invertebrates, fish and birds, using rarity indices. The scores have been determined for all South African estuaries (DWAF 2008, Turpie *et. al.,* 2012b), apart from functional importance, which is scored by the specialists in the workshop (Table 6.1). The Estuary Importance scores for five components and the importance rating are presented in Tables 6.2 and 6.3, respectively.

The functional importance of Mlalazi Estuary is very high with a score of 90.

Table 6.1. Estimation of the functional importance score of the Mlalazi Estuary.

Functionality	Score
a. Estuary: Input of detritus and nutrients generated in estuary	60
b. Nursery function for marine-living fish	90
c. Movement corridor for river invertebrates and fish breeding in sea	70
d. Migratory stopover for coastal birds	40
e. Catchment detritus, nutrients and sediments to sea	60
Functional importance score - Max (a to f)	90

The EIS for the Mlalazi Estuary, is 85 (Table 6.2), indicating that the estuary is rated as “Highly Important” (Table 6.3). Much of this is due to the ecological contributions made by the system and the fact that the biodiversity is high. In addition, there are several iconic as well as red data species present. Furthermore the Mlalazi is important from an economic perspective due to the regional tourism value attached to it. The estuary forms one of the boundaries of the Mlalazi Nature Reserve which has high ecotourism value particularly in relation to birds. The estuary is also situated adjacent to the town of Mtunzini which is the major tourist hub in the area.

Table 6.2 Estuarine Importance scores for the Mlalazi Estuary.

Criterion	Weight	Score
Estuary Size	15	90
Zonal Rarity Type	10	30
Habitat Diversity	25	90
Biodiversity Importance	25	96
Functional Importance	25	90
Estuary Importance Score		**85**

Table 6.3 Estuarine Importance Scores (EIS) and significance.

Importance score	Description
81 – 100	Highly important
61 – 80	Important
0 – 60	Of low to average importance

In addition, the Mlalazi also forms part of the core set of priority estuaries in need of protection to achieve biodiversity targets in the National Estuaries Biodiversity Plan for the National Biodiversity Assessment (Turpie *et al*., 2012). The NBA 2011 (Van Niekerk and Turpie 2012) recommended that the minimum Category for the Mlalazi be a A, that the system be a granted full no-take protection, and that 75 % of the estuary margin be undeveloped (Table 6.4).

Table 6.4 National Estuary Biodiversity Plan requirements for the Mlalazi Estuary (BAS = Best Attainable State).

Estuary Requirements	Mlalazi
National and/or Regional Priority set	**SA**
Recommended extent of protection	**Full**
Recommended extent of undeveloped margin	**75%**
Provisional estimate of Recommended Ecological Category	**A or BAS**

6.2 Recommended Ecological Category

The Recommended Ecological Category (REC) represents the level of protection assigned to an estuary. The Present Ecological State (PES) sets the minimum REC. The degree to which the REC needs to be elevated above the PES depends on the level of importance and level of protection or desired protection of a particular estuary. The PES for the Mlalazi Estuary is a B and the Estuary is rated as “Highly Important” from a biodiversity perspective.

Taking into account the current conditions (PES = B), the reversibility of the impacts, the ecological importance and the conservation requirements of the Mlalazi Estuary, the REC for the system is an A/B Category. This recommendation is also based on the fact that the Mlalazi Estuary is sensitive to mouth closure and declines in oxygen levels and at the same time it needs floods to be able to take out accumulated sediments. The Estuarine and Functional Importance of the system are also high.

The Recommended Ecological Category represents the level of protection assigned to an estuary. The first step is to determine the 'minimum' Ecological Category based on its PES. The relationship between Environmental Health Index (EHI) Score, PES and minimum REC is set out in Table 6.5.

Table 6.5 Relationship between the EHI, PES and minimum REC.

EHI Score	PES	Description	Minimum Ecological Category
91 – 100	A	Unmodified, natural	A
76 – 90	B	Largely natural with few modifications	B
61 – 75	C	Moderately modified	C
41 – 60	D	Largely modified	D
21 – 40	E	Highly degraded	-
0 – 20	F	Extremely degraded	-

The PES sets the minimum REC. The degree to which the REC needs to be elevated above the PES depends on the level of importance and level of protection or desired protection of a particular estuary (Table 6.6).

Table 6.6 Estuary protection status and importance, and the basis for assigning a Recommended Ecological Category.

Protection status and importance	REC	Policy basis
Protected area	A or BAS*	Protected and desired protected areas should be restored to and maintained in the best possible state of health
Desired Protected Area		
Highly important	PES + 1, min B	Highly important estuaries should be in an A or B category
Important	PES + 1, min C	Important estuaries should be in an A, B or C category
Of low to average importance	PES, min D	Estuaries to remain in a D category

* BAS = Best Attainable State

The PES for the Mlalazi Estuary is a B. The Estuary is rated as “Highly Important” from a biodiversity perspective and should therefore be in an A Category. However, as a number of the changes are seen as irreversible the Best Attainable State (BAS) is an A/B.

Based on this study, the above National Biodiversity targets and the reversibility of current impacts, the Recommended Ecological Category for the Mlalazi Estuary is an A/B Category.

7 EVALUATION OF FLOW SCENARIOS

7.1 Description of Scenarios

Table 7.1 provides a summary of a range of water resource development scenarios that could affect the Mlalazi Estuary.

Table 7.1 Description of flow scenarios.

Scenarios	Description	MAR (X10^6 m^3)	% Remaining
Reference	Natural Flow	164.31	100
Present	Present day	124.57	76
Scenario 1	Scenario 1 is the same as present day except it includes an additional demand which is approximately 10% of the present day MAR (13 Mm^3) supplied by the upstream dam which has an increased capacity of 15 Mm^3.	112.46	68
Scenario 2	Present day reduced by 10% through abstraction from lower reaches of river	111.89	68
Scenario 3	Present day reduced by 20% through abstraction from lower reaches of the river.	102.93	63
Scenario 4	Scenario 4 is the same as Scenario 3 except an additional demand of 10% MAR is taken out the upstream catchment from a dam with a capacity of 20 Mm^3 (over and above the 20% demand taken directly from the river).	86.74	53

7.2 Variability in River Flow

The occurrences of the flow distributions (mean monthly flows in m^3/s) under the future Scenarios of the Mlalazi Estuary, derived from an 85-year simulated data set are provided in Table 7.2 to 7.5 and Figure 7.1 to 7.4. The full 85-year series of simulated monthly runoff data for future Scenarios are provided in Table 7.6 to 7.9.

Table 7.2 Summary of the monthly flow (in m^3/s) distribution under Scenario 1.

%ile	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
99.9	35.2	28.0	42.4	53.7	66.7	103.7	41.2	44.8	31.2	40.9	13.8	93.8
99	27.6	23.3	31.3	24.7	58.5	50.2	34.8	25.4	26.7	26.4	12.9	34.6
90	7.5	8.8	10.1	6.8	16.0	18.0	10.2	7.7	5.2	5.0	3.0	4.1
80	4.4	5.3	3.8	4.2	11.4	8.3	5.2	4.6	1.9	1.2	1.2	2.0
70	3.2	3.4	1.8	3.1	4.5	4.6	2.5	1.4	1.0	0.9	0.8	1.1
60	2.1	2.7	1.1	1.4	2.5	3.5	1.6	0.9	0.7	0.7	0.7	0.9
50	1.2	1.6	0.9	0.8	1.5	1.7	1.0	0.7	0.6	0.6	0.6	0.7
40	0.9	1.0	0.7	0.6	0.8	1.0	0.8	0.6	0.5	0.5	0.6	0.6
30	0.7	0.9	0.6	0.5	0.6	0.6	0.5	0.4	0.5	0.5	0.5	0.5
20	0.6	0.7	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
10	0.4	0.6	0.4	0.4	0.3	0.4	0.3	0.3	0.3	0.3	0.3	0.4
1	0.3	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3
0.1	0.2	0.2	0.2	0.2	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2

Table 7.3 Summary of the monthly flow (in m^3/s) distribution under Scenario 2.

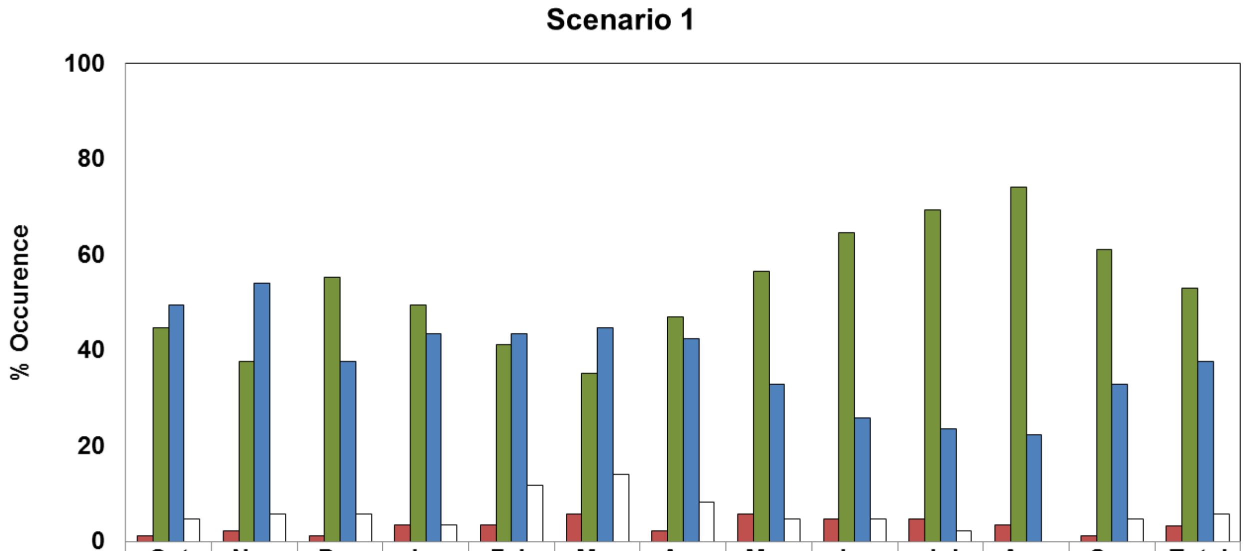
%ile	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
99.9	35.4	30.5	42.4	53.5	66.6	103.4	41.2	44.8	31.5	41.2	13.8	93.7
99	29.4	27.1	31.8	24.9	58.3	50.0	34.7	26.5	26.7	29.5	12.9	35.9
90	9.7	11.5	10.5	8.7	18.8	18.1	13.8	7.7	6.4	5.0	3.9	5.0
80	5.5	5.5	4.3	4.8	11.8	10.1	5.2	4.6	1.5	1.0	1.1	1.9
70	3.9	4.5	1.7	3.3	5.1	5.5	3.1	1.2	0.8	0.7	0.6	0.9
60	2.3	2.7	1.1	1.1	2.4	3.9	1.6	0.8	0.4	0.4	0.4	0.7
50	1.0	1.5	0.6	0.5	1.1	1.8	0.8	0.4	0.3	0.3	0.3	0.4
40	0.6	0.8	0.4	0.2	0.5	0.7	0.5	0.3	0.2	0.2	0.2	0.3
30	0.4	0.6	0.2	0.1	0.2	0.3	0.2	0.1	0.1	0.1	0.1	0.2
20	0.2	0.4	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 7.4 Summary of the monthly flow (in m^3/s) distribution under Scenario 3.

%ile	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
99.9	35.0	30.1	42.0	53.1	66.2	103.0	40.7	44.4	31.1	40.8	13.4	93.3
99	29.0	26.7	31.4	24.5	57.9	49.6	34.3	26.1	26.3	29.1	12.5	35.5
90	9.3	11.1	10.1	8.3	18.3	17.7	13.3	7.3	6.0	4.6	3.5	4.6
80	5.1	5.1	3.9	4.4	11.3	9.7	4.8	4.2	1.1	0.6	0.7	1.5
70	3.5	4.1	1.3	2.9	4.7	5.0	2.7	0.8	0.4	0.2	0.2	0.5
60	1.9	2.3	0.7	0.7	1.9	3.5	1.1	0.3	0.0	0.0	0.0	0.3
50	0.6	1.0	0.2	0.1	0.7	1.4	0.3	0.0	0.0	0.0	0.0	0.0
40	0.2	0.4	0.0	0.0	0.0	0.3	0.1	0.0	0.0	0.0	0.0	0.0
30	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

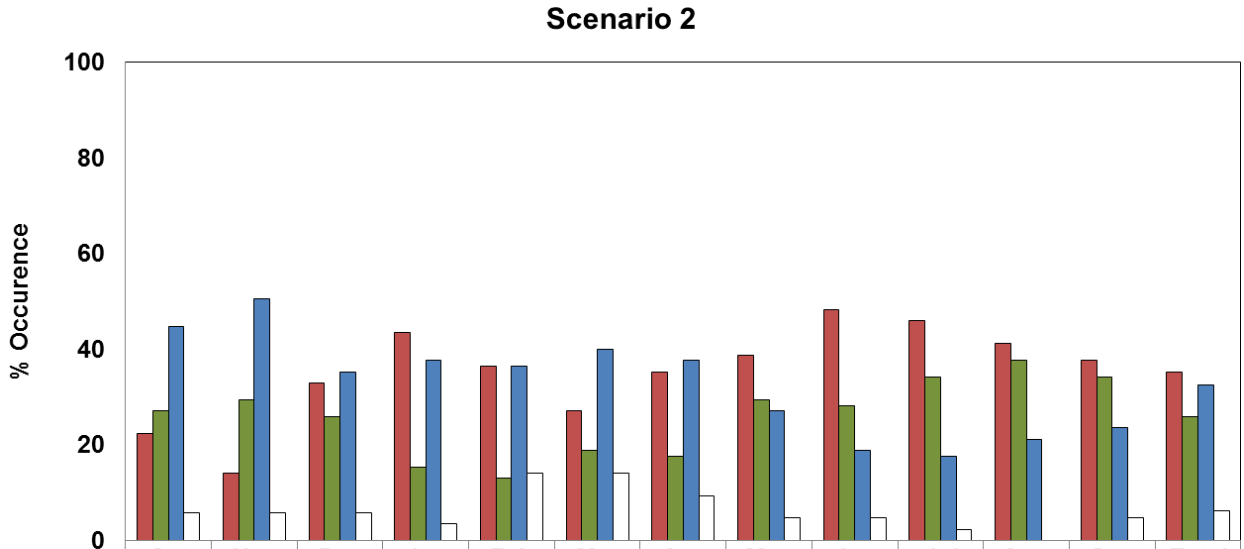
Table 7.5 Summary of the monthly flow (in m^3/s) distribution under Scenario 4.

%ile	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
99.9	34.4	26.2	41.7	52.5	65.4	102.6	39.5	43.5	28.5	39.9	13.1	93.0
99	26.6	20.7	30.3	23.5	57.2	49.0	30.5	23.1	25.6	22.4	12.1	31.8
90	6.8	7.2	8.1	5.5	14.3	15.7	8.7	6.4	4.2	3.7	2.2	3.3
80	3.6	4.2	2.7	3.2	9.2	7.1	3.7	2.3	1.0	0.4	0.4	1.2
70	2.4	2.6	1.0	2.1	3.3	3.4	1.6	0.6	0.2	0.0	0.0	0.3
60	1.2	1.9	0.3	0.6	1.1	2.5	0.7	0.1	0.0	0.0	0.0	0.1
50	0.4	0.8	0.0	0.0	0.5	0.8	0.2	0.0	0.0	0.0	0.0	0.0
40	0.1	0.1	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0



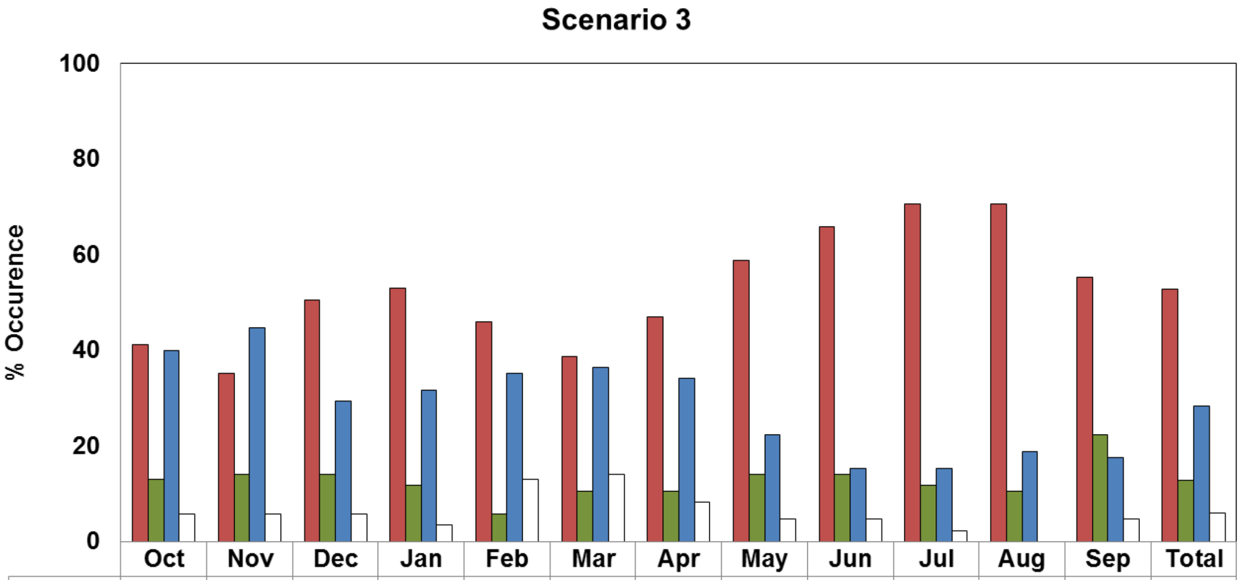
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
State 1	1	2	1	4	4	6	2	6	5	5	4	1	3
State 2	45	38	55	49	41	35	47	56	65	69	74	61	53
State 3	49	54	38	44	44	45	42	33	26	24	22	33	38
State 4	5	6	6	4	12	14	8	5	5	2	0	5	6

Figure 7.1 Graphic presentation of the occurrence of the various abiotic states under Scenario 1.



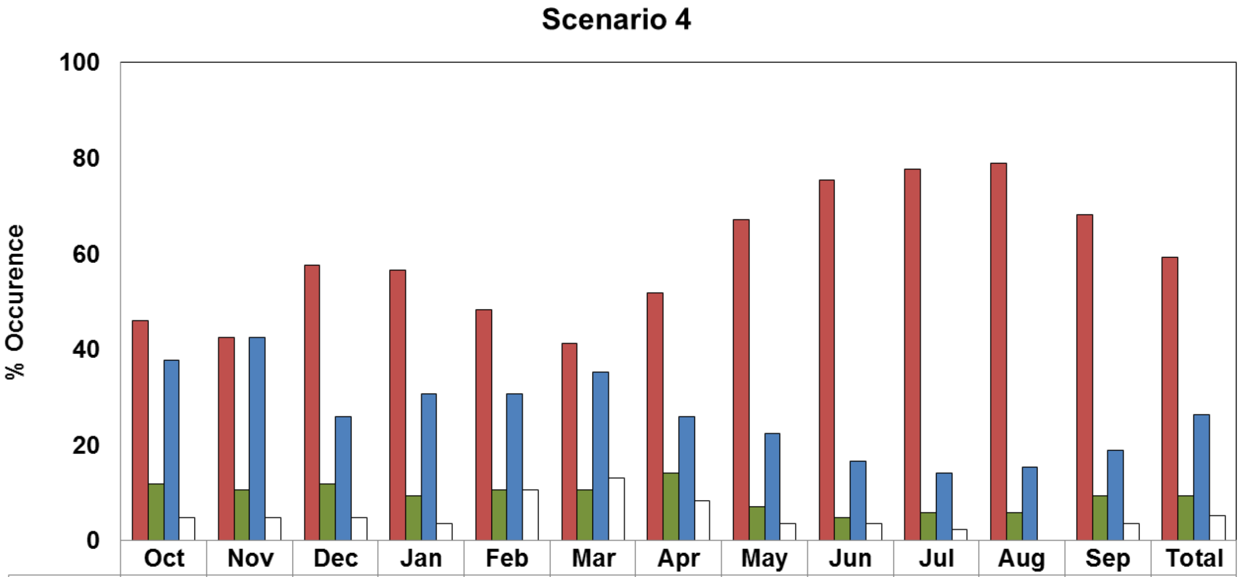
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
State 1	22	14	33	44	36	27	35	39	48	46	41	38	35
State 2	27	29	26	15	13	19	18	29	28	34	38	34	26
State 3	45	51	35	38	36	40	38	27	19	18	21	24	33
State 4	6	6	6	4	14	14	9	5	5	2	0	5	6

Figure 7.2 Graphic presentation of the occurrence of the various abiotic states under Scenario 2.



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
State 1	41	35	51	53	46	39	47	59	66	71	71	55	53
State 2	13	14	14	12	6	11	11	14	14	12	11	22	13
State 3	40	45	29	32	35	36	34	22	15	15	19	18	28
State 4	6	6	6	4	13	14	8	5	5	2	0	5	6

Figure 7.3 Graphic presentation of the occurrence of the various abiotic states under Scenario 3.



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
State 1	46	42	58	56	48	41	52	67	75	78	79	68	59
State 2	12	11	12	9	11	11	14	7	5	6	6	9	9
State 3	38	42	26	31	31	35	26	22	16	14	15	19	26
State 4	5	5	5	4	11	13	8	4	4	2	0	4	5

Figure 7.4 Graphic presentation of the occurrence of the various abiotic states under Scenario 4.

Table 7.6 Simulated monthly flows (m^3/s) to the Mlalazi Estuary for Scenario 1.

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1920	1.16	0.79	2.03	1.43	0.63	2.89	1.64	0.83	0.56	0.41	0.33	1.15
1921	3.56	22.35	16.23	2.55	0.33	0.41	0.44	0.53	0.63	0.46	0.63	0.64
1922	2.43	4.57	1.55	11.06	4.19	0.41	0.30	0.24	0.22	0.24	0.23	0.22
1923	0.20	0.24	0.46	0.39	0.54	1.40	1.09	0.77	0.72	0.62	0.58	2.16
1924	1.40	6.77	10.11	4.36	16.56	109.65	41.89	16.29	5.13	1.05	0.80	0.87
1925	3.43	1.88	0.69	0.44	0.36	3.38	1.59	0.46	0.51	0.49	0.40	0.52
1926	1.67	1.24	1.11	0.83	0.81	6.26	3.29	0.59	0.54	0.61	0.65	0.59
1927	0.72	0.58	0.52	1.75	2.61	1.12	0.74	1.49	1.05	0.60	0.53	0.46
1928	0.46	0.37	0.27	1.33	0.84	20.07	9.32	0.85	1.30	1.12	1.40	2.71
1929	3.04	1.32	0.54	10.87	4.14	0.41	0.47	0.44	0.58	0.73	0.86	2.07
1930	1.18	0.81	0.76	0.44	0.41	0.43	0.53	0.42	0.41	0.46	0.40	0.39
1931	0.49	0.58	0.58	0.45	33.60	18.54	25.75	20.08	4.74	0.63	0.41	0.37
1932	0.49	0.79	1.96	1.19	0.95	0.68	0.48	0.31	0.25	0.27	0.35	0.38
1933	0.43	0.68	1.78	4.20	4.54	1.61	1.76	2.10	3.78	4.80	2.17	0.87
1934	0.59	0.62	10.38	3.84	0.69	0.59	0.56	3.13	31.74	10.41	5.92	2.22
1935	0.54	0.36	0.24	0.53	11.40	5.51	0.96	11.16	4.36	0.81	0.58	0.64
1936	1.67	16.32	5.14	0.43	5.13	4.35	1.52	0.63	0.52	0.55	0.65	0.59
1937	0.48	0.97	7.32	3.50	9.75	2.76	0.40	0.39	0.65	5.29	2.77	0.76
1938	0.69	0.52	0.57	0.52	14.11	9.95	2.06	6.80	2.93	1.36	0.99	12.55
1939	4.30	10.97	3.46	0.47	0.28	1.54	1.23	21.23	25.70	6.10	0.95	0.91
1940	0.75	11.60	6.49	1.05	0.38	0.40	0.46	0.36	0.41	0.42	0.37	0.48
1941	0.44	0.96	0.75	3.80	1.67	4.62	2.18	0.96	1.03	0.85	0.81	1.01
1942	0.88	3.37	15.33	4.69	0.59	17.30	27.61	7.20	0.72	5.25	8.81	2.78
1943	6.80	3.46	0.98	0.37	0.57	1.27	0.85	0.46	5.24	3.86	1.02	15.63
1944	5.49	3.39	1.12	0.38	2.84	19.90	6.86	0.51	0.40	0.31	0.31	0.27
1945	0.31	0.25	0.35	0.57	0.57	0.67	1.03	0.75	0.54	0.34	0.31	0.29
1946	0.45	0.42	0.44	0.42	5.09	4.86	2.46	1.03	0.95	1.48	1.13	1.02
1947	0.93	2.04	1.20	0.83	1.45	0.99	0.93	0.67	0.43	0.28	0.27	0.34
1948	0.42	0.57	0.42	0.36	1.43	0.90	9.41	5.03	0.64	0.55	0.46	0.53
1949	2.97	2.03	13.33	4.67	2.69	1.86	0.97	0.67	0.67	0.53	0.48	0.38
1950	0.32	0.21	0.37	0.40	0.34	0.44	0.44	0.41	0.49	0.60	4.59	2.87
1951	3.13	1.21	0.48	0.44	0.40	0.36	0.43	1.22	0.95	0.78	0.63	0.42
1952	0.29	0.45	0.53	0.45	0.53	0.65	0.50	0.39	0.32	0.31	0.32	0.67
1953	1.76	7.42	3.71	0.66	12.02	4.03	3.75	8.09	3.03	0.84	0.64	4.62
1954	25.64	8.30	0.41	1.62	1.08	12.48	5.05	0.90	0.67	0.43	0.44	0.67
1955	3.24	5.63	1.89	0.38	20.12	16.02	3.57	0.71	1.07	0.86	0.86	2.02
1956	1.30	1.01	28.91	12.20	6.77	4.04	14.45	4.61	0.59	0.63	0.79	18.17
1957	24.52	6.55	0.71	17.23	14.07	2.26	3.55	1.31	0.58	0.59	0.51	2.24
1958	1.84	0.91	0.56	0.55	0.43	0.22	0.16	0.35	0.42	0.34	0.57	1.33
1959	3.71	1.69	1.03	0.55	3.30	2.74	9.75	4.63	0.87	0.59	0.52	0.61
1960	0.65	19.83	43.69	12.83	9.91	3.17	18.81	6.26	10.63	4.68	0.99	1.02
1961	5.35	4.95	1.15	0.56	0.47	0.68	1.00	0.84	0.59	0.43	0.51	0.57
1962	0.91	3.31	1.50	1.46	1.01	3.68	2.83	0.92	15.69	42.57	12.67	0.55
1963	0.62	0.95	0.71	4.20	2.11	0.54	2.08	1.06	0.46	0.49	0.55	0.50
1964	4.51	2.82	0.74	0.38	0.27	0.20	0.28	0.40	1.70	1.19	3.20	3.30
1965	13.66	4.65	0.50	3.24	1.85	0.52	0.41	0.43	0.53	0.47	0.64	0.95
1966	0.78	0.62	0.42	0.52	0.87	7.91	33.44	9.58	0.56	0.57	0.66	0.51
1967	0.61	1.42	0.69	0.39	1.47	3.24	1.38	0.39	0.41	0.40	0.64	0.98
1968	1.18	1.20	1.91	0.78	0.26	19.00	10.58	2.89	1.23	0.66	0.43	0.59
1969	6.01	2.65	0.53	0.38	0.36	0.35	0.41	1.39	1.04	0.57	0.43	0.53
1970	6.96	9.06	1.75	0.66	1.85	5.00	5.62	47.01	15.94	6.64	2.56	0.92
1971	7.73	2.94	0.70	2.56	35.47	11.50	1.10	9.92	4.00	1.01	0.71	0.44
1972	0.42	0.62	0.96	0.79	0.86	0.66	1.60	1.02	0.55	0.42	4.27	22.09
1973	7.21	1.68	0.95	6.57	2.73	0.59	0.54	1.46	1.18	0.77	0.57	0.40
1974	0.30	1.02	0.83	3.82	18.59	6.01	0.80	0.64	0.51	0.45	0.47	6.80
1975	3.29	0.95	1.83	18.53	11.69	38.83	22.64	4.71	0.95	0.64	0.75	0.70
1976	2.82	2.65	7.85	5.55	56.74	26.78	3.50	0.44	0.34	0.32	0.43	1.54
1977	1.23	0.97	0.85	11.45	5.37	1.31	8.45	2.91	0.67	0.78	0.97	1.14
1978	11.51	4.63	0.54	0.38	0.30	0.22	0.33	1.01	0.96	0.71	0.72	1.97
1979	1.28	1.18	0.90	0.63	0.46	0.26	0.25	0.23	0.26	0.24	0.27	5.04
1980	2.09	0.68	0.44	1.66	2.47	0.96	0.60	9.66	7.57	1.29	1.55	8.63
1981	4.41	6.53	1.91	0.45	0.45	1.21	0.93	0.69	0.53	0.38	0.28	0.35
1982	0.82	0.74	0.38	0.23	0.25	0.19	0.20	0.22	0.29	0.47	2.82	1.50
1983	2.06	8.48	4.47	56.90	67.65	17.20	6.41	2.00	0.75	11.77	7.19	1.37
1984	0.68	0.86	0.76	4.40	36.98	10.58	0.36	0.22	0.41	0.71	0.69	0.74
1985	25.99	9.83	0.46	0.38	0.41	0.50	0.68	0.48	0.48	0.38	0.31	0.42
1986	0.60	0.63	4.17	6.42	2.73	4.44	1.78	0.59	13.69	5.11	13.92	100.40
1987	36.05	2.97	0.98	0.41	11.64	18.59	5.10	0.46	0.54	0.61	0.61	0.73
1988	3.54	5.17	19.37	5.93	12.89	3.86	0.41	0.41	0.54	0.65	0.50	0.61
1989	0.95	28.50	10.16	0.56	0.57	5.22	2.49	0.74	0.50	0.33	2.06	1.25
1990	7.00	3.02	1.58	2.15	15.15	20.95	5.64	5.82	2.49	0.89	0.78	0.71
1991	0.96	0.79	0.47	0.24	0.13	0.23	0.30	0.22	0.19	0.18	0.21	0.28
1992	0.32	0.85	0.64	0.45	0.48	0.41	0.34	0.26	0.24	0.21	0.31	0.53
1993	9.34	5.36	0.77	1.02	0.64	0.44	0.37	0.28	0.27	0.28	0.51	0.61
1994	4.26	2.09	0.52	0.16	0.22	4.46	20.69	7.17	8.23	3.23	0.84	0.53
1995	0.85	3.78	11.35	6.99	20.36	10.15	1.86	0.62	0.46	2.44	1.35	0.49
1996	0.57	0.70	0.43	3.43	1.84	0.56	0.62	0.83	1.03	1.00	0.77	1.12
1997	2.21	16.48	5.72	0.30	0.45	0.34	0.37	0.31	0.24	0.30	0.28	0.38
1998	0.59	0.93	0.70	1.64	14.55	6.10	0.48	0.41	0.38	0.48	0.68	1.01
1999	13.41	5.29	0.56	0.53	0.63	0.59	0.60	0.73	0.61	0.40	0.26	0.28
2000	0.31	3.23	1.48	1.02	1.06	0.62	0.53	0.44	0.34	0.28	0.22	0.39
2001	2.65	3.48	2.80	3.24	1.47	0.58	0.50	0.33	0.39	23.30	10.42	1.09
2002	0.76	0.86	0.61	0.39	0.43	0.27	0.34	0.37	0.86	0.92	0.61	0.67
2003	0.63	0.65	0.40	0.56	5.31	3.66	1.26	0.51	0.33	0.51	0.62	0.72
2004	0.63	1.61	0.76	0.44	0.67	1.67	0.86	0.38	0.44	0.40	0.31	0.28

Table 7.7 Simulated monthly flows (m^3/s) to the Mlalazi Estuary for Scenario 2.

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1920	0.75	0.37	1.62	1.02	0.18	2.96	1.67	0.60	0.23	0.04	0.00	0.86
1921	5.14	26.34	16.21	2.58	0.00	0.00	0.02	0.15	0.27	0.06	0.31	0.28
1922	2.41	7.10	2.06	11.16	4.21	0.01	0.00	0.00	0.00	0.00	0.00	0.00
1923	0.00	0.00	0.05	0.00	0.09	0.99	0.67	0.35	0.29	0.30	0.26	2.07
1924	1.28	11.94	10.73	4.35	16.52	109.38	41.88	16.25	5.15	0.92	0.56	0.68
1925	3.97	1.88	0.41	0.04	0.00	3.68	1.49	0.10	0.17	0.13	0.01	0.15
1926	1.43	1.03	0.90	0.55	0.50	10.05	3.49	0.31	0.20	0.32	0.33	0.25
1927	0.44	0.21	0.15	1.47	2.51	0.91	0.47	1.30	0.83	0.31	0.22	0.07
1928	0.09	0.00	0.00	0.92	0.40	25.76	9.32	0.75	1.13	0.99	1.46	3.06
1929	3.03	1.32	0.19	11.20	4.17	0.02	0.09	0.04	0.24	0.42	0.60	1.89
1930	0.98	0.59	0.49	0.03	0.00	0.02	0.12	0.01	0.00	0.07	0.00	0.00
1931	0.09	0.19	0.21	0.04	39.86	18.53	25.69	20.04	4.75	0.40	0.06	0.00
1932	0.14	0.49	1.73	0.96	0.68	0.36	0.08	0.00	0.00	0.00	0.00	0.00
1933	0.01	0.26	1.46	5.94	6.87	1.96	1.61	2.77	4.68	4.79	2.17	0.69
1934	0.31	0.30	11.14	3.85	0.36	0.26	0.19	3.74	32.06	10.42	5.90	2.25
1935	0.23	0.00	0.00	0.12	13.11	5.50	0.77	11.31	4.36	0.67	0.29	0.35
1936	1.47	17.23	5.18	0.05	5.51	4.35	1.51	0.34	0.19	0.24	0.35	0.24
1937	0.11	0.68	9.56	3.51	9.72	2.80	0.01	0.00	0.33	6.35	2.77	0.54
1938	0.46	0.14	0.25	0.13	15.81	9.94	2.08	6.77	2.93	1.36	0.87	12.65
1939	4.32	10.93	3.48	0.12	0.00	1.15	1.00	22.59	25.65	6.11	0.88	0.72
1940	0.52	12.09	6.48	0.97	0.00	0.00	0.04	0.00	0.00	0.01	0.00	0.06
1941	0.03	0.63	0.41	4.82	1.73	6.95	2.83	0.81	0.86	0.65	0.59	0.82
1942	0.66	4.55	15.75	4.72	0.23	17.58	27.55	7.21	0.55	5.39	8.80	2.80
1943	6.77	3.46	0.77	0.00	0.16	0.99	0.52	0.08	7.30	3.86	0.99	15.63
1944	5.50	3.38	1.11	0.00	2.60	20.51	6.88	0.24	0.01	0.00	0.00	0.00
1945	0.00	0.00	0.00	0.16	0.11	0.26	0.66	0.44	0.18	0.00	0.00	0.00
1946	0.04	0.00	0.03	0.01	6.63	7.46	3.23	0.90	0.78	1.42	1.02	0.88
1947	0.76	2.05	1.05	0.59	1.20	0.75	0.69	0.37	0.04	0.00	0.00	0.00
1948	0.01	0.15	0.01	0.00	0.98	0.56	15.26	5.05	0.42	0.24	0.11	0.19
1949	3.63	2.18	13.70	4.68	2.68	1.80	0.76	0.41	0.39	0.21	0.13	0.00
1950	0.00	0.00	0.00	0.00	0.00	0.03	0.02	0.00	0.06	0.19	6.48	3.89
1951	4.92	1.46	0.13	0.03	0.00	0.00	0.00	0.87	0.66	0.54	0.31	0.01
1952	0.00	0.03	0.13	0.04	0.08	0.29	0.08	0.00	0.00	0.00	0.00	0.24
1953	1.50	12.73	4.21	0.40	12.27	4.04	3.73	8.06	3.03	0.69	0.38	5.05
1954	25.58	8.32	0.03	1.33	0.74	13.44	5.05	0.79	0.39	0.07	0.09	0.36
1955	4.23	6.08	1.90	0.00	20.53	15.99	3.58	0.48	0.88	0.64	0.68	2.26
1956	1.28	0.83	29.59	12.19	6.75	4.04	14.41	4.63	0.31	0.37	0.54	18.94
1957	24.48	6.56	0.46	17.42	14.05	2.29	3.51	1.33	0.29	0.29	0.17	2.30
1958	1.88	0.70	0.24	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.90
1959	5.22	2.03	0.81	0.16	3.70	3.26	12.78	4.62	0.73	0.32	0.20	0.30
1960	0.34	21.19	43.59	12.84	9.88	3.18	18.75	6.27	10.58	4.67	0.93	0.86
1961	5.56	4.94	1.16	0.24	0.02	0.35	0.74	0.59	0.24	0.05	0.17	0.21
1962	0.64	4.27	1.62	1.25	0.70	5.09	3.71	0.81	16.24	42.47	12.69	0.27
1963	0.34	0.71	0.40	5.30	2.13	0.21	1.85	0.79	0.11	0.17	0.21	0.13
1964	6.72	2.83	0.47	0.00	0.00	0.00	0.00	0.00	1.27	0.87	4.74	4.93
1965	13.63	4.66	0.14	3.59	1.85	0.15	0.01	0.04	0.16	0.09	0.33	0.68
1966	0.50	0.26	0.01	0.13	0.52	12.18	33.35	9.60	0.29	0.29	0.37	0.14
1967	0.31	1.17	0.32	0.00	1.13	3.96	1.40	0.01	0.03	0.00	0.34	0.71
1968	0.97	1.00	1.73	0.40	0.00	24.26	10.58	2.88	1.23	0.42	0.07	0.29
1969	6.91	2.66	0.19	0.00	0.00	0.00	0.00	1.03	0.76	0.25	0.05	0.17
1970	10.69	9.04	1.77	0.37	1.60	5.49	5.60	46.89	15.96	6.61	2.58	0.76
1971	7.87	2.95	0.43	2.58	35.64	11.50	1.06	9.93	4.00	0.94	0.47	0.07
1972	0.05	0.28	0.68	0.49	0.54	0.32	1.34	0.76	0.21	0.06	6.50	23.72
1973	7.22	1.59	0.70	6.90	2.74	0.28	0.18	1.22	0.98	0.53	0.27	0.00
1974	0.00	0.67	0.52	4.95	20.74	6.02	0.61	0.35	0.15	0.10	0.11	8.41
1975	3.29	0.78	1.64	18.82	11.68	38.73	22.61	4.70	0.85	0.39	0.50	0.42
1976	3.64	2.70	7.82	5.54	56.59	26.76	3.51	0.09	0.00	0.00	0.05	1.27
1977	1.04	0.77	0.62	13.87	5.38	1.18	8.55	2.92	0.42	0.55	0.78	0.98
1978	12.29	4.63	0.19	0.00	0.00	0.00	0.00	0.60	0.60	0.42	0.43	1.77
1979	1.11	1.00	0.68	0.31	0.01	0.00	0.00	0.00	0.00	0.00	0.00	6.52
1980	2.49	0.40	0.04	1.37	2.29	0.67	0.29	14.86	7.56	1.30	1.54	8.61
1981	4.41	6.51	1.93	0.08	0.00	0.90	0.62	0.41	0.16	0.00	0.00	0.00
1982	0.47	0.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	2.40	1.07
1983	2.47	13.84	4.48	56.73	67.53	17.20	6.39	2.02	0.53	11.94	7.19	1.40
1984	0.44	0.60	0.48	5.15	36.88	10.61	0.00	0.00	0.00	0.40	0.37	0.45
1985	28.14	9.85	0.13	0.00	0.00	0.09	0.32	0.08	0.10	0.00	0.00	0.00
1986	0.21	0.25	5.47	9.86	2.77	4.41	1.79	0.30	13.94	5.11	13.88	100.16
1987	36.05	2.97	0.78	0.00	12.30	18.55	5.12	0.13	0.22	0.29	0.30	0.43
1988	4.91	5.37	19.32	5.96	12.83	3.88	0.02	0.04	0.18	0.32	0.12	0.28
1989	0.70	30.93	10.17	0.28	0.18	5.85	2.50	0.51	0.15	0.00	1.92	1.04
1990	8.33	3.04	1.37	2.14	15.32	20.90	5.66	5.78	2.50	0.73	0.57	0.45
1991	0.74	0.51	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1992	0.00	0.42	0.23	0.04	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.11
1993	14.10	5.38	0.57	0.77	0.23	0.06	0.00	0.00	0.00	0.00	0.10	0.18
1994	5.82	2.53	0.16	0.00	0.00	5.34	22.80	7.17	8.19	3.23	0.68	0.20
1995	0.60	4.55	11.32	6.98	20.30	10.14	1.87	0.34	0.10	2.87	1.34	0.15
1996	0.27	0.37	0.03	3.89	1.84	0.22	0.30	0.55	0.81	0.80	0.52	0.91
1997	2.63	19.12	5.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1998	0.18	0.50	0.29	1.35	20.42	6.12	0.16	0.03	0.00	0.13	0.35	0.75
1999	15.43	5.31	0.25	0.16	0.23	0.22	0.23	0.42	0.24	0.00	0.00	0.00
2000	0.00	3.19	1.31	0.77	0.79	0.28	0.16	0.05	0.00	0.00	0.00	0.00
2001	2.31	4.68	3.73	4.46	1.61	0.27	0.12	0.00	0.00	27.01	10.42	1.06
2002	0.53	0.63	0.27	0.00	0.00	0.00	0.00	0.00	0.43	0.61	0.28	0.36
2003	0.30	0.32	0.00	0.18	7.30	5.06	1.33	0.18	0.00	0.18	0.28	0.43
2004	0.30	1.35	0.38	0.06	0.29	1.41	0.49	0.00	0.05	0.00	0.00	0.00

Table 7.8 Simulated monthly flows (m^3/s) to the Mlalazi Estuary for Scenario 3.

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1920	0.34	0.00	1.21	0.61	0.00	2.55	1.25	0.19	0.00	0.00	0.00	0.43
1921	4.73	25.92	15.80	2.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1922	2.00	6.68	1.65	10.75	3.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1923	0.00	0.00	0.00	0.00	0.00	0.57	0.24	0.00	0.00	0.00	0.00	1.64
1924	0.87	11.52	10.32	3.94	16.07	108.96	41.45	15.84	4.72	0.51	0.15	0.25
1925	3.56	1.45	0.00	0.00	0.00	3.27	1.06	0.00	0.00	0.00	0.00	0.00
1926	1.02	0.61	0.49	0.14	0.05	9.64	3.06	0.00	0.00	0.00	0.00	0.00
1927	0.03	0.00	0.00	1.06	2.06	0.50	0.05	0.88	0.40	0.00	0.00	0.00
1928	0.00	0.00	0.00	0.51	0.00	25.35	8.90	0.34	0.70	0.57	1.05	2.63
1929	2.62	0.90	0.00	10.79	3.72	0.00	0.00	0.00	0.00	0.01	0.19	1.47
1930	0.57	0.17	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1931	0.00	0.00	0.00	0.00	39.41	18.12	25.26	19.63	4.32	0.00	0.00	0.00
1932	0.00	0.07	1.32	0.55	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1933	0.00	0.00	1.05	5.53	6.42	1.55	1.18	2.36	4.25	4.38	1.76	0.26
1934	0.00	0.00	10.73	3.44	0.00	0.00	0.00	3.33	31.64	10.01	5.49	1.82
1935	0.00	0.00	0.00	0.00	12.66	5.09	0.34	10.90	3.94	0.26	0.00	0.00
1936	1.06	16.80	4.77	0.00	5.06	3.94	1.09	0.00	0.00	0.00	0.00	0.00
1937	0.00	0.25	9.15	3.10	9.27	2.39	0.00	0.00	0.00	5.94	2.36	0.11
1938	0.04	0.00	0.00	0.00	15.36	9.53	1.65	6.35	2.50	0.95	0.46	12.23
1939	3.91	10.50	3.07	0.00	0.00	0.74	0.57	22.18	25.23	5.70	0.47	0.29
1940	0.11	11.66	6.07	0.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1941	0.00	0.20	0.00	4.41	1.28	6.54	2.40	0.40	0.44	0.24	0.18	0.39
1942	0.25	4.13	15.34	4.30	0.00	17.17	27.13	6.80	0.12	4.98	8.39	2.37
1943	6.36	3.04	0.36	0.00	0.00	0.58	0.10	0.00	6.87	3.45	0.57	15.20
1944	5.09	2.96	0.69	0.00	2.15	20.10	6.45	0.00	0.00	0.00	0.00	0.00
1945	0.00	0.00	0.00	0.00	0.00	0.00	0.23	0.03	0.00	0.00	0.00	0.00
1946	0.00	0.00	0.00	0.00	6.18	7.05	2.80	0.49	0.36	1.00	0.60	0.46
1947	0.35	1.63	0.64	0.18	0.75	0.34	0.27	0.00	0.00	0.00	0.00	0.00
1948	0.00	0.00	0.00	0.00	0.53	0.15	14.83	4.64	0.00	0.00	0.00	0.00
1949	3.22	1.75	13.29	4.27	2.22	1.39	0.33	0.00	0.00	0.00	0.00	0.00
1950	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.07	3.46
1951	4.51	1.04	0.00	0.00	0.00	0.00	0.00	0.46	0.23	0.13	0.00	0.00
1952	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1953	1.09	12.31	3.80	0.00	11.82	3.63	3.31	7.65	2.60	0.28	0.00	4.62
1954	25.17	7.90	0.00	0.92	0.29	13.03	4.63	0.38	0.00	0.00	0.00	0.00
1955	3.82	5.65	1.49	0.00	20.08	15.58	3.16	0.07	0.46	0.23	0.27	1.84
1956	0.87	0.41	29.18	11.78	6.30	3.63	13.98	4.22	0.00	0.00	0.13	18.51
1957	24.07	6.13	0.05	17.01	13.60	1.88	3.09	0.92	0.00	0.00	0.00	1.88
1958	1.47	0.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.48
1959	4.81	1.61	0.40	0.00	3.25	2.85	12.36	4.21	0.31	0.00	0.00	0.00
1960	0.00	20.77	43.18	12.43	9.43	2.77	18.32	5.86	10.15	4.26	0.52	0.44
1961	5.15	4.51	0.75	0.00	0.00	0.00	0.31	0.18	0.00	0.00	0.00	0.00
1962	0.23	3.85	1.21	0.84	0.25	4.68	3.29	0.40	15.81	42.06	12.28	0.00
1963	0.00	0.28	0.00	4.89	1.68	0.00	1.42	0.38	0.00	0.00	0.00	0.00
1964	6.31	2.40	0.06	0.00	0.00	0.00	0.00	0.00	0.85	0.46	4.33	4.51
1965	13.22	4.24	0.00	3.18	1.40	0.00	0.00	0.00	0.00	0.00	0.00	0.25
1966	0.09	0.00	0.00	0.00	0.07	11.76	32.93	9.18	0.00	0.00	0.00	0.00
1967	0.00	0.75	0.00	0.00	0.68	3.55	0.97	0.00	0.00	0.00	0.00	0.29
1968	0.56	0.57	1.32	0.00	0.00	23.85	10.15	2.47	0.81	0.01	0.00	0.00
1969	6.50	2.23	0.00	0.00	0.00	0.00	0.00	0.62	0.33	0.00	0.00	0.00
1970	10.28	8.61	1.36	0.00	1.15	5.08	5.18	46.48	15.53	6.20	2.17	0.33
1971	7.46	2.53	0.02	2.17	35.19	11.08	0.63	9.52	3.57	0.53	0.06	0.00
1972	0.00	0.00	0.27	0.07	0.09	0.00	0.92	0.35	0.00	0.00	6.09	23.29
1973	6.81	1.16	0.29	6.49	2.29	0.00	0.00	0.81	0.56	0.12	0.00	0.00
1974	0.00	0.25	0.10	4.54	20.29	5.61	0.18	0.00	0.00	0.00	0.00	7.99
1975	2.88	0.35	1.23	18.41	11.23	38.32	22.18	4.29	0.43	0.00	0.09	0.00
1976	3.23	2.27	7.41	5.13	56.14	26.35	3.09	0.00	0.00	0.00	0.00	0.85
1977	0.63	0.35	0.21	13.46	4.93	0.77	8.13	2.51	0.00	0.14	0.37	0.56
1978	11.88	4.21	0.00	0.00	0.00	0.00	0.00	0.19	0.17	0.01	0.02	1.34
1979	0.70	0.58	0.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.09
1980	2.08	0.00	0.00	0.96	1.84	0.26	0.00	14.45	7.13	0.89	1.13	8.19
1981	3.99	6.09	1.52	0.00	0.00	0.49	0.20	0.00	0.00	0.00	0.00	0.00
1982	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.99	0.65
1983	2.06	13.41	4.07	56.32	67.08	16.79	5.96	1.61	0.10	11.53	6.78	0.97
1984	0.03	0.18	0.07	4.74	36.43	10.20	0.00	0.00	0.00	0.00	0.00	0.03
1985	27.73	9.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1986	0.00	0.00	5.06	9.45	2.31	3.99	1.37	0.00	13.51	4.70	13.47	99.73
1987	35.64	2.54	0.37	0.00	11.85	18.14	4.70	0.00	0.00	0.00	0.00	0.01
1988	4.50	4.95	18.91	5.54	12.38	3.47	0.00	0.00	0.00	0.00	0.00	0.00
1989	0.29	30.51	9.76	0.00	0.00	5.44	2.07	0.10	0.00	0.00	1.51	0.61
1990	7.92	2.62	0.96	1.73	14.87	20.49	5.24	5.37	2.07	0.32	0.16	0.03
1991	0.33	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1992	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1993	13.69	4.95	0.16	0.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1994	5.41	2.10	0.00	0.00	0.00	4.93	22.38	6.76	7.77	2.82	0.27	0.00
1995	0.19	4.12	10.91	6.57	19.85	9.73	1.44	0.00	0.00	2.46	0.93	0.00
1996	0.00	0.00	0.00	3.48	1.38	0.00	0.00	0.14	0.38	0.38	0.11	0.49
1997	2.22	18.69	5.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1998	0.00	0.08	0.00	0.94	19.96	5.71	0.00	0.00	0.00	0.00	0.00	0.32
1999	15.02	4.88	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
2000	0.00	2.77	0.90	0.35	0.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2001	1.90	4.26	3.32	4.05	1.16	0.00	0.00	0.00	0.00	26.60	10.01	0.64
2002	0.12	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.20	0.00	0.00
2003	0.00	0.00	0.00	0.00	6.85	4.64	0.91	0.00	0.00	0.00	0.00	0.01
2004	0.00	0.93	0.00	0.00	0.00	1.00	0.06	0.00	0.00	0.00	0.00	0.00

Table 7.9 Simulated monthly flows (m^3/s) to the Mlalazi Estuary for Scenario 4.

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1920	0.34	0.00	1.21	0.61	0.00	2.07	0.79	0.00	0.00	0.00	0.00	0.30
1921	2.74	19.49	15.47	1.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1922	1.61	3.72	0.73	7.88	2.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1923	0.00	0.00	0.00	0.00	0.00	0.57	0.24	0.00	0.00	0.00	0.00	1.31
1924	0.58	5.92	7.51	3.02	15.14	108.58	40.52	14.99	4.31	0.22	0.00	0.02
1925	2.77	1.07	0.00	0.00	0.00	2.56	0.74	0.00	0.00	0.00	0.00	0.00
1926	0.85	0.39	0.29	0.01	0.00	5.44	1.61	0.00	0.00	0.00	0.00	0.00
1927	0.00	0.00	0.00	0.93	1.70	0.30	0.00	0.66	0.20	0.00	0.00	0.00
1928	0.00	0.00	0.00	0.51	0.00	16.86	7.93	0.03	0.46	0.30	0.58	1.49
1929	2.25	0.51	0.00	9.59	2.65	0.00	0.00	0.00	0.00	0.00	0.04	1.22
1930	0.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1931	0.00	0.00	0.00	0.00	30.07	17.22	24.43	18.77	3.92	0.00	0.00	0.00
1932	0.00	0.00	1.14	0.37	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1933	0.00	0.00	0.96	3.38	3.64	0.79	0.91	1.28	2.09	2.11	0.87	0.02
1934	0.00	0.00	8.51	2.48	0.00	0.00	0.00	2.31	28.80	9.62	5.15	1.39
1935	0.00	0.00	0.00	0.00	9.46	4.17	0.11	9.32	3.55	0.00	0.00	0.00
1936	0.85	15.69	4.32	0.00	3.40	2.74	0.56	0.00	0.00	0.00	0.00	0.00
1937	0.00	0.12	5.79	2.16	8.31	1.38	0.00	0.00	0.00	3.51	1.98	0.00
1938	0.00	0.00	0.00	0.00	12.22	8.62	0.77	5.38	2.12	0.58	0.17	11.81
1939	3.50	10.20	2.65	0.00	0.00	0.72	0.38	17.80	24.94	5.30	0.13	0.06
1940	0.00	10.93	5.71	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1941	0.00	0.11	0.00	2.98	0.77	3.80	1.33	0.14	0.19	0.03	0.00	0.16
1942	0.06	2.52	9.70	3.32	0.00	15.48	26.28	5.85	0.00	4.52	8.05	1.96
1943	6.04	2.66	0.16	0.00	0.00	0.44	0.00	0.00	3.97	1.91	0.19	13.87
1944	4.70	2.59	0.30	0.00	1.94	17.57	5.45	0.00	0.00	0.00	0.00	0.00
1945	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.00	0.00	0.00	0.00	0.00
1946	0.00	0.00	0.00	0.00	4.19	4.04	1.61	0.21	0.10	0.66	0.31	0.17
1947	0.11	1.19	0.38	0.01	0.55	0.16	0.08	0.00	0.00	0.00	0.00	0.00
1948	0.00	0.00	0.00	0.00	0.52	0.08	7.94	2.40	0.00	0.00	0.00	0.00
1949	2.15	1.18	12.30	3.32	1.66	1.04	0.12	0.00	0.00	0.00	0.00	0.00
1950	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.77	2.03
1951	2.30	0.36	0.00	0.00	0.00	0.00	0.00	0.40	0.10	0.00	0.00	0.00
1952	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1953	0.94	6.57	1.91	0.00	9.09	2.68	2.38	6.77	2.22	0.02	0.00	3.89
1954	24.92	7.47	0.00	0.80	0.18	10.15	3.66	0.08	0.00	0.00	0.00	0.00
1955	2.42	4.46	1.10	0.00	18.11	14.70	2.17	0.00	0.22	0.04	0.04	1.17
1956	0.48	0.16	27.90	10.86	5.31	2.71	13.10	3.26	0.00	0.00	0.00	17.52
1957	23.78	5.72	0.00	15.98	12.62	0.89	2.19	0.49	0.00	0.00	0.00	1.39
1958	1.02	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.48
1959	2.89	0.84	0.21	0.00	2.40	1.92	6.25	2.15	0.02	0.00	0.00	0.00
1960	0.00	18.50	43.01	11.48	8.47	1.81	17.48	4.90	9.86	3.89	0.17	0.17
1961	4.65	4.15	0.35	0.00	0.00	0.00	0.15	0.02	0.00	0.00	0.00	0.00
1962	0.09	2.46	0.68	0.64	0.11	2.86	1.98	0.10	9.69	41.88	11.87	0.00
1963	0.00	0.10	0.00	3.19	1.00	0.00	1.23	0.24	0.00	0.00	0.00	0.00
1964	3.66	1.34	0.00	0.00	0.00	0.00	0.00	0.00	0.85	0.37	2.38	2.33
1965	9.26	3.83	0.00	2.31	0.92	0.00	0.00	0.00	0.00	0.00	0.00	0.10
1966	0.00	0.00	0.00	0.00	0.00	6.68	28.59	8.22	0.00	0.00	0.00	0.00
1967	0.00	0.57	0.00	0.00	0.57	2.42	0.53	0.00	0.00	0.00	0.00	0.13
1968	0.36	0.35	1.09	0.00	0.00	15.40	9.20	1.55	0.41	0.00	0.00	0.00
1969	5.34	1.82	0.00	0.00	0.00	0.00	0.00	0.57	0.19	0.00	0.00	0.00
1970	5.64	6.24	0.94	0.00	0.95	2.99	3.87	45.80	15.12	5.89	1.77	0.07
1971	7.01	2.11	0.00	1.74	33.57	10.15	0.25	8.08	3.19	0.19	0.00	0.00
1972	0.00	0.00	0.14	0.00	0.00	0.00	0.75	0.19	0.00	0.00	3.45	18.87
1973	6.41	0.83	0.13	5.33	1.24	0.00	0.00	0.64	0.33	0.00	0.00	0.00
1974	0.00	0.17	0.01	3.00	15.11	4.66	0.00	0.00	0.00	0.00	0.00	5.02
1975	2.50	0.10	1.00	17.32	10.23	37.59	21.27	3.37	0.10	0.00	0.00	0.00
1976	2.12	1.90	7.09	4.22	55.42	25.46	2.09	0.00	0.00	0.00	0.00	0.69
1977	0.41	0.12	0.03	9.85	3.89	0.49	6.55	1.55	0.00	0.00	0.15	0.29
1978	10.91	3.82	0.00	0.00	0.00	0.00	0.00	0.19	0.12	0.00	0.00	1.12
1979	0.46	0.33	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.19
1980	1.27	0.00	0.00	0.84	1.57	0.14	0.00	7.53	5.17	0.49	0.77	7.84
1981	3.63	5.74	1.10	0.00	0.00	0.39	0.08	0.00	0.00	0.00	0.00	0.00
1982	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.99	0.65
1983	1.24	6.83	2.66	55.72	66.29	15.86	5.04	0.71	0.00	11.00	6.42	0.54
1984	0.00	0.01	0.00	3.18	35.60	9.21	0.00	0.00	0.00	0.00	0.00	0.00
1985	24.33	9.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1986	0.00	0.00	3.35	5.23	1.05	2.54	0.78	0.00	10.11	4.33	13.17	99.83
1987	35.27	2.16	0.16	0.00	9.65	17.29	3.69	0.00	0.00	0.00	0.00	0.00
1988	2.72	4.02	18.65	4.56	11.46	2.49	0.00	0.00	0.00	0.00	0.00	0.00
1989	0.13	26.83	9.37	0.00	0.00	3.48	1.24	0.00	0.00	0.00	1.24	0.41
1990	5.05	2.20	0.75	1.33	13.20	19.65	4.22	4.51	1.68	0.07	0.00	0.00
1991	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1992	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1993	8.03	3.15	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1994	3.44	1.25	0.00	0.00	0.00	3.64	15.19	5.82	7.44	2.44	0.01	0.00
1995	0.03	3.08	10.60	5.66	18.94	8.82	0.68	0.00	0.00	1.62	0.53	0.00
1996	0.00	0.00	0.00	2.61	0.94	0.00	0.00	0.00	0.19	0.18	0.00	0.27
1997	1.39	12.62	4.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1998	0.00	0.08	0.00	0.82	10.69	4.74	0.00	0.00	0.00	0.00	0.00	0.16
1999	11.73	4.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2000	0.00	2.38	0.66	0.20	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2001	1.83	2.63	1.98	2.42	0.57	0.00	0.00	0.00	0.00	18.66	9.63	0.24
2002	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.10	0.00	0.00
2003	0.00	0.00	0.00	0.00	4.41	2.83	0.41	0.00	0.00	0.00	0.00	0.00
2004	0.00	0.76	0.00	0.00	0.00	0.84	0.01	0.00	0.00	0.00	0.00	0.00

7.3 Abiotic components

7.3.1 Hydrology

Table 7.10 provides a summary of the changes in low flows that will occur under the different scenarios.

Table 7.10 Summary of the change in low flow conditions to the Mlalazi Estuary under a range of flow scenarios.

Percentile	Monthly flow (m^3/s)					
	Reference	**Present**	**1**	**2**	**3**	**4**
30%ile	1.3	0.6	0.5	0.2	0.0	0.0
20%ile	1.1	0.5	0.4	0.0	0.0	0.0
10%ile	0.9	0.4	0.4	0.0	0.0	0.0
% Similarity in low flows		**42.5**	**40.5**	**5.5**	**0.0**	**0.0**

Confidence: Low

Table 7.11 provides a summary of the changes in the twenty highest flow months under the various scenarios.

Table 7.11 Summary of the twenty highest simulated monthly volumes to the Mlalazi Estuary under Reference Condition, Present State and a range of flow scenarios.

Date	Monthly volume (x10^6 m^3/month)					
	Reference	Present	1	2	3	4
Mar-25	294.63	294.05	293.69	292.95	291.85	290.83
Sep-87	259.67	260.71	260.24	259.61	258.51	258.77
Feb-84	168.65	165.92	165.11	164.82	163.72	161.81
Jan-84	157.82	153.05	152.39	151.95	150.85	149.24
Feb-77	142.15	139.22	138.5	138.12	137.02	135.28
May-71	128.81	126.68	125.92	125.58	124.48	122.66
Dec-60	122.2	117.85	117.02	116.75	115.65	115.2
Jul-63	117.53	114.85	114.01	113.75	112.65	112.17
Apr-25	111.15	109.65	108.59	108.55	107.45	105.02
Feb-32	110.45	98.39	82	97.29	96.19	73.4
Mar-76	107.71	104.83	104.01	103.73	102.63	100.69
Oct-87	98.98	97.65	96.56	96.55	95.45	94.48
Feb-85	95.71	91.11	90.25	90.01	88.91	86.89
Feb-72	92.74	88.09	86.58	86.99	85.89	81.93
Apr-67	91.64	87.55	86.67	86.45	85.35	74.1
Jun-35	88.28	84.21	82.28	83.11	82.01	74.66
Nov-89	87.7	81.28	73.86	80.18	79.08	69.54
Jul-02	85.74	73.44	62.4	72.34	71.24	49.99
Dec-56	84.28	80.35	77.42	79.25	78.15	74.74
Oct-85	83.96	76.48	69.62	75.38	74.28	65.16
% Similarity in floods		**87.8**	**67.3**	**86.4**	**85.0**	**56.5**

Confidence: Low

A summary of the hydrology scores under different scenarios is provided in Table 7.12.

Table 7.12 EHI scores for Hydrology under different scenarios.

Variable	Scenario Group					
	Present	1	2	3	4	Conf
a. Similarity in low flows	43	41	6	0	0	L
b. Similarity floods	88	67	86	85	57	**L**
Hydrology score	**61**	**51**	**38**	**34**	**23**	**L**

7.3.2 Hydrodynamics and mouth condition

This section provides a description of the changes in the occurrences of mouth conditions for each of the scenarios.

Table 7.13 Predicted % mouth closure under the future senarios.

Present	Mouth closure occurs for about 3-4% of the time under the Present State, while under the Reference Condition it used to occur very seldom.
Scenario 1 to 4	Predicted % mouth closure under the future scenarios: Natural: 0; Present: 3; 1: 3; 2: 35; 3: 53; 4: 59

Natural	Present	1	2	3	4
0	3	3	35	53	59

Table 7.14 provides a summary of the hydrodynamics and mouth condition scores for the Mlalazi Estuary.

Table 7.14 EHI scores for hydrodynamics and mouth condition under different scenarios.

Variable	Scenario					
	Present	1	2	3	4	Confidence
Hydrodynamics and mouth conditions score	97	97	65	47	41	**L**

7.3.3 Water quality

The following section provides a summary of the water quality changes under the various future scenarios.

Table 7.15 Occurrence of the abiotic states under the different scenario groups.

Abiotic State	Reference	Present	Scenario			
			1	2	3	4
State 1: Closed mouth	0	3	3	35	53	59
State 2: Open, Gradient	16	47	53	26	13	9
State 3: Open, Stratified	76	43	38	33	28	26
State 4: Open, Freshwater dominated	8	6	6	6	6	5

Table 7.16 Estimated changes in Water Quality in different zones under different scenarios.

Zones in Estuary	Volume weighting for Zone	Estimated SALINITY concentration based on distribution of abiotic states under a range of Scenario					
		Reference	Present	1	2	3	4
Lower Sur	0.2	25	28	29	26	25	25
Lower Bot	0.2	29	31	31	28	26	26
Middle Sur	0.15	12	17	18	19	19	20
Middle Bot	0.15	19	21	22	22	22	22
Upper Sur	0.1	7	12	13	14	15	15
Upper Bot	0.1	11	14	15	16	16	16
Riverine	0.1	2	6	6	8	10	10

Zones in Estuary	Volume weighting for Zone	Estimated DIN concentration (µg/l) based on distribution of abiotic states under a range of Scenario					
		Reference	Present	1	2	3	4
Lower	0.4	50	80	80	85	95	100
Middle Sur	0.15	50	100	100	90	100	110
Middle Bot	0.15	50	90	80	80	80	85
Upper Sur	0.1	50	130	120	120	110	110
Upper Bot	0.1	50	120	110	110	100	110
Riverine	0.1	50	200	170	170	170	165

Zones in Estuary	Volume weighting for Zone	Estimated DIP concentration (µg/l) based on distribution of abiotic states under a range of Scenario					
		Reference	Present	1	2	3	4
Lower	0.4	10	30	32	35	40	50
Middle Sur	0.15	10	30	30	32	50	55
Middle Bot	0.15	10	20	18	18	25	30
Upper Sur	0.1	10	40	35	35	40	45
Upper Bot	0.1	10	35	32	30	30	32
Riverine	0.1	15	50	50	48	55	58

Zones in Estuary	Volume weighting for Zone	Estimated TURBIDITY (NTU based on distribution of abiotic states under a range of Scenario					
		Reference	Present	1	2	3	4
Lower	0.4	10	10	9	8	10	12
Middle Sur	0.15	10	12	10	10	12	15
Middle Bot	0.15	10	15	13	13	13	12
Upper Sur	0.1	10	15	13	13	13	15
Upper Bot	0.1	10	15	15	15	15	15
Riverine	0.1	10	20	23	23	25	25

Zones in Estuary	Volume weighting for Zone	Estimated DISSOLVED OXYGEN concentration (mg/l) based on distribution of abiotic states under a range of Scenario					
		Reference	Present	1	2	3	4
Lower	0.4	8	8	8	7	6	6
Middle Sur	0.15	8	6.5	6.5	6	6	6
Middle Bot	0.15	8	6	5.5	5	4	4
Upper Sur	0.1	8	6	6	5.5	5	5
Upper Bot	0.1	8	5	5.5	5	4	4
Riverine	0.1	8	8	7	7	6.5	6.5

Table 7.17 Summary of Water Quality changes under different scenarios.

Parameter	Summary Of Changes
Changes in longitudinal salinity gradient and vertical stratification	⇧ due to increase in low flow states. Under Scenario 1 there is a significant increase in the open, marine conditions (State 2), while under Scenarios 2 to 4 the close mouth conditions (State 1) increase significantly.
Inorganic nutrients in estuary	Although nutrients coming into the estuary may decrease slightly due to decreased baseflow, locally derived nutrients such as from sewage treatment works and fish farm will accumulate in the middle and lower zone during flooding due to reduction in dilution effect by freshwater. Increase in dissolved nutrients in lower zone due to reduction in dissolved oxygen.
Turbidity in estuary	Slight decrease in the turbidity in upper estuary. Mixing and wind action will increase turbidity in the middle and lower estuary.
Dissolved oxygen in estuary	Dissolved oxygen will decrease drastically in both the middle and upper zones of the estuary during extended mouth closure.
Toxic substances in estuary	Due to very low concentrations of terrigenous contaminants there may be negligible changes. Extended mouth closure may result in accumulation in the muddy middle zone and lower zone of the estuary.

Table 7.18 EHI scores for Water Quality under different scenarios.

Variable		Scenario					
		Present	1	2	3	4	Conf
1	**Salinity**						
	Similarity in salinity	87	85	85	83	82	L
2	**General water quality in the estuary**						
A	N and P concentrations	85	85	85	80	78	L
B	Turbidity	85	90	87	87	87	L
C	Dissolved oxygen	80	83	75	75	73	L
D	Toxic substances	90	95	90	90	90	L
	Water quality score	**80**	**83**	**75**	**75**	**73**	**L**

$$* \ Score = \frac{0.6*S+0.4*(\min(a \ to \ d)+mean(a \ to \ d))}{2}$$

7.3.4 Physical habitats

A summary of physical habitat changes under different scenarios is presented in Table 7.19, whilst the Environmental Health Index scores for physical habitat under the different scenarios is presented in Table 7.20.

Table 7.19 Summary of Physical Habitat changes under different scenarios.

Parameter		Scenario Group
1a	% Similarity in intertidal area exposed	Sedimentation processes under Scenario 1 are similar to the Present State, but with some loss of resetting floods that would lead to some infilling of the intertidal area. Under Scenario 2 to 4 there are additional loss of intertidal areas due to the increase in mouth closure (State 1) to 35%, 53% and 59 % respectively. Under Scenario 4 the combined effect of loss of floods and increase mouth closure would result in a significant loss in intertidal area..
1b	% Similarity in sand fraction relative to total sand and mud	Information is lacking on changes in % similarity in sand fraction relative to total sand and mud, but the score of 80 (Sc 1), 90 (Sc 2), 90 (Sc 3) and 70 (Sc 4) reflects an expected increase in clay and silt fractions in Zone B to D and a increase in marine sediment in Zone A.
2	% Similarity in intertidal area: depth, bed or channel morphology	Scenario 2 and 3 is similar to the present, but Scenario 1 and 4 will result in infilling of the subtidal habitat due to a loss of floods (as surmised in Table 7.10 and 7.11).

Table 7.20 EHI scores for Physical Habitat under different scenarios.

Variable	Scenario					
	Present	1	2	3	4	Conf
1a. Intertidal areas and sediments	85	75	60	50	40	L
1b.Similarity in sand fraction	90	80	90	90	70	L
2. Subtidal area and sediments	90	70	87	85	60	L
Physical habitat score	**89**	**74**	**81**	**78**	**58**	**L**

7.4 Biotic Component

7.4.1 Microalgae

A summary of change in the Microalgae component is given in Table 7.21 and Environmental Health Index scores under the different scenarios is given in Table 7.22.

Table 7.21 Summary of change in Microalgae component under different scenarios.

Scenario	Summary of Changes
1. (10% reduced MAR)	Change in hydrology is likely to change the mouth configuration, which might have a small adverse effect on microalgal species composition.
2. (10% Abstraction near estuary)	All potential changes are related to hydrology and hydrodynamics. This will cause a further change in Species composition.
3. (20% Abstraction near estuary)	There is a likelihood of species changes due to non-flowing of water. The spatial distribution of the groups will change.
4. (20% Abstraction near estuary plus 10% reduced MAR)	There is a further reduction in water and flow. Mouth stabilisation will likely alter the community composition with the possibility of cyanophytes beginning to become dominate.

Table 7.22 EHI scores for Microalgae component under different scenarios.

Variable	Scenario					
	Present	1	2	3	4	CONF
1. Species richness	90	87	72	64	58	L
2 Abundance	80	90	80	80	75	L
3. Community composition	95	87	80	75	70	L
Biotic component score	**80**	87	72	64	70	**L**

7.4.2 Macrophytes

The duration for which the supratidal and intertidal areas are flooded is important – both are likely to increase with more mouth closures. A summary of change in the Macrophyte component is given in Table 7.23 and Environmental Health Index scores under the different scenarios is given in Table 7.24.

Table 7.23 Summary of change in Macrophyte component under different scenarios.

Scenario	Summary of Changes
1. (10% reduced MAR)	Possibly fairly similar macrophyte expression compared to present. Possibility of submerged macrophytes if floods are reduced – especially in zones B,C & D.
2. (10% Abstraction near estuary)	Loss of mangroves due to increased mouth closure The duration for which the supratidal and intertidal areas are flooded is important – both are likely to increase with more mouth closure.
3. (20% Abstraction near estuary)	Severe loss of mangroves due to increased mouth closure The duration for which the supratidal and intertidal areas are flooded is important – both are likely to increase with more mouth closure.
4. (20% Abstraction near estuary plus 10% reduced MAR)	Severe loss of mangroves due to increased mouth closure. . Possibility of submerged macrophytes if floods are reduced – especially in zones B,C & D. The duration for which the supratidal and intertidal areas are flooded is important – both are likely to increase with more mouth closure.

Table 7.24 EHI scores for Macrophyte component under different scenarios.

Variable	Scenario					
	Present	1	2	3	4	CONF
1. Species richness	90	90	60	55	50	M
2 Abundance	70	65	60	55	50	L
3. Community composition	80	75	50	45	45	L
Biotic component score	**70**	**65**	**50**	**45**	**45**	**M**

7.4.3 Invertebrates

A summary of change in the Invertebrate component is given in Table 7.25 and Environmental Health Index scores under the different scenarios is given in Table 7.26.

Table 7.25 Summary of changes in Invertebrate component under different scenarios.

a) Zooplankton

Scenario	Summary of Changes
1. (10% reduced MAR)	Similar to present condition.
2. (10% Abstraction near estuary)	Changes will start to occur in terms of migration of taxa between the estuary and adjacent environments.
3. (20% Abstraction near estuary)	With further increases in mouth closure events and duration the migration of zooplankton between the estuary and the sea will be limited. This would lead to a reduction in community diversity. Estuarine resident taxa would probably not be affected.
4. (20% Abstraction near estuary plus 10% reduced MAR)	Long term mouth closure will result in the decimation of species such as *Paratylodiplax blephariskios* that relies on an open connection to the sea to complete its life cycle.

b) Macrobenthos

Scenario	Summary of Changes
1. (10% reduced MAR)	Similar to present condition.
2. (10% Abstraction near estuary)	More frequent and longer periods of mouth closure will result in lower salinities for longer and a shift in species composition which will favour freshwater taxa and estuarine taxa that prefer lower salinities.
3. (20% Abstraction near estuary)	Further increases in mouth closure events and duration will cause a decline in species diversity and a more pronounced shift in species composition towards freshwater taxa. Most of the taxa that favour salinities above 10 will disappear. This will probably also favour the invasive snail *T. granifera*, which will further invade previously inaccessible areas.
4. (20% Abstraction near estuary plus 10% reduced MAR)	More prolonged mouth closure events will cause a further decline in species diversity and a more pronounced shift in species composition towards freshwater taxa. Most of the taxa that favour higher salinities, such as *Grandidierella bonnieroides*, will disappear. This will probably cause massive expansion of the distribution of the invasive snail *T. granifera*, into previously inaccessible areas.

c) Macrocrustacea

Scenario	Summary of Changes
1. (10% reduced MAR)	Similar to present condition
2. (10% Abstraction near estuary)	More frequent and longer periods of mouth closure will reduce recruitment of marine prawns as well as mangrove crabs, which will cause a shift in species composition towards freshwater species, with marine species being most affected.
3. (20% Abstraction near estuary)	Further increases in mouth closure events and duration will cause a further decline in the abundance and diversity of crabs and marine prawns due to reduced recruitment and salinities that become unfavourable for larval development. Even freshwater prawn larval development will become affected by the low salinities, if salinities drop below 8.
4. (20% Abstraction near estuary plus 10% reduced MAR)	More prolonged mouth closure periods will cause a further decline in the abundance and diversity of crabs and marine prawns due to reduced recruitment and salinities that become unfavourable for larval development. This will involve a pronounced shift in species composition from marine to freshwater dominated species. However, even freshwater (*Macrobrachium*) and estuarine prawn larval development might become affected by the low salinities, if salinities drop below 8.

Table 7.26 EHI scores for Invertebrate component under different scenarios.

a) Zooplankton

Variable	Scenario					
	Present	1	2	3	4	CONF
1. Species richness	98	95	80	70	60	L
2. Abundance	98	95	80	75	70	L
3. Community composition	98	95	80	75	70	L
Biotic component score	**98**	**95**	**80**	**70**	**60**	**L**

b) Macrobenthos

Variable	Scenario					
	Present	1	2	3	4	CONF
1. Species richness	80	80	75	70	65	M
2. Abundance	90	90	85	80	75	M
3. Community composition	85	85	80	75	70	M
Biotic component score	**85**	**85**	**80**	**75**	**70**	M

c) Marocrustaceans

Variable	Scenario					
	Present	1	2	3	4	CONF
1. Species richness	80	80	70	65	60	L
2. Abundance	80	80	70	65	60	L
3. Community composition	80	80	70	65	60	L
Biotic component score	**80**	**80**	**70**	**65**	**60**	L

d) Overall (Lowest Scores)

Variable	Scenario					
	Present	1	2	3	4	CONF
1. Species richness	80	80	70	65	60	L
2. Abundance	80	80	70	65	60	L
3. Community composition	80	80	70	65	60	L
Biotic component score	**80**	**80**	**70**	**65**	**60**	L

7.4.4 Fish

A summary of change in the Fish component is given in Table 7.27 and Environmental Health Index scores under the different scenarios is given in Table 7.28.

Table 7.27 Summary of change in Fish component under different scenarios.

Scenario	Summary of Changes
1. (10% reduced MAR)	No real change as the frequency of occurrence of each state will be more or less similar to the Present State. The slight reduction in flood frequency and levels will result in a reduced cue (plume) being sent out to the marine environment for the estuarine dependant marine species to detect.
2. (10% Abstraction near estuary)	Mouth closure periods during late winter and early spring increase from 2% under the Present State and Scenario 1 to a significant 28%, resulting in significant loss of connectivity for estuarine dependant marine species needing to migrate into the estuary. The role of the Mlalazi as a nursery habitat will undergo a major reduction. Estuarine species and some estuarine dependant marine species already in the system may benefit slightly from increased mouth closure. Although there will no real reduction in the occurrence of the fresh water state, mouth closure will result in saline waters being distributed further upstream which will have a negative effect of the all the freshwater species present except for *Oreochromis mossambicus* which is tolerant of a wide range of salinities.
3. (20% Abstraction near estuary)	Mouth closure periods during late winter and early spring increase from 2% under the Present State and Scenario 1 to a significant 51%, resulting in a very significant loss of connectivity for estuarine dependant marine species needing to migrate into the estuary. The role of the Mlalazi as a nursery habitat will be significantly reduced. Estuarine species and some estuarine dependant marine species already in the system may benefit slightly from increased mouth closure. Although there will no real reduction in the occurrence of the fresh water state, mouth closure will result in saline waters being distributed further upstream which will have a negative effect of the all the freshwater species present except for *Oreochromis mossambicus* which is tolerant of a wide range of salinities.
4. (20% Abstraction near estuary plus 10% reduced MAR)	Mouth closure periods during late winter and early spring will increase to 59% compared to the Present 2%, resulting in a loss of connectivity for estuarine dependant marine species trying to migrate into the estuary. There is likely to be a severe impact on the role of the Mlalazi as a nursery habitat. Estuarine species and some estuarine dependant marine species already in the system may benefit slightly from increased mouth closure. Only a limited reduction in the occurrence of the fresh water state appears to occur, however during mouth closure saline waters will be distributed further upstream which will have a negative effect of the all the freshwater species present except for *Oreochromis mossambicus* which is tolerant of a wide range of salinities.

Table 7.28 EHI scores for Fish component under different scenarios.

Variable	Scenario					
	Present	1	2	3	4	CONF
1. Species richness	90	85	60	50	40	M
2. Abundance	75	70	55	45	35	M
3. Community composition	75	70	55	45	35	M
Biotic component score	**75**	**70**	**55**	**45**	**35**	**M**

It should be noted that a 5% reduction per scenario has been included for angling and poaching pressures as well as a slight reduction of the loss of Fresh Water flows reducing cues to marine environment in Scenarios 1 and 4.

7.4.5 Birds

A summary of change in the Bird component is given in Table 7.29 and Environmental Health Index scores under the different scenarios is given in Table 7.30.

Table 7.29 Summary of change in Bird component under different scenarios.

Scenario	Summary of Changes
1. (10% reduced MAR)	No real change as the frequency of occurrence of each state will be more or less similar to the Present State.
2. (10% Abstraction near estuary)	Mouth closure periods during late winter and early spring increase from 2% under the Present State and Senario 1 to a significant 28%, resulting in significant loss of intertidal area for the small invertebrate feeding waders to forage in. Reduced fish recruitment due to increased mouth closure will result in reduced availability of food for piscivores. Increased mouth closures will lead to more frequent back flooding, however this will be accompanied by significant reduction in the recruitment of post larval and juvenile fish to the system from the marine environment thus reducing the availability to the large wading and aerial piscivores.
3. (20% Abstraction near estuary)	Mouth closure periods during late winter and early spring increase from 2% under the Present State and Senario 1 to a significant 51%, resulting in an even greater loss of intertidal area for the small invertebrate feeding waders to forage in. Reduced fish recruitment due to increased mouth closure will result in reduced availability of food for piscivores. Increased mouth closures will lead to more frequent back flooding, however this will be accompanied by significant reduction in the recruitment of post larval and juvenile fish to the system from the marine environment thus reducing the availability to the large wading and aerial piscivores.
4. (20% Abstraction near estuary plus 10% reduced MAR)	Mouth closure periods during late winter and early spring will exceed increase from 2% in the Present State to 59%, resulting in an even greater loss of intertidal area for the small invertebrate feeding waders to forage in than under Scenario 3. Reduced fish recruitment due to increased mouth closure will result in reduced availability of food for piscivores. Increased mouth closures will lead to more frequent back flooding, however this will be accompanied by significant reduction in the recruitment of post larval and juvenile fish to the system from the marine environment thus reducing the availability to the large wading and aerial piscivores.

Table 7.30 EHI scores for Bird component under different scenarios.

Variable	Scenario					
	Present	1	2	3	4	CONF
1. Species richness	90	90	75	55	50	H
2. Abundance	80	75	60	45	40	H
3. Community composition	80	75	60	45	40	H
Biotic component score	**75**	**75**	**60**	**45**	**40**	**H**

7.5 Ecological Categories associated with scenarios

The Recommended Ecological Category (REC) represents the level of protection assigned to an estuary. The PES sets the minimum REC. The degree to which the REC needs to be elevated above the PES depends on the level of importance and level of protection or desired protection of a particular estuary. The PES for the Mlalazi Estuary is a B, but the Estuary is rated as "Highly Important" from a biodiversity perspective and should therefore be in an A/B Category. In addition, the system also forms part of the core set of priority estuaries in need of protection to achieve biodiversity targets in the National Estuaries Biodiversity Plan for the National Biodiversity Assessment (Turpie *et al.,* 2013). The NBA 2011 (Van Niekerk & Turpie 2012) recommends that the minimum Category for the Mlalazi be a B, that it be a granted full no-take protection, and that 75 % of the estuary margin be undeveloped.

The individual EHI scores, as well as the corresponding ecological category under different scenarios are provided below in Table 7.31. The estuary is currently in a B Category. Under Scenario 1 the Mlalazi Estuary will decline slightly in health (5%), as a result of more closed mouth conditions, but is expected to only just remain in a B Category. While, under Scenarios 2, 3 and 4 the estuary will deteriorate further in health by about 20%, 30% and 60%, respectively from the Present. This will mainly be as a result of extended closed mouth conditions. Under Scenario 4 this is exacerbated by reduction in floods (frequency & magnitude) which constrains the system even further. This will have a major impact on the cueing effect as the signal to the marine environment will be substantially reduced. Under Scenarios 3 and 4 extended mouth closures will result in salinities gradually decreasing after the marine phase being dominant. Consequently lower salinities will become distributed almost throughout the system and this will have major impacts on the marine and estuarine fauna within the estuary. An additional impact related to this situation is that alien invasive species such as the freshwater snail *Tarebia granifera* would have an increased invasive potential. Decreased salinities would also impact on the breeding success of freshwater *Macrobrachium* prawns which requires a certain level of salt to be present in the water for successful development of their larvae to take place.

Economic Issues related to extended Mouth Closure

Increased closure of the mouth also has economic implications due to the fact that sugar farming is taking place on the flood plain within the 5m a.m.s.l. contour. This will result in pressure being placed on EKZNW to breach the mouth once back flooding starts. Such an action will be in contradiction to the EKZNW policy of allowing the water levels inside the estuary to reach a breaching level of ±3.0m.

Increased closure will have an impact on the offshore Thukela Banks prawn fishery which has recently collapsed due to the extended mouth closure of the St Lucia System. There has also been a knock on effect in the fish populations where it has been found that offshore breeding stocks of *Rhabdosargus sarba* have declined drastically due to the loss of estuarine nursery facilities (Mann & Pradarvand, 2007). Extended closures of other important estuaries which have an important nursery function, such as Mlalazi, could further impact on the declining stocks.

For the Mlalazi Estuary, none of the scenarios achieved the REC of an A/B Category. Due to the uncertainty around the scores, as a result of the Low Level of confidence of the study, the Present State flow in conjunction with a number of management interventions is the recommended ecological flow scenario. The following management interventions are required to achieve the Mlalazi REC of an A/B:

- Hydrological information is required on causes of baseflow declines. Due to this study only being conducted at a Rapid level there is a need to verify the baseflows and to look at how these can be protected, i.e. no futher decrease in flow.

- To ensure the future water quality of the system, introduce compliance monitoring of effluent water from both the Mtunzini WWTW (which is apparently due to be doubled in size) and the Aquaculture Kob Farm.
- Introduce compliance monitoring of effluent water from both the Mtunzini WWTW (which is apparently due to be doubled in size) and the Aquaculture Kob Farm.
- Increase baseflows to the estuary by 10 to 20% to ensure that the mouth does not close.
- Create interventions within the buffer zone that would improve the nutrient status and help with sedimentation issues.
- Undertake restoration of the Mlalazi Flood Plain up to the 5m a.m.s.l. contour and reduce agriculture impacts in the supratidal area of the system.
- Curb Illegal Gill netting of targeted species, as well as illegal seine & cast netting. This has an impact on the nursery function and impacts on prawns, which form part of the bycatch.
- Remove the migration barrier (dumped rocks at vehicle crossing), which is situated some 14 km upstream of the estuary.
- Curb recreational activities in the lower reaches through zonation and improved compliance.
- The nearby Tronox Mine has been looking for wetland offsets, this might be an opportunity to establish something that could have the potential to contribute to the baseflow. This could include the purchase of 'offset' land in the supra tidal zone of the Mlalazi Estuary and possibly the diversion of process runoff water, originating from the Mhlathuze catchment, out of the Siyaya catchment and into the Mlalazi.

Table 7.31 EHI score and corresponding Ecological Categories under the different runoff scenarios.

	Weight	Present	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Confidence
Hydrology	25	61	51	38	34	23	L
Hydrodynamics and mouth condition	25	97	97	65	47	41	L
Water quality	25	80	84	79	78	77	L
Physical habitat alteration	25	89	74	81	78	58	M
Habitat health score		**82**	**76**	**66**	**59**	**49**	**L**
Microalgae	20	80	87	72	64	58	L
Macrophytes	20	70	65	50	45	45	M
Invertebrates	20	80	80	70	65	60	L
Fish	20	75	70	55	45	35	M
Birds	20	80	75	60	45	40	L
Biotic health score		**77**	**75**	**61**	**53**	**48**	**L**
ESTUARY HEALTH SCORE		**80**	**76**	**64**	**56**	**49**	**L**
ECOLOGICAL CATEGORY		**B**	**B**	**C**	**D**	**D**	**L**

8 RECOMMENDATIONS

8.1 Ecological flow requirements

The 'recommended Ecological Flow Requirement' scenario, is defined as the flow scenario (or a slight modification thereof to address low-scoring components) that represents the highest change in river inflow that will still maintain the estuary in the recommended Ecological Category. Where any component of the health score is less than 40, then modifications to flow and measures to address anthropogenic impacts must be found that will rectify this. The REC for the Mlalazi Estuary should be a Category A/B.

The flow requirements for the estuary are the same as those described for the Present State, but with a 10 to 20% increase in the baseflows (baseflow increase to >0.3 to ensure open mouth state). The present flows are summarised in Table 8.1

Table 8.1 A summary of the monthly flow (in m^3/s) distribution under the recommended flow conditions.

%ile	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
99.9	35.8	31.0	42.8	54.0	67.1	103.9	41.6	45.3	31.9	41.6	14.2	94.2
99	29.8	27.5	32.2	25.3	58.8	50.4	35.1	26.9	27.1	29.9	13.3	36.4
95	15.6	17.0	15.7	13.1	33.1	24.0	23.2	14.6	13.7	7.0	7.5	12.3
90	10.2	12.0	10.9	9.1	19.2	18.6	14.2	8.1	6.9	5.4	4.4	5.4
85	7.2	8.0	6.4	6.1	13.9	13.1	8.0	6.4	4.6	3.4	2.4	2.9
80	5.9	5.9	4.7	5.3	12.2	10.5	5.6	5.0	1.9	1.5	1.5	2.4
70	4.3	4.9	2.1	3.7	5.6	5.9	3.6	1.6	1.2	1.1	1.0	1.3
60	2.8	3.2	1.5	1.5	2.8	4.3	2.0	1.2	0.8	0.8	0.8	1.1
50	1.5	1.9	1.0	0.9	1.6	2.2	1.2	0.8	0.7	0.7	0.7	0.9
40	1.0	1.2	0.8	0.6	0.9	1.1	0.9	0.7	0.6	0.6	0.6	0.7
30	0.8	1.0	0.6	0.5	0.6	0.7	0.6	0.5	0.5	0.5	0.5	0.6
20	0.7	0.9	0.6	0.5	0.5	0.5	0.5	0.4	0.5	0.4	0.4	0.5
15	0.6	0.8	0.5	0.4	0.4	0.5	0.5	0.4	0.4	0.4	0.3	0.4
10	0.5	0.6	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.4
5	0.3	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
1	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
0.1	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3

8.2 Resource quality objectives

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 reserve category, which was decided upon by the authorities utilizing environmental, social and economic criteria. Thresholds of potential concern (TPC) are defined as measurable end-points related to specific abiotic or biotic indicators that, if reached, prompts management action. In essence, thresholds of potential concern should be defined such that they provide early warning signals of potential non-compliance to ecological specifications. In essence this concept implies that the indicators (or monitoring activities) selected as part of a long term monitoring programme need to include biotic and abiotic components that are particularly sensitive to ecological changes associated with changes in river inflow into the system. The ecological specifications for the Mlalazi Estuary, as outlined in Table 8.1 and Table 8.2, are set for the PES and Recommended Ecological Category A/B.

Table 8.2 Ecological specifications and thresholds of potential concern for abiotic components.

Abiotic Component	Ecological Specification	Threshold of Potential Concern	Causes
Hydrology	• Maintain a flow regime to create the required habitat for birds, fish, macrophytes, microalgae and water quality	• River inflow distribution patterns differ by more than 5% from that of Present State (i.e. recommended flow scenario for the Mlalazi). • Monthly river inflow < 0.25 m^3/s for more than 3% of the time. • Monthly river inflow < 1.0 m^3/s for more than 50% of the time. • Monthly river inflow > 15.0 m^3/s for less than 6% of the time.	• Dams • Abstraction • Plantations • Agricultural return flow • WW return flow
Hydrodynamics	• Maintain a mouth conditions to create the required habitat for birds, fish, macrophytes, microalgae and water quality	• Mouth closure occurs more than 2 - 4 weeks at a water level > 1.5 m mean sea level. • Mouth closure occurs for more than 2 years out of ten • Mouth closure occurs between September and March • Changes in tidal amplitude at the tidal gauge of more than 20% from Present State (2015)	• Dams • Abstraction • Plantations • Agricultural return flow • WW return flow
Water Quality	• Salinity distribution not to cause exceedance of TPCs for fish, invertebrates, macrophytes and microalgae (see above)	Estuary open: • Salinity values > 5 in the upper reaches (End of Zone C / beginning of Zone D) of the estuary. • Salinity values > 30 in middle reaches (Zone C) during the low flow season • Freshwater dominated < 16% of the time Estuary Closed: • Salinity values > 10 in the upper reaches (End of Zone C/ beginning of Zone D) of the estuary. • Salinity values < 10 in middle reaches (Zone C) • Salinity values < 15 in the lower reaches (Zone A & B)	• Dams • Abstraction • Plantations • Agricultural return flow • WW return flow
	• System variables (pH, dissolved oxygen and turbidity) not to cause exceedance of TPCs for biota (see above)	• River inflow: • 6 < pH > 8.5 consistently over 2 months • DO <6 mg/ℓ • Turbidity >15NTU (low flow) • Turbidity high flows naturally turbid • Estuary: • Average turbidity >10 NTU (low flow) • Turbidity high flow, naturally turbid • 6.0 < pH > 8.5 • Average DO <5 mg/ℓ in a sampling survey in surface water	• Agricultural return flow • Erosion of agricultural land • Municipal wastewater (organic loading)

Abiotic Component	Ecological Specification	Threshold of Potential Concern	Causes
	• Inorganic nutrient concentrations (NO_3-N, NH_3-N and PO_4-P) not to cause in exceedance of TPCs for macrophytes and microalgae (see above)	• River inflow (flows < 5m^3/s): • NO_x-N >200 µg/ℓ over 2 months • NH_3-N> 30 µg/ℓ over 2 months • PO_4-P > 50 µg/ℓ over 2 months • River inflow (flows > 5m^3/s): • Average DIN > 300 µg/ℓ • Average DIP > 50 µg/ℓ • Estuary (river flows < 5m^3/s): • Average NO_x-N > 200 µg/ℓ in a sampling survey • Average NH_3-N > 30 µg/ℓ in a sampling survey • Average PO_4-P > 50 µg/ℓ in a sampling survey • Estuary (river flows > 5m^3/s): • Average NO_x-N > 300 µg/ℓ in a sampling survey • Average NH_3-N > 30 µg/ℓ in a sampling survey • Average PO_4-P > 50 µg/ℓ in a sampling survey	• Agricultural return flow (nutrients) • Municipal wastewater (nutrients) • Fish Farm
	• Presence of toxic substances not to cause exceedance of TPCs for biota (see above)	• River inflow: • Trace metal concentrations in estuary waters exceed target values as per SA Water Quality Guidelines for Aquatic Ecosystems (DWAF, 1996) • Pesticides/herbicide concentrations in estuary waters exceed target values as per SA Water Quality Guidelines for Aquatic Ecosystems (DWAF, 1996) • Estuary: • Total metal concentrations in estuary waters exceed target values as per SA Water Quality Guidelines for coastal marine waters (DWAF, 1995) • Total metal concentration in sediment exceeds target values as per WIO Region guidelines (UNEP/Nairobi Convention Secretariat and CSIR, 2009) • Organic chemicals exceed target values	• Agricultural return flow (e.g. pesticides/herbicides) • Municipal wastewater including industrial trade effluent (e.g. metals) • Boats and diffuse oils.
Sediment Dynamics	• System variables (pH, dissolved oxygen and turbidity) not to cause exceedance of TPCs for biota (see above)	River inflow: • 6 < pH > 8.5 consistently over 2 months • DO <6 mg/ℓ • Turbidity >15NTU (low flow) • Turbidity high flows naturally turbid Estuary: • Average turbidity >10 NTU (low flow) • Turbidity high flow, naturally turbid • 6.0 < pH > 8.5 • Average DO <5 mg/ℓ in a sampling survey in surface water	• Agricultural return flow • Erosion of agricultural land • Municipal wastewater (organic loading)

Abiotic Component	Ecological Specification	Threshold of Potential Concern	Causes
	• Changes in sediment grain size distribution patterns not to cause exceedance of TPCs in benthic invertebrates (see above).	• The median bed sediment diameter deviates by more than a factor of two from levels to be determined as part of baseline studies (Present State 2013). • Sand/mud distribution in middle and upper reaches change by more than 20% from Present State (2013). • Changes in tidal amplitude at the tidal gauge of more than 20% from Present State (2013)	• Reduced floods • Sandmining

Table 8.3 Ecological specifications and thresholds of potential concern for biotic components.

Component	Ecological Specification	Threshold of Potential Concern	Possible causes
Microalgae	• Maintain current microalgae assemblages, specifically >5 diatom species at a frequency >3% of the total population in saline reaches (i.e. Zone A in low flow).	• Medium phytoplankton: >5µg l-1 for more than 50% of the stations. • MPB: > 30mg m2 for more than 50% of the stations in the saline portion of the estuary. • Observable bloom in the estuary.	• Excessive nutrient levels in the water.
Macrophytes	• Maintain the distribution of macrophyte habitats. • Maintain the integrity of the riparian zone particularly in Zone and D • No increase in sugarcane in the EFZ (estuarine functional zone).	• Greater than 10 % change in the area covered by different macrophyte habitats. • Invasive plants (e.g. syringa berry, Spanish reed, black wattle, Brazilian pepper tree) become established in the riparian zone. • Unvegetated, cleared areas along the banks. • Additional sugarcane is present in the estuarine functional zone.	• Reduced flow, sedimentation, infilling and spread of reeds, sedges, grasses. • Disturbance – due to farming or development activities. • Increase in nutrients and possible eutrophication. • Drive to increase sugar production in KZN.
Invertebrates	• Maintain current levels of zooplankton and zoobenthic abundance (including seasonal variation). • Retain an invertebrate community assemblage in the estuary based on species diversity and abundance that includes a variety of indigenous. • Species diversity (between 15 species in summer - 40 species in winter). • Polychaetes, amphipods and tanaeids should numerically dominate during all seasons. However, abundance of all taxon groups should be higher during summer high flow periods and lower during winter low flow period.	• Increase in frequency and duration of mouth closure during early to late summer i.e. primary recruitment period of invertebrates whose life cycle is dependent on an estuarine-marine connection. • Salinities should not decrease by >20% in each of the reaches except for short periods during high flow freshwater dominated conditions. • Salinities should not drop below 10 in the lower and middle reaches, except for short periods during the high flow freshwater state, to allow macrocrustacea larval development. • DO's should not drop below 5 mg/l in >25% of the estuary • Greater than 20% change in the intertidal and subtidal habitats • Occurrence of invertebrate alien species (e.g. *Tarebia granifera*) • Decrease in abundance of zooplankton by >20% in terms of numbers per m^{-2} over entire estuarine area (3 sample sites) over	• Nutrient enrichment • Loss of base flows • Mouth closure and decrease in salinities

Component	Ecological Specification	Threshold of Potential Concern	Possible causes
		3 years • Decrease in macrobenthic densities by >20% in terms of numbers per m^{-2} over entire estuarine area. Shift in prawn community from marine dominated assemblage towards freshwater dominated assemblage and decrease in relative abundance of estuarine dependent marine macrocrustacea species >20% in the middle reaches, or loss of any marine species • Decrease in densities of *Paratylodiplax blephariskios* by >20% in annual sample.	
Fish	• Zone A & B in its entirety acts as a nursery to a diversity of EDCII species (EDCIIa especially). • A good trophic basis exists for predatory estuarine dependant marine species (e.g. *Agyrosomus japonicus, Caranx* spp.). • Estuarine resident species represented by core group (*Glossogobius* spp., *Oligolepis* spp. *Ambassis* spp. and *Gilchistella aestuaria*). Zone C is used by these species as well. • *Oreochromis mossambicus* limited to the upper reaches in Zone D in the low flow period. • Species assemblage comprises indigenous species only. • Connectivity to a healthy transitional marine-estuary water is maintained. • Connectivity down the full length of the historic estuary and into the marine environment is restored.	• An abundance (to be defined as an average with prediction limits) of EDCIIa species as young juveniles in spring and early summer (*Solea bleekeri, Acanthopagrus vagus, Pommadasys comerssonnii, Rhabdosargus holubi*). • Mullet occur throughout the system represented by a full array of size classes. • Any one of the species in bullet one above does not occur in the estuary in two consecutive years. • *Oreochromis mossambicus* distribution extends into Zone A for more than two consecutive years • Alien fish species occur • A decline in nearshore linefish catches (*Rhabdosargus sarba*) (not related to gear changes or bag limit restrictions). • Estuarine species occur in the upper limits of Zone D.	• Hydrological (flow and mouth condition related) and habitat (sediment dynamics) changes. • Water quality changes (toxic impacts, persistent low oxygen levels (< 4 mg/L) or intermittent fish kills (• Changes in salinity gradients resulting from flow and/or mouth condition changes • Water quality impacts, primarily changes in salinity gradient and mouth closure • Loss of trophic bases (prey fish), • Loss of transitional marine-estuary waters. • Loss of connectivity with upper estuary (tidal freshwaters)
Birds	• The most characteristic component of the avifaunal waterbird community are the piscivores and it is this group that would be the most valuable for monitoring • Palearctic migrant wading birds rely on the intertidal estuarine mud- and sand-flats as feeding habitats particularly in Zone A & B	• Resident pair of African Fish Eagle disappears or fails to breed successfully • Pied Kingfishers, White-breasted Cormorants or Reed Cormorants fail to be recorded on more than three consecutive counts spanning a period of 18 months or more • Numbers of waterbird species drop below 10 for 2 consecutive counts • Numbers of migrant wader species drops below 3 for 2 consecutive counts	• Decrease in food availability – fish • Decrease in intertidal feeding habitat and food availability – invertebrates

8.3 Monitoring requirements

Recommended minimum baseline and long term monitoring requirements to ascertain impacts of changes in freshwater flow to the estuary and any improvement or reductions therein are listed in below in Tables 8.4 and 8.5.

Table 8.4 Recommended baseline monitoring requirements.

Ecological Component	Monitoring Action	Temporal Scale (Frequency And When)	Spatial Scale (No. Stations)
Hydrodynamics	• Record water levels	• Continuous	• At mouth
	• Measure freshwater inflow into the estuary	• Continuous	• Above the estuary
	• Aerial photographs of estuary or high resolution satellite imagery	• Every 3 years	• Entire estuary
Sediment dynamics	• Bathymetric surveys: Series of cross-section profiles and a longitudinal profile collected at fixed 500 m intervals, but in more detailed in the mouth (every 100m). The vertical accuracy should be about 5 cm.	• Every 3 years	• Entire estuary
	• Set sediment grab samples (at cross section profiles) for analysis of particle size distribution (PSD) and origin (i.e. using microscopic observations)	• Every 3 years (with invert sampling)	• Entire estuary (7 -8 stations)
Water Quality	• Longitudinal salinity and temperature profiles (and any other in situ measurements possible e.g. pH, DO, turbidity) collected during high and low tide **at 0.5 m depth intervals**): • end of low flow season (i.e. period of maximum seawater intrusion/closed mouth) • peak of high flow season (i.e. period of maximum flushing by river water)	• Every 3 years	• Entire estuary (7 – 8 stations)
	• In situ salinity probes (small instruments) about 1 m below the surface	• Continuous (data collected every 3 months)	• Sites: - Lower reach (-28.9516, 31.77588) - At bridge (-28.9355 31.78042) - Confluence (-28.91961 31.750123)
	• Measurements of dissolved nutrients, organic content and toxic substances (e.g. trace metals and hydrocarbons) in sediments along length of the estuary, where considered an issue (must also include sediment grain size analysis of samples).	• Every 3-6 years	• Focus on sheltered, depositional areas • Also place sites below the WWTW and Kob Farm discharge points

Ecological Component	Monitoring Action	Temporal Scale (Frequency And When)	Spatial Scale (No. Stations)
Microalgae	• Record relative abundance of dominant phytoplankton groups, i.e. flagellates, dinoflagellates, diatoms, green and blue-green microalgae . • Chlorophyll-a measurements taken at the surface, 0.5 m and 1 m depths, under typically high and low flow conditions using a recognised technique, e.g. HPLC, fluoroprobe. • Intertidal and subtidal benthic chlorophyll-a measurements.	• Monthly sampling for 2 years (seasonal trends)	• Entire estuary (7 stations)
Macrophytes	• Fixed-point photos to record change. • Map the area covered by the different .macrophyte habitats during a field survey. • Compile a species list and check for expansion of invasive plants, reed, sedge and grass areas. • Use semi-quantitative methods to record intensity and coverage of infestations.	• As soon as possible – then 3-yearly.	• Entire system.
Invertebrates	• Record species and abundance of zooplankton and macrocrustacea, based on samples collected across the estuary at each of a series of stations along the estuary. • Record benthic invertebrate species and abundance, based on subtidal and intertidal core samples at a series of stations up the estuary, and counts of sandprawn hole densities. • Measures of sediment characteristics at each station.	• Summer and winter survey for 3 years	• Entire estuary (7 stations, 4 stations for zooplankton)
Fish	• Not required		
Birds	• Undertake counts of all water associated birds, identified to species level.	• A series of monthly counts for a year.	• Entire estuary (4 sections).

Table 8.5 Recommended long term monitoring requirements.

Ecological Component	Monitoring Action	Temporal Scale (Frequency And When)	Spatial Scale (No. Stations)
Hydrodynamics	• Record water levels.	• Continuous	• At bridge
	• Measure freshwater inflow into the estuary.	• Continuous	• Above the estuary
	• Aerial photographs of estuary or high resolution satellite imagery.	• Every 3 years	• Entire estuary
Sediment dynamics	• Bathymetric surveys: Series of cross-section profiles and a longitudinal profile collected at fixed 500 m intervals, but in more detailed in the mouth (every 100m). The vertical accuracy should be about 5 cm.	• Every 3 years	• Entire estuary
	• Set sediment grab samples (at cross section profiles) for analysis of particle size distribution (PSD) and origin (i.e. using microscopic observations)	• Every 3 years • (with invert sampling)	• Entire estuary (7 stations)
Water quality	• Water quality (e.g. system variables, nutrients and toxic substances) measurements on river water entering at the head of the estuary	• Monthly continuous	• DWA WQ monitoring station

Ecological Component	Monitoring Action	Temporal Scale (Frequency And When)	Spatial Scale (No. Stations)
	• Longitudinal salinity and temperature profiles ((and any other in situ measurements possible e.g. pH, DO, turbidity) collected during high and low tide at: • end of low flow season (i.e. period of maximum seawater intrusion/closed mouth) • peak of high flow season (i.e. period of maximum flushing by river water)	• Seasonally every year	• Entire estuary • (7-8 stations)
	• In situ salinity probes (small instruments) about 1 m below the surface	• Continuous (data collected every 3 months)	• Sites: - Lower reach (-28.9516, 31.77588) - At bridge (-28.9355 31.78042) - Confluence (-28.91961 31.750123)
	• Water quality parameters (i.e. system variables, and inorganic nutrients) taken along the length of the estuary (at least surface and bottom samples) • Measurement must include the discharge streams for the WWTW and Fish Farm (potential nutrient contributors during flooding or mouth closure)	• Coinciding with biotic surveys or when significant change in quality expected	• Entire estuary (7 stations)
	• Measurements of organic content and toxic substances (e.g. trace metals and hydrocarbons) in sediments along length of the estuary, where considered an issue (must also include sediment grain size analysis of samples).	• Every 3-6 years	• Focus on sheltered, depositional areas • Also place sites below the WWTW and Kob Farm discharge points
Microalgae	• Record relative abundance of dominant phytoplankton groups, i.e. flagellates, dinoflagellates, diatoms and blue-green microalgae. • Chlorophyll-a measurements taken at the surface, 0.5 m and 1 m depths, under typically high and low flow conditions using a recognised technique, e.g. HPLC, fluoroprobe. • Intertidal and subtidal benthic chlorophyll-a measurements.	• Summer and winter survey every 3 years.	• Entire estuary (5 stations).

Ecological Component	Monitoring Action	Temporal Scale (Frequency And When)	Spatial Scale (No. Stations)
Macrophytes	• Fixed point photos to record change. • Map the area covered by the different macrophyte habitats during a field survey. • Use GIS techniques to detect changes in area of macrophyte communities. • Compile a species list and check for expansion of invasive plants, reed, sedge and grass areas.	• Initiate fix point photos as soon as possible and then repeat every three years • Survey every 3 years • Whenever new high-resolution imagery is available – or at least once every 3 years • Use semi-quantitative methods to assess abundance – and to detect changes in abundance	• 30 to 50 fixed point photos – in all habitats and throughout the estuary. • Entire estuary
Invertebrates	• Record species and abundance of zooplankton, macrobenthos and macrocrustaceans, based on samples collected across the estuary at each of a series of stations along the estuary. • Record benthic invertebrate species and abundance, based on subtidal and intertidal core samples at a series of stations up the estuary, and counts of sandprawn hole densities. • Measures of sediment characteristics at each station.	• Winter/low flow survey every year. • Time prawn survey based on baseline monitoring, probably early and late summer	• Entire estuary (7 stations, 4 stations for zooplankton)
Fish	• Record species and abundance of fish, based on seine net and gill net sampling.	• Late spring/ summer and winter survey every year. Repeated within season if any ecospecification is not met.	• Entire estuary (7 stations)
Birds	• Undertake counts of all water associated birds, identified to species level.	• Winter and summer surveys every year (CWAC)	• Entire estuary

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Appendix A

Mlalazi Estuary Mouth State

STATE OF ESTUARY MOUTHS	Datee	
% Open		96
% Closed		4
Total		907
open	o	623
open & joined	oj	0
constricted	con	16
closed but overtopping	ct	17
closed - not overtopping	cc	7
closed artificially	ca	0
state not known	?	238
breached naturally	bn	2
breached artificially	ba	4
Feb-93	2	o
	9	o
	16	o
	23	o
	30	o
Mar-93	6	
	13	
	20	
	27	
Apr-93	4	
	11	
	18	
	25	
Jan-96	6	
	13	
	20	
	27	
Feb-96	3	
	10	
	17	
	24	
Mar-96	3	
	10	
	17	
	24	
	31	
Apr-96	5	o
	12	o
	19	o
	26	o
May-96	3	o
	10	o
	17	o
	24	o
	31	
Jun-96	2	o
	9	o
	16	o
	23	
	30	
Jul-96	7	
	14	
	21	
	28	
Aug-96	4	
	11	
	18	
	25	
Sep-96	1	o
	8	o
	15	o
	22	o
	29	o
Oct-96	6	o
	13	o
	20	o
	27	o
Nov-96	2	o
	9	o
	16	o
	23	o
	30	
Dec-96	7	o
	14	o
	21	o
	28	o

Jan-97	4	o
	11	o
	18	o
	25	o
Feb-97	2	o
	9	o
	16	o
	23	o
Mar-97	2	o
	9	o
	16	o
	23	o
	30	o
Apr-97	6	
	13	
	20	
	27	
May-97	4	
	11	
	18	
	25	
Jun-97	1	
	8	ct
	15	ct
	22	o
	29	o
Jul-97	6	o
	13	o
	20	o
	27	o
Aug-97	3	o
	10	o
	17	o
	24	o
	31	o
Sep-97	7	o
	14	o
	21	o
	28	o
Oct-97	5	o
	12	o
	19	o
	26	o
Nov-97	2	o
	9	o
	16	o
	23	o
	30	
Dec-97	7	o
	14	o
	21	o
	28	o
Jan-98	4	o
	11	o
	18	o
	25	o
Feb-98	1	o
	8	o
	15	o
	22	o
Mar-98	1	o
	8	o
	15	o
	22	o
	29	o
Apr-98	5	o
	12	o
	19	o
	26	o
May-98	3	o
	10	o
	17	o
	24	o
	31	o
Jun- 98	7	o
	14	o
	21	o
	28	o
Jul-98	5	o

	12	o
	19	o
	26	o
Aug-98	2	o
	9	con
	16	con
	23	con
	30	con
Sep-98	6	con
	13	con
	20	con
	27	con
Oct-98	4	con
	11	o
	18	o
	25	o
Nov-98	1	o
	8	o
	15	o
	22	o
	29	o
Dec-98	6	o
	13	o
	20	o
	27	o
Jan-99	3	o
	10	o
	17	o
	24	o
	31	o
Feb 1999	7	o
	14	o
	21	o
	28	o
Mar 1999	7	o
	14	o
	21	o
	28	o
Apr 99	4	o
	11	o
	18	o
	25	o
May 99	2	o
	9	o
	16	o
	23	o
	30	o
June 99	6	o
	13	o
	20	o
	27	o
July 99	4	o
	11	o
	18	o
	25	con
Aug 99	1	con
	8	con
	15	o
	22	o
	29	o
Sept99	5	
	12	
	19	
	26	
Oct99	3	
	10	
	17	
	24	
	31	
Nov99	7	
	14	
	21	
	28	
Dec99	5	
	12	
	19	
	26	
Jan2000	2	
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Feb2000	6	
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Mar2000	5	
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Apr-00	2	
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May-00	7	
	14	
	21	
	28	
Jun-00	4	
	11	
	18	
	25	
Jul-00	2	
	9	
	16	
	23	
	30	
Aug-00	6	
	13	
	20	
	27	
Sep-00	3	
	10	
	17	
	24	
Oct-00	1	
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	15	
	22	
	29	
Nov-00	5	
	12	
	19	
	26	
Dec-00	3	
	10	
	17	
	24	
	31	
Jan-01	7	
	14	
	21	
	28	
Feb-01	4	o
	11	o
	18	o
	25	o
Mar-01	4	o
	11	o
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Apr-01	1	o
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May-01	6	o
	13	o
	20	o
	27	o
Jun-01	3	o
	10	o
	17	o
	24	o
Jul-01	1	o
	8	o
	15	o

	22	o
	29	o
Aug-01	5	o
	12	o
	19	o
	26	o
Sep-01	2	o
	9	o
	16	o
	23	o
	30	o
Oct-02	7	o
	14	o
	21	o
	28	o
Nov-02	4	o
	11	o
	18	o
	25	o
Dec-02	2	o
	9	o
	16	o
	23	o
	30	o
Jan-02	6	o
	13	o
	20	o
	27	o
Feb-02	3	o
	10	o
	17	o
	24	o
Mar-02	3	o
	10	o
	17	o
	24	o
	31	o
Apr-02	7	o
	14	o
	21	o
	28	o
May-02	5	o
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Jun-02	2	o
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	16	o
	23	o
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Jul-02	7	o
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Aug-02	4	o
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Nov-02	3	o
	10	o
	17	o
	24	
Dec-02	1	o
	8	o
	15	o
	22	o
	29	o
Jan-03	5	o
	12	o
	19	o

	26	o
Feb-03	2	cc
	9	cc
	16	ba
	23	cc
Mar-03	2	cc
	9	cc
	16	cc
	23	cc
	30	bn
Apr-03	6	o
	13	o
	20	
	27	o
May-03	4	o
	11	o
	18	o
	25	o
Jun-03	1	o
	8	o
	15	o
	22	o
	29	
Jul-03	6	
	13	
	20	
	27	
Aug-03	3	
	10	
	17	
	24	o
	31	o
Sep-03	7	o
	14	o
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Oct-03	5	
	12	
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	26	
Nov-03	2	o
	9	o
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	23	o
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Dec-03	7	o
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	28	
Jan-04	4	
	11	
	18	
	19	
	25	
Feb-04	1	
	8	o
	15	o
	22	o
	29	
Mar-04	7	
	14	
	21	
	28	o
Apr-04	4	o
	11	o
	18	o
	25	o
May-04	2	o
	9	o
	16	o
	23	o
	30	
Jun-04	6	o
	13	o
	20	o
	27	
Jul-04	4	
	11	o
	18	o

	25	o
Aug-04	1	
	8	o
	15	o
	22	
	29	o
Sep-04	5	o
	12	o
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Oct-05	3	
	10	
	17	
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Nov-05	7	o
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Dec-05	5	o
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Jan-05	2	
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Feb-05	6	o
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Mar-05	6	o
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	20	o
	27	o
Apr-05	3	o
	10	o
	17	o
	24	o
May-05	1	o
	8	o
	15	o
	22	o
	29	o
Jun-05	5	o
	12	o
	19	o
	26	o
Jul-05	3	o
	10	o
	17	o
	24	
	31	o
Aug-05	7	o
	14	o
	21	o
	28	o
Sep-05	4	o
	11	o
	18	o
	25	o
Oct-05	2	o
	9	o
	16	o
	23	o
	30	
Nov-05	6	
	13	
	20	
	27	
Dec-05	4	o
	11	o
	18	o
	25	o
Jan-06	1	o
	8	o
	15	o
	22	o

	29	o
Feb-06	5	o
	12	o
	19	o
	26	o
Mar-06	5	o
	12	o
	19	o
	26	o
Apr-06	2	o
	9	o
	16	o
	23	o
	30	o
May-06	7	o
	14	o
	21	
	28	o
Jun-06	4	o
	11	o
	18	o
	25	o
Jul-06	2	o
	9	o
	16	o
	23	o
	30	
Aug-06	6	o
	13	o
	20	o
	27	o
Sep-06	3	o
	10	o
	17	o
	24	o
Oct-06	1	o
	8	o
	15	o
	22	o
	29	
Nov-06	5	o
	12	o
	19	o
	26	o
Dec-06	3	o
	10	o
	17	o
	24	o
	31	o
Jan-07	7	o
	14	o
	21	o
	28	o
Feb-07	4	o
	11	o
	18	o
	25	o
Mar-07	1	o
	8	o
	15	o
	22	o
	29	o
Apr-07	1	o
	8	o
	15	o
	22	o
	29	
May-07	6	o
	13	o
	20	o
	27	ct
Jun-07	3	o
	10	o
	17	o
	24	o
Jul-07	1	bn
	8	o
	15	o
	22	ct

	29	ct
Aug-07	5	ct
	12	ct
	19	ct
	26	ct
Sep-07	2	ct
	9	ba
	16	ct
	23	ct
	30	ba
Oct-07	7	o
	14	o
	21	o
	28	o
Nov-07	4	o
	11	o
	18	o
	25	o
Dec-07	2	o
	9	o
	16	o
	23	o
	30	o
Jan-08	6	o
	13	o
	20	o
	27	o
Feb-08	3	o
	10	o
	17	o
	24	o
Mar-08	2	o
	9	o
	16	o
	23	o
	30	o
Apr-08	6	o
	13	
	20	
	27	
May-08	4	o
	11	o
	18	o
	25	o
Jun-08	1	o
	8	o
	15	o
	22	o
	29	o
Jul-08	6	o
	13	o
	20	o
	27	ct
Aug-08	3	o
	10	o
	17	o
	24	o
	31	o
Sep-08	1	ct
	8	ba
	15	ct
	22	ct
	29	ct
Oct-08	5	o
	12	o
	19	o
	26	o
Nov-08	2	o
	9	o
	16	o
	23	o
	30	o
Dec-08	7	o
	14	o
	21	o
	28	o
Jan-09	4	o
	11	o
	18	o

	25	o
Feb-09	1	
	8	
	15	o
	22	o
Mar-09	1	
	8	
	15	o
	22	o
	29	
Apr-09	5	
	12	o
	19	o
	26	
May-09	3	
	10	
	17	
	24	
	31	con
Jun-09	7	
	14	o
	21	
	28	
Jul-09	5	con
	12	o
	19	con
	26	o
Aug-09	2	o
	9	o
	16	con
	23	o
	30	o
Sep-09	6	o
	13	o
	20	o
	27	o
Oct-09	4	o
	11	o
	18	o
	25	
Nov-09	1	o
	8	
	15	
	22	
	29	o
Dec-09	6	o
	13	o
	20	o
	27	
Jan-10	3	o
	10	o
	17	o
	24	o
	31	
Feb-10	7	o
	14	o
	21	o
	28	o
Mar-10	7	o
	14	o
	21	o
	28	o
Apr-10	4	o
	11	o
	18	o
	25	o
May-10	2	o
	9	o
	16	o
	23	o
	30	o
Jun-10	6	o
	13	
	20	
	27	o

Jul-10	4	o
	11	
	18	
	25	o
Aug-10	1	o
	8	o
	15	o
	22	o
	29	o
Sep-10	5	o
	12	o
	19	
	26	
Oct-10	3	
	10	
	17	
	24	
	31	
Nov-10	7	
	14	
	21	
	28	
Dec-10	5	
	12	
	19	
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Jan-11	1	
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Feb-11	6	
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	27	
Mar-11	6	o
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	27	o
Apr-11	3	o
	10	o
	17	o
	24	o
May-11	1	o
	8	o
	15	
	22	o
	29	
Jun-11	5	
	15	
	22	o
	29	o
Jul-11	3	o
	10	o
	17	o
	24	
	31	o
Aug-11	7	o
	14	o
	21	o
	28	o
Sep-11	4	
	11	o
	18	o
	25	o
Oct-11	2	o
	9	o
	16	o
	23	o
	30	o
Nov-11	6	o
	13	o
	20	o
	27	o
Dec-11	4	o

	11	o
	18	o
	25	o
Jan-12	1	o
	8	
	15	o
	22	o
	29	o
Feb-12	5	o
	12	o
	19	
	26	o
Mar-12	4	o
	11	o
	18	o
	25	o
Apr-12	1	o
	8	o
	15	o
	22	o
	29	o
May-12	6	o
	13	o
	20	o
	27	o
June	3	
	10	o
	17	o
	24	o
Jul-12	1	
	8	
	22	
	29	
Aug-12	5	
	12	
	19	
	26	
Sep-12	2	
	9	
	16	
	23	
	30	o
Oct-12	7	
	14	o
	21	o
	28	o
Nov-12	4	o
	11	o
	18	o
	25	o
Dec-12	2	o
	9	o
	16	o
	23	o
	30	o
Jan-13	6	
	13	o
	20	o
	27	

Appendix B

Mlalazi Estuary water level and salinity measurements used to derive the abiotic states

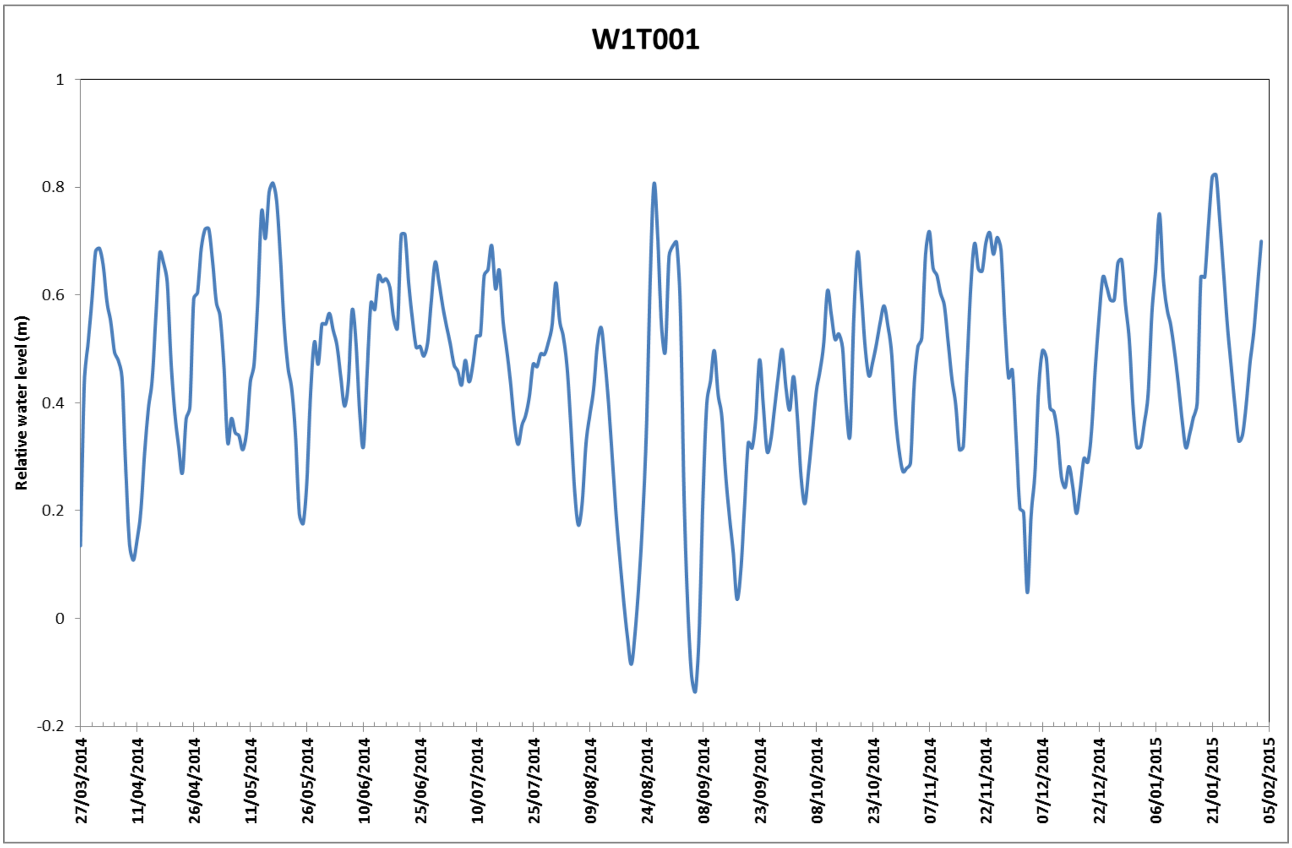

Figure A.1: Continous daily water levels (W1T001) in the Mlalazi Estuary for the period March 2014 to February 2015.

Table A1: Surfance and bottom salinity data meused in the Mlalai Estuary from August 1999 to JulY 2000.

Date	Distance from mouth	Site	Salinity (Surface)	Salinity (Bottom)
Aug-99	8.4	1	24.7	24.8
Aug-99	6.7	2	26.4	26.5
Aug-99	5.4	3	28.3	28.3
Aug-99	4.75	4	28.7	29.1
Aug-99	3.5	5	29	29
Aug-99	2.5	6	30.2	30.6
Sep-99	8.4	1	8.11	8.7
Sep-99	6.7	2	8.4	22.9
Sep-99	5.4	3	14.9	15
Sep-99	4.75	4	15.1	16.9
Sep-99	3.5	5	16.5	26.6
Sep-99	2.5	6	21.2	29.2
Sep-99	0.5	7	27.2	34.5
Oct-99	8.4	1	19.21	21.9
Oct-99	6.7	2	21.5	22.1
Oct-99	5.4	3	24.8	24.8
Oct-99	4.75	4	25.2	25.2
Oct-99	3.5	5	25.5	26.5
Oct-99	2.5	6	28.7	32.1
Oct-99	0.5	7	32.7	34.5

Date	Distance from mouth	Site	Salinity (Surface)	Salinity (Bottom)
Nov-99	8.4	1	18.3	19.3
Nov-99	6.7	2	22.1	22.8
Nov-99	5.4	3	23.2	23.3
Nov-99	4.75	4	23.4	25.5
Nov-99	3.5	5	27.4	32.2
Nov-99	2.5	6	32.8	34.7
Nov-99	0.5	7	33	35.3
Dec-99	8.4	1	9.9	15.6
Dec-99	6.7	2	14.7	16.9
Dec-99	5.4	3	17.5	17.5
Dec-99	4.75	4	18.2	20.3
Dec-99	3.5	5	19.4	20.3
Dec-99	2.5	6	20.9	27
Dec-99	0.5	7	25	30.1
Jan-00	8.4	1	1.4	4
Jan-00	6.7	2	2.6	2.5
Jan-00	5.4	3	7.9	16.9
Jan-00	4.75	4	5.4	28.1
Jan-00	3.5	5	10.5	30.5
Jan-00	2.5	6	15	34.2

Date	Distance from mouth	Site	Salinity (Surface)	Salinity (Bottom)
Jan-00	0.5	7	22	34.2
Feb-00	8.4	1	0.4	4.8
Feb-00	6.7	2	1.6	1.6
Feb-00	5.4	3	3.7	3.6
Feb-00	4.75	4	2.8	28.3
Feb-00	3.5	5	4.1	28.3
Feb-00	2.5	6	5.9	30
Feb-00	0.5	7	13.6	31
Mar-00	8.4	1	1.7	5.4
Mar-00	6.7	2	5.5	14.3
Mar-00	5.4	3	12.6	12.6
Mar-00	4.75	4	9.2	18.9
Mar-00	3.5	5	10.1	24.2
Mar-00	2.5	6	13.5	29.2
Mar-00	0.5	7	23.6	31.7
Apr-00	8.4	1	0.4	1.6
Apr-00	6.7	2	1.5	4.4
Apr-00	5.4	3	11.6	11.6
Apr-00	4.75	4	12.5	28.1
Apr-00	3.5	5	15.2	28.3
Apr-00	2.5	6	15.8	30.3
Apr-00	0.5	7	21.5	30.8
May-00	8.4	1	1	1
May-00	6.7	2	1	1
May-00	5.4	3	2	2
May-00	4.75	4	2	2
May-00	3.5	5	2	2
May-00	2.5	6	2	30
May-00	0.5	7	2	2
Jun-00	8.4	1	6	23.4
Jun-00	6.7	2	8	27.2
Jun-00	5.4	3	15.3	15.3
Jun-00	4.75	4	12	30.5
Jun-00	3.5	5	12.8	31.8
Jun-00	2.5	6	15.4	33.3
Jun-00	0.5	7	20.7	35.5
Jul-00	8.4	1	19.1	20.4
Jul-00	6.7	2	21.8	23
Jul-00	5.4	3	25	25
Jul-00	4.75	4	25.1	25.9
Jul-00	3.5	5	25.3	26.9
Jul-00	2.5	6	26.7	28.6
Jul-00	0.5	7	28.9	34.6
Sep-12	8.4	1	0.4	1.1
Sep-12	6.7	2	0.6	20.4
Sep-12	5.4	3	1.1	1.6
Sep-12	4.75	4	1.3	24.4
Sep-12	3.5	5	1.4	1.4
Sep-12	2.5	6	1.9	21.2
Sep-12	0.5	7	2.6	3
Sep-12	0	Drain	3.8	3.91

Appendix C

Data available on the Mlalazi used for the Study

Data available for the Mlalazi Rapid Reserve Study

Component	Baseline information requirements for high confidence	Data available for this study
Hydrology	Measure freshwater inflow into the estuary	No data available
	Aerial photographs of estuary (spring low tide)	1937, 1957, 1961, 1975, 2006, 2010, 2014
Bathymetry	Bathymetric surveys: Series of cross-section profiles and a longitudinal profile collected at fixed 500 m intervals, but in more detailed in the mouth (every 100m). The vertical accuracy should be about 5 cm.	Some historical information available, but no recent data
Hydrodynamics	Record water levels	W1T001 (1 year)
Sediments	Set sediment grab samples (at cross section profiles) for analysis of particle size distribution (PSD) and origin (i.e. using microscopic observations)	May 2013
Water quality	River inflow quality data	None
	Water quality measurements (temperature pH, dissolved oxygen and turbidity) taken along the length of the estuary (surface and bottom samples) on a spring and neap high tide at: • end of low flow season • peak of high flow season	Data from one sampling trip (six sites) May 2013. Historical data from 1999-2000 (CRUZ); & 2005-2008 (H.Mzimela, PhD in progress). Salinity (CRUZ): May 2013, Aug 1999, Sep 1999, Oct 1999, Nov 1999, Dec 1999, Jan 2000, Feb 2000, Mar 2000, Apr 2000, May 2000, Jun 2000, Jul 2000
	Water quality measurements (inorganic nutrients) taken along the length of the estuary (surface and bottom samples) on a spring and neap high tide at: • end of low flow season • peak of high flow season	Data from one sampling trip (six sites) May 2013. Historical data from 1999-2000 (CRUZ) & 2005-2008 (H.Mzimela, PhD in progress) .
	Measurements of organic content and toxic substances (e.g. trace metals and hydrocarbons) in sediments along length of the estuary	Data from one sampling trip (six sites) May 2013.
Microalgae	Chlorophyll-a measurements taken at 5 stations (at least) at the surface, 0.5 m and 1 m depths thereafter. Cell counts of dominant phytoplankton groups i.e. flagellates, dinoflagellates, diatoms and blue-green algae. Measurements should be taken coinciding with the different Abiotic States.	Data from only one sampling trip (six sites) May 2013.
	Intertidal and subtidal benthic chlorophyll-a measurements taken at 5 stations. Epipelic diatoms need to be collected for identification.	Data from only one sampling trip (six sites) May 2013.
	The microalgal survey must be done at the same time as the water quality survey.	Data from only one sampling trip (six sites) May 2013.
Macrophytes	Aerial photographs of the estuary (ideally 1:5000 scale) reflecting the present state, as well as the reference condition (earliest year available). A GIS map of the estuary must be produced indicating the present and reference condition distribution of the different plant community types.	2009 colour orthophotos (from Maps & Survey)
	Number of plant community types, identification and total number of macrophyte species, number of rare or endangered species or those with limited populations documented during a field visit. The extent of anthropogenic impacts (e.g. trampling, mining) must be noted.	See report (Appendix E)

Component	Baseline information requirements for high confidence	Data available for this study
	Permanent transects (fixed monitoring stations that can be used to measure change in vegetation in response to changes in salinity and inundation patterns) must be set up along an elevation gradient: Measurements of percentage plant cover of each plant species in duplicate quadrats (1 m^2). Measurements of sediment salinity, water content, depth to water table and water table salinity.	None set up
Invertebrates	Detailed study (at least four trips) sampling invertebrates along the full length of the estuary (zooplankton, hyperbenthos, and macrozoobenthos). Although some data exists, no quantitative information on the macozoobenthos and the hyperbenthos. Quantitative information also required for shrimps and prawns in the upper reaches of the system. Six sites along the estuary – following previous data sets.	Zooplankton - Data from only one sampling trip (six sites) May 2013. Macrozoobenthos – Data from one sampling trip (subtidal = six sites, intertidal = four sites) May 2013. Historical data; Mabaso (2000) for subtidal benthos only from 1989-1090 & 1999-2000. CRUZ data for subtidal benthos only from 2005-2006 & 2008. Macrocrustacea - Data from only one sampling trip (six sites) May 2013.
Fish	Require detailed study (at least four trips) sampling fish along the full length of the estuary.	Data from only one sampling trip (six sites) May 2013.
Birds	Detailed study (at least four trips) sampling birds along the full length of the estuary.	Data from only one full estuary count May 2013.

Appendix D

Specialist Report Microalgae

Mlalazi Estuary Rapid Assessment
Historical Data & Fieldtrip Report

Microalgae
Prof G C Bate, Diatom and Environmental Management cc

Introduction
Diatom and Environmental Management cc (DEM) was commissioned by CRUZ-E to undertake an assessment on the microalgal biomass as microphytobenthos (MPB) and phytoplankton in the Mlalazi (-28.9489907/031.796778) Estuary KwaZulu Natal and to establish if there was any historical microalgae data. A literature search for the latter did not yield any historical data.

Materials and Methods
The field samples were collected on 19 November 2013 (summer).
Sampling stations:
Five stations were sampled at the positions identified by the coordinates collected with a Garmin GPS (Figure 1).

Mlalazi 7 – Mouth	-28.943797	031.811018
Mlalazi 6	-28.948559	031.793114
Mlalazi 4	-28.953793	031.775004
Mlalazi 2	-28.942521	031.786087
Mlalazi 1	-28.932741	031.771844
Mlalazi A	-28.930649	031.755459

The Mlalazi Estuary was open on the day of sampling. However there was a small amount of overtopping of the berm. The purpose of the microalgal sampling was to assess the biomass of the phytoplankton and phytomicrobenthos present.

Salinity measurements
Salinity was measured and the data were captured by the fish and benthos team at the same time that the microalgal sampling was done..

Phytoplankton biomass
Water column samples were collected for phytoplankton chlorophyll a from 0 m, 0.5 m, 1 m and then 1 m intervals to the bottom and were gravity filtered through plastic Millipore towers using Whatman (GF/C) glass fibre filters. The samples were collected using a 500 ml weighted pop-bottle. The phytoplankton chlorophyll a was extracted later by placing the filters into glass vials containing 10 ml of ethanol (Merck 4111). The samples were frozen until they were refiltered through Whatman (GF/C) glass fibre filters. The chlorophyll a in the filtrate was read in a spectrophotometer at 665 nm before and after the addition of two drops of 10% HCl. The equation used was that of Hilmer (1990), derived from Nusch (1980):

$$\textbf{Chlorophyll } \underline{a} \textbf{ biomass } (\mu g\ l^{-1}) = (E_{b665} - E_{a665}) \times 29.6 \times (v/(V \times L))$$

Where:
- E_{b665} = absorbance at 665 nm before acidification
- E_{a665} = absorbance at 665 nm after acidification
- v = volume of solvent used for the extraction (ml)
- V = volume of the sample filtered (l)
- L = path length of the spectrophotometer cuvette (cm)

29.6 = a constant calculated from the maximum acid ratio (1.7) and the specific absorption coefficient of chlorophyll-a in ethanol (82g l^{-l} cm^{-1})

Figure 1. Google Earth image (.jpg) of the sampling sites on 14 May 2013 in the Mlalazi Estuary (Mouth = Mlalazi 7; Head = Mlalazi A).

Microphytobenthic biomass

- Microphytobenthic biomass was estimated using benthic chlorophyll-a content as an index (mg chlorophyll a.m^{-2}). Mud cores were extracted from the intertidal sediment using a 20mm ID corer, following the recommendations of Rodrigues (1993). The sampler described by Rodriques (1993) was found to be very suitable for the muddy sediments of the Eastern Cape but less suitable in the sandy to coarse sand samples of KwaZulu-Natal. To this end, a modification was introduced to the sampler whereby the base of the sample core was closed off by a "gate" to prevent the sand in the tube dropping out the bottom before the 10mm surface sample can be collected.
- The sediment core was removed from the corer by pushing on the bottom with a rod having a diameter slightly smaller than that of the corer. The mud core was pushed upwards through the corer until the surface water flowed away leaving a section of exposed sediment core. The core (10mm) was then cut off and placed with a second (replicate) core into 30ml absolute ethanol. The chlorophyll a in each core was allowed to extract in the dark overnight in a refrigerator. The ethanol/mud mix was filtered and the light absorbance at 665 nm of the supernatant was determined, using a spectrophotometer, before and after the addition of 2 drops of 0.1N HCl. Chlorophyll-a absorbance was measured at 665 nm. The chlorophyll a concentration was determined from the absorbance readings using the modified equation of Nusch (1980):

$$\textbf{Chl } \underline{\textbf{a}} \textbf{ biomass (mg m}^{2}\textbf{)} = (E_b - E_a) \times 29.6 \times (V/A) \times 1000$$

Where: E_b & E_a = sample absorbance measured using the spectrophotometer at 665 nm before and after the addition of 0.1N HCl.

29.6 = constant calculated from the maximum acid ratio (1.7) and the specific absorption coefficient of chl a in ethanol (82 g l^{-1} cm^{-1})

V = volume of ethanol used to extract the pigment (ml)

A = the basal area of the sample in mm^2

1000 = Conversion factor for $\mu g.mm^{-2}$ to mg. m^{-2}

Identification of major phytoplankton groups

A surface water sample and one from 0.5 m below the surface (250 ml) were collected in a pop-bottle from each site and preserved with 1 ml of 25% glutaraldehyde with 1 drop Rose Bengal solution for phytoplankton identification. A 100 ml sample of this preserved water was settled for 24 hours before being reduced to 10 ml. The cells were left to settle for 24 hours before being transferred to 2x 1.5 microfuge tubes and sent by post to the NMMU microscope laboratory where the microalgal groups were identified using a Zeiss IM 35 inverted microscope at the maximum magnification of x630.

A minimum of 100 cells were counted for each sample and the cells were classified according to different microalgal groups; i.e. flagellates, diatoms, dinoflagellates, cyanophytes (blue-green algae), chlorophytes (green algae) and zooflagellates (flagellates with no visible chloroplast). Cell density was calculated using the formula:-

$$\textbf{Cells ml}^{-1} = ((\pi r^2)/A) \times C/V$$

Where: r = radius of the chamber

A = Area of each frame (mm^2)

C = number of cells in each frame

V = volume of the settled sample (ml).

In the case of this study, the number of plankton cells counted (>200 cells) was:

$$\text{Counts/l} = \frac{\text{No. cells counted x 33443}}{\text{No frames viewed x 100ml}}$$

This was done to normalise the data for comparison with other RDM studies.

Results

Table 1. Salinity of the water samples.

Site\Depth (m)	Water salinity (PSU)			
	Surface	0.5	1.0	2.0
Mlalazi 7	32	33	-	-
Mlalazi 6	25	29	-	-
Mlalazi 2	8	9	19	-
Mlalazi 1	0	1	-	-
Mlalazi A	0	0	-	-
3D Average	**13**	**14**	**19**	**-**

Table 2. Secchi disc readings.

Site	Secchi depth (m)
Mlalazi 7	0.7
Mlalazi 6	0.7
Mlalazi 4	1
Mlalazi 2	0.7
Mlalazi 1	0.5
Mlalazi A	0.7

Table 3. Phytoplankton biomass data for the six Mlalazi sample sites collected on 19 November 2013 (summer).

Phytoplankton biomass (µg chlorophylla l^{-1})			
Site	**Surface**	**0.5 m**	**1.0 m**
MLZ 7	2.96	2.52	-
MLZ 6	9.92	-	-
MLZ 4	11.25	8.44	-
MLZ 2	5.33	4.74	13.17
MLZ 1	5.18	12.14	-
MLZ A	2.96	2.52	-
Ave	**6.27**	**6.07**	**13.17**

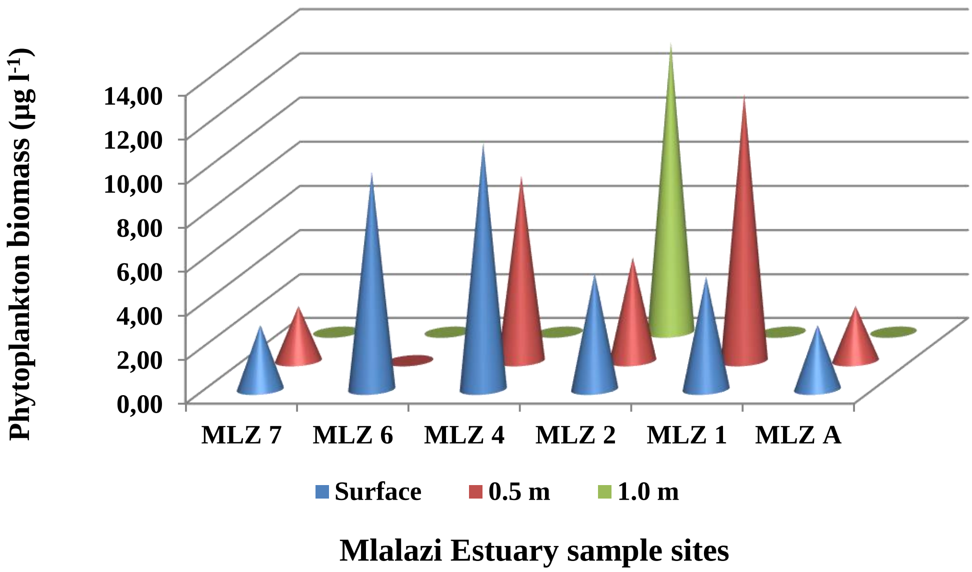

Figure 2. 3D representation of the phytoplankton biomass (µg Chlorophyll a l^{-1}).

Table 4. Microphytobenthic biomass (mg chlorophyll a m-2) data for the six Mlalazi sample sites collected on 19 November 2013 (summer).

Microphytobenthic biomass (mg m^{-3})			
Site	**Subtidal**	**Intertidal**	**Ave**
MLZ 7	0.07	0.63	**0.35**
MLZ 6	2.09	1.53	**1.81**
MLZ 4	5.37	6.28	**5.83**
MLZ 2	0.77	5.30	**3.04**
MLZ 1	9.56	4.00	**6.78**
MLZ A	17.30	1.40	**9.35**
Ave	**5.86**	**3.19**	**4.53**

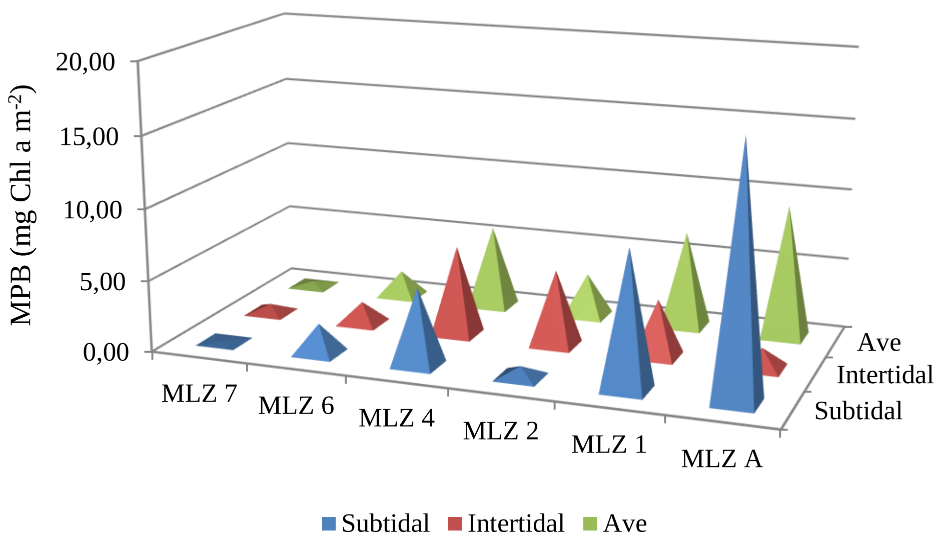

Figure 3. **Three dimensional graphical details of the microphytobenthic biomass (MPB) (mg Chl. a m^{-2}) of the Mlalazi Estuary at 6 sites on 14th May 2013.**

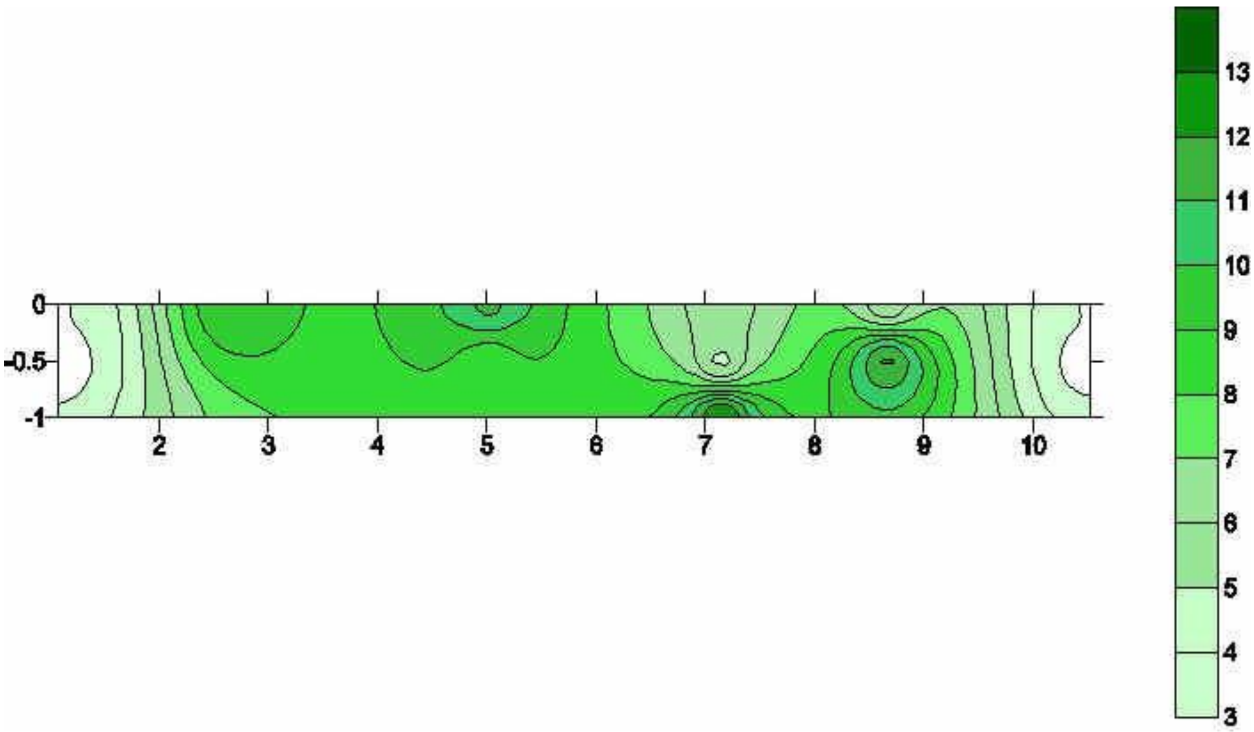

Figure 4. **Contour diagram generated in Surfer 7® from the phytoplankton biomass data in Table 3.**

Table 5. Cell counts (Cells l^{-1}) of the different plankton groups in the Mlalazi Estuary in May 2013.

Site/Depth	Flagellates	Diatoms	Dino-flagellates	Blue greens	Total	Comment
A 0m	1025	434	14	0	1473	Chains of Skeletonema sp
A 0.5m	1143	202	14	98	1456	
1 0m	481	3762	125	0	4368	Chains of Skeletonema sp
1 0.5m	780	1672	167	0	2620	Chains of Skeletonema sp
2 0m	669	3567	557	0	4793	Chains of Skeletonema sp
2 0.5m	543	7943	167	0	8653	Chains of Skeletonema sp
4 0m	984	3541	98	0	4623	Chains of Skeletonema sp
4 0.5m	1533	4320	84	0	5936	Chains of Skeletonema sp
6 0m	557	5574	28	0	6159	Chains of Skeletonema sp
6 0.5m	836	3595	0	0	4431	Chains of Skeletonema sp
7 0m	780	1605	11	0	2397	Chains of Skeletonema sp
7 0.5m	885	1279	0	0	2164	Chains of Skeletonema sp
Average	851	3125	105	8		

Discussion

At the time the samples were collected on the 14th May 2013, the estuary was open. Figure 1 shows that site 7 was close to the mouth while Site A was at the head. The salinity of the water near the mouth (Table 1) was 32 psu on the surface and 33 psu at 0.5 m depth, showing that there was a big tidal influence. The salinity at the head (Site A), however, was near to zero indicating a significant flow of fresh river water. The data in Table 1, therefore, shows both vertical and longitudinal stratification which is a desirable salinity condition in an estuary.

The secchi disc data in Table 2 show that the water transparency was uniform throughout the estuary but not very clear.

The sediment sampler commonly used to extract MPB sediment samples was originally designed in the Eastern Cape where the sediment grain in size in estuaries is normally very fine sand to mud. Sediment grain size is important in the sampling procedure because while fine particles are easy to retain in the sampling tube and easy to push out, coarse grain size causes two main problems: Firstly, the water above the sample washes easily through the tube while being withdrawn from the sediment. This can cause some of the surface MPB to wash through the sample, potentially reducing the amount assayed. Secondly, very coarse grains can get between the wall of the sampler and the wooden rod being used to push the sample to the top. It is likely that coarse grain sizes may, using the existing method, yield lower than true MPB values. A visual inspection of the sediment from each of the samples showed that 5 of the 10 MPB samples contained coarse-grained sand particles. Ultimately, however, the presence of the coarse grains did not appear to have a significant effect on the biomass recovered.

The phytoplankton biomass data (Table 3, Figures 2 and 4) showed higher chlorophyll a values in the middle section of the estuary, indicating that both the river water and sea water had a lower biomass than did the middle regions. Only a single station (MLZ 4) was deep enough to collect a sample from 1.0 m and this produced the highest biomass 13.17µg l^{-1}. This distribution is expected in an estuary that has some water flow because the diatom component which is unable to retain buoyancy on its own, is picked up by turbulent flow into the deeper regions, i.e. the microphytobenthos becomes part of the phytoplankton.

The numerical values for the microphytobenthic component cannot be compared to those of the phytoplankton because the units are different (mg m^{-2} sediment vs µg l^{-1} water). These MPB data in Table 4 show that the biomass was variable from very low values (0.07 mg m^{-2}- MLZ7 subtidal) to substantially higher values (17.30 mg m^{-2} - MLZA). Some of the variability may be due to the method of sampling which is not ideal where coarse sand is the major component of the sediment and some cells may have been washed through the core.

The values of phytoplankton (Table 5a) and phytomicrobenthos (Table 5b) biomass as chlorophyll a in numerous estuaries in South Africa were recorded by Snow and Adams (2008). These values serve as a guide in determining the status of the measured values in other systems.

Table 5a. Classification scheme of median phytoplankton chlorophyll a for a whole estuary obtained using microalgal biomass data from freshwater requirement studies. (After Snow & Adams 2008).

Biomass class	Median chl a
Very low	Less than 1.0 µg l^{-1}
Low	1 to 3.5 µg l^{-1}
Medium	3.5 to 8.0 µg l^{-1}
High	>8.0 µg l^{-1}

Table 5b. Intertidal benthic microalgal biomass classification scheme based on the median chlorophyll a content and concentration obtained using chl a data from freshwater requirement studies. (After Snow & Adams 2008).

	Median chl a content (median chl a concentration)
Low	< 3.5 µg g^{-1} (< 11 mg m^{-2})
Medium	3.5 to 7.2 µg g^{-1} (11 to 23 mg m^{-2})
High	7.2 to 13.4 µg g^{-1} (23 to 42 mg m^{-2})
Very high	>13.4 µg g^{-1} (> 42 mg m^{-2})

Using the foregoing data on a site by site basis, the interpretation is the average phytoplankton biomass in the surface water falls into the medium range with sites MLZ 6 and 4 falling into the high range. At 0.5 m depth the average biomass falls into the medium range but with sites MLZ 4 and MLZ 1 falling into the high range. At the single 1.0 m depth (MLZ 2) where a sample could be retrieved, the biomass value of 13.17 puts this site into the high range, which is not unreasonable in a shallow estuary with some water flow.

The cell count data showing the numbers in the different groups are rather different to many other estuaries sampled. This is due to the unusually high dominance of diatoms at most of the sites. Normally flagellates are very dominant with diatoms much less dominant. Another most unusual feature of these counts is that the diatom population consisted almost entirely of chains the genus *Skeletonema* (Greville) Cleve which is a marine species. This clearly indicated a big marine influence in this estuary. What is even more unusual and difficult to explain is how a marine species was so dominant near the head of the estuary at a very low salinity.

Except for the phytoplankton group species counts, the Mlalazi Estuary appears to be in good condition from the perspective of the microalgae. The final interpretation, however, will have to be made in the light of the hydrological (annual volume of fresh water), hydrodynamic (patterns of flow and flooding frequency), water quality (especially nitrogen and phosphorus loads) and the status of the macrophyte population. The macrophyte condition relative to the reference state is of great importance because epipelic diatoms adhere to the macrophytes and supply food to juvenile fish in a protective habitat.

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Appendix E

Specialist Report Macrophytes

Mlalazi Estuary Rapid Assessment
Historical Data & Fieldtrip Report

Macrophytes
by
Ricky Taylor
Independent Ecologist

Introduction

The Mlalazi Estuary has a diversity of vegetation habitats and is rich in macrophyte species. This is a result of the mouth being predominantly open and the tidal rise-and-fall that extends for a very long distance up-stream. There is a gradient of plant species ranging from those that are closely associated with seawater salinities near the mouth, to those that are more characteristic of the fresh conditions which occur at the river-estuary interface. The Mlalazi Estuary has particularly fine stands of mangrove and salt-marsh communities. The only historical information on the macrophytes of the Mlalazi Estuary is in the form of Macnae (1963) and Hill (1966).

Delineation of Estuary

Downstream Boundary

This is taken to be the estuary mouth. There is not much lateral spread of the estuary here as it is contained by vegetated coastal dunes. In recent decades the mouth has ranged over a linear beach distance of about 1 km.

Upstream Boundary

The extreme limit of the tidal ebb and flow is regarded to be opposite the settlement of Sbhamu. For convenience we consider the bridge over the district road (coordinates; -28.9184 S; 31.7283 E) to be the upper water limit of the Mlalazi Estuary. This is 2.7 km upstream of the confluence with the Ntuze tributary and a distance of 15 km from the mouth.
(If the upstream boundary is defined by the extent of back-flooding during extreme high water conditions, this boundary could be still further upstream). It also extends to the existing weir (Figure 1) on the Ntuze tributary (coordinates; -28.9074 S; 31.7625 E) – which is 800 m upstream of its confluence with the Mlalazi. (Table 1).

The area of the estuary water is 140 ha.

Figure 1: The weir on the Ntuze tributary. The water dammed up by the weir is used as a back-up supply for the town of Mtunzini. In the past the tidal ebb and flow point was upstream of this point. Nowadays this is the upper reach of the estuary on this tributary.

Table 1: Measurements of distances in the Mlalazi Estuary.

Mlalazi - from	**To**	**Distance (km)**
Mouth	Rail Bridge	7.7
Mouth	N2 Bridge	10.5
Mouth	Old Road Bridge	10.8
Mouth	Confluence with the Ntuze Tributary	12.4
Mouth	Confluence with Bhadi tributary	13.7
Mouth	Bridge on regional road north of Sbhamu	15.1 (estimated point of ebb and flow)
Tributaries - from	**To**	**Distance (km)**
Confluence (Mlalazi/Ntuze)	Weir	0.8
Weir	Watercourse in farmlands	1.3 (Possibly extent prior to weir construction)
Confluence (Mlalazi/Bhadi)	Bridge crossing Bhadi tributary south of Sbhamu	2.2 (to estimated ebb and flow)

Historically, Hill (1966) regarded the inland limits of the estuary to be Balcombe's rocks about 8 km from the mouth which he regarded to be the limit to brackish water intrusion (Figure 2). However, recent Ezemvelo salinity measurements indicate that saline water does, at times, extend upstream of the N2 Bridge.

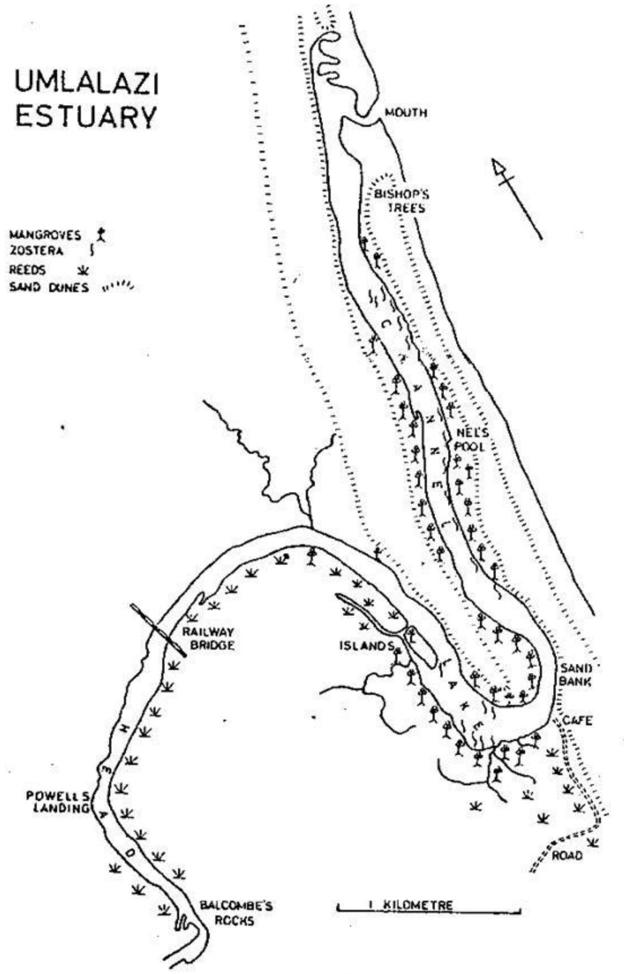

Figure 2: Map of the Mlalazi Estuary from Hill (1966). Note the location of the *Zostera capensis* beds near the mouth.

The lateral boundaries Lateral Boundaries

of the estuary are defined mainly by the 5 m a.m.s.l. contour. This has been provided by Ezemvelo KZN Wildlife as a shape file. In places, based on vegetation, this is deemed to be incorrect – and for the map (Figure 3) has been modified to a small extent based on the map as part of this study.

The area of the lateral extent of the estuary (including the water area) = 1119 ha.

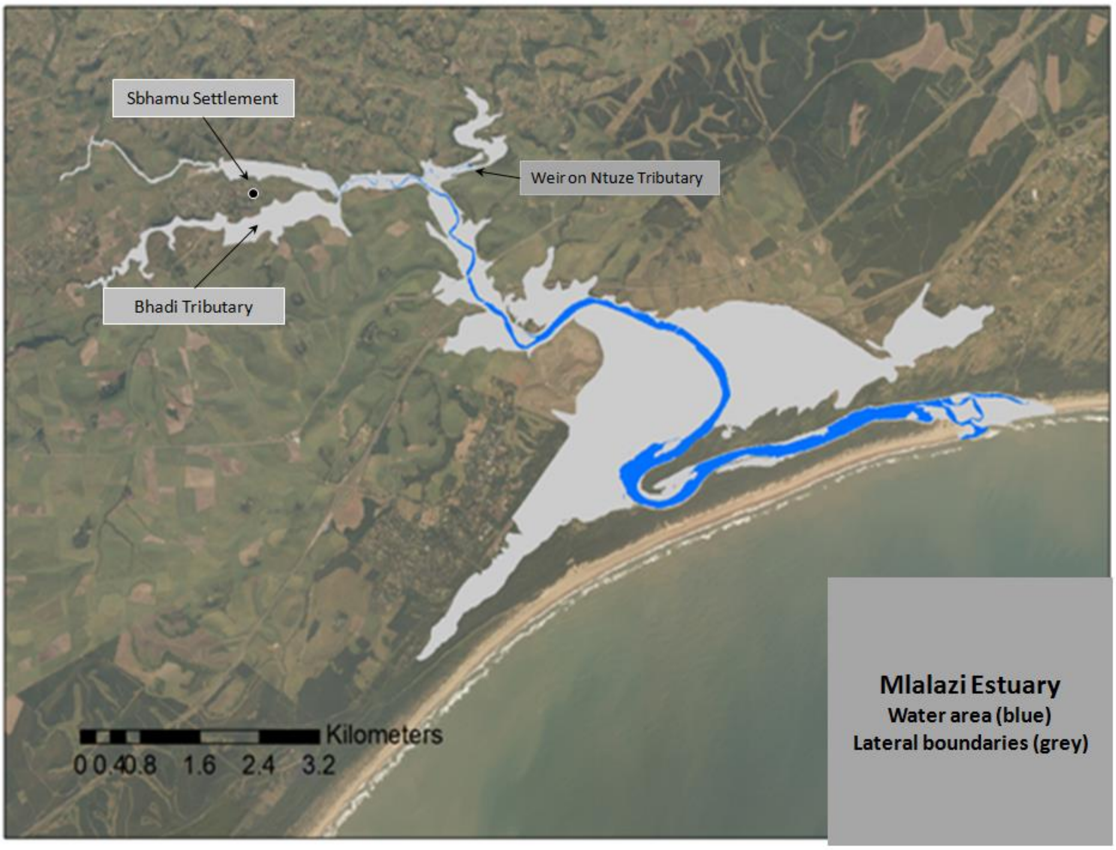

Figure 3: Geographical boundaries of the Mlalazi Estuary indicated on an ortho-photo, showing the mouth (downstream boundary, the Bridge at Sbhamu and the Weir on the Ntuze Tributary (upstream boundaries) and the +5 m a.m.s.l. contour (lateral boundaries).

<u>Vegetation mapping</u>

The mapping of the vegetation has been done using the 2009 colour orthophoto coverage (Surveys and Mapping) to map the communities (using ArcMap 10). This has then been ground-truthed on 20 September 2013, backed up several informal visits to the estuary. The map is shown in Figure 4 a, b & c. Figure 4a is of the full area, 4b gives most of the estuary water surface which is affected by tides and salinity under normal conditions, and 4c shows the core area in which there is the greatest diversity.

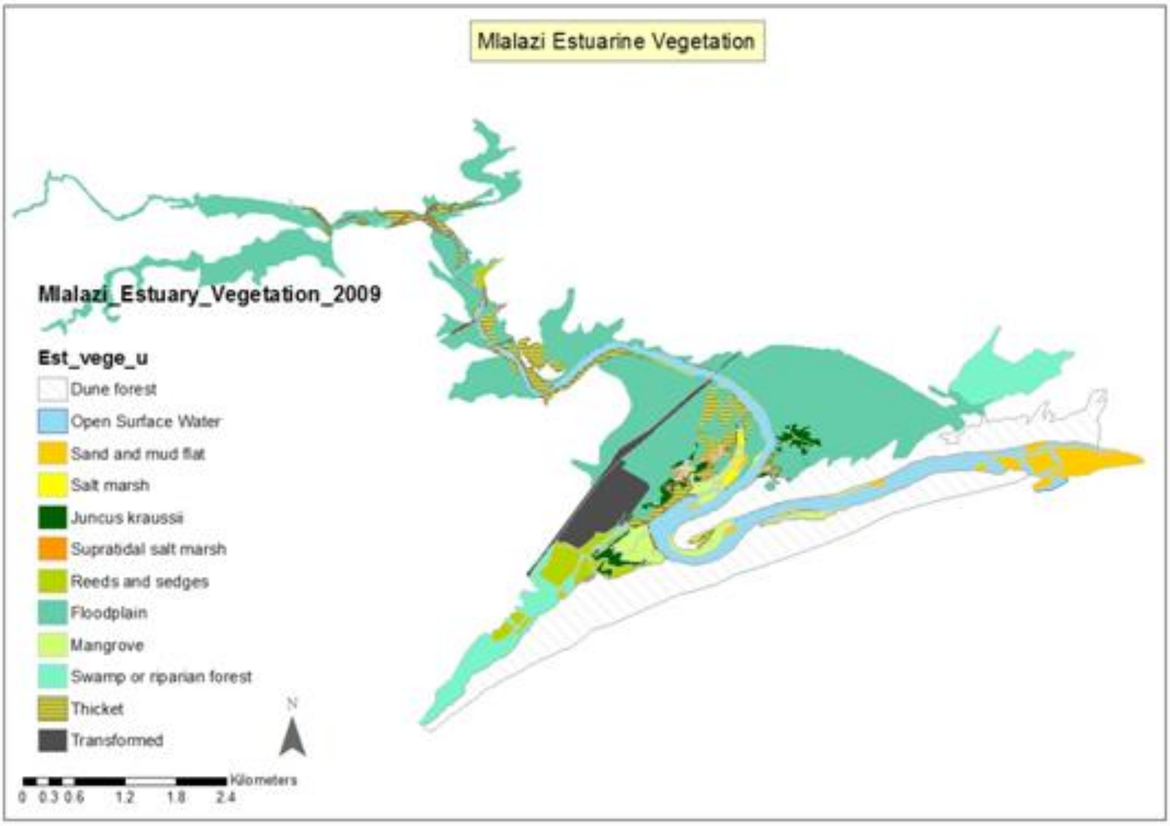

Figure 4a. Vegetation and habitat map for Mlalazi Estuary (full area).

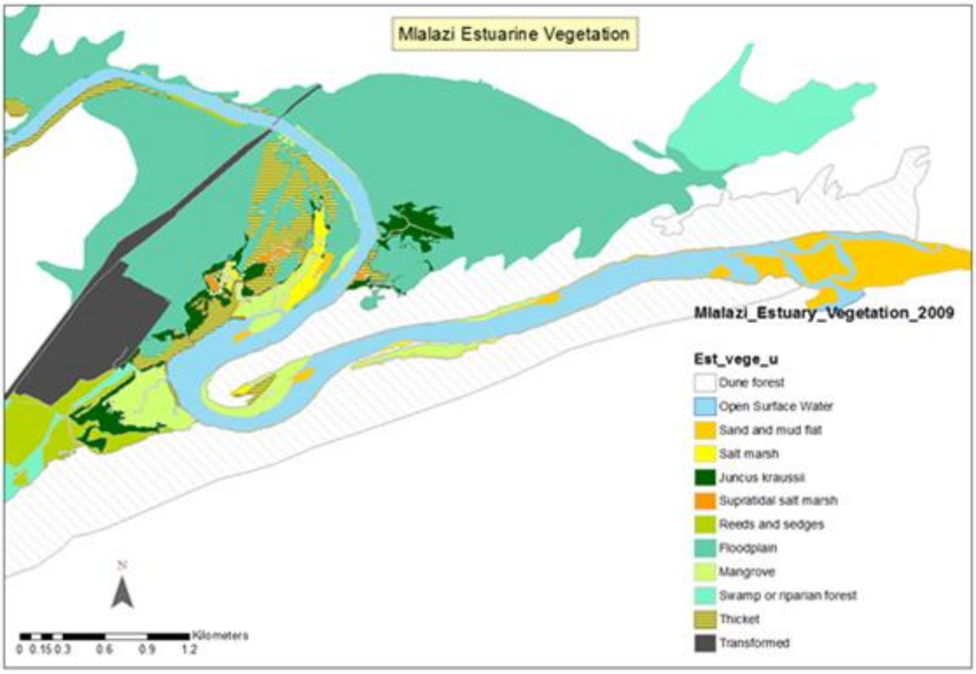

Figure 4b. The main estuary area.

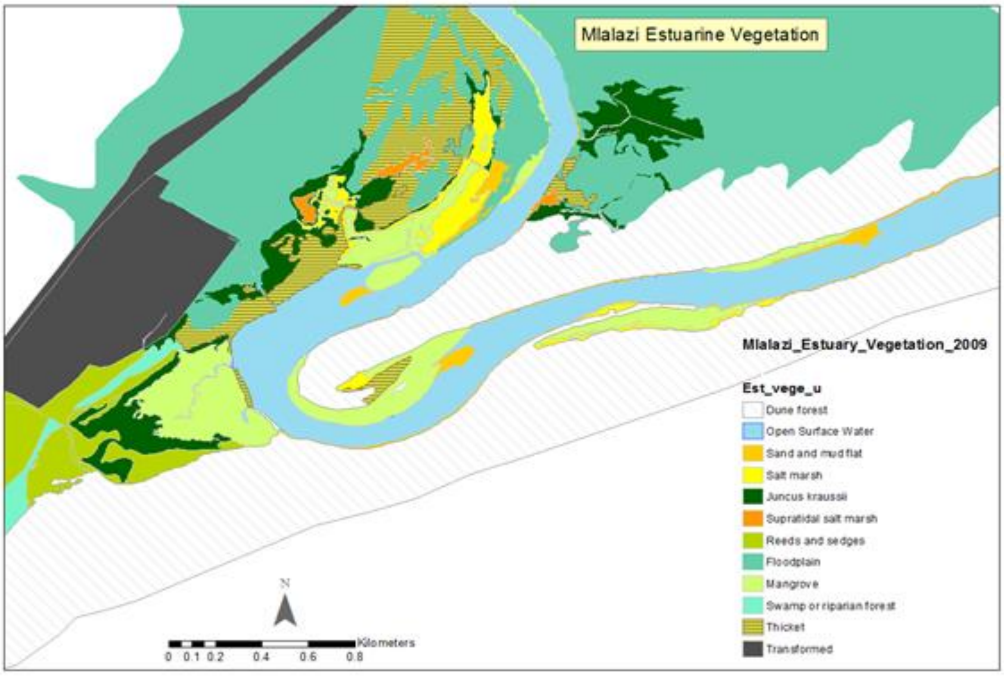

Figure 4c. The core area, the area with greatest habitat diversity.

The mapping units used, with some of the characteristic species in each unit, are given in table 2. The table also provides the area of each community in hectares.

Table 2. Area of the different vegetation and habitat units in the Mlalazi Estuary.

Habitat Type	Area (ha)	Indicator species/comments
Open surface water area	**140**	Habitat available for phytoplankton
Intertidal sand and mudflats.	**45**	Habitat available for benthic microalgae. (Included intertidal rocks)
Submerged macrophyte beds	**0**	*Zostera capensis* (in very low quantity). No *Stuckenia pectinatus* or *Ruppia cirrhosa*
Macroalgae	**0**	Charophytes, *Enteromorpha,* algae on pneumatophores
Intertidal salt marsh Succulent salt marsh	**11**	(Succulent salt marsh) *Sarcocornia natalensis*, *Triglochin striatus*
Intertidal salt marsh Juncus salt marsh	**31**	(Juncus salt marsh) *Juncus kraussii, Phragmites australis, Acrostichum aureum, Diplachne fusca*

Supratidal: Salt marsh (shoreline and saline lawns) Floodplain	**568**	*Sporobolus virginicus, Canavalia rosea, Diplachne fusca. Imperator cylindrica, Hemarthria altissima, Stenotaphrum secundatum.* Much of this category has been converted to sugarcane farms
Reeds and sedges	**43**	*Phragmites australis, Schoenoplectus scirpioides.*
Mangroves	**40**	*Avicennia marina, Rhizophora mucronata, Bruguiera gymnorrhiza*
Swamp forest /Riparian forest	**104**	*Barringtonia racemosa, Hibiscus tiliaceus, Ficus trichopoda, Voacanga thouarsii, Rauvolfia cafra.*
Transformed	**61**	Prawn farm, Road and rail (areas where soil has been reworked)
Thicket	**77**	*Acacia/Ekebergia/Schinus/Melia*
Total area	**1119**	

A checklist of the estuary-associated species is given in Table 3 (at the end of this document).

<u>Annotated description of each habitat type and its component vegetation</u>

Open surface water (140ha)

This consists of the main channel of the estuary as well as the small creeks that drain into it from the mangroves, salt marshes and floodplain areas. The estuary is a TOCE which is well flushed when the mouth is open. There is a salinity gradient from the sea inwards. There also can be a well-defined vertical salinity gradient. During low flow periods the salinity can reach 10 km from the mouth – often with the heavier saline water standing in the deeper parts of the estuary.

The estuary is tidal for about 15 km and backing up of water during flood conditions is possibly even further upstream of this.

There is little sign of nutrient accumulation in the open water – possibly because there is very good tidal flushing and also the full estuary flushes during spates in the river. However there is concern that the amount of agricultural chemicals in the runoff from farmlands is increasing. There is also a major concern about influent nutrients from the prawn farm (which is currently being converted into a fish farm for Kob) and from the Mtunzini town sewerage works (and there are proposals to expand this considerably).

Intertidal sand and mudflats (45ha)

The tidal rise and fall of the water creates areas of intertidal sand and mud flats, and also affects the few areas of rocks. In the upper reaches of the estuary sand is also exposed on meanders when the river flow is low.

There are small outcrops of rocks in the estuary upstream of the Railway Bridge. On the north bank near the mouth is about 200 m of 'rip-rap' – huge rocks piled along the shoreline in 1962 (Hill, 1966) to stabilise the mouth area. The sand and mud flats and the rocks all form discrete habitats – but there is no evidence of vascular plants or macrophytic algae on them at present.

Submerged macrophytes (0ha)

In the Mlalazi Estuary the area of open water in this estuary is currently free of submerged macrophytes. This is possibly due to the strong wind and tide generated currents and the strong flood events that occur a few times most years. However there used to be beds of Zostera *capensis.* This species was collected from Mlalazi by Ward in Feb and August 1962 about 1 km up from the mouth (data from herbarium specimens deposited in the Bews Herbarium, UKZN, Pietermaritzburg). *Zostera* was also recorded in Mlalazi Estuary by Hill (1966). There are no recent records of this species occurring in the estuary. The distributing of *Zostera capensis* has declined in recent years in the estuaries of KZN – so this absence is of concern.

(Post script – 10 Feb 2015. In late 2014 two small beds of Zostera were found in the estuary – showing that it still is present.)

Macroalgae (0ha)

Traces of macroalgae entering from the sea were noted near the mouth. Some small traces of a Charaphyte alga were found tangled on the *Avicennia marina* pneumatophores half way up the estuary (opposite the public car park) (Figure 5).

Figure 5. An unidentified Charaphyte found in very small quantities tangled on Avicennia pneumatophores – although it looked healthy, it was translucent and had no green colour.

The most significant biomass of macroalgae is that which grows on the *Avicennia* pneumatophores (Figure 6a & b). There is also a high biomass of the algae on the intertidal bases of the *Bruguiera gymnorrhiza* trees in the vicinity of the creek into which there is outflow of the town sewage and the runoff from the aquaculture ponds. The area of this has not been measures as it occurs in a very narrow band along the intertidal shoreline of the mangrove communities and the estuary.

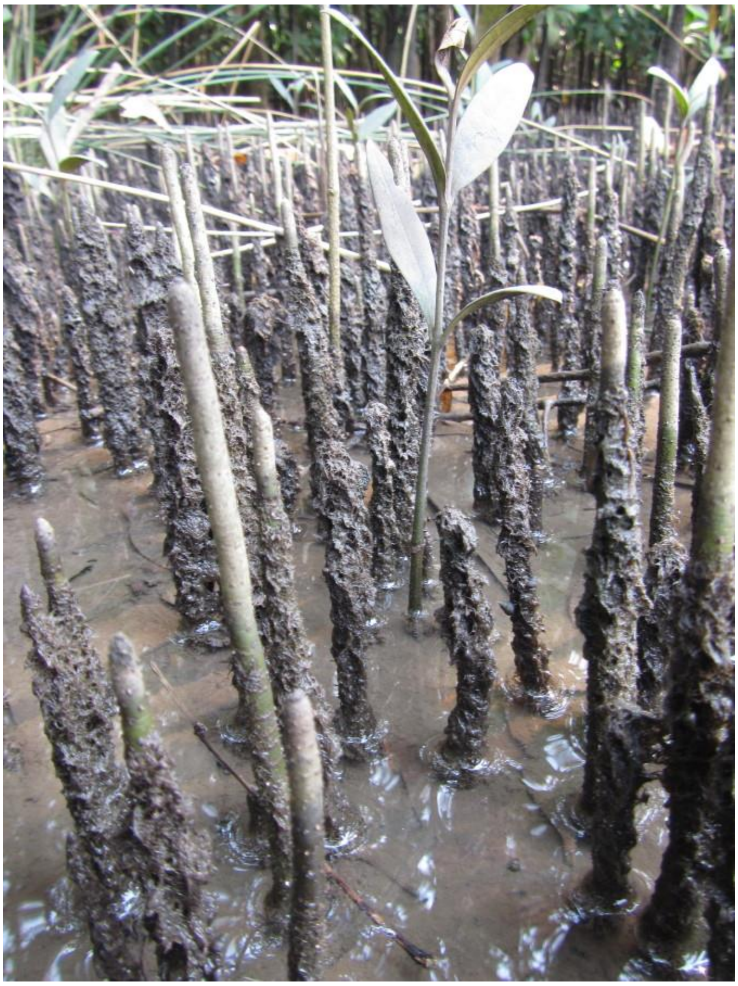

Figure 6a. Algae growing epiphytically on *Avicennia* pneumatophores.

Figure 6b. Algae on pneumatophores near the mouth.

Intertidal salt marsh (45ha)

Saline grasses

In various localities where there is inundation only at very high water levels there are patches of the grasses *Sporobolus virginicus, Stenotaphrum secundatum*, and *Hemarthria altissimus*, and also the occasional clumps of *Diplachne fusca* (Figure 7). These areas are too small to map individually.

Figure 7a & b. The grass *Diplachne fusca* growing in clumps on the edge of the estuary.

Succulent salt marsh (11 ha)

There is a large area of mudflat and salt marsh on the southern side of the estuary from the slipway towards the rail bridge. The characteristic plant of this area is *Sarcocornia natalensis*. (Figure 8). Others include *Triglochin striatus* and the grass *Sporobolus virginicus* along the margins (Figure 9).

The salt marsh is formed by the large river floods which have formed the mud flats here. Then area is inundated by estuary water during extreme tidal periods and during mouth closures. It is during these conditions that salt may be deposited in the mud – which is concentrated by evaporation to form a salt cap. The *Sarcocornia* is killed by flooding during periods of mouth closure, but regenerates rapidly once the mudflats are once again exposed. The seeds are of Sarcocornia are stimulated to germinate by exposure to fresh water (e.g. by a rainfall event). The periodic flooding and die-offs of the *Sarcocornia* 'reset' the system and prevent the invasion of the area by other species.

The salt marsh has been severely impacted by the construction of the railway bridge – which reduces flood scour effects. It was also affected by the dredging in the 1960s which resulted in a levee of dredger spoil being deposited around the salt marsh which prevented much of the tidal flooding. This was partly rectified in the 1990s when a breach in the spoil levee was cut to reinstate the salt marsh. This resulted in a very effective recovery. At present the salt marsh is bisected by a road which affects the hydrology of the area.

Recently this road has been closed and the intention is to reclaim the hydrological flows by removing the road berm. Ezemvelo protects this salt marsh by minimising the trampling effects by the public.

Figure 8a. At very high tides, or during river floods, the succulent salt-marsh is flooded.

Figure 8b. The succulent salt marsh plant, *Sarcocornia natalensis.*

Figure 9. *Sporobolus virginicus* (It is noteworthy that no *Paspalum vaginatum* was seen in the Mlalazi Estuary as in other estuaries it is often is found growing together with *S. virginicus*)

Juncus salt marsh (31 ha)

A feature of the Mlalazi estuary are the *Juncus kraussii* (Ncema) beds which are opened most years in may for harvesting by Zulu women to cut the stems for weaving material. These are more or less mono-specific stands of Juncus, but there are places where there is an incursion of *Phragmites australis* reeds, which in time shade out and replace the Ncema. (Figure 10).

Figure 10. Large areas of *Juncus kraussii* occur in salt marshes on both sides of the estuary. This plant is extensively harvested as a fibre for weaving.

Supratidal (568ha)

Usually, supratidal refers to the zone that stretches from the mean high water mark to the highest point reached by the equinox spring tides. Along the margins of the Mlalazi Estuary there are only a few very small, but interesting, sites where this supratidal effect is that of the highest of tides combined with wave action. However, as part of the Mlalazi estuarine ecosystem there are large areas where the main reason for flooding is the back-flooding of these areas when the mouth is closed and the water level is allowed to rise , or alternatively flooding occurs during particularly large river floods. In the former instance the salinity of the water is very low, and in the latter salinity is absent. The manipulations of the mouth, the dredging activities and the construction of embankments at the road and rail bridges have damaged much of this habitat – and also enabled mangroves to thrive in an abundance that was not possible under more natural conditions. The boundary to this supratidal 'floodplain' is arbitrarily taken to be the 5 m a.m.s.l. line

Salt marsh (shoreline and saline lawns)

There are only small areas of this community. Too small to measure

Floodplain

Much of the floodplain has been converted to sugar fields. It seems as if most of the manipulations of the mouth and estuary in the past have been to protect the sugar from rising water (Figure 11). To prevent water from standing on the fields, drainage ditches have been cut. In the natural condition a large area of *Juncus* marsh occurred on the north bank of the estuary and what is now left is a remnant of this.

Figure 11. There are numerous drainage channels, similar to the one shown above, that enter the estuary from the adjacent sugar farms. This drainage prevents water from accumulating on the floodplain and enables the planting of sugar in what formerly was wetland.

Reeds and sedges (43 ha)

Large portions of the middle stretch of the estuary have a fringe of *Phragmites australis* reeds. In places, possibly where there is freshwater seepage into the estuary, the fringe is of *Schoenoplectus scirpioides*.

Much of the floodplain, prior to planting of cane, would have been under reeds.

Mangroves (40ha)

The Mlalazi estuary has a significant area of mangroves – mainly *Avicennia marina* and *Bruguiera gymnorrhiza*, but there are also a few plants of *Rhizophora mucronata*. The mangrove fern, *Acrostichum aureum*, is also found in the upper parts of the estuary – from near the Ezemvelo chalets all the way to the confluence with Ntuze tributary. In places the mangroves are intermingled with *Hibiscus tileaceous*.

The mangroves have not always been a feature of the system. Macnae (1963) reported "*the mangrove, although not extensive, is of comparatively recent origin. In 1913 there were no mangroves at all and the river ran between sandbanks to the sea and a large lagoon was associated with the estuary. This lagoon is now completely silted up and occupied by a marsh, part dominated by Phragmites and part dominated by Juncus kraussii. The riverward end of this marsh is occupied by a mangrove swamp quite typical of the rivers just to the north.*

The estuary is long and narrow, running to sea between sand dunes. On the inner bank on curves mangroves occur in the lowest four kilometres or so and stop about 1 km from the sea. The Juncus associations and the lowermost Phragmites associations are invaded by saplings of Avicennia and Bruguiera (but no Rhizophora or Ceriops)."

Hill (1966) mentions the "*large scale changes due to deposition of mud from cultivated areas and a simultaneous rapid colonisation by mangroves chiefly Avicennia*". (Note: Hill did his fieldwork in 1963). Hill also reports that local reports as well as the 1937 photos indicate that there were no mangroves in the estuary before 1940 – and that they made their appearance in the late 1940s or early 1950s In the 1940s the mouth used to close for a few months each year. In the 1940s it was breached regularly to protect sugar cane (Hill, 1966).

We have no proof as to why the mangroves have increased so much in the system – but it is likely to be first due to the artificial breaching of the 1940s and later by the dredging of the estuary and the construction of the rock wall which has stabilised the mouth to some degree. Currently the mangroves are thriving, although there is a small unexplained dead patch in the island, as evident from the dead stumps of *Avicennia* there (Figure 16).

In the early 1990s the Ezemvelo altered its mouth breaching policy. Prior to this the policy was to breach within two weeks of closure (to protect the mangroves). The altered policy allows the mouth to remain closed for much longer – and the water level of the closed mouth to build up more. This has had the effect of killing some of the *Avicennia* in lower elevations. It is likely that these had been able to colonise a lower elevation than possible without mouth breaching.

Currently are only two *Rhizophora mucronata* trees which are large enough to be fruiting are known in the system. These are in the channel between the slipway and the visitors' parking area. (Coordinates: -28.9527S; 31.7726E). Near these adult trees there are several seedlings. I suspect that the adult *Rhizophora* trees could have been introduced and have not colonised naturally.

The most upstream *Bruguiera gymnorrhiza* is immediately upstream of the old bridge on the Old Main Road (R102) (Coordinates: -28.9286S; 31.7552E). The most upstream *Avicennia marina* seen was near 'Powell's Landing' (Coordinates: -28.9329S; 32.7737E.) The most upstream *Hibiscus tiliaceus* was seen a shore distance downstream of the N2 bridge (Coordinates: -28.9341 S; 31.7588 E).

Mlalazi has one of the most important stands of mangroves in the country. The trees are healthy and propagating well. However it should be remembered that these trees are likely to be an artefact of human manipulations of the estuary. (Figures 12 to 16).

Figure 12. *Avicennia* seedlings in a fringe of pneumatophores.

Figure 13. A typical stand of *Avicennia* and Bruguiera, with a lot of exposed mud.

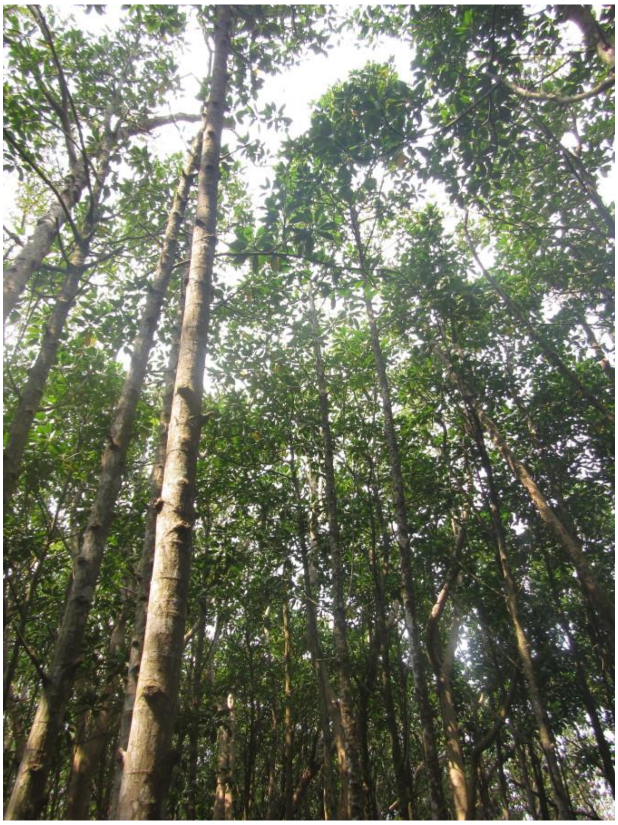

Figure 14. A stand of tall *Bruguiera* trees. These trees are all about 10 m tall. This is unusual and is the result of the high density of the trees causing them to grow upwards in a competition for light.

Figure 15. An eroding shoreline. It looks as if this site was created by the dredging of the 1960s, was colonised by mangroves and now is eroding exposing their roots.

Figure 16. Dead *Avicennia* mangroves in the island.

Swamp forest/Riparian forest (104ha)

The catchment area of the Mlalazi Estuary has numerous remnants of riparian forest and water-course swamp forests. In most cases these cannot be regarded as estuarine habitats, but some of the forest is below the 5 m a.m.s.l. contour. There is a gradient of change from what is estuarine and what is freshwater. There are two discrete plant communities; the *Barringtonia racemosa* dominated areas and the *Ficus/Syzygium* dominated communities.

These swamp forests are being reduced by human impacts and these remnants have considerable conservation importance. The main threats to them are physical destruction, damage to the outer forest margins by human activities, invasion by alien plants and alteration of hydrology and of water quality.

Many of the swamp forests have had *Raphia* palms planted in them, and one such swamp forest is regarded as a National Monument because of a boardwalk through the palms. However, it should be remembered that these palms never occurred naturally here and the southernmost natural ones are at Kosi Bay

Transformed land (61ha)

This mapping unit has been included to show that areas where the topography of the landscape has been altered earth-moving activities. The transformed areas include the prawn farm and the road and rail embankments.

In 1965 a start was made with the dredging the Mlalazi Estuary (Hill, 1966). There are few records of the reasons for undertaking this or how much dredging was done. However, the evidence of the dredging is in the artificial banks along the margins of various sections of the estuary.

Thicket (77ha)

Adjacent to the estuary water, especially in the upper portions of the estuary, there may be a raised levee (Figure 17). Typical dryland trees occur, usually in there form of a thicket and occasionally as a low-canopy forest. Typical trees include as *Phoenix reclinata, Bridelia micrantha Trema orientalis, Albizia adianthifolia, Burchellia bubalina , Trichilia dregeanum, Ekebergia capensis, Acacia robusta, Ficus capreifolia, Rhus nebulosa, Strelitzia Nicolai,* and *Apodytes dimidiata*. In the thicket there are vines and scramblers such as *Dalbergia armata, Flagellaria guineense, Combretum microphylla, Acacia kraussiana, Scutia myrtina, and Smilax anceps.* In sandy areas: *Dodonaea* and *Chrysanthemoides*, and *Passerina rigida* are present. In the extreme upper areas plants characteristic of freshwater, such as the floating grass *Echinochloa pyramidalis* may be along the estuary margins.

This is the community where there has been a lot of human disturbance. Due to the disturbance it contains many alien species. In places the thicket community has been cut out completely and is planted to sugar (Figure 20).

Figure 17. Aliens *Melia azedarach* and *Schinus terebinthifolius* and the dryland reed, *Phragmites communis* on the banks of the upper reaches of the estuary.

Figure 18: The quite waters of Ntuze tributary near the weir. Note the water lilies and the floating *Echinochloa pyramidalis* grass which indicate fresh conditions. During droughts this water becomes slightly saline.

Alien Plants

Alien invasive plants are abundant in the upper parts of the estuary (Figure 19). The most prevalent alien plants are:

Trees: *Melia azedarach*, *Schinus terebinthifolius*, *Casuarina equisetifolia*

Shrubs: *Chromolaena, Lantana, Sesbania, Solanum*, Senna and *Opuntia*,

Annuals/ low perennials: *Xanthium, Conyza, Ageratum houstonianum, Blue salvia, Ricinus*

Herbaciaous plants. Hydrocotyl , Ravinia humilis,

Creepers: *Ipomoea purpurea, Cardiospermum*,

Casuarinas were planted in the 1950s to stabilise the mobile sands at the mouth (Begg, 1978)

Figure 19: There are many alien plants that colonise the disturbed sand deposits lateral to the upper reaches of the estuary. Here plants such as *Xanthium* and *Senna* are common.

Assessment

The Mlalazi estuary contains a variety of estuarine habitats for plants. These include succulent salt marsh, *Juncus kraussii* beds and mangroves. These are all communities we value and as such we tend to consider the Mlalazi Estuary to be in a good condition. However there have been major alterations. The system has shifted a long way away from a reference condition based on old aerial photographs. Much of the floodplain has been altered for cane (Figure 20), the breaching regime, although more natural now, is still artificial at times. There has been dredging in the 1960's and there is anecdotal evidence that there is sediment accumulating in the estuary.

Figure 20: Sugar planted to the edge of the estuary.

The result is that there is a healthy 40 ha stand of mangroves – one of the finest in the country – which can be regarded as being human-induced. Also, it is likely that the manipulations of the estuary have resulted in the local extirpation of *Zostera capensis* from the system.

There are also the *Raphia* palms that have been introduced to the swamp forests within the defined estuarine area that need to be considered. More and more are being spread to the swamp forests with the long-term effect of reducing the natural swamp forests. And in a similar vein, should the introduction of plants such as *Rhizophora mucronata* be accepted within the estuary, and if it is accepted, why not *Ceriops*, *Lumnitzera* and *Xylocarpa* – all mangroves that occur at Kosi? It is important that a statement on the management of non-natural plants and communities be made as part of the Water Reserve determination as these do result in a deviation from the reference condition. What really needs to be asked is "Are the natural processes that drive the dynamics of the estuary being compromised?"

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Table 3: List of key plant species occurring in, and associated with, the Mlalazi Estuary

A = abundant
P = present
*** = alien species

Habitat / Family and species	Intertidal mud flat	Succulent salt marsh	Juncus marsh	Shoreline and saline lawn	Floodplain	Reeds and sedges	Mangroves	Swamp and riparian forest	Thicket
Acacia kraussiana									**A**
Acacia robusta									**A**
Acrostichum aureum			**P**	**P**		**P**	**P**		
Ageratum houstonianum ***					**P**				**A**
Albizia adianthifolia									**A**
Allophylus natalensis									**P**
Apodytes dimidiata									**A**
Avicennia marina	**P**	**P**	**P**	**P**			**A**		
Bambusa balcooa ***									**P**
Barringtonia racemosa					**P**			**A**	
Bridelia micrantha									**A**
Bruguiera gymnorrhiza		**P**	**P**				**A**		
Burchellia bubalina								**P**	**P**
Canavalia bonnieri				**P**					
Cardiospermum grandiflorum ***									**A**
Casuarina equisetifolia ***				**P**					
Charophyte							**P**		
Chromolaena odorata ***									**A**
Chrysanthemoides monilifera				**P**	**P**				**P**
Conyza sp ***									**A**
Cynodon dactylon		**P**		**A**	**A**				**P**
Dalbergia armata									**A**
Deinbollia oblongifolia								**P**	**P**
Diplachne fusca				**A**	**A**				**P**
Dodonaea viscosa				**P**					**P**

Habitat Family and species	Intertidal mud flat	Succulent salt marsh	Juncus marsh	Shoreline and saline lawn	Floodplain	Reeds and sedges	Mangroves	Swamp and riparian forest	Thicket
Echinochloa pyramidalis					**P**	**P**		**P**	
Ekebergia capensis									**A**
Ficus capreifolia									**P**
Ficus trichopoda Baker								**A**	
Flagellaria guineense									**A**
Hemarthria altissima			**P**	**A**	**A**	**P**			**P**
Hibiscus tiliaceus	**P**			**A**		**P**			
Hydrocotyle bonariensis ***				**A**	**A**	**P**		**P**	**P**
Imperata cylindrica				**P**	**A**				**P**
Ipomoea cairica						**A**		**A**	**P**
Ipomoea pes-caprae				**P**					
Ipomoea purpurea ***									**A**
Juncus kraussii	**P**	**P**	**A**	**P**	**A**	**A**	**P**		
Kraussia floribunda									**A**
Lantana camara ***									**A**
Leersia hexandra					**A**	**P**		**A**	
Melia azedarach ***									**A**
Opuntia monocantha ***									**P**
Passerina rigida				**P**					
Phoenix reclinata								**P**	**A**
Phragmites australis				**P**	**A**	**A**			
Phragmites mauritianus					**A**	**A**		**P**	
Raphia australis								**A**	
Rauvolfia caffra								**A**	**P**
Rhizophora mucronata							**P**		
Ricinus communis ***				**P**	**P**				**P**
Rivina humilis ***					**P**				**P**
Sarcocornia natalensis.		**A**	**P**	**P**			**P**		
Schinus terebinthifolius ***					**P**				**A**
Schoenoplectus scirpioides				**P**	**A**	**A**		**P**	
Scutia myrtina									**A**

Habitat Family and species	Intertidal mud flat	Succulent salt marsh	Juncus marsh	Shoreline and saline lawn	Floodplain	Reeds and sedges	Mangroves	Swamp and riparian forest	Thicket
Searsia nebulosa									**A**
Senna didymobotrya ***				**P**					**P**
Sesbania punicea ***				**P**	**P**				**P**
Sideroxylon inerme									**A**
Smilax anceps									**A**
Sporobolus virginicus	**p**	**P**	**P**	**P**	**P**	**P**	**P**		**P**
Stachytarpheta urticifolia ***									**P**
Stenotaphrum secundatum			**P**	**A**	**A**	**P**			**P**
Strelitzia nicolai									**A**
Syzygium cordatum								**A**	**P**
Trema orientalis									**A**
Trichilia dregeanum									**A**
Triglochin striata	**P**	**P**		**P**		**P**	**P**		
Typha capensis					**P**			**P**	
Voacanga thouarsii								**A**	
Xanthium strumarium ***				**P**	**P**				**P**

Appendix F

Specialist Report Zooplankton

Mlalazi Estuary Rapid Assessment
Historical Data & Fieldtrip Report

Zooplankton

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Available information

The present study is a first attempt to investigate the mesozooplankton community of the Mlalazi Estuary and forms part of a rapid assessment of the biota of the estuary. The only published study, reporting on aspects of zooplankton of this estuary, is a study done on larval strategies of brachyuran developmental stages on two occasions during 1997 and 1998 (Papadopoulos *et al*. 2002).

Methods

Mesozooplankton samples were collected during May 2013. Sampling took place at six sites, 1 near the head of the estuary and 6 near the mouth (Figure 1) along the main axis of the estuary, during night-time.

Figure 1. Location of zooplankton sampling sites (1 - 6) for the May 2013 sampling session in the Mlalazi Estuary.

Zooplankton samples were collected using a double, 200 µm mesh, plankton net. Each net was 2 m long with a mouth diameter of 300 mm. One net was fitted with a flowmeter to quantify the samples. The nets were towed in mid-water depth using a small, motorized boat at slow speed for about 3 minutes. To avoid interference from the boat the nets were attached to a boom and towed in front of the bow.

Samples were preserved in the field in about 4% estuarine water formalin. A sub-sampling method was used to analyse zooplankton samples in the laboratory. Taxa were identified to the lowest practical taxonomic rank and counted in a Bogorov tray using stereo dissecting and compound microscopes.

Results and Discussion

A total of 28 mesozooplankton taxa were recorded in the samples collected from the six sites (Table 1). Estuarine calanoid copepods were numerically dominant.

A salinity gradient was evident along the main axis of the estuary at the time of sampling; salinities at the upper sampling site ranged between 6 and 10 in the surface and near bottom waters and increased progressively to seawater levels at the lower sampling site near the mouth. The zooplankton community composition reflected this salinity pattern with coastal marine taxa recorded in the lower reaches of the estuary (Figure 2). At the upper site the zooplankton was dominated by the estuarine zooplankters *Acartiella natalensis* and *Pseudodiaptomus* spp. (Figure 3). The latter genus was represented by two species, *P. stuhlmanni* and *P. hessei*. This is a somewhat uncommon occurrence in estuaries along the Zululand coast, where either one of the two is normally recorded in any one system. *P. hessei* is normally associated with relict estuarine lakes and *P. stuhlmanni* with the estuaries (e.g. Jerling *et al*. 2010, Jerling and Cyrus 1999). Freshwater cyclopoids were also recorded in low densities at the upper site, emphasizing the low salinities.

The densities of the estuarine species declined progressively as salinities increased towards the mouth (Figure 3). At the lower two sampling sites coastal marine species were recorded, including calanids, paracalanids, chaethognaths. Densities of mud crab zoeae (*Paratylodiplax blephariskios*) increased towards the lower estuary and dominated the zooplankton at the mouth sampling site (Figure 3). *Paratylodiplax blephariskios* is a species relying on an open connection to the sea to complete its life cycle. Diversity, in terms of species richness, also increased towards the lower estuary with highest species richness recorded at the site near the mouth. This is a result of the influx of coastal marine taxa and has been recorded for a number of local estuarine systems (e.g. Jerling 2008, Jerling *et al*. 2010).

Sampling for this study occurred during autumn and densities of many of the zooplankton species would be lower than during summer, approaching winter levels. Although the present study is based on only one sampling session, the results indicate a normal mesozooplankton community for KwaZulu-Natal estuaries associated with a salinity gradient along its main axis.

Table 1. Mesozooplankton taxa recorded in samples from six sites (1-6) in the Mlalazi Estuary during May 2013.

Taxon	Sites recorded
Cnidaria	3
Ctenophores	6
Polychaete larvae	1, 5, 6
Calanoida	
Pseudodiaptomus spp.	1, 2, 3, 4, 5, 6
Acartia natalensis	1, 2, 3, 4, 5, 6
Calanus sp.	6
Subeucalanus sp.	5, 6
Paracalanidae	5, 6
Temora turbinate	6
Centropages sp.	6
Poecilostomatoida	
Corycaeidae	5, 6
Cyclopoida	
Oithona spp.	3, 4, 5, 6
Unid. Freshwater? Cyclopoid	1
Harpacticoida	5, 6
Mysidacea	
Mesopodopsis africana	4
Rhopalophthalmus sp	4, 5
Cypris larvae	3, 4, 5, 6
Tanaidacea	2, 3
Isopoda	2
Amphipoda	1, 6
Decapoda	
Prawn larvae	4, 6
Crab zoeae	2, 3, 4, 5, 6
Megalopa	1, 2, 3, 4, 5
Mollusca	
Gastropod larvae	3, 4, 5, 6
Chaetognaths	6
Fish eggs	2
Fish larvae	1, 2, 4

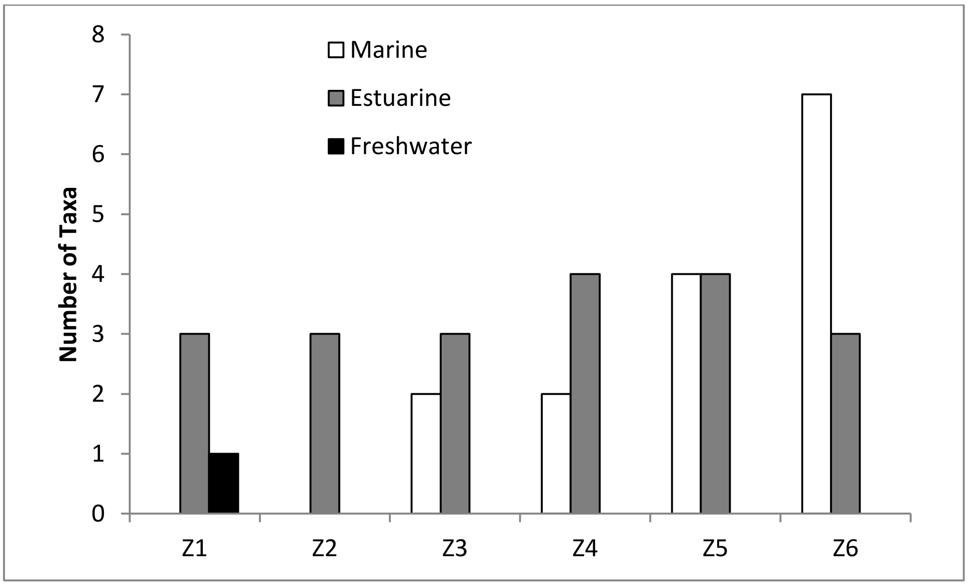

Figure 2. Numbers of marine, estuarine and freshwater mesozooplankton taxa recorded at the different sampling sites in the Mlalazi Estuary during May 2013.

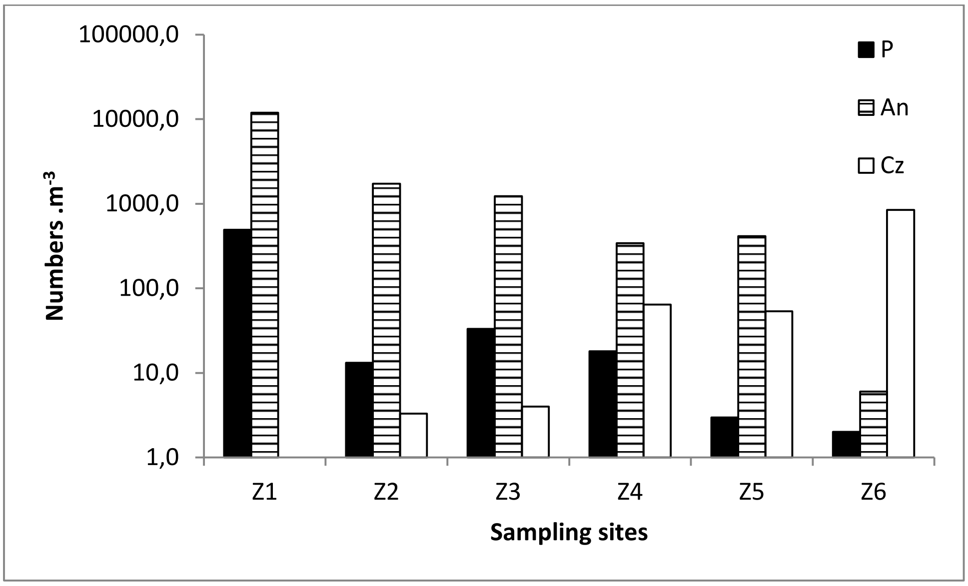

Figure 3. Densities (Numbers.m^{-3}) on a log scale of numerically dominant mesozooplankton taxa recorded at six sites in the Mlalazi Estuary during May 2013. P = *Pseudodiaptomus* spp., An = *Acartiella natalensis*, Cz = crab zoeae.

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Appendix G

Specialist Report Macrobenthos

Mlalazi Estuary Rapid Assessment
Historical Data & Fieldtrip Report

Macrobenthos
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Available information

There is limited information in the literature on the macrobenthos of the Mlalazi Estuary, although a number of research reports by CRUZ contain some historical data. The most detailed information to date is provided by Mabaso (2000), who studied the system in 1999-2000 and compared the benthic community from prior to and after initiation of the aquaculture activities associated with a prawn farm on the estuary.

Methodology

a) Subtidal macrobenthos

The macrobenthos was sampled at eight sites in the Mlalazi Estuary (Figure 1). A Zabalocki-type Ekman grab, sampling an area of 0.0236 m^2, was used to collect five replicate benthic samples from each site. Samples were sieved through a 0.5mm mesh sieve and preserved in a 10% formalin solution, and stained with the vital dye Phloxine B to aid sorting in the laboratory. Counts of individuals in each taxon were converted to densities (no.m^{-2}) and averaged for each site to show the community structure and abundance at each site.

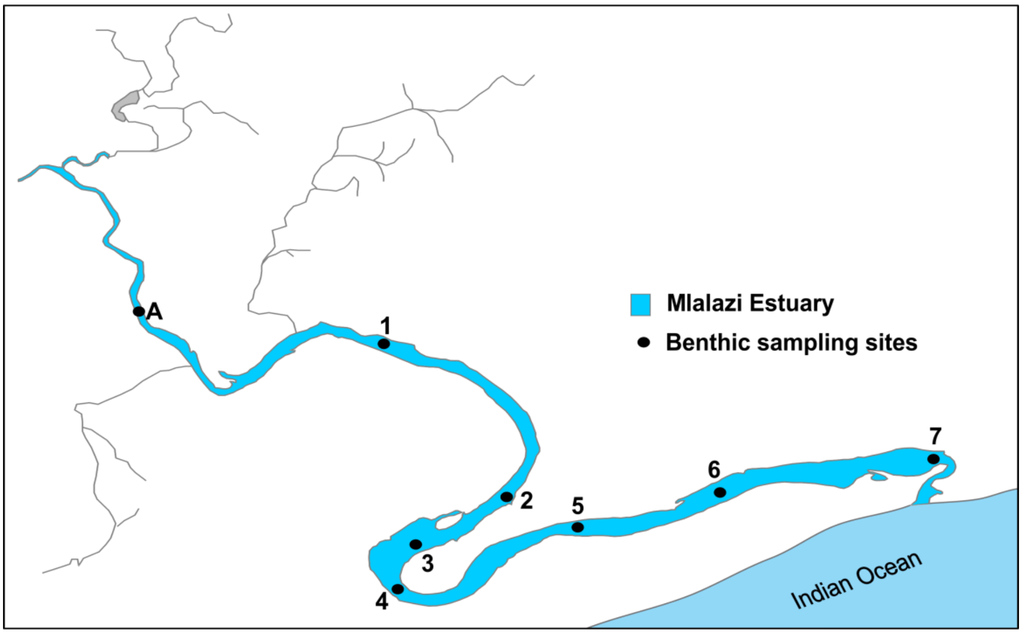

Figure 1. Map of the Mlalazi estuary showing the macrobenthic sampling sites.

b) Intertidal macrobenthos

The intertidal zoobenthic community was sampled at each site using a PVC corer, 110mm in diameter and sampling an area of 0.0094 m^2 . The corer was inserted into the sediment to a depth of 250mm. Five replicate samples were collected and sieved through a 1mm mesh sieve. Samples were preserved in a 10% formalin solution, and stained with the vital dye Phloxine B to aid sorting in the laboratory. Counts of individuals in each taxon were converted to densities (ind.m^{-2}) and averaged for each site to show the community structure and abundance at each site.

Results and Discussion

a) Subtidal macrobenthic community

A total of 33 subtidal macrobenthic taxa were recorded in the Mlalazi Estuary, being numerically dominated by the polychaetes *Prionospio sexoculata*, *Dendronereis keiskamma* and *Desdemona ornata*, the tanaid *Apseudes digitalis* and Tubificidae oligochaetes (Table 1). Highest densities were recorded in the soft muddy substrate at Site 4, where highest densities of the mud crab, *Paratylodiplax blephariskios* and oligocheates were recorded. The number of taxa per site ranged from 10-18. The highest number of taxa per site was recorded at Sites 2 and 3. The fact that the highest number of taxa per site was 18, yet 33 taxa were recorded in total, is indicative that there was considerable variation is species composition between sites. Polychaetes dominated the benthic community in terms of species number and abundance, with only low densities of crustaceans such as amphipods and isopods being recorded.

The number of taxa per site were considerably lower compared to that recorded during previous sampling periods, but the average benthic densities were comparable and even higher at certain sites. The number of taxa per site at comparable sites (Sites 1-4) ranged from 18-20 during 1989-1990, 17-22 during 1999-2000 and 23-25 during 2005-2006 (Table 2) (Mabaso 2002, Cyrus and Vivier 2008). The benthic densities during 1989-1990 were very high, being dominated by five polychaete taxa, notably *Prionospio* and *Capitella* polychaetes, the tanaid *Apseudes digitalis* and most importantly, the amphipods *Corophium triaenonyx* and *Grandidierella bonnieroides*. During 1999-2000, the densities of all numerically dominant taxa such as *Prionospio* and *Capitellid* polychaetes were substantially lower than during 1989-1990, while the number of polychaete taxa doubled. The polychaetes *Dendronereis arborifera* and *Ceratoneries keiskamma* were also abundant, while amphipods were still present but in much reduced numbers. During 2005-2006, the number of polychaete taxa further increased, with benthic densities being dominated by *Prionospio* polychaetes and by Oligochaetes, while a new tanaid species also became abundant. Amphipods were present but only in low numbers. During the present study, the benthic community was dominated by *Prionospio* polychaetes and oligochaetes and the tanaid *Apseudes digitalis*, with amphipods only occurring in very low numbers. Although the reason for this shift in species composition is not clear, as there are no obvious indications of nutrient enrichment and poor habitat quality in the system, the abundance of opportunistic polychaete taxa such as *Prionospio* spp and oligochaetes is often regarded as indicative of disturbed estuarine habitat.

Table 1. Densities of subtidal macrobenthic taxa (no.m^{-2}) recorded at eight sampling sites in the Mlalazi Estuary.

	Site									
Taxa	**A**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Total**	**% Contri-bution**
Ancistrocyllis constricta		33.9		33.9		33.9	381.4	59.4	542.5	2.0
Apseudes digitalis		59.3	25.4	8.5	2059.3		881.4	50.8	3084.7	**11.3**
Callichirus kraussi				33.9		67.8		8.5	110.2	0.4
Capitella capitata		8.5					178.0	25.4	211.8	0.8
Ceratonereis keiskamma	93.2	16.9	220.3						330.5	1.2
Corophium triaenonyx	135.6		8.5			152.5			296.6	1.1
Cyathura carinata					16.9				16.9	0.1
Dendronereis arborifera	135.6	144.1	2516.9	67.8	635.6		398.3	118.7	4017.0	**14.7**
Desdemona ornata	16.9	25.4	762.7	1186.4	33.9	1355.9	25.4	50.9	3457.7	**12.7**
Dosinia hepatica				110.2		118.6		50.9	279.7	1.0
Eriopsia chilkensis		8.5			8.5				16.9	0.1
Gastropod sp1	118.6								118.6	0.4
Glycera convoluta			16.9	8.5		8.5	25.4	8.5	67.8	0.2
Grandidierella bonnieroides	50.8	50.8	25.4	135.6	42.4	67.8	84.7	8.5	466.1	1.7
Heteromastus sp			25.4				8.5		33.9	0.1
Hiatula linulata			50.8						50.8	0.2
Hirudinia			8.5						8.5	0.0
Iphinoe truncata			8.5			101.7		17.0	127.2	0.5
Leptanthura laevigata			296.6	8.5				8.5	313.6	1.2
Leptochelia barnardi	16.9		8.5						25.4	0.1
Macoma littoralis		8.5					8.5	8.5	25.4	0.1
Mediomastus capensis				25.4		59.3	76.3		161.0	0.6
Mesopodopsis africanus	8.5	8.5							16.9	0.1
Paratylodiplax blephariskios			8.5	161.0	1542.4		855.9		2567.8	9.4
Prionospio cirrifera				25.4			8.5		33.9	0.1
Prionospio pinnata	491.5	186.4	16.9	33.9	50.8	8.5	8.5		796.6	2.9
Prionospio sexoculata		33.9	381.4	1745.8	67.8	2440.7	525.4	381.4	5576.3	**20.5**
Solen cylindraceus			8.5	42.4					50.8	0.2
Tarebia granifera		8.5							8.5	0.0
Tellina sp				42.4			101.7		144.1	0.5
Tharax filibranchia						144.1			144.1	0.5
Tharax marioni						50.8			50.8	0.2
Tubificidae	245.8	788.1	330.5	144.1	2296.6	59.3	8.5	212.0	4084.9	**15.0**
No of taxa	**10**	**14**	**18**	**17**	**10**	**14**	**16**	**14**	**33**	
Total Density	**1313.6**	**1381.4**	**4720.3**	**3813.6**	**6754.2**	**4669.5**	**3576.3**	**1009.0**	**27237.8**	

The species composition of the Mlalazi estuary, being classified as a permanently open estuary, is very different from that of nearby temporarily open closed estuaries, such as the Siyaya and Nhlabane Estuaries (Mackay 1996, Mackay and Cyrus 2001). These smaller estuaries are dominated by tubiculous detritivore amphipods such as *Corophium triaenonyx* and *Grandidierella lignorum* and the carnivorous polychaete *Ceratoneries keiskamma*.

Table 2. Densities and number of taxa of subtidal macrobenthic taxa (no.m^{-2}) at Sites 1-4 in the Mlalazi Estuary over four sampling periods from 1989 to present.

		Site1	Site 2	Site 3	Site 4
1989-1990	Density	14589	13834	36282	4173
	No of taxa	18	19	18	20
1999-2000	Density	5959	3988	3960	3102
	No of taxa	22	20	22	17
2005-2006	Density	7854	9441	9199	6648
	No of taxa	26	25	23	24
2013	Density	1381	4720	3813	6754
	No of taxa	14	18	17	10

b) Intertidal macrobenthic community

A total of 23 taxa were recorded in the intertidal habitat, with the number of taxa per site ranging from 8-16, increasing from the upper reaches towards the mouth of the estuary (Table 3). Intertidal samples were only recorded from Site 3 downwards, as the vertical *Phragmites* lined banks at Site A, 1 and 2 prevented intertidal samples from being collected.

The intertidal benthic community was dominated by the polychaetes *D. arborifera* and *P. sexoculata*, the gastropod *Assimnea ovata* and the Tubificidae oligochaetes. These four taxa comprised 88% of the intertidal organisms recorded. Crustaceans such as amphipods, tanaids and isopods were only recorded in relatively low numbers. The small gastropod *A. ovata* was particularly abundant in the lower reaches (Sites 5-7), while *D. arborifera* was very abundant at Sites 3 and 4. Highest densities were recorded at Site 3 and 4, yet the lowest number of taxa was found at these two sites.

It is noteworthy that the invasive snail *Tarebia granifera*, which is highly abundant in the Amatikulu Estuary and was recorded in the subtidal benthos at Site 3, was not recorded in the intertidal benthos at any of the sites sampled. In comparison, the snail completely dominated the upper low salinity intertidal areas in the Amatikulu Estuary. *Tarebia granifera* is a freshwater snail and although it is capable of living in brackish water, seems to avoid high salinity systems such as the Mlalazi.

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Table 3. Densities of intertidal macrobenthic taxa (no.m^{-2}) at Sites 3-7 in the Mlalazi. Estuary.

Taxa	***Site***					***Total***	***% Con-tribution***
	3	***4***	***5***	***6***	***7***		
Apseudes digitalis	*357.9*				*126.3*	*484.2*	*1.5*
Assimnea ovata			*2484.2*	*2884.2*	*2484.2*	*7852.6*	***24.9***
Ancistrocyllis constricta		*126.3*	*42.2*	*400.0*	*147.4*	*715.9*	*2.3*
Brachidontes virgiliae		*21.1*				*21.1*	*0.1*
Capitella capitata					*63.2*	*63.2*	*0.2*
Cyathura carinata	*21.1*					*21.1*	*0.1*
Ceratonereis keiskamma	*42.1*					*42.1*	*0.1*
Dendronereis arborifera	*5600.0*	*5684.2*	*316.5*	*126.3*	*294.7*	*12021.8*	***38.2***
Dosinia hepatica			*42.1*	*42.1*	*42.1*	*126.3*	*0.4*
Desdemona ornata			*189.9*	*526.3*	*126.3*	*842.5*	*2.7*
Eriopsia chilkensis	*126.3*					*126.3*	*0.4*
Grandidierella bonnieroides		*21.1*			*21.1*	*42.1*	*0.1*
Glycera convoluta		*21.1*	*84.4*	*42.1*	*21.1*	*168.6*	*0.5*
Hiatula linulata		*168.4*	*21.1*	*21.1*		*210.5*	*0.7*
Iphinoe truncata				*42.1*	*42.1*	*84.2*	*0.3*
Leptanthura laevigata	*105.3*	*84.2*			*21.1*	*210.5*	*0.7*
Mesopodopsis africanus				*21.1*		*21.1*	*0.1*
Macoma littoralis			*126.3*	*126.3*	*21.1*	*273.7*	*0.9*
Callichirus kraussi					*21.1*	*21.1*	*0.1*
Tubificidae	*3284.2*	*378.9*	*232.2*	*42.1*	*526.3*	*4463.8*	***14.2***
Prionospio cirrifera					*147.4*	*147.4*	*0.5*
Prionospio pinnata	*42.1*					*42.1*	*0.1*
Prionospio sexoculata			*1242.1*	*1305.3*	*947.4*	*3494.7*	***11.1***
No of taxa	***8***	***8***	***10***	***12***	***16***	***23***	
Total Density	***9578.9***	***6505.3***	***4781.0***	***5578.9***	***5052.6***	***31496.7***	

Appendix H

Specialist Report Macrocrustacea

Mlalazi Estuary Rapid Assessment
Historical Data & Fieldtrip Report

Macrocrustacea
Dr L.Vivier
Department of Zoology, University of Zululand

Available information

There is no information in the literature on the macrocrustacea of the Mlalazi Estuary.

Methodology

Prawns were collected using a beam trawl and small and large seine nets from six sites, A,1, 2, 4, 5 & 7 (Figure 1). The beam trawl had a bar mesh size of 10 mm; the bag mesh size was 6 mm with a mouth 1.5 m in width. Each trawl comprised a three minute haul behind a motorised boat over a distance of 150m. The small seine net (10 m in length with a bar mesh size of 6 mm) and the large seine net (70 m in length with a mar mesh bag of 10 mm) were pulled onto exposed banks. Captured prawns were preserved in 4% formalin and identified to species level according to Kensley (1972), Day et al. (2001) and De Freitas (2011). Due to current uncertainty with regard to the taxonomy of penaeids (De Freitas 2011), the classification followed by Forbes and Demetriades (2005) was used.

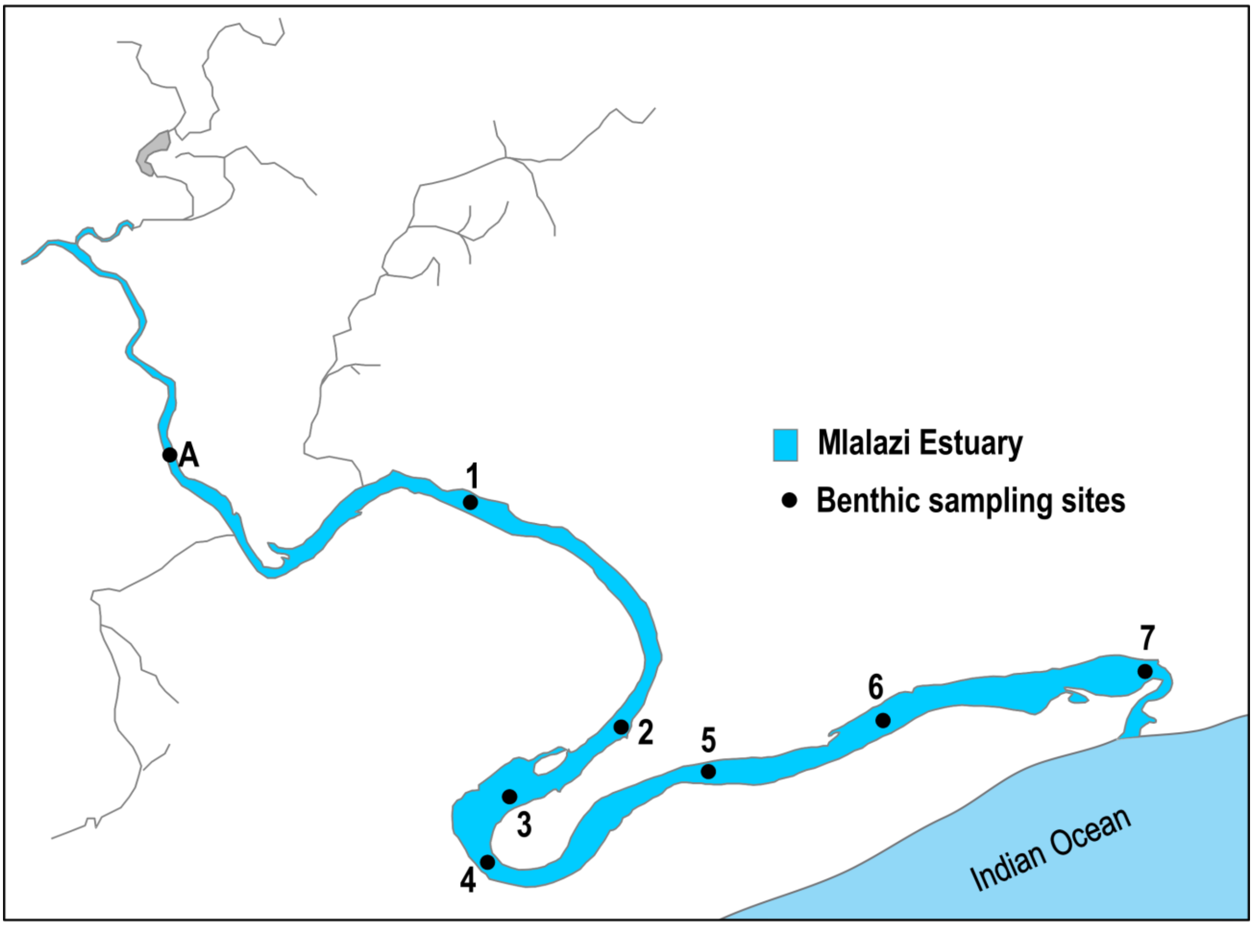

Figure 1. Macrocrustacea sampling sites in the Mlalazi Estuary.

The catch per unit effort (CPUE) for beam trawl and seine net catches was calculated for each species at each site. For the seine nets, CPUE was calculated as the number of individuals recorded at each site per square meter of the area covered (No. m^{-2}). For beam trawls, the CPUE was calculated as the number of individuals recorded at each site per square meter of the area covered by the beam trawl (No. m^{-2}). For prawn traps, the CPUE was calculated as the number of prawns per species per trap per hour of trapping (no.trap.hr^{-1}).

Results and Discussion

A total of eight prawn species were recorded in the Mlalazi estuary in seine nets and beam trawls (Table 1). This is considerably lower than the 12 and 13 species recorded in the Amatikulu (this study) and Mfolozi (Collocott et al. 2014) estuaries, respectively. A total of 11 species were recorded in St Lucia (Kensley 1972, Day et al. 2001, De Freitas 2011), Weerts et al. (2003) recorded 14 prawn species in Richards Bay Harbour, while seven prawn species were reported from the Mhlatuze Estuary adjacent to Richards Bay Harbour (Forbes and Cilliers 1999). The relatively low number of species in the Mlalazi is understandable given that only one freshwater species, *Macrobrachium equidens*, was recorded, whereas in the Mfolozi Estuary, six freshwater species were recorded. The low number of freshwater species in the system is an indication that the system is largely unsuitable for freshwater species, probably due to the relatively high salinities in the system during most of the year.

The prawn community was dominated by marine spawning prawns (families Penaeidae and Sergestidae), notably the small sergestid *Acetes erythraeus* (45%) and the penaeids *Fenneropenaeus indicus* (28%) and *Metapenaeus monoceros (22%).* These three species comprised 94.5% of the prawns recorded in the system. The dominance of *A. erythraeus* was due to a very large catch of the species in the muddy substrate at Site 4, while the species also occurred in relatively low numbers at Sites 3 and 5. Members of the genus *Acetes* mainly occur in estuarine or shallow coastal waters, where they often dominate the prawn community, and are seasonally very abundant. In Richards Bay Harbour, over two years of sampling, the total catch was dominated by *A. erythraeus* (67%), followed by *Palaemon peringueyi* (16%), and the two penaeid species *M. monoceros* (7%) and *Penaeus japonicus* (4%) (Weerts et al. 2003). In the harbor, *A. erythraeus* were found in highest densities in close proximity to mangrove lined muddy channels. This would explain the high catch in the muddy substrate at Site 4 in the Mlalazi Estuary, adjacent to a large mangrove stand. Little is known of the ecology of *A. erythraeus*, but large seasonal variations in numbers with summer swarming (possibly pre-spawning aggregations) has been reported. Weerts et al. (2003) noted that the abundance of *A. erythraeus* in the harbour throughout the year suggests that it is a very important prey species for benthic feeding juvenile fishes that utilize the harbour as a nursery area and as such contribute significantly towards the food budget of the large fish population in the port.

Five of the seven penaeid prawn species known to occur along the KwaZulu-Natal coastline (Forbes and Demetriades 2005) were recorded in the Mlalazi during this study. The penaeid *M. monoceros* was abundant throughout the system, while *F. indicus* was most abundant at Site 5. *Metapenaeus monoceros* was the only prawn recorded in the upper reaches at Sites 1A and 1, suggesting that this species is capable of penetrating the upper, low salinity reaches of estuaries. De Freitas (1986) commented that *M. monoceros* in Maputo Bay were not restricted to muddy mangrove areas and appeared capable of coping with low salinities.

Fenneropenaeus indicus is usually the most common penaeid prawn species in South African estuaries (Forbes and Demetriades 2005). The abundance of *F. indicus* in the present study (50%) is very similar to that recorded in the Amatikulu Estuary (59%) (this study) and in the Mfolozi-Msunduzi estuarine system (57%) (Collocott et al. 2014). *Metapenaeus monoceros* is the second most important commercial prawn species after *F. indicus* (Forbes and Demetriades 2005). This suggests that the Mlalazi Estuary is one of the primary nursery areas along the northern KwaZulu-Natal coastline not only for the commercially important species, *F. indicus*, but also for *M. monoceros*. In Richards Bay Harbour, *M. monoceros* was also the second most dominant species, which Weerts et al. (2003) stated as confirmation of the importance of Richards Bay and the adjacent Mhlathuze Estuary as nursery area for *M. monoceros* and for its contribution to the offshore stocks of commercially important prawns.

Table 1. Densities of macrocrustacea (no.m^{-2}) recorded at six sampling sites using seine netting and beam trawling in the Mlalazi Estuary.

Species	Site 1A		Site 1		Site 2		Site 4		Site 5		Site 7		Total	
	CPUE	%	CPUE	%	CPUE	%	CPUE	%	CPUE	%	CPUE	%	CPUE	%
Family Penaeidae														
Fenneropenaeus indicus					0.020	5.5	0.063	3.3	0.964	**69.0**	0.008	**11.5**	1.054	**27.7**
Metapenaeus monoceros	0.030	**100**	0.059	**100**	0.214	**58.7**	0.189	**10.0**	0.347	**24.8**			0.839	**22.0**
Penaeus japonicus											0.023	**34.1**	0.023	0.6
Penaeus monodon									0.006	0.4	0.000	0.5	0.006	0.2
Penaeus semisulcatus					0.010	2.7	0.004	0.2	0.007	0.5	0.036	**53.8**	0.056	1.5
Family Sergestidae														
Acetes erythraeus					0.011	3.0	1.626	**86.1**	0.067	4.8			1.704	**44.8**
Acetes natalensis							0.007	0.4					0.007	0.2
Family Palaemonidae														
Macrobrachium equidens					0.110	**30.1**			0.007	0.5			0.117	3.1
No of species	**1**		**1**		**5**		**5**		**6**		**4**		**8**	
Total CPUE	**0.030**		**0.059**		**0.366**		**1.889**		**1.396**		**0.066**		**3.805**	

Penaeus japonicus was only recorded at the mouth, although in very low numbers. In Maputo Bay, *P. japonicus* was found only on the intertidal flats in bare, sandy mud (De Freitas 1986). Only low numbers of the freshwater prawn *Macrobrachium equidens* was recorded, with this species only found in the upper (Site 2) and middle (Site 5) reaches.

The densities of prawns recorded using prawn traps are presented in Table 2. Only three species of penaeid prawns were recorded in the traps and in relatively low numbers. The prawn trap catch was dominated by *Fenneropenaeus indicus*, which was recorded at all three sites where prawns were recorded, including Site 1, indicating that this species is capable of inhabiting the upper reaches of the estuary.

Not only do penaeid prawns require a regular estuarine-marine connection for reproductive migration, but it has been shown that other macrocrustaceans such as crab species inhabiting mangrove lined sub-tropical estuaries, such as the Mlalazi Estuary, also have an obligate marine phase during larval development. Larvae of the most crab species resident in the Mlalazi Estuary complete development in the marine environment and therefore require access to the marine environment (Papadopoulos et al. 2002). This is a common developmental strategy for estuarine decapods. The requirement for a marine phase of larval development necessitates that an estuarine tidal inlet be open at the time of larval release and recruitment. Papadopoulos et al. (2002) concluded that passage for estuarine fauna with an obligate marine life stage should be a clear objective for the management of estuarine inlets.

Although the macrocrustacean sandprawn, *Callichirus kraussi*, was not recorded during this study, its burrows were observed on intertidal sandflats in the lower reaches of the estuary. The sandprawn is commonly collected as bait by anglers. Studies have shown that in areas where bait collection occurred, recovery of sandprawn populations often took up to 18 months as a result of sedimentary compaction during sampling as well as the physical removal of organisms from the population (Wynberg and Branch 1994). Based on the removal rate of the sandprawns, it was concluded that disturbance and sedimentary compaction have greater effects than the removal of sandprawns per se.

Table 2. Densities of macrocrustacea (no. trap. hour^{-1}) recorded at Sites 1, 2 and 4 in the Mlalazi Estuary using baited prawn traps.

Species	Site 1	Site 2	Site 4	Total	
				CPUE	%
Family Penaeidae					
Fenneropenaeus indicus	0.083	0.583	3.333	4.00	**94.1**
Metapenaeus monoceros		0.083	0.083	0.17	3.92
Penaeus monodon			0.083	0.08	1.96
No of species	**1**	**2**	**3**	**3**	
Total CPUE	**0.083**	**0.667**	**3.500**	**4.25**	

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Appendix I

Specialist Report Fish

Mlalazi Estuary Rapid Assessment
<u>Historical Data & Fieldtrip Report</u>

Fish

Prof D.P.Cyrus

CRUZ Environmental

Historical Data

The first publication on fish for the Mlalazi Estuary comprises a list of species recorded by Hill (1966). Subsequent to this the Coastal Research Unit of Zululand, Department of Zoology, University of Zululand undertook monthly surveys of the fish fauna over the periods 1980 to 1982 and 1989 to 1990 (CRUZ Unpublished Data). The latter data has been used extensively in this report and for the assessment of the fish of the system for the EWR.

Fieldtrip Report

A single fieldtrip was budgeted for this project and it was undertaken during May 2013.

Methods

Six sampling sites were used (Figure 1). Three sampling methods were used, small and large seine netting as well as gill netting. The small seine net (10 x 1.5 m, 6 mm mesh) was deployed 10m off the beach and pulled onto an exposed bank, while the large seine net (70 x 1.5 m, 10 mm mesh) was deployed in a semi-circle from the shore and then pulled onto an exposed bank. At least three small seine and two large seine hauls were done at each site. A fleet of gill nets of varying size mesh were laid for fixed periods at each site. All fish collected were identified, measured (standard length) and then returned to the system. Physical water quality parameters (water temperature, salinity, pH, dissolved oxygen concentration, % oxygen saturation and depth) were measured at each site using a YSI 6920 Sonde (YSI Incorporated).

Results and Discussion

A total of 90 fish species have been recorded from the Mlalazi Estuary based on detailed monthly records from 1981-82 and 1989-90 (CRUZ) and a once-off sampling in May 2013 (this project)(Table 1). The fauna utilizing the system can be divided into five categories based on their life cycle traits (Whitfield, 1994 & 1998). These categories, their definitions, species number and percentage contribution and examples of each are listed in Table 2. From this it is clear that the dominant group are the Euryhaline marine species which breed at sea but with juveniles that show varying degrees of dependence on estuaries. They made up 48% of the species recorded. The dominance of this group, in terms of frequency of occurrence, number of species and relative abundance, indicates the importance of this estuary as a nursery habitat for these marine species. Marine species not dependent on estuaries comprised 40%, reflecting the dominance of an open stratified system, while Estuarine Residents only made up 8%. If one looks at the 2013 data only there are an even greater percentage of estuarine dependant marine species present (62%) with the marine species only contributing 18% and estuarine residents 17% (Table 2). These latter results might indicate that more recently the Mlalazi may have moved from an open gradient system towards a more open stratified system.

In terms of feeding guilds the species recorded in the Mlalazi Estuary are representative of four major feeding groups, detrivores, zooplanktivores, zoobenthivores and piscivores, indicating the availability of prey for all groups within the system.

Figure 1. Fish sampling sites in the Mlalazi Estuary.

Table 1. Fish species recorded in the Malalzi Estuary 1980-2013 (EDC = Estuarine Dependence Category).

Species	EDC	2013-05	1989-90	1980-82	Total List
Acanthopagrus vagus	IIa	1	1	1	1
Ambassis gymnocephalus	Ib	1	1	1	1
Ambassis natalensis	Ib	1	1	1	1
Ambassis ambasis (productus)	Ia	1	1	1	1
Amblyrhynchotes honckenii	III	1	1	1	1
Antenarius hispidus	III			1	1
Aplycia sp	III		1		1
Argyrosomus japonicus	IIa	1	1	1	1
Arothron immaculatus	III	1	1	1	1
Athernomorus lacunosus	III		1		1
Bothus pantherinus	III		1	1	1
Cantherines hispidus	III			1	1
Cantherines pardalis	III			1	1
Carangoides sp	III				
Caranx ignobilis	IIa		1	1	1
Caranx heberi	IIc			1	1
Caranx sem	IIc		1	1	1
Caranx sexfasciatus	IIb	1	1	1	1
Crenidens crenidens	III			1	1
Drepane longimanus	III		1	1	1
Electis sp	III			1	1
Eleotris fusca	Ia			1	1
Elops machnata	IIa		1	1	1
Epinephalus andersoni	III			1	1
Epinephalus caeruleopunctatus	III			1	1
Epinephalus malabaricus	III	1	1		1
Gaza minuta	III		1		1
Gerres longirostris	IIb	1	1	1	1
Gerres filamentosus	IIb	1	1	1	1
Gerres oyena	IIc		1		1
Gerres methuenei	IIb	1	1	1	1
Gilchristella aestuaria	Ia	1	1		1
Glossogobius callidus	Ia	1	1		1
Glossogobius giuris	IV	1	1	1	1
Glossogobius tenuiformis	Ia	1			1
Hilsa kelee	IIc	1	1		1
Hymantura uarnak	III	1	1	1	1
Leiognathus equula	IIb	1	1	1	1
Lichia amia	IIa		1	1	1
Liza alata	IIa	1	1	1	1
Liza dumerilii	IIb	1	1	1	1
Liza macrolepis	IIa	1	1	1	1
Liza tricuspidens	IIb		1	1	1
Lutjanus argentimaculatus	IIb		1	1	1

Table 1: continued.

Species	EDC	2013-05	1989-90	1980-82	Total List
Lutjanus fulviflamma	IIc			1	1
Megalops cyprinoides	Vb		1		1
Mene maculate	III			1	1
Monodactylus argenteus	IIb	1	1	1	1
Monodactylus falciformis	IIa		1		1
Mugil cephalus	IIa	1	1	1	1
Muraenesox bagio	IIc			1	1
Myxus capensis	Vb	1	1	1	1
Oligoleis keiensis	Ia	1			1
Oreochromis mossambicus	IV		1		1
Platycephalus indicus	IIc	1	1	1	1
Pomadasys commersonnii	IIa	1	1	1	1
Pomadasys kaakan	IIc	1	1	1	1
Pomadasys mulmaculatum	III		1		1
Pomadasys olivaceum	III		1		1
Pomatomus saltatrix	IIc		1	1	1
Pseudorhombus arsius	III	1	1	1	1
Pterois miles	III	1		1	1
Rhabdosargus holubi	IIa	1			1
Rhabdosargus sarba	IIb	1	1	1	1
Rhabdosargus thorpei	IIb			1	1
Salad Fish	III		1		1
Sardinella albella	III			1	1
Scomberiodes lysan	IIb	1	1	1	1
Scomberoides tala	III		1		1
Scomberiodes tol	III		1	1	1
Siganus sutor	III			1	1
Sillago sihama	IIc	1	1	1	1
Solea turbynei	IIb	1	1	1	1
Spade sp	III		1		1
Sphyraena barracuda	IIb		1		1
Sphyraena jello	IIc	1	1	1	1
Sphyraena qenie	III			1	1
Stethojulis sp	III			1	1
Stolephorus commersonnii	III			1	1
Stolephorus holodon	IIc	1			1
Syngnathus acus	III	1			1
Terapon jarbua	IIa	1	1	1	1
Thryssa vitrirostris	IIb	1	1	1	1
Trachinotus blochii	III			1	1
Trachinotus botla	III			1	1
Trichiurus sp	III			1	1
Upeneus vittatus	III	1	1	1	1
Valamugil buchanani	IIc	1	1	1	1
Valamugil cunnesius	IIa	1	1	1	1
Valamugil robustus	IIa		1	1	1
Valamugil seheli	IIc		1		1
	Total	**44**	**63**	**67**	**90**

Table 2. The major life cycle categories of Fish utilising the Mlalazi Estuary based on Whitfield (1998) and the number & percentage contribution of species from each category recorded in the estuary (n = 90 species).

	All Data		2013-05		
Category	**Number**	**%**	**Number**	**%**	**Defining features and typical/dominant species**
I	**7**	**8**	**7**	**16**	**Estuarine species which breed in estuaries:**
	5		5		I a Resident species which have not been recorded spawning in marine or freshwater environments (*Ambassis ambassis & Eleotris fusca)*.
	2		2		I b Resident species which have been recorded spawning in marine or freshwater environments (*Ambassis natalensis & Glossogobius callidus)*.
II	**43**	**48**	**27**	**62**	**Euryhaline marine species which breed at sea but with juveniles that show varying degrees of dependence on estuaries:**
	14		9		IIa Juveniles dependent on estuaries as nursery areas (*Acanthopagrus vagus & Liza macrolepis)*.
	15		11		IIb Juveniles occur mainly in estuaries but are also found at sea (*Caranx sexfasciatus & Gerres methuenei)*.
	14		9		IIc Juveniles occur in estuaries but are usually more abundant at sea (*Platycephalus indicus & Solea bleekeri)*.
III	**36**	**40**	**8**	**18**	**Marine species which occur in estuaries in small numbers but are not dependent on these systems** (*Amblyrhynchotes honckenii & Epinephalus malabaricus).*
IV	**2**	**2**	**1**	**2**	**Euryhaline freshwater species. Includes some species which may breed in both freshwater and estuarine environments (***Oreochromis mossambicus* & *Glossogobius giuris***).**
V	**2**	**2**	**1**	**2**	**Obligate catadromous species which use estuaries as transit routes between the marine and freshwater environments:**
	0		0		Va Obligate catadromous species which require a freshwater phase for their development (*Anguilla mossambica)*.
	2		1		Vb Facultative catadromous species which do not require a freshwater phase for their development (*Myxus capensis)*.
Species	**90**		**44**		

Appendix J

Specialist Report Birds

Mlalazi Estuary Rapid Assessment
Historical Data & Fieldtrip Report

Birds
Prof D.P.Cyrus
CRUZ Environmental

Historical Data

A search for published bird data (including the Grey Literature) on the Mlalazi Estuary did not yield any results. The only information obtained was from the Ezemvelo KZN Wildlife office at the Mlalazi Nature Reserve in the form of a bird checklist for the reserve. This list contains a number of bird species associated with the estuarine habit, a large number of which were not observed during the current field survey. Additional bird records for the National Quarter Degree Grid Square in which the system falls were sourced from the Bird Atlas of Natal (Cyrus & Robson, 1980). There are no detailed counts available relating to the avifauna of this Mlalazi Estuary.

Fieldtrip Report

A single full count of the water birds present along the length of the estuary was undertaken during May 2013

Methods

Fieldwork related to all biotic components of the Rapid Reserve on the Mlalazi Estuary was undertaken over an eight day period during May 2013. During four of the days, whilst other sampling was been undertaken notes were kept of water associated birds present in the system. Following that nearly a full day was spent obtaining a full bird could for the system from the entire area accessible by rubber duck.

Results and Discussion

Table 1 comprises the total list of species that were found during the field survey of the Mlalazi Estuary, this comprised 19 species comprising 48 individuals. It should be noted that a flock of about 20 to 30 terns & gulls was noted roosting on a sand spit near the mouth but they did not allow close enough approach for identification of the species present.

Without a full count being undertaken on a monthly basis over a twelve months period and without the historical literature search having been undertaken it is difficult to make any definitive statements regarding the avifauna of the Mlalazi Estuary.

The species composition present during the fieldwork phase could be divided into four broad groups based on when they utilize the estuary;

1. *Resident/Local Area Species*

   This group comprises those species that are resident at the estuary or visit it from time to time from other adjacent aquatic systems in the area. They use the system for feeding and in some cases may breed there, they comprised 74% of the species present (=14). The main species within this group are the herons, kingfishers and Fish-eagle.

2. *Summer Migrant Species*

   This group comprises the migrants from the Northern Hemisphere which use the system for feeding during the northern winter, two such species were present in May 2014. The estuary is a critical component for the groups survival. It should be noted that as this survey was undertaken in May after the bulk of migrants had already returned to the Northern Hemisphere that there was an undercount of species & numbers from this group that would be present during the Summer months. The main species within this group are the sandpipers and sandplovers.

3. *Roosting Species*

This group consists exclusively of the terns and gulls which utilize the safety of islands/sandspits in the estuary for roosting when they are not out feeding at sea. The flock of birds that flew out to sea at the mouth of the estuary almost certainly comprised Common and Crested Terns and Grey-headed Gulls. The Common Tern is a Northern Hemisphere Summer Migrant and the Swift Tern breeds in the Western Cape and migrates up the KwaZulu-Natal coast for the winter, this also forms part of its post breeding dispersal of juvenile of the year.

4. *Winter Migrant Species*

Despite the fact that no winter migrants were identified during the May 2014 fieldtrip it is likely that there will be a small component of the aquatic bird fauna that are only present at the Mlalazi Estuary during the winter months, having moved down to the coast from the interior.

In terms of feeding guilds, six groups were identified based on the species records from all sources, these were;

1. *Swimming Piscivores*

Birds of open deeper water swimming species which catchtheir prey underwater. This group includes Reed & White-breasted Cormorant & African Dater. They may be found along the entire length of the estuary. It is possible that small numbers of Cape Cormorant may also utilize the estuary during the winter-spring period.

2. *Aerial Piscivores*

Plunge diving species catch their prey in the shallows or in open water. This group includes the Fish Eagle, Osprey, Pied, Giant & Malachite Kingfishers as well as Common & Swift Terns. The estuary is used by several tern species as a roosting site when they are not feeding offshore.

3. *Large Wading Piscivores*

Prey capture is undertaken by stealth wading in the shallows, intertidal areas and on the edges of the Phragmites beds. These species are characteristic of wetland shorelines and have the ability to move into inundated areas to hunt. The extent of this is determined by size and leg length of the species. This group includes the Grey Heron, Little, Yellow-billed & Great Egret.

4. *Small Wading Invertebrate Feeders*

This group mainly forages in the intertidal sand- and mud-flats for macrobenthic invertebrates but also exploit shallow inter-tidal areas. They include the Greenshank, Wood & Common Sandpiper, Common Whimbrel and Little Stint which are all migratory Palaearctic waders that visit the estuary during the summer months. Most are wholly reliant on these habitats for feeding during the non-breeding season. Also present occasionally are a number of other wading birds including Black-winged Stilt and Water Thick-knee.

5. Swimming Herbivorous Waterfowl

These species tend to use the open water areas for feeding or the shoreline and small tidally exposed sandbank islands for roosting. The occurrence of this group in estuaries is to a large extent determined by the salinity regime of the system as higher salinities tend to restrict the growth of submerged vegetation thus reducing the food supply for these herbivores. This group includes White-faced & Yellow-billed Duck and Egyptian & Spur-winged Goose.

6. Carnivorous and Scavenging Gulls

Scavengers, with a substantial range of foraging strategies, feeding on a wide range of both live and dead vertebrates and invertebrates. The estuary is also used by individuals of the same species as a roosting site, along with the terns, when they are not feeding offshore. The primary species in this group are the Grey-headed and Kelp Gull.

Table 1. Water associated birds recorded in the Mlalazi Estuary, May 2013 (+ = No Count).

Common Name	Scientific Name	Present May 2013	Count 05-2013
Cormorant, Reed	*Phalacrocorax africanus*	1	2
Egret, Great	*Egretta alba*	1	1
Egret, Little	*Egretta garzetta*	1	8
Finfoot, African	*Podica senegalensis*	1	1
Fish-Eagle, African	*Haliaeetus vocifer*	1	2
Goose, Spur-winged	*Plectropterus gambensis*	1	1
Greenshank, Common	*Tringa nebularia*	1	1
Gull, Grey-headed	*Larus cirrocephalus*	1	+
Kingfisher, Giant	*Megaceryle maximus*	1	1
Kingfisher, Malachite	*Alcedo cristata*	1	1
Kingfisher, Pied	*Ceryle rudis*	1	19
Plover, Three-banded	*Charadrius tricollaris*	1	1
Plover, White-fronted	*Charadrius marginatus*	1	4
Sandpiper, Common	*Actitis hypoleucos*	1	1
Stork, Woolly-necked	*Ciconia episcopus*	1	2
Tern, Common	*Sterna hirundo*	1	+
Tern, Swift	*Sterna bergii*	1	+
Thick-knee, Water	*Burhinus vermiculatus*	1	2
Vulture, Palm-nut	*Gypohierax angolensis*	1	1
	Totals	**19**	**48**