THE AQUATIC BIODIVERSITY AND TOURISM VALUE OF SELECTED SOUTH AFRICAN RAMSAR WETLANDS

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WATER RESEARCH COMMISSION

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Report to the

WATER RESEARCH COMMISSION

by

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EXECUTIVE SUMMARY

BACKGROUND AND RATIONALE

The Ramsar Convention for Wetlands of International Importance came into force in South Africa on 21 December 1975. The first two designated Ramsar sites in South Africa were De Hoop Vlei and Barberspan Bird Sanctuary. Since then, South Africa has steadily increased the number of designated sites and currently it stands at 23 sites. The latest designation was in March 2017 when the Bot-Kleinmond estuarine system was designated as a Ramsar Wetland of International Importance. Thus, the total area under the Ramsar Convention in South Africa currently stands at approximately 800 000 ha (Ramsar, 2016). The Ramsar sites are scattered across eight of South Africa's nine provinces. The exception is the Eastern Cape Province, which currently has no Ramsar sites.

The Ramsar Convention requires that the management authorities of the specific Ramsar sites monitor and manage each system to protect it, while still encouraging wise use of the wetlands. The Ramsar Information Sheet (RIS) is a summary of the site that is used to designate the site as well as monitor its status through RIS documents that should be updated every six years. However, many countries, including South Africa, regularly fail to update these documents. In South Africa, many of our earlier Ramsar sites have been neglected in terms of monitoring and, as such, no information was available for the management authority to update the RIS or to do biological monitoring. The lack of information was highlighted by the Department of Environmental Affairs and the Water Research Commission as a priority research area in 2013.

Furthermore, baseline aquatic information for the Ramsar wetlands management plans is lacking and therefore no adequate monitoring of these systems can be completed. Baseline data on diatoms, zooplankton, macroinvertebrates, fish and amphibians is fundamental information that is needed for any management plan for Ramsar sites. Ideally, baseline conditions should be available from the date of designation, but, for many sites, this is not the case. Therefore, current information is vital to establish baseline data for monitoring programmes in the future.

Even though wetlands are accepted these days as being vitally important as water resources and as ecological infrastructure, many of South Africa's Ramsar wetlands have been neglected in terms of research on their structure, function, importance and the services that they provide. Furthermore, many of these vitally important wetlands have little to no information on the biotic communities present within the aquatic ecosystem. Many of the wetlands are well studied in terms of the birdlife, but information on the lower ecosystems is scarce at best. As an example, Barberspan Bird Sanctuary has been recognised as a vital component in migratory water bird lifecycles and this is reflected in the amount of water bird research that is available. However, when looking at the biotic community within Barberspan (i.e. zooplankton, macroinvertebrates and fish) very little is known or published. The last detailed information on this system dates back to the 1970s. Although more recent work has probably been completed, it has never been published and thus it is generally inaccessible. When this lack of research is combined with the lack of a wetland monitoring programme in South Africa, there is very little current information about many of our Ramsar wetlands, and wetlands in general.

Therefore, to start to address this lack of aquatic biodiversity information for Ramsar wetlands in South Africa, this research project was initiated. The broad aim was to collate any existing aquatic biodiversity information available on selected Ramsar wetlands in South Africa and to fill in selected gaps within this research. The knowledge gaps will take many years to address but this is a good starting point to further our knowledge of the Ramsar wetlands and determine what research is needed.

AIMS

The following aims were selected for the project to achieve the overall project goal:

1. A literature review of available aquatic information for South African Ramsar sites
2. An aquatic assessment of selected Ramsar sites in South Africa
3. Linking the effect of land use to the Ramsar site condition
4. Determining the effect that the Ramsar site condition potentially has on tourism to Ramsar sites.

METHODOLOGY

The various Ramsar wetlands that were selected for inclusion in this project necessitated different methodologies due to the different nature of each system. However, where possible, the following methodologies were implemented at each of the systems.

<u>Water quality</u>: Water quality samples were collected in pre-washed polyethylene bottles for the analysis of ions, metals and nutrient variables. All of the samples were kept on ice until analysis in the laboratories of North-West University. The selection of these variables was based on the potential impacts associated with these systems, i.e. mining, agricultural, human

settlements and unimpacted conditions. The results of the water quality data were used in various statistical analyses with the aim to indicate changes within these systems due to anthropogenic impacts.

Sediment quality: Sediment samples were collected in 500 mL polyethylene jars at each site to coincide with water quality sampling. The samples were kept on ice during transport and frozen until analysis in the laboratories of North-West University.

Diatoms: The sampling of diatoms has been described in detail by Taylor et al. (2007) and the methodology that was used in this study is based on those methods. The sampling of macrophytes was done by cutting the vegetation approximately 10 cm below the surface, transferring it into a plastic bag, and then vigorously rubbing the plastic bag (taking care not to puncture it) to transfer the diatoms into the water. The water was then transferred into a plastic container for transport and storage until analysis. Each diatom sample was preserved with ethanol to reach a final concentration of approximately 20% by volume. The diatom samples were taken to a laboratory of North-West University for cleaning and slide preparation using the potassium permanganate and hot hydrochloric acid method, as described by Taylor et al. (2007).

Macroinvertebrates: Sampling of the macroinvertebrates included the use of a sweep net as well as sampling of marginal vegetation, at each site. Marginal vegetation sampling followed a set protocol that could be reproduced at each study area. This entailed the agitation of all types of marginal vegetation for a set time, approximately 5–10 min, depending on habitat availability. The sediment dwelling organisms were sampled by the agitation of the bottom substrate using a kick and stir method and then sweeping the net through the disturbed area. Microinvertebrate sampling was completed with a plankton net (100 µm mesh) and filtering of approximately 200 L of water.

Fish: Various sampling techniques were used to quantify the fish community as recommended by the River Health Programme (Mangold, 2001) and RDM (resource directed measure) sampling techniques (Kleynhans, 2007). Electrofishing for fish was employed in the shallow habitats and in between the marginal vegetation of the study areas (Meador et al., 1993; Barbour et al., 1999). Netting techniques were used in the deeper water sections at the various sites. The nets consisted of a medium (30 m; 22 mm mesh size) bagged seine net and medium-sized (50 cm x 10 m; 22 mm mesh size) fyke nets. All fish caught were identified using the appropriate taxonomic keys (Skelton, 2001), measured and enumerated.

Various databases were made use of for the amphibian (FrogMap) and bird (SABAP2) communities at each of these systems. Literature surveys focused on the occurrence, distribution and abundance of amphibian and bird species. Any protected or endangered species were also identified.

RESULTS AND DISCUSSION

This information is based on a combination of the literature review and sample data from the current project. Generally, information on the selected Ramsar sites was lacking thus the RIS for each site was used as baseline information. All of the information from the RIS has been updated during the project with more current information. Brief results for each aim are presented here.

Aim 1

Ramsar sites were selected based on the available information at each site, taking into account the priorities of stakeholders, accessibility, budget, and the type of system. Various wetland types and representative sites were used to look at the information available relating to specific wetland types. The wetlands that were selected included: Barberspan Bird Sanctuary, De Hoop Nature Reserve, De Mond Nature Reserve (Heuningnes Estuary), Kosi Bay, Lake Sibaya, Makuleke Wetlands, Blesbokspruit, Ntsikeni Nature Reserve, and Seekoeivlei Nature Reserve (added during 2016). A literature review for each of these sites was compiled using journal articles, research reports and any grey literature that could be found. The literature review focused on available aquatic biodiversity information, i.e. diatoms, zooplankton, macroinvertebrates and fish communities. Frog and bird lists were collated from various citizen science projects, i.e. FrogMAP and the Southern African Bird Atlas Project 2 (SABAP2).

Aim 2

The aquatic assessment of the selected Ramsar sites was implemented during the project with numerous field visits, as well as the collection of diatoms, zooplankton, macro-invertebrates and fish for an assessment of the present biodiversity. The following is a summary of the field surveys and the data that was collected:

<u>Barberspan</u>: Field surveys for diatoms, zooplankton, macroinvertebrates, fish community and fish health were completed during April and July 2014. An additional field survey for zooplankton was completed during October 2015. Diatoms, zooplankton, macroinvertebrates and fish taxa identified during the project are presented in the Barberspan section of the report. Following training of nature conservation staff and the provision of equipment, a biomonitoring

programme from February 2016 to January 2017 was implemented by assessing the macroinvertebrates present at selected sites in the reserve. A survey of small fishes within Barberspan was also completed during 2014 and 2015 with new host records and localities identified for monogenean and cestode fish parasites.

De Hoop Vlei: A once-off field survey was completed during March 2015 to sample zooplankton, macroinvertebrates and fish from the De Hoop Vlei and depressions within the reserve. Sediment and water samples were also collected and analysed for nutrients and metal concentrations. The zooplankton, macroinvertebrates and fish taxa identified during the project are presented in the relevant section.

De Mond Nature Reserve: A once-off field survey was completed during March 2015 to sample zooplankton, macroinvertebrates and fish from the Heuningnes Estuary. Sediment and water samples were also collected and analysed for nutrients and metal concentrations. The zooplankton, macroinvertebrates and fish taxa identified during the project are presented in the relevant section.

Makuleke Wetlands: The field surveys to Makuleke Wetlands were completed during April 2015, September 2015 and October 2015. Additional surveys were planned but, due to the severe drought, all of the systems dried up during 2016. The samples collected during the various field surveys included water, sediment, diatoms, zooplankton, macroinvertebrates, as well as fish community and fish health (including parasites) data at the various selected pans. The diatom, zooplankton, macroinvertebrates and fish taxa identified during the project are presented in the relevant section. This was the first time that diatom, zooplankton and macroinvertebrates had been collected and identified from the Makuleke Wetlands.

Kosi Bay: Field surveys to Kosi Bay were completed during August 2015, November 2015 and February 2016. Water, sediment, diatom, benthic macroinvertebrates and fish samples were collected. Fish tissue was analysed for metal concentrations as well as the health of the fish and possible exposure to metal pollutants. Fish tissue samples were also given to the University of the Witwatersrand for DDT determinations. Fish were screened for monogenean and cestode parasites and water and sediment samples were screened for nutrient and metal concentrations.

Lake Sibaya: Field surveys to Lake Sibaya were completed during August 2015, November 2015 and February 2016. Water, sediment and diatoms were collected. Water and sediment samples were screened for nutrient and metal concentrations. Diatom community structure and responses to water quality indicated a rich diatom biodiversity within Lake Sibaya.

Ntsikeni Nature Reserve: Field surveys to Ntsikeni Nature Reserve were completed during July 2015, December 2015 and April 2016. Water, sediment, diatoms, zooplankton and macroinvertebrates were collected during these surveys. The diatom, zooplankton, macroinvertebrates and fish taxa identified during the project are presented in the relevant section. This was the first time that diatom, zooplankton and macroinvertebrates had been collected and identified from the Ntsikeni Nature Reserve.

Blesbokspruit: Two field surveys at selected sites on the Blesbokspruit were completed during April and July 2016. Water, sediment, diatoms, zooplankton and macroinvertebrates were collected at the various sites. Water and sediment were analysed for nutrients and metal concentrations. The diatom, zooplankton, and macroinvertebrates identified during the project are presented in the relevant section. This was the first time that diatom, zooplankton and macroinvertebrates had been collected and identified from the Blesbokspruit.

Seekoeivlei Nature Reserve: A once-off field survey to Seekoeivlei was completed during July 2016 and samples were collected at 22 different sites in the Nature Reserve. Samples collected included water, sediment, diatoms, zooplankton and macroinvertebrates. Another field survey was completed during December 2016. The zooplankton and macroinvertebrate taxa identified during the project are presented in the relevant section. This was the first time that diatom, zooplankton and macroinvertebrates had been collected and identified from Seekoeivlei.

Aim 3

The third aim was to link the effects of land use to the Ramsar site condition The results of this aim are captured within each of the chapters on the specific Ramsar sites as well as in the appendices. The results showed that land use has an impact on Ramsar condition especially on Ramsar sites that are situated within or downstream of major agricultural and mining activities. Where Ramsar sites are found within the upstream catchments of river systems, as with Ntsikeni Nature Reserve for instance, environmental impacts from land use are less pronounced. Various land uses were identified as the cause of eutrophication of the Ramsar sites and these included agriculture, mining, wastewater discharges and urban (or rural settlements). Ramsar sites that showed eutrophication included Lake Sibaya, the Makuleke Wetlands, Barberspan, and Blesbokspruit. The increasing population of Memel was identified as a threat to Seekoeivlei as it could potentially lead to eutrophication in the system. Other smaller impacts identified within the systems included metal pollution within the Blesbokspruit and Makuleke Wetlands.

Aim 4

The fourth aim of the project was to initiate a review of the available information on tourism impacts if the Ramsar status was to be lost. However, it was found that very little information was available on this issue, though numerous studies have been completed looking at the value of biodiversity and tourism for protected areas. Some studies have shown that environmental degradation does affect tourism and leads to lowered tourist numbers. Literature has also shown that tourism activities can have significant negative impacts on protected environments.

GENERAL CONCLUSION

The results of this research into the aquatic ecosystems indicated that many of the Ramsar sites are unique or have specific features that make assessment of the sites difficult. For example, the diatom and macroinvertebrate communities within the Makuleke Wetlands indicate that each depression (pan) within the wetland is unique and contributes to the overall diversity of the system. If one depression (pan) is degraded, it could impact on the overall diversity within the Ramsar wetland. Furthermore, many of the Ramsar sites have unique features making them eligible as a Ramsar site. Thus, management of the systems would be site specific and no single monitoring programme would appropriately suit the uniqueness of each Ramsar site.

There can be no doubt that some form of anthropogenic activity threatens each of the Ramsar wetlands that were included in this project. In general, these threats can be summarised as habitat loss, nutrient enrichment, numerous pollutants, urban and rural encroachment, alien invasive species, poor land use practices and organic enrichment. All of these could pose a significant threat to the Ramsar sites, presently as well as in the future. Management and proper monitoring will be the only effective tool to track and provide an early warning for the degradation of these Ramsar wetlands.

The results of this project are invaluable for future monitoring of the aquatic ecosystems at the Ramsar wetlands selected for this project. The results gathered here will provide a current baseline for monitoring, especially the detailed information provided for many aspects in the appendices. This data could also be valuable to various management authorities in order to update the RIS that form part of the requirements of the Ramsar Convention. If all of the RIS sheets for these nine selected Ramsar wetlands could be updated using the information from this study, it will potentially enhance the standing of South Africa within the Ramsar wetlands community.

The chapter on tourism indicates that ecotourism at the Ramsar wetlands could be invaluable in generating income for the specific sites. However, it was obvious that the ecotourism potential of many of the Ramsar wetlands was still underutilised. Thus, there is significant potential to develop sustainable ecotourism and education initiatives at many of South Africa's Ramsar wetlands. The potential should be realistically assessed, taking into account the potential impact that tourism could have on the environmental condition at the Ramsar sites (both good and bad). Thus, detailed studies should be carried out at each Ramsar wetland to assess the viability of ecotourism as well as the extent to which it will benefit the Ramsar site and not be detrimental to the environment.

RECOMMENDATIONS FOR FUTURE RESEARCH

Numerous recommendations have been identified during the project and specific recommendations for each Ramsar site are provided in the specific section. The following general recommendations were made:

- Continuous monitoring of aquatic ecosystem components should be implemented at South Africa's Ramsar sites. The initial methodology for the National Wetlands Monitoring Programme, recently completed, should be adapted by the Department of Environmental Affairs for site-specific monitoring programmes for each Ramsar site.

- The correct ecosystem components must be monitored at each Ramsar wetland – thiese should be selected based on the available information, National Wetland Monitoring Programme protocols (when available) and communication with local stakeholders reliant on the system. The information generated during this project should form part of the baseline data that each of the Ramsar sites will be monitored against.

- Monitoring and research of South Africa's Ramsar sites should be managed from one institution to ensure that efficient and sustainable protocols are followed, especially regarding data storage and management. This will facilitate Ramsar Convention monitoring and reporting requirements.

- It was cause for concern that numerous alien invasive organisms were present within the Ramsar wetlands, even though these systems are in protected areas or national parks. Therefore, it is recommended that further research into alien invasive organisms, and especially alien invasive fish parasites, should be conducted to determine the extent of the invasion.

- It is recommended that buffer zone determination guidelines from previous Water Research Commission projects (K5/2463, K5/2200) be implemented in all of the catchments associated with Ramsar sites. This will potentially ensure that Ramsar sites remain minimally impacted by anthropogenic activities within their catchments.

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LIST OF ABBREVIATIONS

DEA	Department of Environmental Affairs
DEAT	Department of Environmental Affairs and Tourism
DWS	Department of Water and Sanitation
EI	Environmental Importance
ES	Environmental Sensitivity
HGM	Hydrogeomorphic
ICP-MS	inductively coupled plasma mass spectrophotometer
IUCN	International Union for Conservation of Nature
KNP	Kruger National Park
MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff
MERIS	Medium Resolution Imaging Spectrometer
NFEPA	National Freshwater Ecosystem Protected Areas
NWCS	National Wetland Classification System
PES	Present Ecological State
PESEIS	Present Ecological State Environmental Importance and Sensitivity
RIS	Ramsar Information Sheet
SABAP2	Southern African Bird Atlas Project 2
SANBI	South African National Biodiversity Institute
SANParks	South African National Parks Board
SAWS	South African Weather Service
SoER	State of the Environment Reporting
TMG	Table Mountain Group
USA	United States of America
USFWS	United States Fish and Wildlife Service
WWTW	Waste Water Treatment Works

1 INTRODUCTION AND OBJECTIVES

1.1 Introduction

The word “wetland” can be used to describe many forms of aquatic ecosystem, including riverine floodplains, tree-covered swamps, high-altitude rain pools and even saline lakes (Dallas and Day, 2004). Ponds, lakes, rivers, marshes, swamps and bogs are also listed as wetlands; in short, any open water areas that are shallow and either intermittently covered or saturated (Matthews, 1993). In South Africa, wetlands are defined by the National Water Act (no. 36 of 1998) as, “land which is transitional between terrestrial and aquatic systems where the water table is usually at or near the surface, or the land is periodically covered with shallow water, and which land in normal circumstances supports or would support vegetation typically adapted to life in saturated soil.” This definition was derived from the United States Fish and Wildlife Service (USFWS) Classification System for Wetlands and Deepwater Habitats in the USA (Breedt and Dippenaar, 2013). Another definition for wetlands was provided by the Ramsar Convention for Wetlands of International Importance, stating “wetlands are areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres” (Matthews, 1993; Duguid et al., 2005). Furthermore, “wetlands may incorporate riparian and coastal zones adjacent to the wetlands, and islands or bodies of marine water deeper than six metres at low tide lying within the wetlands” (Duguid et al., 2005).

The classification of South African wetland systems became important with the National Water Act of 1998 and its specifications for the protection of aquatic ecosystems. The first draft National Wetland Classification System was completed in 2006 (Ewart-Smith et al., 2006) in response to the requirements of the National Wetland Inventory. The classification was relatively broad to ensure that all wetlands defined by the Ramsar Convention were included (SANBI, 2009). The wetland classification was then refined in a follow-up project commissioned by the South African National Biodiversity Institute (SANBI). The aim was to develop and refine the draft National Wetland Classification System so that it could be widely used throughout South Africa (SANBI, 2009). As part of the refined classification system, a user manual was developed to facilitate the system and make it easy and efficient to use. The user manual would also potentially ensure that the classification system is used in a similar manner by every user to enable comparability. With the revision of the system, it also underwent a name change and is now officially referred to as the Classification System for Wetland and Aquatic Ecosystems.

The classification system is composed of six levels that are used to discuss and characterise each wetland or wetland unit. The first level in the system is to determine if the wetland in question is an inland, estuarine or marine ecosystem. This is determined by the degree of connectivity that the wetland shares with the ocean. Inland systems are characterised by no direct, existing connection to the sea while marine systems are part of the open ocean. Estuarine systems are transitional between marine and inland systems and can be either permanently open to the sea or only periodically open, depending on the water flow coming from the freshwater environment.

Inland aquatic ecosystems are classified according to the hydrogeomorphic premise which deals with the hydrology and geomorphology of the system. These characteristics are the two basic features of a system that determine how the system functions, irrespective of the climate, soils, vegetation or origin (Semeniuk and Semeniuk, 1995; Finlayson et al., 2002; Ellery et al., 2008; Kotze, 2010). These features were key to the development of the hydrogeomorphic approach to wetland classification (Brinson, 1993). This approach has found widespread approval in the scientific community and the system has proven to be robust and consistent (Ollis et al., 2013). This classification system was widely used throughout this study to classify the different wetland types found at each Ramsar site.

1.2 Ramsar Convention for Wetlands of International Importance

The Ramsar Convention had its beginnings in 1971 when representatives of 18 nations placed their signatures on a treaty in the small town of Ramsar, in Iran, on the 3rd of February (Matthews, 1993). According to Matthews (1993), the Ramsar Convention is the first among a number of modern instruments which aim to conserve natural resources on a global scale. Koester (1989) states that “the Ramsar Convention is the oldest of the global nature conservation treaties, and the only one to deal with a particular ecosystem type.” The Ramsar Convention establishes that wetlands across the globe should be selected based on their international significance with regard to limnology, zoology, botany, ecology or hydrology (Ramsar, 2016). The Ramsar List (Ramsar, 2016) states that its vision is, “to develop and maintain an international network of wetlands which are important for the conservation of global biological diversity and for sustaining human life through the ecological and hydrological functions they perform.”

The Ramsar Convention has set out nine criteria, along with accompanying guidelines, to assist contracting parties in identifying their priority sites for designation (Ramsar Convention Secretariat, 2010). These criteria were adopted by the 4th, 6th and 7th meetings of the Conference of the Contracting Parties to aid as a guide to implement Article 2.1 on the designation of Ramsar sites (Duguid et al*.,* 2005). These criteria, according to the Ramsar Convention Secretariat (2010), are divided into Group A criteria which refers to "sites containing representative, rare or unique wetland types" and Group B criteria which refers to "sites of international importance for conserving biodiversity".

There are currently 169 contracting parties that form part of the convention (as of January 2016) (RAMSAR Handbook, 2016). Countries that form part of the convention include Australia, Germany, Belgium, New Zealand, South Africa, and the United States of America (RAMSAR Handbook, 2016). These countries currently protect 2 245 Ramsar sites across the world and these sites cover approximately 215 million ha.

Table 1: The specific criteria that are used by the Ramsar Convention to determine if a wetland is of international importance

Group A criteria Sites containing representative, rare, or unique wetland types		**Criterion 1:** A wetland should be considered internationally important if it contains a representative, rare or unique example of a natural or near-natural wetland type found within the appropriate biogeographic region.
Group B of the Criteria Sites of international importance for conserving biodiversity	Criteria based on species and ecological communities	**Criterion 2:** A wetland should be considered internationally important if it supports vulnerable, endangered, or critically endangered species or threatened ecological communities.
		Criterion 3: A wetland should be considered internationally important if it supports populations of plant and/or animal species important for maintaining the biological diversity of a particular biogeographic region.
		Criterion 4: A wetland should be considered internationally important if it supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions.
	Specific criteria based on waterbirds	**Criterion 5:** A wetland should be considered internationally important if it regularly supports 20 000 or more water birds.
		Criterion 6: A wetland should be considered internationally important if it regularly supports 1% of the individuals in a population of one species or subspecies of water bird.
	Specific criteria based on fish	**Criterion 7:** A wetland should be considered internationally important if it supports a significant proportion of indigenous fish subspecies, species or families, life-history stages, species interactions and/or populations that are representative of wetland benefits and/or values and thereby contributes to global biological diversity.
		Criterion 8: A wetland should be considered internationally important if it is an important source of food for fishes, a spawning ground, a nursery and/or migration path on which fish stocks, either within the wetland or elsewhere, depend.
	Specific criteria based on other taxa	**Criterion 9:** A wetland should be considered internationally important if it regularly supports 1% of the individuals in a population of one species or subspecies of wetland-dependent non-avian animal species.

In South Africa, the Department of Environmental Affairs (DEA, previously known as DEAT, Department of Environmental Affairs and Tourism) is responsible on a national level for implementation of Ramsar Convention requirements. Management of any particular wetland can fall under the responsibility of a number of departments or under any of the nine provincial governments; however, the South African National Parks Board (SANParks) takes full responsibility for all the wetlands in the national parks (Cowan, 1995; Kidd, 2011).

1.2.1 Montreux Record

According to Ramsar (2016), the Montreux Record is "a record of Ramsar sites where changes in ecological character have occurred, are occurring or are likely to occur" which is maintained by the secretariat in consultation with the contracting party concerned. In 1996, the Blesbokspruit was removed from the list of wetlands of international importance and was placed on the Montreux Record after it was contaminated by large quantities of polluted water discharged from adjacent Grootvlei Proprietary Mines Limited (SoER, 1999). A continuous improvement in the surface water quality would enhance the restoration of the Blesbokspruit wetland and thereby support the delisting of this wetland from the Montreux Record (Ambani, 2013).

The second South African Ramsar site on the Montreux Record is the Orange River Mouth. This is a transboundary site shared with Namibia that has extensive freshwater lagoons, marshes, sandbanks and reedbeds, and extensive salt marshes. The site was listed on the Montreux Record in 1996 following extensive degradation of the salt marsh areas from diamond mining operations in the area. Furthermore, flow regulation from the Upper Orange River, due to domestic water demand, has exacerbated the impacts on this system. The Orange River Mouth provides invaluable habitat for resident and migrant water birds that depend on the habitat in the estuary for survival in an otherwise very arid region (Ramsar, 2016).

Currently, there are indications that the Blesbokspruit might be removed from the Montreux Record and re-designated as a fully protected Ramsar site of international importance. However, currently no such change is envisaged for the Orange River Mouth. In both instances, increased and improved monitoring, coupled with rehabilitation activities, could have improved conditions within these sites over the last 20 years, if implemented.

1.3 Ramsar sites in South Africa

South Africa was one of the original countries that signed the Ramsar Convention in Iran in 1971. The first two sites that were declared as Ramsar sites in this country were De Hoop Vlei and Barberspan in 1975. Since then, Ramsar sites have been added on a routine basis. The current number of Ramsar sites in South Africa is 22, with sites scattered across South Africa (Figure 1; Table 2). The latest Ramsar site was declared in April 2015 when the False Bay Wetland Park was added. This latest addition results in an area of approximately 800 000 ha (Ramsar, 2016) that is protected under the Ramsar Convention. The various sites generally comprise seven different broad ecosystem types, namely estuaries, floodplains, coastal lakes, highland wetlands, inland lakes, wetlands and others (such as turtle beaches and Prince Edward Island).

When the selection of the various sites for the current study was made, it was decided to focus on at least one out of each of these types of sites. Furthermore, it was decided to focus on areas that have not been well studied in the past and aim to increase the available knowledge on these systems. Nine sites were selected (Figure 1; Table 2), based on these criteria. The selected sites were Makuleke Wetlands, Kosi Bay, Lake Sibaya, Ntsikeni Nature Reserve, De Hoop Vlei, Heuningnes Estuary, Barberspan, Blesbokspruit, and Seekoeivlei.

Table 2: South African Designated Ramsar Sites as of 2016. The shaded sites were included in this study (Adapted from Ramsar, 2016).

Ramsar Site	Designation Date	Area (ha)	Province	Ramsar Site No.	Most Recent RIS Update:	Threats
De Hoop Vlei	12/03/1975	750	Western Cape	34	1998	Military test range
Barberspan	12/03/1975	3 118	North West	35	1998	External agricultural activities
De Mond (Heuningnes Estuary)	02/10/1986	918	Western Cape	342	1998	Oil spills at sea and agricultural activities
Blesbokspruit	02/10/1986	1 858	Gauteng	343	1995	Contamination by polluted water discharged from adjacent mines
Turtle beaches/coral reefs of Tongaland	02/10/1986	39 500	KwaZulu-Natal	344	1984	Oil spills at sea
St. Lucia System	02/10/1986	155 500	KwaZulu-Natal	345	1998	Large-scale mining for heavy metals
Langebaan	25/04/1988	6 000	Western Cape	398	1991	Oil spills at sea, possible development of resorts and human disturbances
Wilderness Lakes	28/06/1991	1 300	Western Cape	524	1990	Agriculture, suspensoids, pesticides and deforestation
Verlorenvlei	28/06/1991	1 500	Western Cape	525	1990	Water used for irrigation and cattle grazing
Orange River Mouth	28/06/1991	2 000	Northern Cape	526	1990	Diamond mining activities
Kosi Bay	28/06/1991	10 982	KwaZulu-Natal	527	1995	Non-sustainable slash-and-burn cultivation, water pollution and DDT pollution
Lake Sibaya	28/06/1991	7 750	KwaZulu-Natal	528	1988	Livestock grazing and cultivation
Natal Drakensberg	21/01/1997	243 813	KwaZulu-Natal	886	1996	Soil erosion and invasion by alien plant species

Ramsar Site	Designation Date	Area (ha)	Province	Ramsar Site No.	Most Recent RIS Update:	Threats
Ndumo Game Reserve	21/01/1997	10 117	KwaZulu-Natal	887	1996	Poaching, agriculture, alien invasive plants and water abstraction
Seekoeivlei Nature Reserve	21/01/1997	4 754	Free State	888	1996	Uncontrolled burning and alien invasive plant species
Nylsvlei Nature Reserve	07/07/1998	3 970	Northern Province	952	1997	Alien invasive plant species
Verloren Valei Nature Reserve	16/01/2001	5 891	Mpumalanga	1110	2000	Possible exotic plant species
Makuleke Wetlands	22/05/2007	7 757	Limpopo	1687	2007	To be determined
Prince Edward Islands	22/05/2007	37 500	Western Cape	1688	2007	Illegal, unreported and unregulated fishing
Ntsikeni Nature Reserve	02/02/2010	9 200	KwaZulu-Natal	1904	2010	Commercial afforestation (alien invasive species)
uMgeni Vlei Nature Reserve	19/03/2013	958	KwaZulu-Natal	2132	2013	Invasive American bramble (*Rubus cuneifolius*)
False Bay Nature Reserve	02/02/2015	1 542	Western Cape	2219	2014	Alien/non-native invasive species

1.4 Aims and objectives

The following aims were set for the project:

- Literature review of available aquatic information for South African Ramsar sites
- Aquatic assessment of selected Ramsar sites in South Africa
- Link the effect of land use to Ramsar site condition in South Africa
- Determine the effect that the Ramsar site condition potentially has on tourism to Ramsar sites.

The project aims were achieved with the following objectives:

- To complete a literature review of the selected South African Ramsar sites
- To complete aquatic assessments for Barberspan Nature Reserve, Kosi Bay, Lake Sibaya, Makuleke Wetlands, Ntsikeni Nature Reserve, Blesbokspruit and Seekoeivlei Nature Reserve
- To complete an assessment of tourism and the impact of environmental degradation on tourism and the tourism potential of the selected Ramsar wetlands.

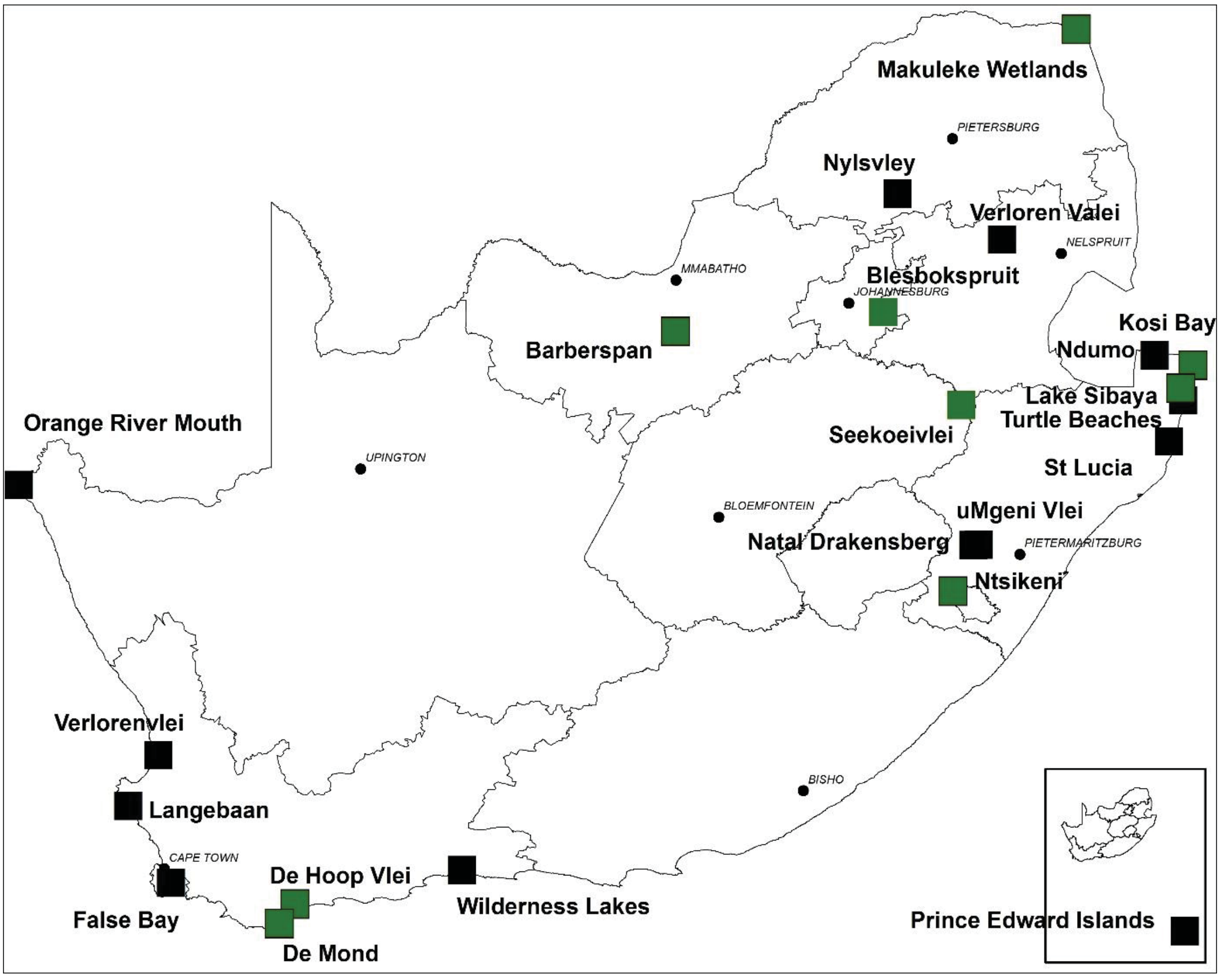


Figure 1: Map indicating the 22 Ramsar sites in South Africa as of November 2016; the selected sites included in this study are indicated by green blocks

1.5 Report structure

The report structure that follows assigns a section to each of the selected Ramsar sites that were included in the project. Each of the Ramsar site sections provides a brief overview of the location, physical characteristics, wetland classification, present ecological state and the various diverse aquatic biota found at the site. There is also an assessment of the current impacts and threats to the Ramsar site as well as the current tourism activities in the surrounding areas. Detailed information on each ecological component from the Ramsar site is then provided in a specific appendix.

2 BARBERSPAN

2.1 Introduction

Barberspan Bird Sanctuary was one of two sites in South Africa to receive protection under the Ramsar Convention for Wetlands of International Importance in 1975. Barberspan is classified as a natural, shallow, perennial, alkaline lake and is one of the few permanent waterbodies in the western highveld during the dry months (Swart and Cowan, 1994; de Necker et al., 2016). The pan provides food and shelter for large numbers of waterfowl during the dry winter months and many migrating bird species use the pan as a stopover. The majority of the other pans in the general area are non-perennial and dry up during the winter months. Within the Ramsar site, approximately 365 different species of birds have been identified, of which about 60 species are migratory. Barberspan was originally a non-perennial system but a connection with the nearby Harts River was constructed in 1918 and that resulted in more water within the pan, changing the system from a non-perennial to a perennial system. This influx of water has also created an ideal habitat for fish, thereby resulting in a popular recreational angling destination.

2.2 Site location

Barberspan Bird Sanctuary is situated in North West Province, approximately 17 km north-east of Delareyville (Figure 2). The sanctuary is approximately 3 118 ha of which almost 2 000 ha is water, depending on the season. Barberspan is around 600 m wide and about 1 500 m long. The average elevation above sea level is between 1 345 m and 1 360 m (Swart and Cowan, 1994). The Barberspan Bird Sanctuary is protected as a provincial nature reserve that was first proclaimed in 1954. The current management authority is the North West Provincial Government and the specific department is North West Tourism.

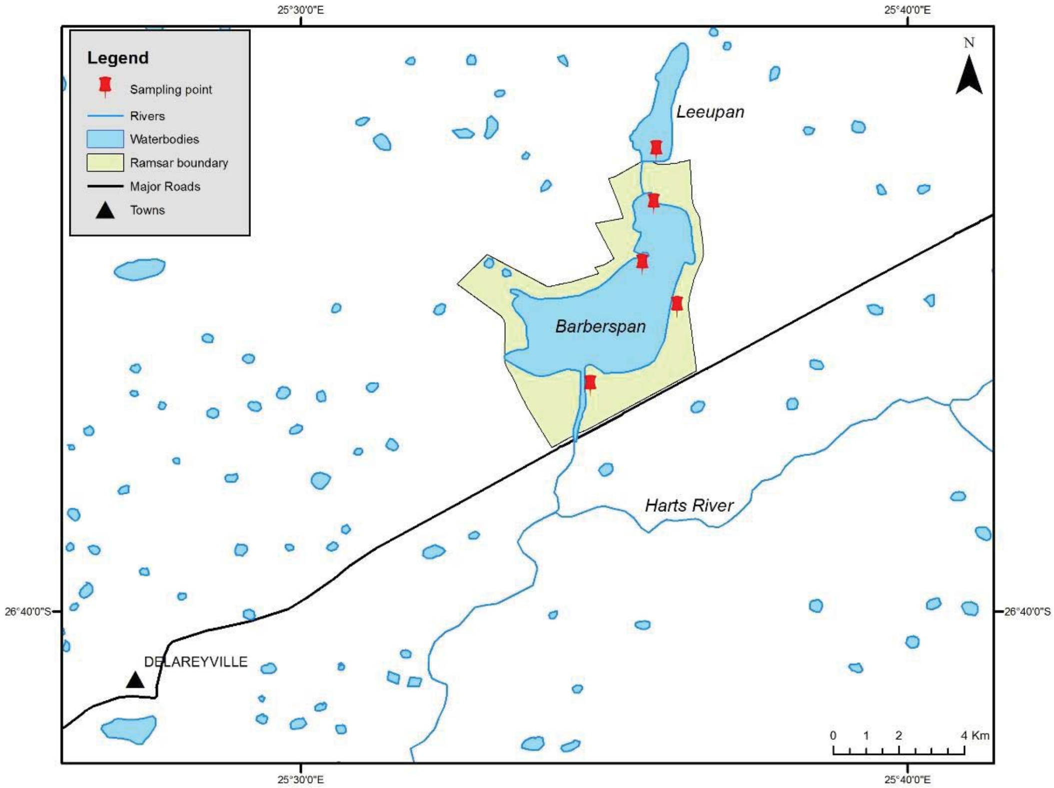


Figure 2: Map of Barberspan Bird Sanctuary indicating the various sampling sites used during the field surveys in 2014

Field surveys of Barberspan were completed during a high-flow and low-flow season, during April and August 2014, respectively. The water level during the surveys (Figure 3) was higher than normally reported levels. However, with the drought experienced during 2016, the water levels decreased.

2.3 Ramsar criteria

Barberspan Bird Sanctuary was designated as a wetland of international importance due to the following Ramsar criteria that were met by the sanctuary (Swart and Cowan, 1994):

- It is an example of a specific type of wetland which is rare or unusual in the biogeographical area – Barberspan is a grass pan
- It maintains a large number of threatened plants and/or animals
- It is of special value for the maintenance of the ecological diversity of the region
- It is of special value as habitat to plants and animals in a critical part of their life cycles
- It maintains large numbers of individuals of specific groups of water birds, which indicates the value, productivity and diversity of the wetland.

Figure 3: Photographs indicating the habitat present at (A) site BP1; (B) Site BP2; (C) site BP3 and (D) site BP4, during August 2014

2.4 Physical features

2.4.1 Climate

Barberspan lies in a summer rainfall region, with the average rainfall approximately 557 mm per year. However, the general region is located within an arid zone while average temperatures are below 18°. The water pH ranges from 8.2 to 9.8, while surface water temperatures range from 15–17°C (Winter – June) to 31°C (Summer – December) (Swart and Cowan, 1994).

2.4.2 Geology

Barberspan is the largest in a series of pans on the Harts River fossil bed, underlain by amygdaloidal lava of the Ventersdorp System, which is covered with surface limestone. The quality of the limestone varies from pure limestone to calcrete, being harder on the surface but softer and more granular underneath. Like the pan, the soil is shallow and alkaline. It is calcerous, with sandy patches in certain sections, and has predominately Mispah and Katspruit forms in the sanctuary and near the water respectively (Milstein, 1975).

2.4.3 Vegetation

Available studies on the vegetation of Barberspan are limited to non-existent. The most recent vegetation information indicates that the area lies within the AZa5 Highveld Alluvial Vegetation type (Mucina and Rutherford, 2006). Important taxa occurring are trees and shrubs: *Acacia karroo*, *Salix mucronata*, *Ziziphus mucronata*, *Celtis africana*, *Rhus lancea*, *Gymnosporia buxifolia*, *Rhus pyroides*, *Diospyros lycioides*, *Ehretia rigida*; Graminoids: *Setaria verticillata*, *Agrostis lachnantha*, *Andropogon eucomus*, *Imperata cylindrica*, *Miscanthus junceus*, *Panicum maximum*, and *Phragmites australis.*

2.4.4 Hydrology

Originally, Barberspan was an ephemeral pan (depression wetland) dependant on its small catchment and precipitation for its water and, as such, it dried up most winters. However, in 1918 an artificial canal was dug to divert water from the Harts River to Barberspan. This resulted in Barberspan becoming a perennial water body in an area of otherwise seasonal depressions. The artificial canal connecting the Harts River and Barberspan has completely changed the hydrology and ecology of Barberspan (Arderne, 2011).

Currently, Barberspan is a shallow (5–9.5 m), alkaline, natural, perennial pan with a storage capacity varying according to the depth (from 33 000 m^3 × 10 to 96 000 m^3 × 10) (Swart and Cowan, 1994). It is 9 m lower than the Harts River, which is its main water source, and connected via a canal. The immediate catchment for the pan is 39 km^2 (Barnes et al., 2014). The catchment receives an annual runoff of only 77 610 m^3, while the average flow from the Harts River is over 60 times as much annually (Swart and Cowan, 1994). However, no recent flow data was available.

The current drought in South Africa has resulted in no flow being present within the Harts River and the canal connecting it to Barberspan. In recent years, before the drought, Barberspan was also connected by a narrow channel to Leeupan that lies to the north. Leeupan is a shallow, ephemeral saline pan. Even though these systems are periodically connected, Leeupan dries up every year during the dry season.

2.4.5 Water quality

Water quality data was scarce for Barberspan Bird Sanctuary as no specific monitoring programme is in place. The water entering Barberspan Bird Sanctuary is periodically monitored by the Department of Water and Sanitation (DWS) but this data was found to be very difficult to obtain. The field surveys and monitoring carried out at Barberspan Bird Sanctuary during this project sampled various aspects of water quality. The *in situ* water quality for these surveys is provided in Table 3 below. This table provides water quality ranges for pH, electrical conductivity, temperature, and oxygen concentrations for the various surveys.

Table 3: Water quality ranges for selected parameters determined during surveys from 2014 to 2016

Water quality parameter	Unit	Barberspan Bird Sanctuary
Oxygen saturation	%	37–100
Oxygen content	mg/L	4–9.8
pH	–	7.9–9.36
Temperature	°C	9–22
Electrical conductivity	µs/cm	995–1 613

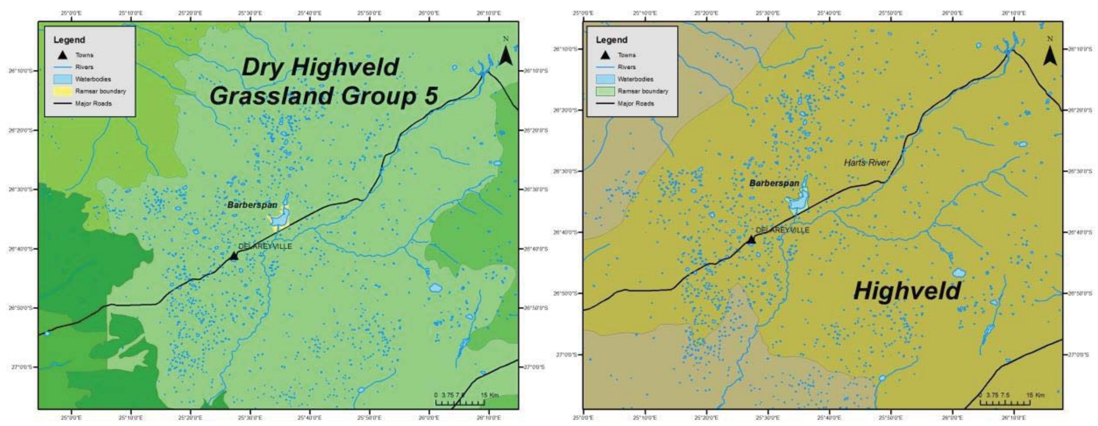
2.5 Wetland classification

The wetlands within the Barberspan Ramsar area were classified using the National Wetland Classification System (NWCS) (Ollis et al., 2013). The various wetlands were classified up to Level 4. Although the adjacent Leeupan is not included within the Ramsar area, it was included in the assessment as it is such an interlinked system. The summary classification for Levels 1 to 3 is provided in Table 4. The Barberspan and Leeupan systems are both inland systems situated between 1 345 m and 1 360 m above sea level (Swart and Cowan, 1994).

Table 4: Summary of the classification of the Barberspan and Leeupan systems using Level 1 to 3 of the NWCS (confidence ratings of the classification are given in brackets for each level)

Wetland Name	Level 1	Level 2		Level 3
	System	DWA Ecoregion	NFEPA WetVeg Group/s	Landscape Unit
Barberspan, Leeupan	Inland	Highveld (high)	Dry Highveld Grassland Group 5 (high)	Plain (high)

The Level 2 regional setting was determined using two GIS layers, the National Freshwater Ecosystem Protected Areas (NFEPA) WetVeg Group for wetland vegetation (Nel et al., 2011) and the DWS Level 1 ecoregions (Kleynhans et al., 2005). The wetland vegetation was identified as Dry Highveld Grassland Group 5 (Figure 4A), while the DWS ecoregion layer identified the area as Highveld (Figure 4B). The confidence rating for these assessments was high as field surveys during 2014 confirmed that the vegetation was mostly grassland situated within the highveld.



A **B**

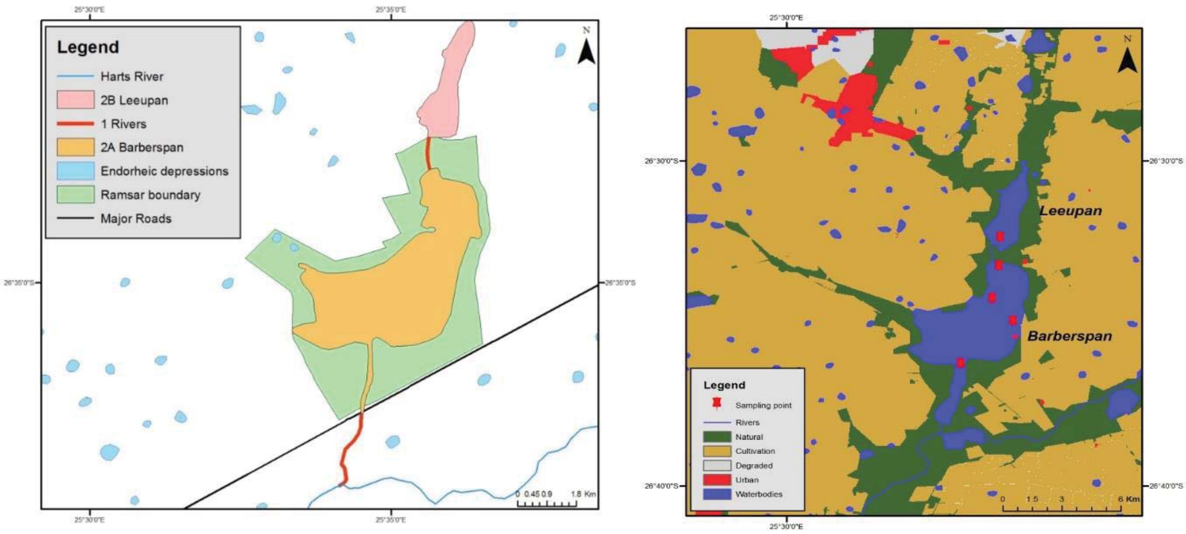
Figure 4: (A) NFEPA wetland vegetation group (Nel et al., 2011); (B) Department of Water and Sanitation Level 1 Ecoregion (Kleynhans et al., 2005)

The landscape setting for Barberspan and Leeupan at Level 3 was determined using Google Earth and 5 m contour lines. This approach established that Barberspan and Leeupan are not situated on a slope, or within 500 m of valley slopes, thus indicating that they are situated within a plain. The confidence rating for the landscape setting was high due to the desktop work as well as the field surveys that were completed in 2014.

The classification system Level 4 was applied to the wetland within the Barberspan Ramsar area using desktop mapping and field survey information (Figure 5). All guidelines in Ollis et al. (2013) were followed to classify the wetlands to Level 4. The main Barberspan area generally had three different Level 4 units, namely rivers, depressions and seeps (Table 5). The river sections had clearly defined banks, and concentrated flows were periodically present. These sections included the inflow from the Harts River into Barberspan as well as the channel that connects Barberspan and Leeupan. These river sections generally have lowland characteristics with an active channel. The confidence for this assessment was deemed low due to the artificial nature of these sections.

Table 5: NWCS Level 4 hydrogeomorphic classification of the various units present at Barberspan and Leeupan

Wetland name	Unit	Level 4 : HGM Unit		
		4A	4B	4C
Barberspan	1	River (low)	Lowland (low)	Active Channel
	2A	Depression (high)	Endorheic (high)	With channelled inflow (high)
	3	Seeps (low)	Not assessed	Not assessed
Leeupan	2B	Depression (high)	Endorheic (high)	With channelled inflow (high)



A **B**

Figure 5: (A) Level 4 classification of the Barberspan Ramsar area indicating the various subunits present. (B) Land use map of the area surrounding the Barberspan Ramsar area.

The second unit at Level 4A was the main waterbodies of Barberspan and Leeupan that were classified as depressions with a high confidence level. The level 4B classification indicated that each of these waterbodies is endorheic with a channelled inflow (Level 4C). This classification was deemed high confidence. However, both of these systems have altered hydrology and Barberspan could possibly also be classified as exorheic due to the channel that connects Barberspan and Leeupan. One of the last hydrogeomorphic units found at Barberspan is numerous seeps in the surrounding grassland. This classification was only completed based on desktop information and future field surveys will verify the amounts and location of these seeps. The land use map of the Barberspan region (Figure 5B) also indicates the amount of small seeps or possibly depressions that are found outside the boundaries of the Ramsar area.

2.6 PES/Ecosystem services

The present ecological state (PES) assessments for Barberspan are problematic, as many of the methods do not directly apply. However, a risk assessment study by Golder Associates (2011) indicated that the system is moderately modified due to various anthropogenic impacts on the system. The ecosystem services assessment (Figure 6) indicated that Barberspan is most important for tourism and recreation. As it is generally an endpoint for water from the Harts River, it does not fulfil any other water quantity or quality functions. It is also able to support carbon storage to some degree.

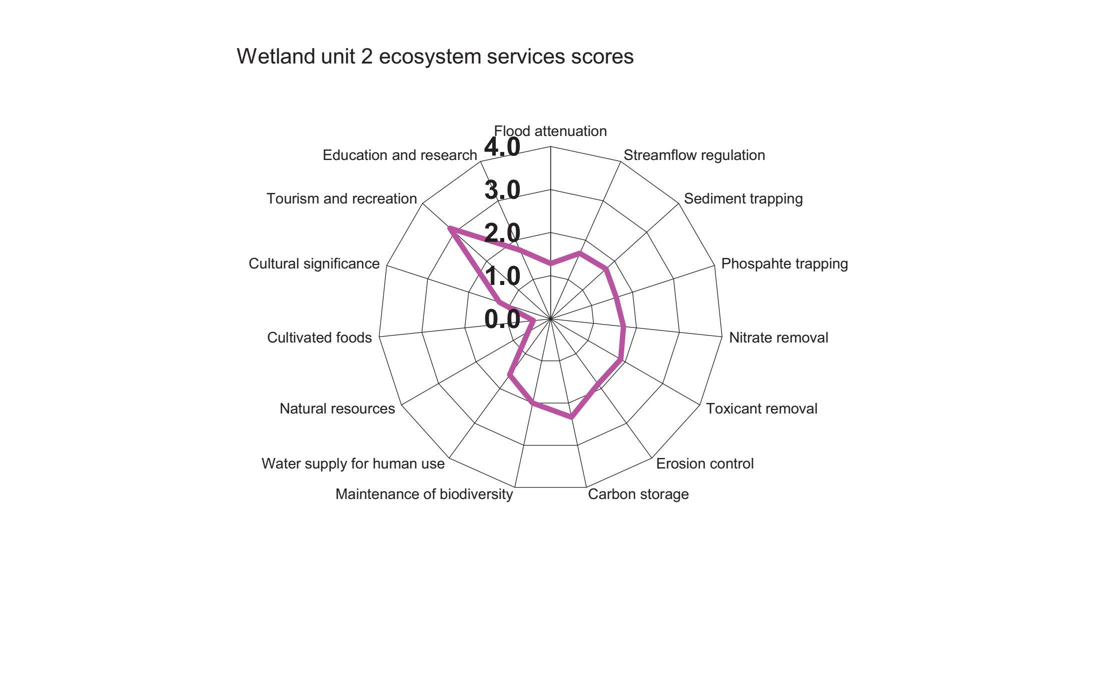


Figure 6: Ecosystem services for Barberspan Nature Reserve based on field surveys and desktop analysis during 2014 to 2016

2.7 Land use and threats

The main threats to Barberspan are currently coming from the inflow of the Harts River, as poor land use and municipal waste water treatment works (WWTW) in the upper reaches are polluting the Harts River (Golder Associates, 2011; Grant, 2013). These pollutants are then trapped within the Barberspan system. Agricultural activities are also placing pressure on the system due to various agricultural pollutants like fertilisers, pesticides and herbicides. The presence of recreational anglers is also increasingly becoming a problem due to littering (Swart and Cowan, 1994). Previously, quarrying was also present in the catchment but this type of activity should be prohibited in future (Swart and Cowan, 1994).

The current land use within the Ramsar protected boundary is protected in terms of the nature reserve and bird sanctuary that has been established since 1954. Barberspan is also used as a popular recreational angling venue on the southern side while the northern side is mainly reserved for the bird sanctuary. Some recreational water sport activities are also allowed in the southern section. The land use within the surrounding areas is mainly agriculture in the form of cattle and maize farming. The Harts River catchment mainly supports agricultural activities and a few urban catchments. Limited mining activity takes place in the headwaters of the Harts River.

A recent study by Van der Schyff et al. (2016) indicated that eggs of Grey Heron in Barberspan were found to contain high concentrations of gold (Au), uranium (U), thallium (Tl) and platinum (Pt). Van der Schyff et al. (2016) investigated four study sites in the Vaal River catchment and concluded that many of the bird eggs in the catchment had high concentrations of selected metals when compared to other studies. However, as limited mining was present within the Barberspan catchment, the study attributed the concentrations to the grey herons feeding in more polluted areas (to the east of Barberspan) and then migrating to Barberspan for breeding purposes (Van der Schyff et al., 2016).

Another recent publication determined the status and trends of eutrophication, cyanobacterial blooms and surface scum for 50 of South Africa's largest water bodies, between 2002 and 2012 (Matthews and Bernard, 2015). Satellite data from the Medium Resolution Imaging Spectrometer (MERIS) satellite, dating from 2002 to 2012, was used to detect eutrophication. Barberspan was found to be one of the three water bodies that are most severely impacted by cyanobacterial blooms that covered an average of greater than 45%. However, an assessment of the trend from 2005 to 2011 indicated that the cyanobacterial blooms were decreasing. The study concluded that Barberspan was heavily impacted by eutrophication and cyanobacterial blooms (Matthews and Bernard, 2015).

2.8 Current recreation and tourism

The current recreation and tourism activities are mainly associated with the bird sanctuary and recreational angling. The bird sanctuary has a few houses and a camping site, together with a few walking trails and bird hides for guests. The southern section of Barberspan is reserved for angling and water sports. The Barberspan Hotel, situated on the reserve, also provides accommodation. Agreements are in place with the owners of Leeupan to extend tourism activities onto their grounds in terms of the walking trails and bird watching.

There has been a successful land claim on the western side of Barberspan Bird Sanctuary (pers. com., Mr Sampie van der Merwe) and it will potentially be developed into more tourism ventures.

2.9 Aquatic biodiversity information

2.9.1 Diatoms

The algae, and specifically the diatoms, of Barberspan have not been well studied and no published information was found. Some samples were reported for the Desmid algal group collected from 1928 (Levanets and van Rensburg, 2011). The surveys in 2014 sampled diatoms from vegetation at four selected sites during a high- and low-flow period. These surveys resulted in 22 different diatom taxa from the various sites and surveys (Table 6). These taxa were mostly found to be indicative of eutrophic conditions.

Table 6: Diatom species present at Barberspan Nature Reserve from two surveys in 2014

Baberspan Bird Sanctuary Species	Date described
Amphora sp. C.G. Ehrenberg	1844
Amphora veneta Kutzing	1844
Aulacoseira granulate (Ehr.) Simonsen	1979
Craticula halophilla Mann	1990
Cyclotella meneghiniana Kutzing	1844
Epithemia sorex Kutzing	1844
Fragilaria capucina Desmazieres	1825
Fragilaria sp. H.C. Lyngbye	1819
Gomphonema insigne W. Gregory	1856
Gomphonema parvulum (Kutzing) Kutzing	1849
Gomphonema pseudoaugur Lange-Bertalot	1979
Navicula tripunctata (O.F. Muller) Bory	1822
Nitzschia filiformis (W.M. Smith) Van Heurck	1896
Nitzschia frustulum (Kutz.) Grunow	1861
Nitzschia linearis (Agardh) W.M. Smith	1853
Nitzschia palea (Kutzing) W. Smith	1856
Nitzschia reversa W. Smith	1853
Nitzschia A.H. Hassall	1845
Nitzschia sp. 1 A.H. Hassal	1845
Rhopalodia gibba (Her.) O. Muller	1895
Staurosirella D.M. Williams & F.E. Round	1987
Ulnaria acus (frag. ulna var. acus)(Kutzing)	–

2.9.2 Zooplankton

Very little research has gone into the zooplankton found at Barberspan. A masters study on the zooplankton looked at qualitative and quantitative aspects of the plankton, but this was done in 1996 (Combrinck, 1966). Since then, very little information has been published. Recent work on endorheic pans in the Delareyville area included Barberspan as a study site. The study completed three surveys during various seasons but only qualitative data was available (Henri et al., 2014; Foster et al., 2015; de Necker et al., 2016). The majority of the available data in those studies is macroinvertebrate data with very little zooplankton data.

A study by Reynolds and Cumming (2015) studied the dispersal of aquatic organisms via waterbirds, either via endo- or ectozoochory. One of their study sites was in the Barberspan Bird Sanctuary, and they found that both bryozoan and cladocera could be transported via either faecal matter or feathers to other aquatic ecosystems.

Zooplankton samples were collected during three surveys in 2014 and 2015 from the Barberspan sites (Figure 2). The samples were identified to the lowest possible taxonomic level and the various taxa present in these results are presented in Table 7. The surveys resulted in 12 taxa being identified, from six different families.

2.9.3 Macroinvertebrates

Not much information was available for macro-invertebrates of Barberspan. Another masters study focused only on the benthic taxa at Barberspan but again this work was completed many years ago, in 1970 (Roode and van Eeden, 1970). No other published work was found, with the exception of the recent study done by Henri et al. (2014) on the endorheic pans in the Delareyville area. This research was again qualitative and was completed over three surveys during 2012/ 2013 at only one site in the Barberspan Bird Sanctuary. This data was also published with further analyses in Foster et al. (2015) and de Necker et al. (2016). Those studies identified 19 different zooplankton and macroinvertebrate taxa from one site in Barberspan. This site corresponded with one of the sites from the current study.

The current project identified approximately 48 taxa (Table 7) between Barberspan and Leeupan during three surveys in 2014 and 2015. Therefore, this study has shown that a more detailed and extensive aquatic invertebrate survey can lead to additional taxa being identified that occur within the system. More detailed zooplankton and macroinvertebrate information and data from Barberspan can be found in Appendix A.

Table 7: Zooplankton and macroinvertebrate species recorded in Barberspan and Leeupan during the surveys in 2014 and 2015

Zooplankton taxa	Macroinvertebrate taxa	Macroinvertebrate taxa
Crustacea – Cladocera	**Insecta – Coleoptera**	**Insecta – Hemiptera**
Chydoridae:	**Curculionidae:** Neochetina sp.	**Aphelocheiridae:**
Alona sp.	**Dytiscidae:**	*Aphelocheirus* sp.
Leydigia sp.	*Hydaticus* sp.	**Corixidae:**
Pleuroxus sp.	*Tikoloshanes* sp.	*Micronecta* sp.
	Yola sp.	*Sigara* sp.
Daphniidae*:*	**Elmidae:** *Potamodytes* sp.	**Gerridae:** *Aquarius distanti*
Ceriodaphnia dubia	**Hydraenidae:** *Parasthetops* sp.	**Hebridae:** *Hebrus* sp.
Daphnia barbata	**Hydrophilidae:**	**Mesoveliidae:** *Mesovelia*
Daphnia carinata	*Amphiops* sp.	*vittigera*
Daphnia lumholtzi	*Berosus* sp.	**Naucoridae:** *Laccocoris* sp.
	Enochrus sp.	**Notonectidae:**
Macrothricidae:	*Laccobius* sp.	*Anisops* sp.
Macrothrix	*Sternolophus* sp.	*Enithares* sp.
Moinidae*:*	*Spercheus* sp.	*Plea* sp.
Moina micura	**Scirtidae**	**Saldidae:**
Crustacea – Copepoda		*Rupisalda* sp.
Cyclopoida	**Insecta – Diptera**	*Saldula* sp.
Calanoida*:*	**Chironomidae**	**Veliidae:** *Tenagovelia* sp.
Lovenula falcifera	**Culicidae:**	
Metadiaptomus	*Anopheles* sp.	**Insecta – Odonata**
meridianus	*Coquillettidia* sp.	*Anaciaeschna* sp.
	Uranotaenia sp	*Platycypha* sp.
Crustacea – Ostracoda	**Sciomyzidae**	*Ceriagrion* sp.
	Tabanidae	*Ischnura* sp.
		Pseudagrion sp.
	Insecta – Ephemeroptera	*Sympetrum fonscolombii*
	Baetidae	
		Mollusca – Gastropoda
		Ferrissia sp.
		Physa acuta

2.9.4 Fish

The fish community of Barberspan is not very diverse, with ten different species occurring. Fish research has really been limited to work done in the 1960s by Goldner (1967) and Enslin (1966) as part of two MSc projects. These studies focused on a population study of the freshwater fish in Barberspan (Goldner, 1967) and a feeding habit study of various fish species from Barberspan (Enslin, 1966). Another article was published on the food habits of fish in Barberspan (Schoonbee, 1969). The fish community present in Barberspan is closely related to the species found in the Harts River. The species most commonly found are *Labeobarbus aeneus*, *Labeo umbratus*, *Labeo capensis*, *Cyprinus carpio* (alien), *Micropterus salmoides* (alien), *Pseudocrenilabrus philander*, *Tilapia sparrmanii*, *Gambusia affinis* (alien), *Barbus paludinosus*, *Barbus anoplus* and *Clarias gariepinus*. The endangered largemouth yellowfish, *Labeobarbus kimberleyensis* does occur in the Harts River but there is no record of it occurring in Barberspan.

One of the major problems related to Barberspan is the presence of fish species in the nearby Leeupan. These species moved from Barberspan into Leeupan during extreme high flow events. However, the saline, eutrophic conditions in Leeupan often result in fish kills of specifically *Cyprinus carpio* that can lead to botulism in birds. The most recent fish kill event occurred in November 2013 (Grant, 2013). The cause of the event was related to a proliferation of diatoms that were trapped on the gills that then resulted in oxygen deprivation (Grant, 2013).

The fish surveys during 2014 and 2015 indicated that the fish taxa were similar to the Schoonbee (1969) study. However, no *M. salmoides* (bass) were sampled during the current surveys. The current survey also assessed the fish health of *Labeo capensis*, *Labeo umbratus* and *Clarias gariepinus* during the surveys in 2014. Although organ abnormalities were present in the selected fish species, the overall health of the fish was good. Metal concentrations in *L. capensis* and *C. gariepinus* were determined using microwave digestion and ICP-MS analysis. Metal concentrations in *L. capensis* and *C. gariepinus* were found to be mostly from natural origins (Malherbe et al., 2015). More detailed results for these studies are presented in Appendix A.

The fish surveys also found extensive populations of *Argulus japonicus,* mostly on *Labeo umbratus* and *Cyprinus carpio*. Additionally, *Pseudocrenilabrus philander* and *Enteromius paludinosus* were assessed for the presence of parasites. The assessment on *P. philander* identified the copepod *Lernaea cyprinacea*, the monogenean *Gyrodactylus thlapi* and four gryporhynchid metacestode (Cyclophyllidea) species: *Paradilepis scolecina*, *Paradilepis maleki, Neogryporhynchus lasiopeius* and *Valipora campylancristrota*. The assessment of *Enteromius paludinosus* indicated that the monogenean parasites *Dogielius intorquens*, *Dactylogyrus teresae*, and three *Dactylogyrus* spp. were sampled (Truter et al., 2016).

2.9.5 Amphibians

Very little information is available for amphibians from Barberspan and no specific amphibian information for Barberspan could be found. The information in the amphibian list (Table 5) was extracted from FrogMAP (2016).

Table 8: A list of the amphibian species expected to occur within Barberspan Bird Sanctuary (from FrogMap)

Species code	Family	Genus	Species	Common name	Red list category
320	Bufonidae	*Sclerophrys*	*garmani*	Olive toad	Least concern
330	Bufonidae	*Sclerophrys*	*gutturalis*	Guttural toad	Least concern
660	Hyperoliidae	*Kassina*	*senegalensis*	Bubbling kassina	Least concern
1050	Pipidae	*Xenopus*	*laevis*	Common platanna	Least concern
780	Ptychadenidae	*Ptychadena*	*anchietae*	Plain grass frog	Least concern
400	Pyxicephalidae	*Cacosternum*	*boettgeri*	Common caco	Least concern
850	Pyxicephalidae	*Pyxicephalus*	*adspersus*	Giant bull frog	Near threatened
990	Pyxicephalidae	*Tomopterna*	*cryptotis*	Tremelo sand frog	Least concern

2.9.6 Birds

Barberspan is renowned for its research on various aspects of bird taxonomy, ecology and other characteristics. These articles would be too numerous to mention here but research has focused on taxonomy, physiology, ringing, distribution, migration, dispersal of seeds and numerous other topics of interest. A full list of the bird species found in Barberspan is presented in Appendix B. The bird list is based on Southern African Bird Atlas Project 2 data (SABAP2, 2016) gathered by citizen scientists and avid birders, based on quarter degree squares and pentads. The yearly coordinated water bird count data for 2014–2016 was also used for the bird list in Appendix B. Overall, Barberspan Bird Sanctuary is home to approximately 365 bird species and it is an extremely important habitat in an otherwise arid region.

2.9.7 Aquatic mammals and other fauna

Information on aquatic mammals present in Barberspan is limited, with the major presence probably that of the Cape clawless otter (*Aonyx capensis*) and water mongoose (*Atilax paludinosus*).

2.10 Conclusion and recommendations

Barberspan Bird Sanctuary has been a Ramsar site of international importance since 1975 and, as such, is, together with De Hoop Vlei, the oldest designated site in South Africa. Despite this, very limited aquatic research has been completed at Barberspan during this time, with the majority of the research being focused on the bird community. Research on fish, macroinvertebrates and zooplankton was carried out during the 1960s, but since then no research on these aspects has been published.

Currently, the main threat to Barberspan Bird Sanctuary is the discharge of untreated or partially treated wastewater from various towns in the Harts River catchment. This has led to eutrophication and *E. coli* counts in the sanctuary being unacceptable. The surveys during this study have indicated that the fish, macroinvertebrate and zooplankton communities are still surviving despite the threat of pollution in the system.

The increased research focus from this study, as well as national initiatives to improve tourism around inland aquatic ecosystems, will likely have a positive influence on Barberspan. The main tourism activities for Barberspan remain birding tourism and fishing within the designated areas. The opportunities with new tourism initiatives will hopefully spark a revival in interest and research in the bird sanctuary.

The following research topics are recommended for future studies:

- Investigate changes in the fish community as compared to the studies in the 1960s, especially due to the introduction of alien invasive fish
- Implement a sustainable monitoring programme for water quality and macroinvertebrates in Barberspan
- Investigate the trophic structures within Barberspan using stable isotopes to determine the impact of pollution from sewage discharges
- Investigate the potential impact of *Argulus japonicus* (invasive fish parasite) on the fish community
- Further investigate fish parasites within the system – especially taking into account the migratory bird species present in the sanctuary.

3 DE HOOP NATURE RESERVE

3.1 Introduction

The De Hoop lake is 18 km long and 0.5 km wide, with a surface area of 6.2 km^2 when full. The depth of the lake is variable, from a maximum of 7 m during periods of flooding (only twice this century) to nearly completely dry (at least once this century) (Butcher, 1984). As a consequence of these extreme variations in water levels, the salinity can drop from 60 ppt to 3 ppt within a period of only two months (Butcher, 1984). During occasions of extensive flooding, which have occurred only twice this century, in 1906 and 1957 (Butcher, 1984), an area of up to 3 000 ha on the plain southwest of De Hoop Vlei may be inundated to a depth of up to 3 m. The water receded gradually after the 1957 inundation and provided very favourable conditions for a variety of wetland-dependent birds for up to 10 years afterwards.

3.2 Site location

The lake is situated on a coastal plain between 4 m and 11 m above mean sea level. The wetland is situated about 56 km east-north-east of the town of Bredasdorp, in the south-west of the Western Cape Province, along the southern Cape coast, at the tip of the African continent, in the south-west of the Republic of South Africa (34°26'S; 20°22'E) (Figure 7).

The Ramsar site is part of the De Hoop Provincial Nature Reserve, which is one of the largest natural areas managed by CapeNature. The terrestrial portion of the reserve covers an area of about 35 546 ha (355 km^2), while the marine portion of the reserve covers an area of approximately 25 300 ha (253 km^2). The surrounding area outside the reserve is all privately owned. The original reserve was declared in 1957 but the additions to the reserve in the 1980s were only declared part of the reserve in 1990. The Ramsar site is one of the important facets of the Reserve and is dealt with appropriately in the management plan. The only monitoring carried out on the wetland is the quarterly counts of waterfowl.

Field surveys of De Hoop Vlei were completed during the low-flow season in March 2015. The water level during the surveys (Figure 8) was higher than normal reported levels. However, with the drought experienced during 2016, the water levels decreased.

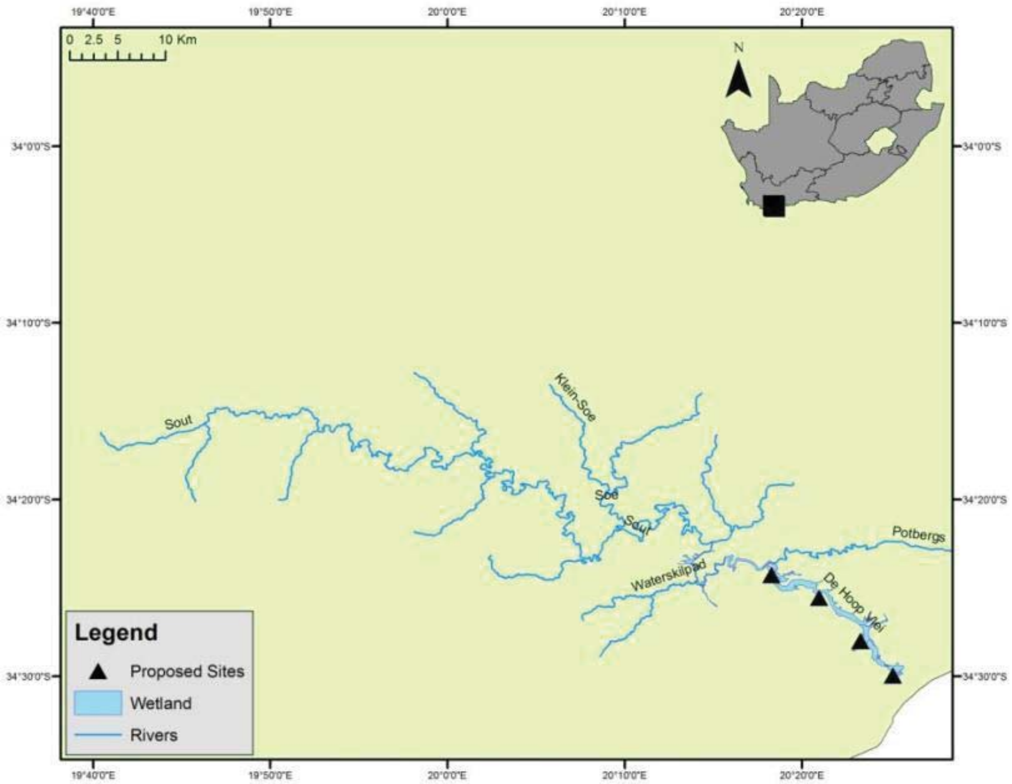


Figure 7: Site locations for De Hoop Vlei

Figure 8: Photographs of different habitats at De Hoop Vlei. (A) Western side with dead vegetation (B) Algal scum in shallow areas (C). Beach areas on the western side of De Hoop Vlei (D). Inflow to De Hoop Vlei from the Sout River

3.3 Ramsar criteria

De Hoop Vlei was designated as a wetland of international importance due to the following Ramsar criteria that were met:

- Criteria for representative or unique wetlands
  - A particularly good representative example of a natural or near-natural wetland type common to more than one biogeographical region
- General criteria based on plants and animals
  - It supports an appreciable assemblage of rare, vulnerable or endangered species or subspecies of plant or animals, or an appreciable number of individuals of any one or more of these species
- Specific criteria for using waterfowl
  - Where data on populations is available, it regularly supports 1% of the individuals in a population of one species or subspecies of waterfowl.

3.4 Physical features

3.4.1 Climate

The Ramsar site is situated in the eastern part of the temperate winter rainfall region, which has a Mediterranean climate. The mean annual rainfall is approximately 380 mm (at the De Hoop Nature Reserve Office), with the maximum mean monthly rainfall occurring in August and the minimum in December and January. Rainfall can vary by 15–17% from one year to the next, however. Summer rains commonly occur as cloudbursts, but rainfall is predominantly cyclonic associated with eastward movement of low-pressure cells crossing the south-western and southern Cape (Butcher, 1984; Toens, 1994). Orographic rainfall may account for large differences in rainfall between the lowlands and the high-lying ground such as the limestone hills and the Potberg, particularly towards the eastern extremity of the Potberg. Rainfall on the dunes may exceed 400 mm and that on the Potberg may exceed 700 mm per year. The mean annual precipitation for the Sout River catchment is 369 mm (Toens, 1994). Precipitation in the form of mist occurs in autumn and winter. At times, the whole Overberg area can be covered in a thick mist bank. Frost and hail occur occasionally. The warm Agulhas current results in temperate winters and warm summers.

Temperatures average 16.8°C per annum, with an average summer temperature of 20.5°C and average winter minimum of 13.2°C (Toens, 1994). The warmest month is January, with a mean air temperature of 22°C. The coldest month is July, with a mean air temperature of 11°C. Windy conditions are common, particularly in summer when the prevailing wind direction is south-westerly with an average velocity of 35 km/h. Wind speeds may reach 60 km/h or more at times.

3.4.2 Geology

The northern boundary of the reserve is characterised by the high-lying terrain of the Potberg range and the Hard Dunes (limestone hills) with a maximum height of 611 m and 224 m above sea level respectively. A hard calcrete capping, less than 0.5 m thick, generally occurs in the older limestone terrain, with softer material below.

The Potberg represents the remnant of a syncline of the Cape Folded Ranges, which is truncated to the south by a major fault at the base of the range. The Table Mountain Group (TMG) quartzite strata dip northwards, forming steeper slopes and cliffs on the southern side (scarp slopes) and more gently dipping northerly slopes (dip slopes). Thick boulder talus and alluvial fans occur at the southern foot of the range. The TMG quartzites form sea cliffs where they are exposed beneath the Bredasdorp limestone.

The basement geology of the area comprises sedimentary rocks of the TMG (quartzites), Bokkeveld Group (shales and mudstones) and Uitenhage Group (mainly shale conglomerates). The resistant quartzites of the TMG form the Potberg range while the softer shales and conglomerates have been planed by marine transgressions into a gently southward sloping series of terraces.

The greater part of the reserve is underlain by tertiary limestone of the Bredasdorp Formation. These limestones cover most of the Bokkeveld and Uitenhage basement rocks within the reserve. Exposed Bokkeveld Shales and only very small exposures of the red conglomerates of the Uitenhage Formation can be found in the eastern section of the reserve. The Bredasdorp limestones were deposited as shallow marine environments (the De Hoop lagoon formation with shell fossils) and as coastal dunes (most of the rest of the deposits). The oldest deposits (Wankoe Formation) form the higher lying dunes into which the coastal plain had been eroded during subsequent marine transgressions. Subsequently, new dune systems (Klein Brak and Waenhuiskrans Formations) were formed on the coastal plain. The most recent member of the Bredasdorp Group was deposited within the last 10 000 years as a strip of unconsolidated dunes along the coast (Strandveld Formation). The sandstone and quartzite are approximately 4 000 million years old and the limestone 5 million years.

3.4.3 Vegetation

The margin of the lake is mostly bare and only a few *Phragmites australis* reedbeds are present, mainly around freshwater springs. The submerged macrophyte, *Potamogeton pectinatus,* forms extensive beds when suitable environmental conditions exist and may cover the greater part of the lake (Heÿl, 1983). This apparently contributes largely to the maintenance of the rich animal life in the vlei habitat. Other submerged macrophytes include *Ruppia* and *Chara* species. *Salicornia* species are dominant on the exposed bed of the lagoon.

3.4.4 Hydrology

The Sout River and its tributary, the Potteberg River, are the most important rivers feeding the De Hoop Vlei. There are also several fountains that discharge water into the northern part of the lagoon, which ensures that this area does not become as brackish as the rest of the lagoon. The greater part of the Sout River catchment of De Hoop Vlei falls outside the reserve.

Seasonal fluctuations of the De Hoop Vlei occur, with the lagoon drying up almost completely during the summer months and filling up during winter. The permanence of water in the lagoon depends on the amount of water flowing into the system and the type of summer (wind speed, length, temperature).

3.4.5 Water quality

The field survey in March 2015 sampled water at five sites within De Hoop Vlei as well as one depression that contained water. This field survey data was combined with other known data from De Hoop Vlei to determine a possible range of water quality for specific parameters within the site. The water quality ranges for the *in situ* and nutrient parameters in Table 9 were a combination of all these data sources. It is evident that the water quality can be quite variable depending on the site and the parameter, with oxygen and phosphate concentrations showing the largest variability. The electrical conductivity indicates the saline nature of the water in De Hoop Vlei while the oxygen, temperature and nutrients are different when compared between the depression and De Hoop Vlei itself.

Table 9: Water quality ranges for selected parameters determined during a survey in March 2015

Water quality parameter	Unit	De Hoop Vlei	Depressions
Oxygen saturation	%	29–108	140
Oxygen content	mg/L	2.4–9.1	11.3
pH	–	8.6–8.8	8.62
Temperature	°C	20–24	28.4
Electrical conductivity	ms/cm	8.8–10.2	15.1
Total Dissolved Solids	g/L	6.1–7.1	10.3
Nitrate	mg/L	1–1.5	1.1
Ammonium	mg/L	0.08	0.08
Phosphates	mg/L	0.3–7.5	0.84

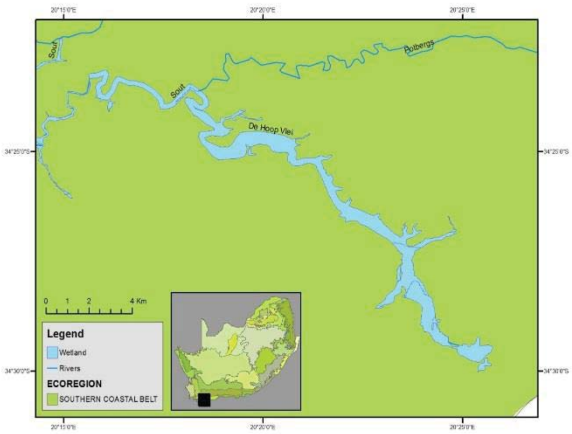
3.5 Wetland classification

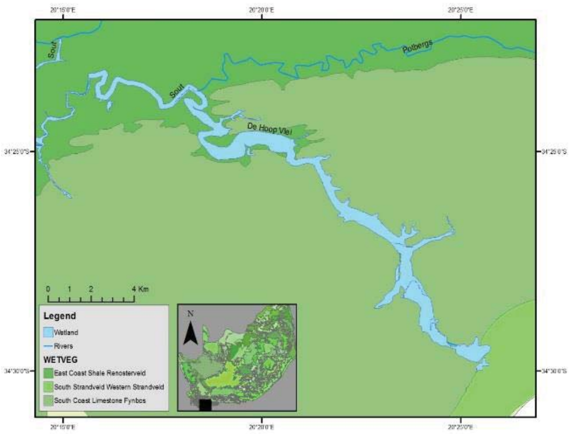
The classification of the various wetlands within the De Hoop Vlei Nature Reserve for Level 1 to Level 3 are provided in Table 10. The fieldwork focused on the main waterbody, De Hoop Vlei, and some of the other selected wetlands. Even though De Hoop Vlei is situated close to the Atlantic Ocean, none of the wetlands in Table 10 are estuarine or marine ecosystems as the focus was on the inland aquatic ecosystems. The reserve varies from sea level to around 224 m on the northern boundary, situated on the Potberg Mountain Range. The highest peak is situated at 611 m at Potberg. The Level 2 classification looked at the DWS ecoregion maps and the NFEPA WetVeg GIS layers to determine in which area De Hoop lies. The DWS layer indicated that De Hoop falls in the Southern Coastal Belt (Figure 9) while the NFEPA layer indicated that the reserve mainly falls in the South Coast Limestone Fynbos (Figure 9). When looking at Figure 9 it is also evident that the upper reaches fall in the East Coast Shale Renosterveld while the most southern lower reaches fall into the South/West Strandveld region (Figure 9). These classifications were done at a medium confidence level.

Table 10: Summary of the classification of De Hoop Vlei wetlands using Levels 1 to 3 of the NWCS (confidence ratings of the classification are given in brackets for each level)

Wetland Name	Level 1	Level 2		Level 3
	System	DWA Ecoregion	NFEPA WetVeg Group/s	Landscape Unit
De Hoop Vlei	Inland	Southern Coastal Belt	South Coast Limestone Fynbos	Valley floor (medium)
Depressions 1–3; 5–7	Inland	Southern Coastal Belt	South Coast Limestone Fynbos	Valley floor (medium)
Depression 4	Inland	Southern Coastal Belt	South Coast Limestone Fynbos	Plain (medium)

The landscape setting was determined using Google Earth and 5 m contour lines of the area. The landscape unit, Level 3, for the main waterbody, De Hoop Vlei, was deemed to be a valley floor with medium confidence. Within the De Hoop Nature Reserve, numerous depressional wetlands were present. Most of these did not have water during the March 2015 survey, as it was the low-flow survey. One of the depressions did have water and thus samples of the macroinvertebrates, water and plankton were taken. For the classification of these depressions, it was deemed that most of these systems were situated within a valley floor landscape setting. This was determined with medium confidence from the desktop and field surveys. Depression 4, which is situated at the south of De Hoop Vlei, was deemed to be a plain, at a medium confidence level. This depression is closely associated with De Hoop Vlei and potentially functions as a floodplain of the system.





A **B**

Figure 9: (A) Department of Water and Sanitation Level 1 Ecoregion (Kleynhans et al., 2005) for De Hoop Vlei Nature Reserve (B) NFEPA wetland vegetation group (Nel et al., 2011) for De Hoop Vlei Nature Reserve

As the field survey was completed during March 2015, the Level 4 classification of De Hoop Nature Reserve was also completed and the results are given in Table 11. The main De Hoop Vlei was found to be an endorheic depression with a channelled inflow. This was determined at a high confidence. The inflow into De Hoop Vlei is mainly from the Sout River, which drains a sizeable inland catchment, while a smaller river, the Potberg River also enters De Hoop Vlei in the upper reaches. The other wetlands that were sampled were all classified as depressions, at a high confidence level (Table 11). Although Depression 5 was classified as a depression, it was also deemed to be a floodplain and thus at Level 4 B it was deemed a floodplain depression. All the depressions were also found to be endorheic and none of the depressions had any channelled inflow. With the exception of Depression 5, which had a medium confidence level, the classification was completed with a high confidence level.

Table 11: NWCS Level 4 Hydrogeomorphic classification of the various units present at De Hoop Vlei Nature Reserve

Wetland Name	Level 4 : HGM Unit		
	4A	**4B**	**4C**
De Hoop Vlei	Depression (high)	Endorheic (high)	With channelled inflow (high)
Depressions 1–4; 6–7	Depression (high)	Endorheic (high)	Without channelled inflow (high)
Depression 5	Floodplain wetland (medium)	Floodplain depression (medium)	n/a

3.6 Present ecological state

The DWS (2014) Present Ecological State Environmental Importance and Sensitivity (PESEIS) assessment model was used for each of the Ramsar sites. This model provides the PES, environmental importance (EI) and environmental sensitivity (ES). EI looks at the biophysical aspects that are related to the wetland's capacity to function sustainably. ES considers attributes that relate to the sensitivity of the biophysical components to general environmental changes such as flow, water quality and geomorphological modifications. When the model was designed, it was with the objective of providing only a desktop model with information on ecological issues that are important for the protection and management of river reaches. The PESEIS model was specifically designed for rivers and some limited aspects of valley bottom wetlands. In the Ramsar sites case, the information within the model is useful to determine a PES for aquatic ecosystems that enter the Ramsar sites in many cases, or for downstream catchments that the Ramsar site provides services to. The De Hoop Vlei receives water from the Sout River. The PESEIS model evaluated the De Hoop Vlei reach of the river and the PES was given as Largely Natural. The EI was found to be Moderate while the ES was found to be High (DWS, 2014).

3.7 Land use and threats

Virtually the entire catchment area of the lake (1 108 km^2) is under private ownership and has largely been converted to agricultural land. Approximately 85% of the site, (i.e. within the nature reserve), is state owned. There are plans to remove dykes that were once built along the lake edge.

The fish *Oreochromis mossambicus* has been introduced to the lake and is now numerous. The native aquatic turtle *Pelomedusa subrufa* was very common as recently as the 1960s, but may have become a rarity. An interpretation centre is located at the nature reserve.

The development and operation of the Overberg Test Range has not resulted in a significant disturbance to the bird life of De Hoop Vlei as the aircraft flights are kept well away from the lake. The possible impact of the missile testing range is being monitored and strict requirements have been laid down for the operation of the testing range to ensure that disturbance is kept to acceptable minimum levels. (See report on the environmental implications of the proposed experimental weapons test and evaluation facility between Waenhuiskrans and Cape Infanta, Bredasdorp, dated 22 November 1983).

The possibility that land-use practices in the catchment may threaten the lake due to eutrophication by fertiliser runoff, pesticides and siltation due to increased erosion should be investigated.

3.8 Current recreation and tourism

A small amount of recreation in the form of game viewing, hiking, and mountain biking is taking place at the reserve under the management of CapeNature. However, limited overnight accommodation, camping, and picnic facilities are available at De Hoop. The accommodation has been outsourced as a concession. Facilities and numbers of visitors are limited to ensure that no damage is caused to the prime conservation-worthy resources of the reserve. There are proposals in the management plan to develop bird hides and a self-interpretative nature trail along the edge of the wetland.

3.9 Aquatic biodiversity information

3.9.1 Diatoms

Currently, no information on algae, diatoms or phytoplankton from the De Hoop Vlei has been published.

3.9.2 Zooplankton

Currently, no information on zooplankton from the De Hoop Vlei has been published.

3.9.3 Macroinvertebrates

A study undertaken between 1999 and 2007 revealed that the arachnids within the De Hoop Vlei were strongly dominated by gnaphosids (*Zelotes* and *Xerophaeus* spp., and *Drassodes ereptor*), lycosids (*Geolycosa* and *Pardosa* spp.), and *Heliophanus* spp. (Salticidae). Various gnaphosids, corinnids and pseudoscorpions were common in sifted leaf litter of *Sideroxylon inerme* (milkwood) trees near to the wetland (Haddad and Dippenaar-Schoeman, 2009).

The field survey of De Hoop Vlei Nature Reserve was completed during March 2015 and aquatic macroinvertebrates were sampled from sites on De Hoop Vlei as well as from one depression that still contained water (Table 12). The sampling resulted in 17 different families that occurred across all of the different sites. The most dominant taxa were found to be

Pomatiopsidae, Chironomidae and Corixidae. There were 11 families sampled in the ephemeral depression and these taxa are mostly generalist taxa expected to occur in these types of systems.

Table 12: Preliminary macroinvertebrate taxa collected at the various sites within the De Hoop Vlei area during the March 2015 sampling survey

Taxa	De Hoop Vlei	Depression
Pomatiopsidae	Yes	–
Aeshnidae	Yes	Yes
Chironomidae	Yes	Yes
Caenidae	Yes	Yes
Nematoda	Yes	–
Ostracods	Yes	–
Pontarachnidae	Yes	–
Amphipoda	Yes	–
Platycnemididae	Yes	Yes
Ceratopogonidae	Yes	Yes
Libellulidae	Yes	Yes
Hydrophilidae Berosus	Yes	Yes
Corixidae	Yes	Yes
Potamonautidae	Yes	–
Notonectidae	–	Yes
Baetidae	–	Yes
Dytiscidae	–	Yes

3.9.4 Fish

Only one indigenous fish species, *Sandelia capensis* has been recorded for De Hoop Vlei (Siegfried, 1963), but it is possible that *Galaxias zebratus* also occurs in the lake. *Oreochromis mossambicus* has been introduced to the lake and now occurs in large numbers (Van Rensburg, 1966; Scott and Hamman, 1988). No other published fish information was available.

The field survey completed at De Hoop Vlei during March 2015 sampled fish at approximately five localities within the main De Hoop Vlei. The fish sampled was predominantly *O. mossambicus* but *S. capensis* was also collected. No *G. zebratus* were collected during this field survey.

3.9.5 Amphibians

The Cape clawed frog (*Xenopus laevis*) is common (Heÿl, 1983), but water turtles (*Pelomedusa subrufa*) which were present in large numbers until the 1960s (Brand, 1961) may have become a rarity (Butcher, 1984). Currently, no other available information on amphibians from the De Hoop Vlei has been published. The information in the amphibian list (Table 13) was extracted from FrogMAP (2016).

Table 13: A list of the amphibian species expected to occur within De Hoop Vlei (from FrogMap)

Species code	Family	Genus	Species	Common name	Red list category
210	Brevicipitidae	*Breviceps*	*montanus*	Cape mountain rain frog	Least concern
240	Brevicipitidae	*Breviceps*	*rosei*	Sand rain frog	Least concern
370	Bufonidae	*Sclerophrys*	*capensis*	Raucous toad	Least concern
290	Bufonidae	*Vandijkophrynus*	*angusticeps*	Sand toad	Least concern
1050	Pipidae	*Xenopus*	*laevis*	Common platanna	Least concern
890	Pyxicephalidae	*Amietia*	*fuscigula*	Cape river frog	Least concern
400	Pyxicephalidae	*Cacosternum*	*boettgeri*	Common caco	Least concern
930	Pyxicephalidae	*Strongylopus*	*bonaespei*	Banded stream frog	Least concern
950	Pyxicephalidae	*Strongylopus*	*grayii*	Clicking stream frog	Least concern
1000	Pyxicephalidae	*Tomopterna*	*delalandii*	Cape sand frog	Least concern

3.9.6 Birds

A full list of the bird species found in De Hoop Vlei is presented in Appendix B. The bird list is based on SABAP2 (2014) gathered by citizen scientists and avid birders, based on quarter degree squares and pentads. The yearly coordinated water bird count data for 2014–2016 was also used for the bird list. To date, 259 bird species, which represents 70% of the 369 species known in the south-western Cape, have been recorded in the De Hoop Nature Reserve (Heÿl, 1983). This high species richness is ascribed to the high habitat diversity in this area (Uys and Macleod, 1987).

At least 75 bird species which are dependent on wetlands have been recorded at De Hoop Vlei, including 12 of the 18 South African waterfowl species (Heÿl, 1983). Regular monthly or quarterly counts of the birds on De Hoop Vlei have been undertaken since 1979 (Heÿl, 1983).

3.9.7 Aquatic mammals and other fauna

Currently, no available information on aquatic mammals from De Hoop Vlei has been published.

3.10 Conclusion and recommendations

The field survey of De Hoop Vlei in March 2015 provided some interesting information about the fish and macroinvertebrate community. The fish survey only yielded two fish species but the abundance (or biomass) of these fish was high. From literature and personal experience, it was evident that the alien invasive fish, *Oreochromis mossambicus*, was a dominant invader species in De Hoop Vlei and has the potential to lead to the extinction of the *Sandelia capensis*.

The establishment of the De Hoop Nature Reserve has led to increased protection of the reserve as well as the aquatic ecosystem.

The following research topics are recommended for future studies:

- Investigate the viability of the Cape kurper (*Sandelia capensis*) within De Hoop Vlei
- Investigate the presence of alien invasive fish and their effect on the *Sandelia capensis*
- Determine the ecosystem function using macroinvertebrates and indicator organisms
- Study the macroinverbrates for each site and determine their variability and any organisms that need the survived eppendorfs
- Survey the fish parasites on *O. mossambicus* and *Sandelia capensis.*

4 DE MOND NATURE RESERVE (HEUNINGNES ESTUARY)

4.1 Introduction

The Heuningnes Estuary extends along approximately 6.5 km of the Indian Ocean coast and 12 km across the flat coastal plain of the Zoetendals Vallei farm area; but it is only the lower 2 km stretch which shows estuarine characteristics. The estuary breaks out to the sea through a double dune ridge at De Mond Nature Reserve. De Mond Nature Reserve is Ramsar site number 342 and consists of the estuary, dune system and saltmarsh where shifting dunes are isolating the estuary. The landward part of the site is surrounded by agricultural land and the area is important for numerous birds breeding in the area. The site is seasonally important for locally migrant water birds. The site also provides habitat for various reptiles, notably crustaceans and the sea horse, *Hippocampus* sp.

4.2 Site location

De Mond Nature Reserve (34°41'–34°45'S; 20°05'–20°10'E) is located approximately 25 km from Bredasdorp, in the south-west of the Western Cape Province, between the coastal towns of Arniston and Struisbaai, at an altitude of between 0–30 m above mean sea level. The Indian Ocean forms the southern boundary of the site, with agricultural land forming the northern boundary where it meets coastal sand dunes (Figure 10). The site is managed by CapeNature.

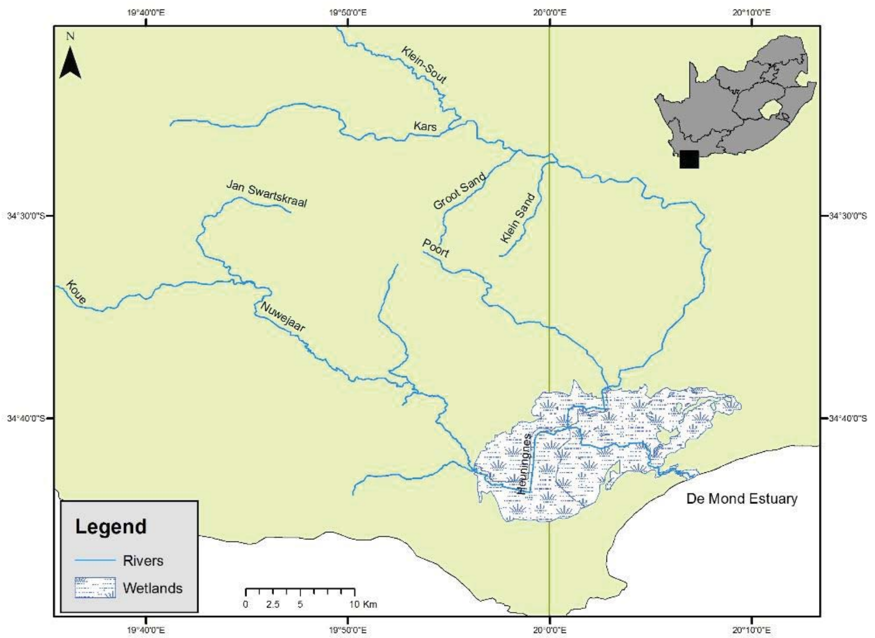


Figure 10: Site map of the De Mond Estuary situated in the Agulhas region in the Western Cape

A field survey was completed at De Mond Nature Reserve during March 2015 at the end of the low-flow season. The sites were selected according to even distribution from the mouth of the estuary, differences between areas and the time and resources available. Figure 10 shows the various sites that were selected for sampling in the estuary, with site 1 at the mouth of the estuary and the rest of the sites distributed inland. Figure 11 shows some of the different sites.

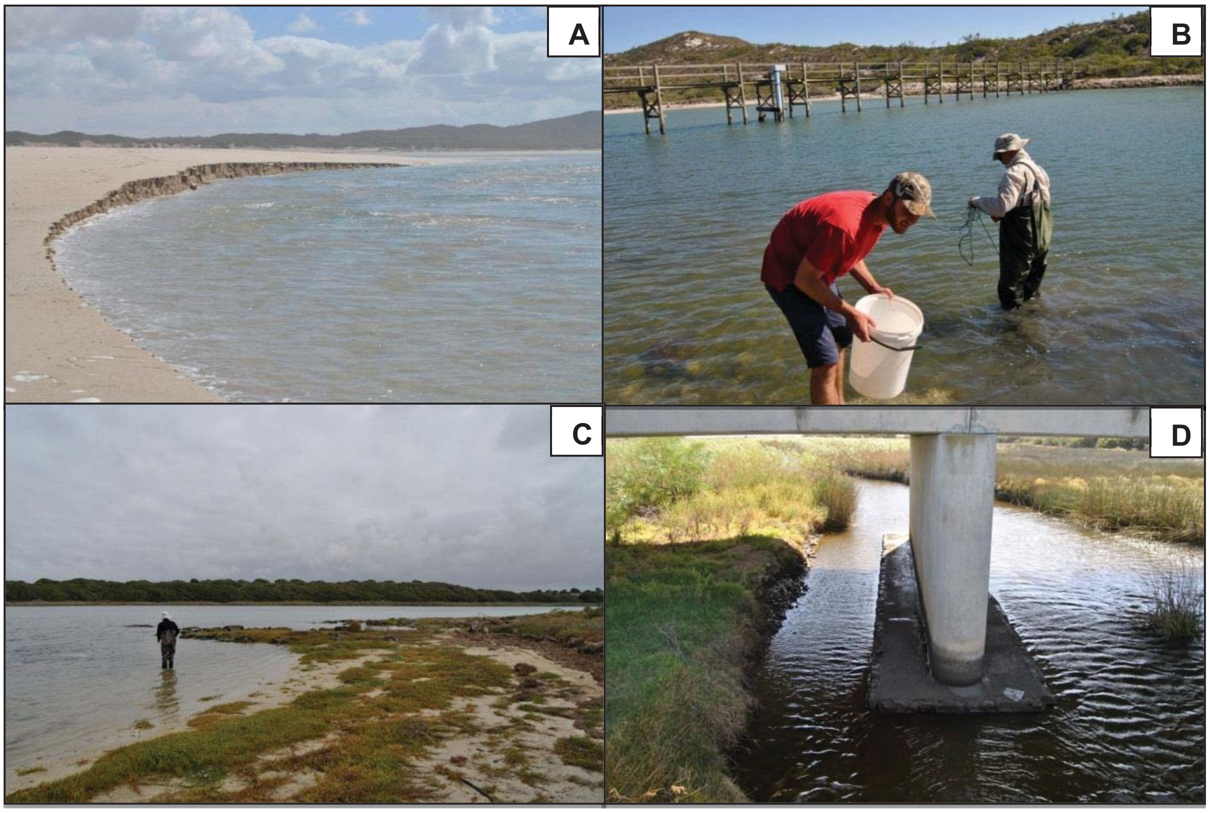


Figure 11: Site photographs for the Heuningnes Estuary. (A) Mouth (B) Bridge across (C) Salt marsh vegetation in the middle reaches (D) Bridge support in the upper reaches of the Heuningnes

4.3 Ramsar criteria

De Mond Nature Reserve was designated as a wetland of international importance due to the following Ramsar criteria that were met:

- Criteria for representative or unique wetlands
    - A particularly good representative example of a natural or near-natural wetland type common to more than one biogeographical region.
- General criteria based on plants and animals

- It supports an appreciable assemblage of rare, vulnerable or endangered species or subspecies of plant or animals, or an appreciable number of individuals of any one or more of these species
- It is of special value for maintaining the genetic and ecological diversity of a region because of the quality and peculiarities of its fauna and flora.

The Heuningnes Estuary is the most southerly estuary in Africa and is therefore scientifically important for species distribution extremities. Three tropical species, the ginger prawn (*Penaeus japonicus*), the giant mud crab (*Scylla serrata*), both crustaceans, and a tropical gastropod, *Nerita albicilla*, have been recorded in this estuary. These are the southernmost distribution records for these species.

4.4 Physical features

4.4.1 Climate

The Heuningnes and its catchment lie within a Mediterranean climatic region, receiving most rainfall in the winter from about May to September and characterised by a warm to hot and dry summer. The mean annual rainfall over most of the catchment is between 400 and 600 mm, with a mean annual precipitation of 447 mm for the Heuningnes drainage system. The effective catchment area for the estuary is 1 185 km^2. The average daily maximum temperature is 28°C in January and 17°C in July. The average daily minimum temperature is 15°C in January and 6°C in July. Sunshine duration varies from about 60% of the possible duration in July to over 70% in January.

4.4.2 Geology

The geology of the upper catchment of the Kars River is dominated by TMG sandstone, quartzite and shales of the Heuningberg Mountain near Bredasdorp in the southern parts and Bokkeveld Shales in the undulating northern parts. Further downstream, east of Bredasdorp, the river traverses calcified dune sand and coastal limestone of the Bredasdorp Beds. The geology of the upper catchment of the Nuwejaars River is dominated by sandstone, quartzite and shales of the TMG. Post Malmesbury, pre-Cape granite outcrops occur on the southfacing slopes of the Heuningnes Mountain. Further downstream, near Elim, the Nuwejaars River transverses shale and sandy shale of the Bokkeveld Group, which persists eastwards to where the Nuwejaars River enters Zoetendalsvlei.

From Zoetendalsvlei and Nachtwacht, almost to the mouth of the Heuningnes River, the drainage system transverses calcified dune sand and coastal limestone of the Bredasdorp

Beds. Approximately 2 km from the mouth, the Heuningnes Estuary is situated on unconsolidated sand.

4.4.3 Vegetation

Habitat within the Ramsar site can be classified into three broad types: the estuary and associated river system; the dune system and associated pebble slacks; and vegetated areas. According to Acocks (1953), the vegetation of the area is classified as Coastal Macchia. Heydorn and Tinley (1980), however, describe the vegetation of the area as Dune Thicket and Coastal Heath, while Moll et al. (1984) describe it as South Coast Strandveld, being an open to closed (40–80% canopy cover) mid-high vegetation with evergreen and deciduous broad-leafed and less conspicuous succulent elements. Graminoid components and herbaceous species form the understorey.

4.4.4 Hydrology

The Heuningnes Estaury receives its water from the Nuwejaars and Kars Rivers, which drain into Zoetendals Vlei before the water flows into the Heuningnes Estuary. The Heuningnes Estaury experiences tidal influences up to the main road connecting Bredasdorp with Struisbaai; however, in the dry season this can extend to a weir just below Zoetendals Vlei.

4.4.5 Water quality

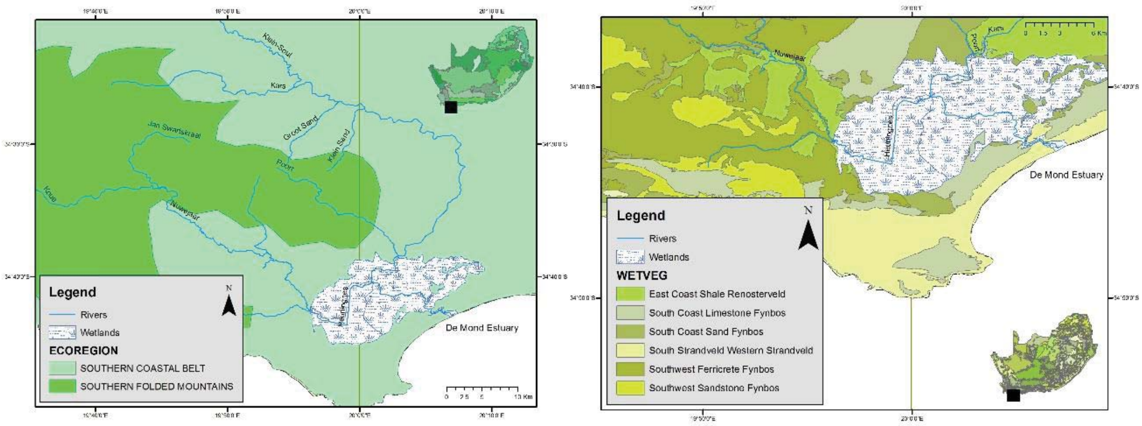
Water quality data was available from previous studies as well as a once-off survey during the current project in March 2015. Monthly pH values at three sampling stations in the Heuningnes Estuary were in the range of 8.0 to 8.6. The average water temperature in summer is 19.8°C, in autumn it is 17.5°C, in winter it is 13.3°C and in spring it is 17.3°C (Table 14). All of the other variables (pH, nutrients) showed very little variation across sites.

Table 14: Water quality ranges for selected parameters determined during a survey in March 2015

Water quality parameter	Unit	De Mond Nature Reserve
Temperature	°C	13–19
pH	–	8–8.4
Nitrate	mg/L	0.3–0.6
Nitrite	mg/L	0.02–0.13
Ammonium	mg/L	< 0.02
Phosphates	mg/L	0.14–3

4.5 Wetland classification

The De Mond Nature Reserve with the Heuningnes Estuary is situated within the Southern Coastal Belt DWS Ecoregion (Figure 12) and many of the rivers that feed into it are situated in the Southern Folded Mountains ecoregion. The vegetation groups present within the reserve, based on the NFEPA WetVeg GIS layer, are mainly South and Western Strandveld at the lower reaches of the estuary while further inland the vegetation is mainly South Coast Limestone Fynbos while small areas of South Coast Sand Fynbos are also present (Figure 12).



A B

Figure 12: (A) Department of Water and Sanitation Level 1 Ecoregion (Kleynhans et al., 2005) for De Mond Nature Reserve (B) NFEPA wetland vegetation group (Nel et al., 2011) for De Mond Nature Reserve

Estuarine classification is less complicated than classifying inland systems in South Africa as the diversity in types is lower. A breakdown of the estuarine classification from Level 1 to Level 4 is provided in Table 15 for reference. The table was adapted from SANBI (2009). The SANBI (2009) report can be consulted for more detail on each of the specific estuary types. The Heuningnes Estuary was classified using Table 15 and the results for Level 1 to Level 4 are provided in Table 16. The Heuningnes Estuary is mainly situated within the warm-temperate zone for the Level 2 classification; however, the distinction between warm- and cold-temperate is made at Cape Agulhas, which is approximately 30 km away. Thus, there could potentially be overlapping features and species. At Level 3 of the classification, it was deemed from previous studies that the Heuningnes Estuary is a permanently open estuary. When classifying the Heuningnes Estuary further, it is evident that the estuary is currently an open estuary. Open estuaries are permanently open systems that have a confined channel of a drowned river valley as well as tidal flats adajcent to the channel. The characteristics of these systems include the presence of vertical and horizontal salinity gradients and an average salinity between 10 and 35 (SANBI, 2009).

Table 15: The classification structure for estuarine systems in South Africa from Level 1 to Level 4 (adapted from SANBI, 2009)

<table>
<tr><th>Level 1: System</th><th>Level 2: Regional Setting</th><th>Level 3: Subsystem</th><th>Level 4: Hydrogeomorphic Unit</th></tr>
<tr><td>Connectivity to the open ocean</td><td>Biogeographic zones</td><td>Periodicity of connection</td><td>Landforms and hydrodynamics</td></tr>
<tr><td rowspan="7">Estuarine</td><td rowspan="7">Cool-temperate zone
Warm-temperate zone
Subtropical zone</td><td rowspan="4">Permanently open</td><td>Estuarine bay</td></tr>
<tr><td>Estuarine lake</td></tr>
<tr><td>Open estuary</td></tr>
<tr><td>River mouth</td></tr>
<tr><td rowspan="3">Temporarily open / closed</td><td>Estuarine lake</td></tr>
<tr><td>Closed estuary</td></tr>
<tr><td>River mouth</td></tr>
</table>

Note: The 2nd row of the table provides the criteria to distinguish between the wetland units in each column.

Table 16: The classification of the Heuningnes Estuary in the De Mond Nature Reserve from Level 1 to Level 4

Level 1: System	Level 2: Regional Setting	Level 3: Subsystem	Level 4: Hydrogeomorphic Unit
Estuarine	Warm-temperate zone	Permanently open	Open estuary

4.6 PES/Ecosystem services

The DWS (2014) PESEIS assessment model was used for each of the Ramsar sites and this model provided the present ecological state (PES), environmental importance (EI) and environmental sensitivity (ES). EI looks at the biophysical aspects that are related to its capacity to function sustainably. ES considers attributes that relate to the sensitivity of the biophysical components to general environmental changes such as flow, water quality and geomorphological modifications. When the model was designed, the objective was to provide only a desktop model with information on the ecological issues that are important for the protection and management of river reaches. The PESEIS model was specifically designed for rivers and some limited aspects of valley bottom wetlands. In the Ramsar site case, the information within the model is useful to determine a PES and what the current expected biodiversity should or could be.

The Heuningnes Estuary is fed by the Heuningnes River, which receives water from the Kars River as well as Zoetendalsvlei, which receives water from the Nuwejaars River. At present, the PESEIS model did not determine a PES for the Heuningnes River or the Kars River. The Nuwejaars River had a PES of largely modified.

4.7 Land use and threats

The land use is generally agriculture outside the boundaries of the De Mond Nature Reserve, which can result in numerous impacts on the estuary. The main agricultural activities are generally rotational grains and pastures, with livestock farming often found in the floodplain areas. Pesticides and artificial nutrients are already widely used by the agricultural sector in the area. Recreational and coastal development pressures are also increasing in all South African coastal areas.

Human activities within the site include management of the site, and low impact recreation, e.g. hiking and fishing. The coastal towns of Struisbaai and Waenhuiskrans are in close proximity, and during school holidays these towns attract a large number of holidaymakers. A number of these visitors travel along the beach looking for fishing spots and may end up in the Ramsar site. There are also a few visitors that take long walks along the beach and may enter the reserve.

4.8 Current recreation and tourism

The De Mond Nature Reserve has the following activities and facilities:

- The 7 km Sterna Day Trail, for hikers and mountain bikers, passes through riverine vegetation, dune forest and stabilised dunes before following the coast to the river mouth and saltmarshes
- Both freshwater and marine angling are permitted, but angling licences must be obtained from CapeNature or the gate office at De Mond
- No canoeing is permitted
- Overnight accommodation is available in a fully equipped three-bedroom cottage that sleeps six
- Picnic sites are available for day visitors.

4.9 Aquatic biodiversity information

4.9.1 Diatoms

No published information is available, but filamentous green algae (*Enteromorpha linga* and other *Enteromorpha* species), an *Ulva* species as well as an *Arthrocarcia* species have been reported from this area (Mehl, 1973).

4.9.2 Zooplankton

A study undertaken on the zooplankton composition, distribution and abundance in selected south and west coast estuaries of South Africa provided the following information for the Heuningnes Estuary (Montoya-Maya and Strydom, 2009b). The dominant groups were found to be Copepoda (81%), Amphipoda (6.1%) and Cladocera (5.1%). Dominant taxa were *Pseudodiaptomus hessei* (44.1%), Cyclopoida (22.3%) and Harpacticoida (8.5%). No other zooplankton studies were available for the De Mond Nature Reserve.

4.9.3 Macroinvertebrates

The Heuningnes Estuary has a tidal influence for 12 km upstream. The mouth has been kept open artificially since 1976. This has resulted in a strong marine influence on the aquatic fauna of the estuary. As this is the southernmost estuary in Africa it is important for documenting the southernmost extremities in the distribution of estuarine species. Examples of these are the ginger mud prawn, *Penaeus japonicus*, the giant mud crab, *Scylla serrata*, (both tropical crustaceans), and a tropical gastropod, *Nerita albicilla*. Hodgson (2010) undertook a study on the reproductive seasonality of southern African inshore and estuarine invertebrates and the Heuningnes Estuary formed part of the study area. The Heuningnes Estuary was the study site for a study on the sea-grass relationships in temperate South African estuaries focusing on the interplay between patch size, within-patch location and algal fouling (Källén et al., 2012).

The field survey data from March 2015 for the Heuningnes Estuary is presented in Table 12 for the combined data from all of the sampling sites. The macroinvertebrate results identified approximately 50 taxa and included taxa from Polychaeta, Bivalvia, Hirudiniae, Decapoda, Amphipoda, Mollusca, Gastropoda, and Isopoda. The full list of macroinvertebrates found in the estuary is found in Appendix C.

4.9.4 Fish

The presence of marine species such as baardman (*Umbrina canariensis*), galjoen (*Coracinus capensis*), zebra (*Diplodus cervinus*), and strepies (*Sarpa salpa*), not often found in estuaries, illustrates the marine influence on the estuary. The occurrence of the sea horse (*Hippocampus* sp.) is also noteworthy.

Cambray and Stuart (1985) undertook a study on the redfin minnow (*Barbus burchilli*). They mentioned that this species is endemic to the Heuningnes River system, although the study only focused on fish populations in the Breede River system. The Western Cape Province State of Biodiversity Report (2007) mentions that the Heuningnes redfin (*Pseudobarbus* cf. *burchelli)* is in a critically endangered state (unique species or lineage that only occurs in one catchment and under severe risk of extinction) as it is only known to occur in one location in the Upper Heuningnes River. The Agulhas *Galaxia* sp. is in an endangered state (less than three populations left and under severe risk of extinction) as it is known to be found in two locations in the Heuningnes and one in the Nuwejaars (CapeNature, 2007).

The ecology, osmoregulation and reproductive biology of the white steenbras (*Lithognathus lithognathus*) in the Heuningnes Estuary was recorded in 1974 (Mehl, 1973). The study indicated that the river estuary provided an abundant and varied diet for steenbras. Steenbras were present in the river throughout the year in large numbers and provided an ideal nursery ground for the younger fish.

The Heuningnes Estuary is a permanently open, freshwater deprived estuary and the fish below were caught there during a larval fish composition study undertaken in 2003–2004 (Montoya-Maya and Strydom, 2009a). A total of 18 species were caught from 11 families. The dominant families were Gobiidae with 89.4% of the total catch, Atherinidae with 4.2% of the total catch and Blenniidae with 3.4% of the total catch. The dominant species were *C. gilchristi* which comprised 72.9% of the total catch, *P. knysnaensis* with 12.5% of the total catch and *A. breviceps* with 4.2% of the total catch. The mean fish larvae density per 100 m^3 was 103, ranging between 0 and 2 415.

A study undertaken by Swartz et al. (2009) looked at the phylogeny and biogeography of the genus *Pseudobarbus* sp. (Cyprinidae). A study undertaken by Harrison (2002) also assessed the biogeography of fishes in South African estuaries based on a dataset collected over the time period 1993–1999. The study found 24 fish species in the Heuningnes Estuary during this assessment. Of these, two species were freshwater species (*Sandelia capensis* and *Galaxia zebratus*); five species were estuarine; fourteen species were estuarine-dependent marine taxa; and lastly, three species were marine species.

The field survey completed during March 2015 was limited in the amount of fish work that could be achieved. However, during the survey, eight fish species were collected. More detailed information can be found in Appendix C.

4.9.5 Amphibians

Currently, no information was found to be available on the amphibians of the Heuningnes Estuary or De Mond Nature Reserve. The information that is available was extracted from FrogMAP and is included for reference in Table 17 (FrogMAP, 2016).

Table 17: A list of the amphibian species expected to occur within De Hoop Vlei (from FrogMAP, 2016)

Species code	Family	Genus	Species	Common name	Red list category
210	Brevicipitidae	*Breviceps*	*montanus*	Cape mountain rain frog	Least concern
240	Brevicipitidae	*Breviceps*	*rosei*	Sand rain frog	Least concern
370	Bufonidae	*Sclerophrys*	*capensis*	Raucous toad	Least concern
290	Bufonidae	*Vandijkophrynus*	*angusticeps*	Sand toad	Least concern
580	Hyperoliidae	*Hyperolius*	*horstockii*	Arum lily frog	Least concern
1050	Pipidae	*Xenopus*	*laevis*	Common platanna	Least concern
890	Pyxicephalidae	*Amietia*	*fuscigula*	Cape river frog	Least concern
400	Pyxicephalidae	*Cacosternum*	*boettgeri*	Common caco	Least concern
950	Pyxicephalidae	*Strongylopus*	*grayii*	Clicking stream frog	Least concern
1000	Pyxicephalidae	*Tomopterna*	*delalandii*	Cape sand frog	Least concern

4.9.6 Birds

A full list of the bird species found in De Mond Nature Reserve (Heuningnes Estuary) is presented in Appendix B. The bird list is based on the Southern African Bird Atlas Project 2 data (SABAP2) gathered by citizen scientists and avid birders, based on quarter degree squares and pentads (SABAP2, 2016). The yearly coordinated water bird count data for 2014–2016 was also used for the bird list in Appendix B.

Bird species that regularly nest in the dunes within the reserve include kelp gulls (*Larus dominicanus*), Caspian terns (*Hydroprogne caspia*), the African black oystercatcher (*Haematopus moquini*), the blue crane (*Anthropoides paradisea*), the spotted prinia (*Prinia maculosa*), the Kittlitz sandplover (*Charadrius pecuarius*) and the Egyptian goose (*Alopochen aegyptiacus*) (Underhill, 1984). The pied kingfisher (*Ceryle rudis*) also nests in the area.

4.9.7 Aquatic mammals and other fauna

Currently no information was found to be available on the aquatic mammals of the Heuningnes Estuary.

4.10 Conclusion and recommendations

The De Mond Nature Reserve and Heuningnes Estuary are extremely important in many marine fish life cycles where juvenile fish need to enter an estuary as a nursery ground. Various fish surveys have been completed within the system that have signified its ability to support a large fish community. The diversity of macroinvertebrates is also extensive, and many tropical species have been found here as their southernmost distribution limit.

However, the research indicated that the Heuningnes Estuary is facing threats from agriculture, increasing human demand for water resources, pollution, and increased urban or semi-urban populations. The current condition for the Heuningnes Estuary was not determined but the estuary is in a very good condition (based on previous assessments), despite some impacts entering the system from the freshwater environment.

The following research topics are recommended for future studies:

- Further research should be completed on the benthic invertebrate community distribution throughout the estuarine system
- Water quality assessments should be implemented on a routine basis
- Further sediment quality assessments should be completed to determine possible sources of pollution from agricultural land use in the catchment
- Research on fish parasites is lacking and should be completed.

5 MAKULEKE WETLANDS

5.1 Introduction

The Makuleke Wetlands are situated in the north of the Kruger National Park (KNP) and are classified as a floodplain vlei (Deacon, 2007; Antrobus, 2014). The wetlands' boundary falls within the flood level of the Luvuvhu and Limpopo Rivers (Deacon, 2007). The Limpopo River, which is the border between Zimbabwe and South Africa, is the northern boundary of the Ramsar wetland (Deacon, 2007; Antrobus, 2014). The border with Mozambique is the eastern boundary of the wetland, with Banyini Pan and KNP being the western boundary (Deacon, 2007). The Hapi drainage line, south of the Luvuvhu, is the southern boundary of the wetland (Deacon, 2007). The wetland comprises a total of 7 756.98 ha and the pans comprise approximately 347 ha of the total area (Deacon, 2007). Banyini Pan has the highest elevation, at 235 m above sea level (asl), and the confluence between the Limpopo-Luvuvhu has the lowest, at 190 m asl (Deacon, 2007). The origins of the wetlands are due to geographical features (Tinley, 1978). The wetland falls in the "tropical premontane arid thorn woodland" climate area, with winter months being dry and mild and summer months being humid and hot (Deacon, 2007).

5.2 Site location

The Makuleke Wetlands Ramsar site is situated in the northeast corner of South Africa, bordered by Zimbabwe to the north and Mozambique to the east. The largest portion of the site is found within the KNP and only a small section is situated outside the KNP, in the Makuleke Property Area. This whole section that has been established as a Ramsar site is part of the Makuleke Concession Park within the KNP. The nearest town is Thoyandou, located approximately 65 km to the southwest, in the Limpopo Province.

The biogeographic region of the Makuleke Wetlands is situated within the southern temperate biogeographical region of the world. The specific biogeographic area can be classified as Southern Temperate Highveld Freshwater (ERSI, 2001). The regional classification within South Africa using the Ecoregion Classification Scheme indicates that the site is situated in the Limpopo Plain (Ecoregion 1.01) (State of the River Report, 2001).

Ten pans were selected in Febraury 2015 to be included in the study, and these were Banyini, Gila, Hapi, Hulukulu, Jachacha, Makwadzi, Mapimbi, Nhlangaluwe, Nwambi and Reedbuck Vlei (Figure 13). The pans were selected from both the Limopopo and Luvuvhu floodplains. All the pans were sampled during the wet season; however, only Makwadzi, Mapimbi and Hapi pans were sampled during the dry season as the other pans were dry (Figure 14).

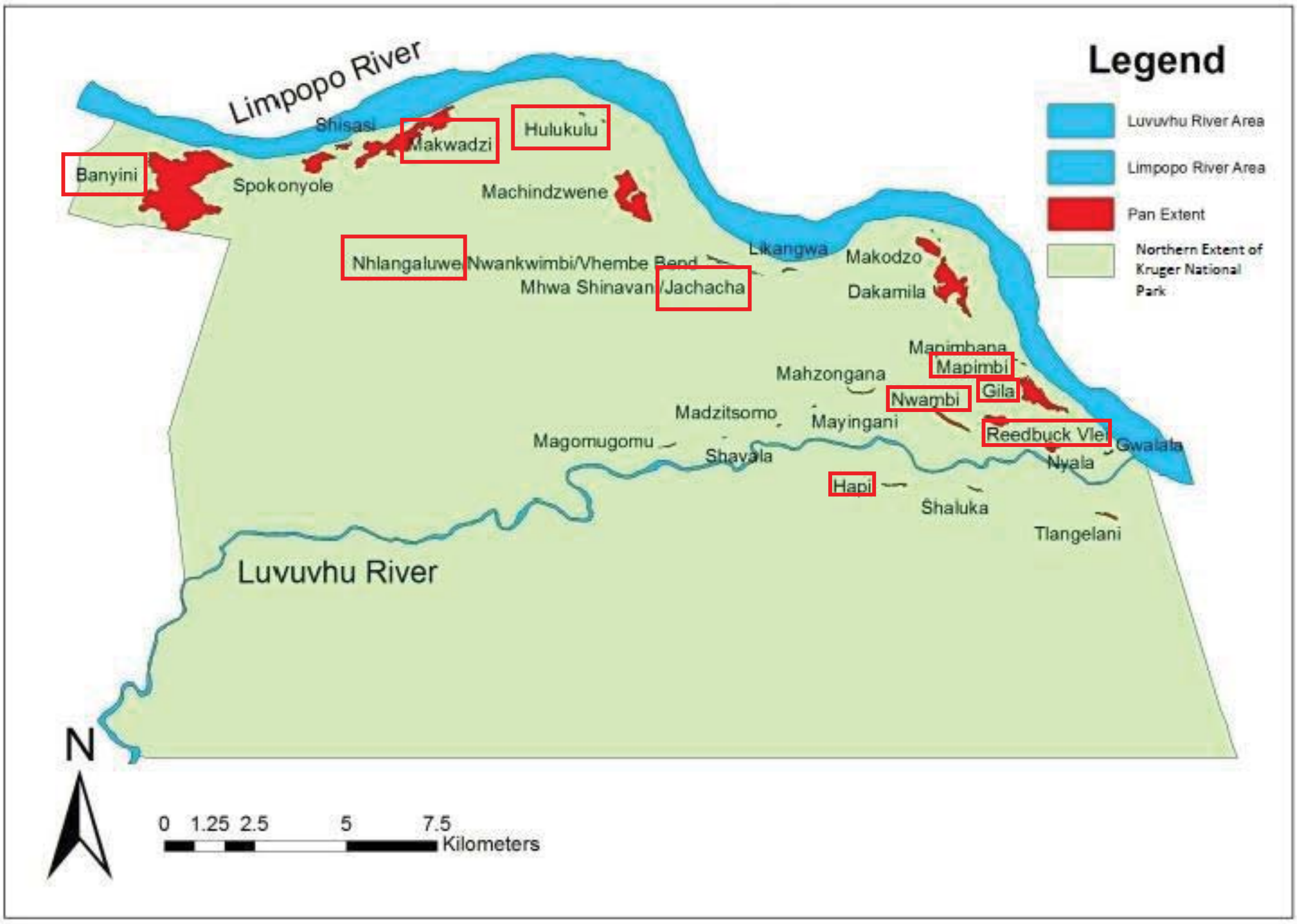


Figure 13: Map showing the pans found in the Makuleke Wetlands. Highlighted pans are those from which samples were collected. (Source: Nesbitt, 2014)

5.3 Ramsar criteria

The Ramsar Convention on Wetlands of International Importance has a set of nine criteria that are used to determine if a wetland is of international importance. These criteria are divided into two main groups, with one looking at the representativeness, rareness and uniqueness of the wetland, while the second category focuses on conserving biological diversity. In the case of the Makuleke Wetlands, four out of the nine criteria were met and, based on these, the site was included as a Ramsar protected wetland. A short description of each criterion is given below:

Figure 14: Site photographs of the various wetlands and pans associated with the Makuleke Wetlands (A) Banyini in the dry season (B) Jachacha in the wet season (C) Reedbuck Vlei in the dry season (D) Nwambi in the dry season (E) Mapimbi in the dry season (F) Mapimbi indicating the low water levels and algal presence in some of the wetlands

Criterion 1: The Makuleke Wetlands are an example of a floodplain vlei wetland that is characteristically found in the northern parts of South Africa and the eastern part of Mozambique. The riverine area can either be seasonal of permanent but the floodplain grassland is only inundated occasionally by larger flood events. The Luvhuvhu and Limpopo rivers have been affected in terms of lower flows due to human needs in the catchment but the floodplains within the Makuleke area have been relatively unaffected by anthropogenic activities.

Criterion 2: The Makuleke Wetlands have been part of the KNP for over 50 years and, as such, protection of the natural resources has been fairly good. Together with the variety of habitats present within the site, it is able to support a variety of endangered fauna and flora that are either dependent or not dependent on the wetlands itself. Vulnerable species dependent on the wetlands include nyala (*Tragelaphus angasii*), hippopotamus (*Hippopotamus amphibius*), Nile crocodile (*Crocodylus niloticus*) and African rock python (*Python sebae*). Other species, not dependent on the wetlands, that occur in the area include aardwolf (*Proteles cristatus cristatus*), brown hyaena (*Hyaena brunnea*), serval (*Leptailurus serval*), leopard (*Panthera pardus*) and African wild dog (*Lycaon pictus).* The Makuleke area is also important for the critically endangered Venda cycad (*Encephalartos hirsutus*). A number of nationally threatened bird species are also present at the site.

Criterion 3: The Makuleke Wetlands support a high biodiversity of species which includes species that have only been recorded from this area and species that have a wider distribution. Species that have only been recorded from the surrounding area include bats like Rüppel's bat (*Rhinolophus fumigatus*), Swinny's horseshoe bat (*Rhinolophus swinnyi*), the Madagascar large free-tailed bat (*Tadarida fulminans*) and Commerson's leaf-nosed bat (*Hipposideros commersoni*). The Ramsar site is also the southern limit for amphibians like the dune squeaker, *Arthroleptis stenodactylus*. The riparian areas support rare mammal species like the samango monkey (*Cercopithecus mitis erythrarchus*), four-toed elephant shrew (*Petrodromus tetradactylus*) and African civet (*Civettictis civetta*). Rare bird species such as the pygmy goose (*Nettapus auritus*), white-crowned plover (*Vanellus albiceps*), nesting white-backed vultures (*Gyps africanus*), Pel's fishing owl (*Scotopelia peli*), Böhm's spinetail (*Neafrapus boehmi*) and mottled spinetail (*Telacanthura ussheri*) occur in the area.

Criterion 4: The Makuleke Wetlands support populations in critical stages of their life cycles, which include breeding and feeding of terrestrial as well as aquatic animals. The area is also a refuge for water dependent organisms such as fish species, frogs and waterfowl. Nesting records for waterfowl such as the black stork (*Ciconia nigra*), yellowbilled stork (*Mycteria ibis*), marabou (*Leptoptilos crumeniferus*), open-billed storks (*Anastomus lamelligerus*), and three-banded courser (*Rhinoptilus cinctus*) are from this site. The wetlands also provide an important stopover for migrating waterfowl such as the lesser gallinule (*Porphyrula alleni*), the green sandpiper (*Tringa ochropus*) and a number of more common water birds. In terms of terrestrial mammals, the Makuleke area is also a migration corridor for elephant and antelope, as it links the KNP with the transfrontier parks in Zimbabwe and Mozambique.

Criterion 5: The Makuleke Wetlands are an important refuge area for breeding stocks of fish. The floodplain pans are generally recolonised by migrating fish during flooding events. When these flood events occur, large numbers of fish will migrate into the flooded area to feed and to breed. Once the spawning run has taken place, the adult fish will return to the main river as the water recedes. The eggs then have the opportunity to hatch, and fry can develop with less predation. Follow-up flood events then result in the fry moving into the main stem of the rivers. The main fish species found within the wetlands include Hamilton's barb (*Enteromius afrohamiltoni*), straightfin barb (*Enteromius paludinosus*), East coast barb (Enteromius *toppini*), tigerfish (*Hydrocynus vittatus*), various robbers (*Micralestes acutidens* and *Brycinus imberi*), *Labeo rosae, Labeo congoro, Labeo ruddi*, *Schilbe intermedius* and *Synodontis zambezense.* If no follow-up flood events occur, the floodplain becomes an important food source for piscivorous animals such as birds, mammals and reptiles that feed on the fish species trapped in the pans.

5.4 Physical features

5.4.1 Climate

The climate in the Makuleke Wetlands is characterised as dry lowveld with an annual rainfall of approximately 440 mm. The rainfall is mostly restricted to the summer season (85%). Evaporation in the Ramsar site is approximately 1 900 mm per annum and this occurs predominantly from October to March. The average maximum temperature is around 25°C. There is rarely frost in this Ramsar site.

5.4.2 Geology

The Makuleke area has nine different geological features with different rock types that determine the heterogeneity of habitats in the area (Venter, 1990; Viljoen, 2015). The main rock types are quartzite, sandstone, mudstone, shale and basic lavas (Waterberg, Stormberg and Karoo sedimentary rocks and lavas). Extensive floodplain alluvium occurs at the confluence of the Luvhuvhu and Limpopo rivers. The land is flat to slightly undulating. The Limpopo River has a well-developed levee and adjacent floodplain. Small, rounded, basaltic koppies sporadically protrude through the alluvium, and some of them (e.g. Timhisi) are capped by well-rounded, quartzitic boulders and cobblestones (Deacon, 2007). The Luvhuvhu River makes spectacular gorges upstream of the Makuleke Wetlands and when it exits Lanner Gorge the river flows onto the broad alluvial deposit that runs all the way to the confluence with the Limpopo River (Heritage, 1994). In the floodplain, the altitude seldom varies by more than

50 m (Venter, 1990). The main rock types on the border of the Limpopo River in the Makuleke Wetlands are gneisses, schist calcsilicate rocks and marble and metaquartzite of the Limpopo Metamorphic Complex.

When assessing the rivers that drain the north east of South Africa, it can be seen that the Luvuvhu River differs from the others as it flows over different rock types (Tinley, 1978; Nesbitt, 2014). To the west these rock types include quartzite and sandstone, the eastern rock types are basalt and the central area rock type consists of sedimentary rocks (Deacon, 2007; Nesbitt, 2014; Viljoen, 2015). The Luvuvhu River is underlain by floodplain alluvium that was formed when most of the Luvuvhu River's sediment load was deposited as it exits Lanner Gorge (Deacon, 2007; Smit et al., 2013). Schist calcsilicate rocks, metaquartzite, gneisses and marble are the main types of rock that occur in the Makuleke Property that is situated on the border of the Limpopo River in the west of KNP (Deacon, 2007).

5.4.3 Vegetation

The areas which occur immediately on either side of the Luvuvhu and Limpopo rivers are dominated by riverine forest; stands of tall and dense ana trees (*Faidherbia albida*), common cluster figs (*Ficus sycomorus*) and nyala trees (*Xanthocercis zambesiaca*). Tall fever trees (*Acacia xanthophloea*) are often dominant on the edges of pans (Antrobus, 2014). More than 256 plant taxa have been recorded in the Luvuvhu/Limpopo region (Zambatis and Zambatis., 1996), two of which are listed as threatened in the Red Data List of plants. Parts of this area, including the floodplain pans, have been poorly studied. Additional taxa can therefore be expected to be found here (Venter, 1990).

5.4.4 Hydrology

The Pafuri area is drained by the Limpopo and Luvuvhu Rivers and is characterised by steep gorges and high relief due to the Luvuvhu River's erosive action and the underlying geology's resistance to weathering (Deacon, 2007). The Luvuvhu River's catchment is approximately 5 941 km^2 (Smit et al., 2013). The Luvuvhu River forms a wide floodplain and, downstream of Lanner Gorge, numerous ephemeral pans (Tinley, 1978). The Luvuvhu River has recently stopped flowing in the winter months due to forestry, agricultural and mining activities that occur outside the boundaries of the KNP (Deacon, 2007; Smit et al., 2013). The Luvuvhu River has a mean annual runoff (MAR) of 395 million m^3/a which is unevenly distributed throughout the catchment (Deacon, 2007) with a mean annual precipitation (MAP) of 608 mm, and 1 678 mm mean annual evaporation (Smit et al., 2013).

Characteristics of the Limpopo River include a wide, sandy riverbed with a floodplain consisting of many large pans (Deacon, 2007). It should be noted that this is a seasonal river (Deacon, 2007; Nesbitt, 2014). During the summer months (when the river is flowing), the river can have a width of about a kilometre, and can spill its banks to fill the pans found within in the floodplain (Deacon, 2007). The Limpopo River has a MAR of 2 290 million m^3/a (Deacon, 2007).

The majority of the pans have large enough individual catchment areas to fill during heavy local rain showers or high floods. It is also possible to have groundwater seepage into the pans closest to the rivers (especially pans on the Limpopo River) when surface flow is high (Van der Waal, 1996). When there is high surface flow in the rivers the pans closest to them can be filled by groundwater seepage (Nesbitt, 2014). High floods and Limpopo River backflooding, are the two identified flood types on the Luvuvhu River (Deacon, 2007). The pans (Van der Waal, 1996) are generally shallow and can be alternatively dry or filled for more than one consecutive year. It is suggested that the pans become dry once in three years in normal situations. It is essential for the pans to be connected with the rivers in a flooding event in order to ensure recolonisation and exchange of fish and certain invertebrate species with the rivers.

5.4.5 Water quality

No water quality data was available for the depressions (pans) found within the Ramsar site in the Makuleke Concession. Some limited data was available for the Luvuvhu River but no data was found for the Limpopo River in the Makuleke Wetlands. The field surveys completed during 2015 (April, September and October) indicated variability in the water quality of the different pans. The ranges for the major water quality variables (Table 18) show that most variables varied during the surveys. Oxygen, electrical conductivity, pH, TDS and phosphates were shown to vary the most.

Table 18: Water quality ranges for selected parameters determined during surveys from 2014 to 2016

Water quality parameter	Unit	Makuleke Wetlands
Oxygen saturation	%	12–220
Oxygen content	mg/L	1–18
pH	–	7–10
Temperature	°C	22–33
Electrical conductivity	µs/cm	274–4270
TDS	mg/L	165–2940
Nitrate	mg/L	1–3
Nitrite	mg/L	0.01–0.6
Ammonium	mg/L	0.25–2.7
Phosphates	mg/L	0.4–5.5

5.5 Wetland classification

The summary classification for Levels 1 to 3 is provided in Table 19. The Makuleke Wetland systems are inland systems with elevation above sea level that ranges from 190 m at the Limpopo-Luvhuvhu confluence to 235 m at Banyini Pan on the western boundary of the Ramsar area (Deacon, 2007). The Level 2 regional setting was determined using two GIS layers, the NFEPA WetVeg Group for wetland vegetation (Nel et al., 2011) and DWS Level 1 ecoregions (Kleynhans et al., 2005). The wetland vegetation was identified as Mopane Group 1 and Mopane Group 2 (Figure 15) while the DWS ecoregion layer identified the area as situated on the Limpopo Plain (Figure 16). The ecoregion classification was high confidence while the wetland vegetation classification was medium confidence.

Table 19: Summary of the classification of the Makuleke Wetland systems using Level 1 to 3 of the NWCS (confidence ratings of the classification are given in brackets for each level)

Wetland Name	Level 1	Level 2		Level 3
	System	DWA Ecoregion	NFEPA WetVeg Group/s	Landscape Unit
All pans	Inland	Limpopo Plain (high)	Mopane Group 1/2 (medium)	Plain (high)
Limpopo River	Inland	Limpopo Plain (high)	Mopane Group 1/2 (medium)	Plain (high)
Luvhuvhu River	Inland	Limpopo Plain (high)	Mopane Group 1/2 (medium)	Plain (high)

The landscape setting was determined using Google Earth and 5 m contour lines of the area. This approach established that the various wetlands in Table 19 are not situated on a slope, or within 500 m of valley slopes, thus indicating that they are situated within a plain. The confidence rating for the landscape setting was high, from desktop work as well as the field surveys that were completed in 2015.

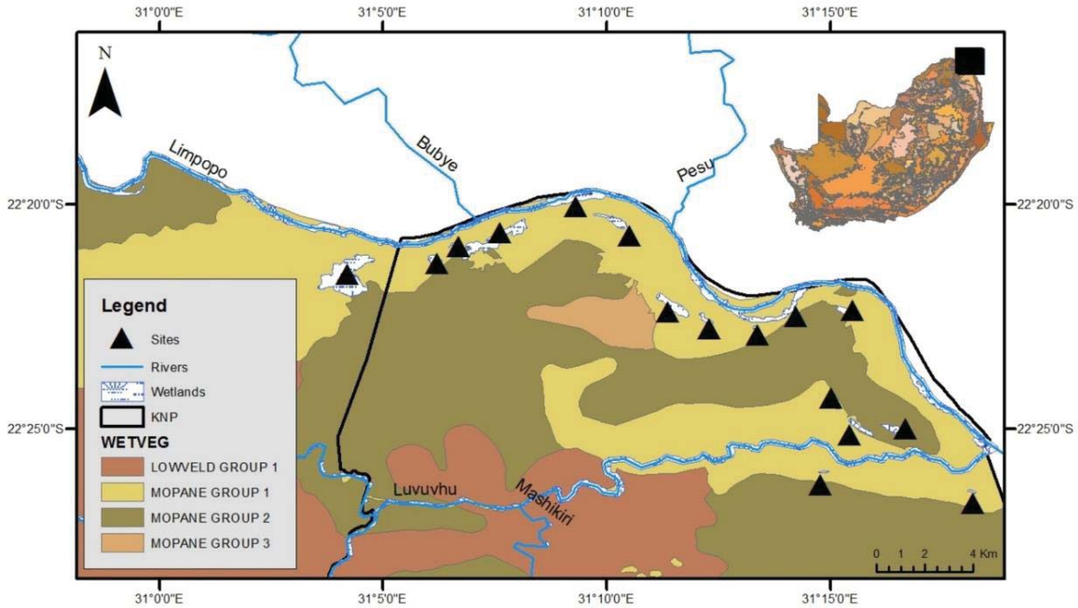


Figure 15: NFEPA wetland vegetation groups (Nel et al., 2011) for the Makuleke Wetlands Ramsar area

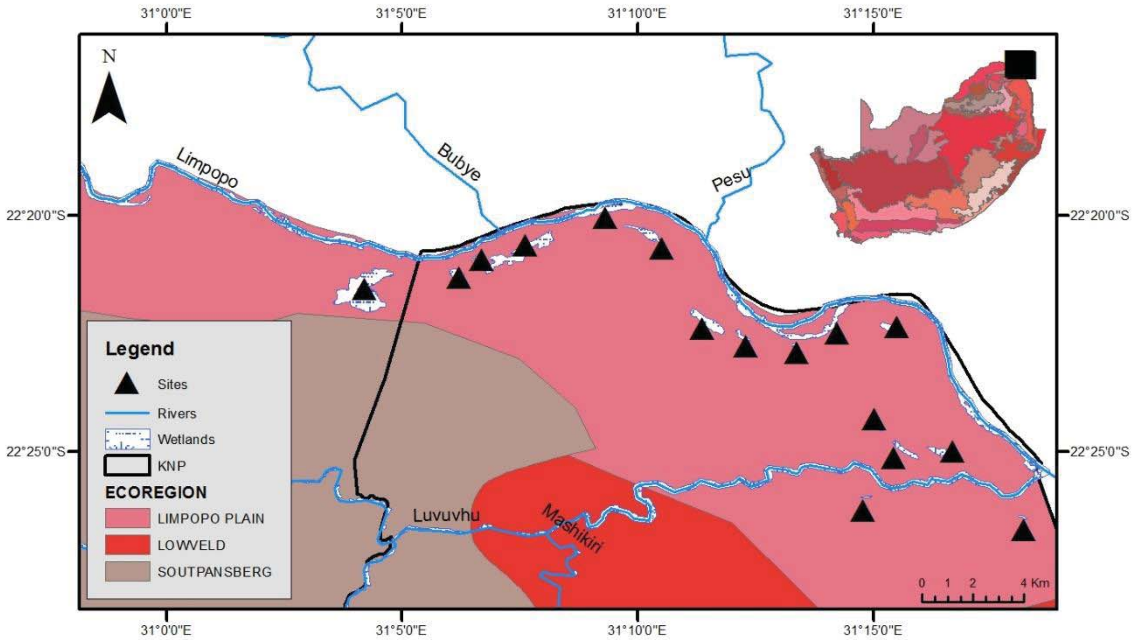


Figure 16: Department of Water and Sanitation Level 1 Ecoregion (Kleynhans et al., 2005) for the Makuleke Wetlands Ramsar area

The classification of the hydrogeomorphic wetland units for Level 4 of the classification system is provided in Table 20. Literature indicates that there are approximately 30–33 different specific wetlands in the floodplains of the Limpopo and Luvhuvhu rivers. For this current assessment, only selected systems were included in the classification as access to many of these areas is difficult. It is often also the case that these systems form massive wetland complexes depending on the water present. As many of these systems are located within the floodplains, it is also a dynamic system that will show variation due to flooding and deposition processes from the two rivers. Thus, the classification is based on the current information following field surveys during 2015.

Table 20: NWCS Level 4 hydrogeomorphic classification of the various units present at the Makuleke Wetlands

Wetland Name	Unit	Level 4 : HGM Unit		
		4A	4B	4C
Banyini, Makwadzi, Nhlangaluwe, Jachacha	1	Floodplain wetland (high)	Floodplain depression (medium)	With channelled inflow (high)
Gila, Hulukulu, Mapimbi, Hapi, Reedbuck Vlei, Nyala, Gwalala	6	Floodplain wetland (high)	Floodplain depression (medium)	Without channelled inflow (medium)
Nwambi	9	Depression (medium)	Endorheic (medium)	Without channelled inflow (medium)
Limpopo River	13	River (high)	Lowland river (high)	Active channel
Luvhuvhu River	14	River (high)	Lowland river (high)	Active channel

The two major features within the Makuleke Wetland Ramsar area are the Limpopo and Luvhuvhu rivers. These rivers drive many of the hydrological and geomorphological features in the wetlands highlighted in Table 20. Both of these rivers are lowland type rivers with slow-flowing water and sediment dominated substrates. The active channel of both of these rivers is well defined. The assessment of these systems is of a high confidence due to previous surveys, desktop reviews and the current surveys during 2015. The 12 different wetlands in the area that were classified up to Level 4 of the classification system are indicated in Table 14. No specific order was used to indicate these systems but in general it is ordered with Banyini being the furtherst west and Gwalala the more eastern site close to the confluence of the rivers. The data in Table 20 indicates that most of these systems are located within the floodplain of either the Luvhuvhu or Limpopo rivers at Level 4A hydrogeomorphic classification. The exception was Nwambi, which was deemed to be a depression; however, this was of medium confidence as Nwambi is located on the outer edge of the floodplain of the Luvhuvhu River and no direct evidence of a connection to the river was present. It is expected that Nwambi will receive water from the Luvhuvhu River at infrequent intervals and thus it generally functions more like an endorheic depression that does not have a channelled inflow.

The other wetlands were all deemed to be floodplain wetlands at Level 4A and floodplain depressions at Level 4B. The level 4A classification was high confidence while the level 4B was deemed to be medium confidence. However, when looking at aerial imagery and GIS maps it is evident that within these systems another distinction can be made in terms of the inflow drainage. The classification system does not currently make provision for a Level 4C categorisation for floodplain wetlands (Ollis et al., 2013). But within the Makuleke Wetlands there is a distinct difference between the floodplain depressions that have a channelled inflow and the ones that do not have channelled inflow. Therefore, it was decided to include a Level 4C for these systems to distinguish between the two types.

The vegetation present at each wetland is indicated in more detail in Figure 17. This is based on a GIS layer from SANBI that was generated by the Limpopo provincial government. Six different vegetation types are present, i.e. Limpopo Ridge Bushveld, Lowveld Riverine Forest, Makuleke Sandy Bushveld, Mopane Basalt Shrubland, Musina Mopane Bushveld and Subtropical Alluvial vegetation. The Subtropical Alluvial vegetation and Lowveld Riverine Forest have been classified as threatened. These two vegetation types are generally surrounding the wetlands identified in Table 20, with one of the characteristic trees in these groups being the fever tree, *Acacia xanthlophloea.* It must be noted that on a desktop scale it seems that Banyini, the furthest western site, is also closely associated with the Limpopo Ridge Bushveld and Musina Mopane Bushveld.

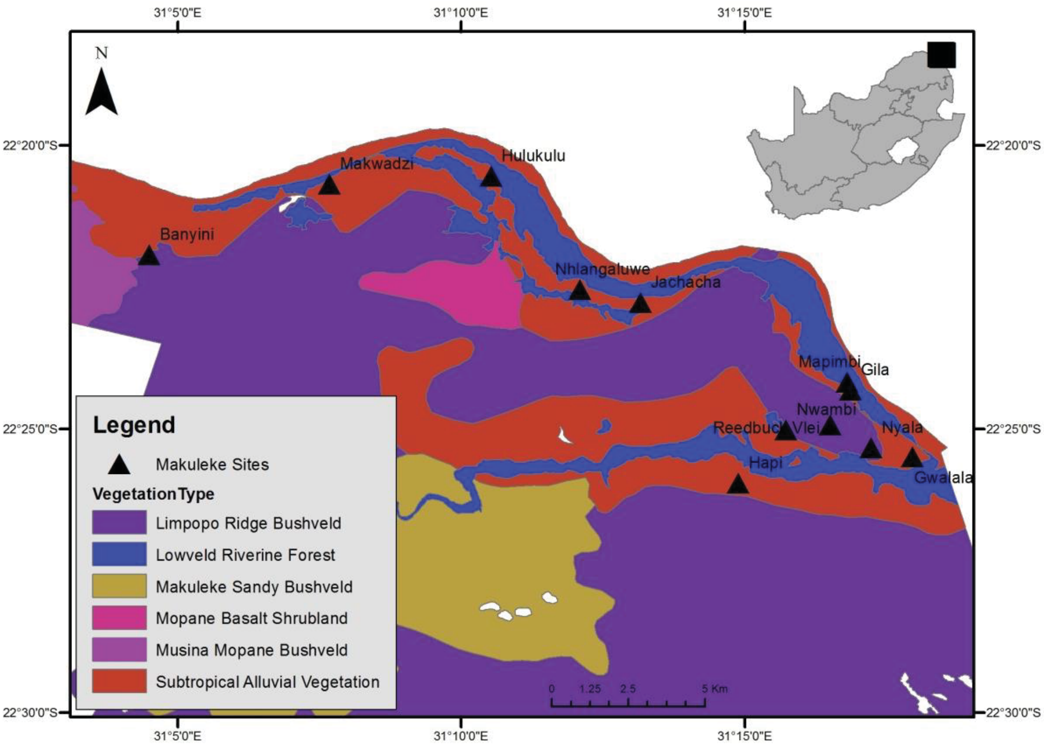


Figure 17: More detailed vegetation map of the Makuleke Wetlands area as well as the different wetlands that were sampled during April 2015

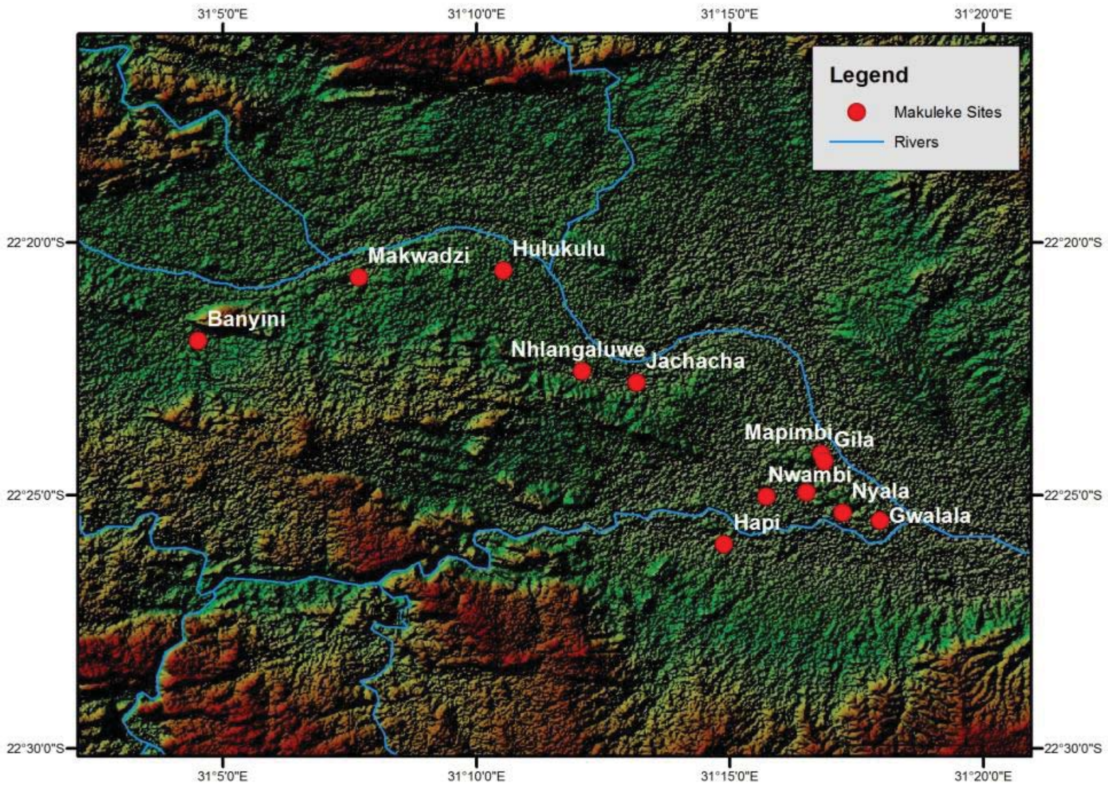


Figure 18: Digital elevation model for the Makuleke Wetlands Ramsar site in the northern part of the Kruger National Park

A digital elevation model was also constructed for the Makuleke Wetlands using contour data from the US Geological Survey. In Figure 18, the floodplains of the Limpopo and Luvhuvhu rivers are fairly obvious and extensive. The figure also indicates the drainage systems that are entering into many of these systems apart from the influence from the rivers in the Ramsar area.

5.6 PES/Ecosystem services

The DWS (2014) PESEIS assessment model was used for each of the Ramsar sites and this model provided the present ecological state (PES), environmental importance (EI) and environmental sensitivity (ES). EI looks at the biophysical aspects that are related to the site's capacity to function sustainably. ES considers attributes that relate to the sensitivity of the biophysical components to general environmental changes such as flow, water quality and geomorphological modifications. When the model was designed, the objective was to provide only a desktop model with information on the ecological issues that are important for the protection and management of river reaches. The PESEIS model was specifically designed for rivers and some limited aspects of valley bottom wetlands. In the Ramsar site case, the information within the model is useful to determine a PES and what the current expected biodiversity should or could be.

The Makuleke Wetlands Ramsar site has two main river reaches that are responsible for the maintenance of the floodplain wetlands, i.e. the Limpopo and Luvhuvhu River. The maintenance of the Ramsar sites is largely dependent on the maintenance of the water source and as such the river reaches are very important. The PESEIS model indicates that both reaches found within the Makuleke Wetlands have a PES of Largely Natural. The EI and ES of the Limpopo is High. The EI of the Luvhuvhu River is Very High while the ES is in the High category. Both of these reaches support up to 56 macroinvertebrate families and 36 fish species (Table 23).

The ecosystem services assessment for the Makuleke Wetlands (Figure 19) indicates that tourism and recreation, as well as the maintenance of biodiversity, are the main services that this wetland provides. Phosphate trapping, nitrate removal, toxicant removal and cultural significance are also important services.

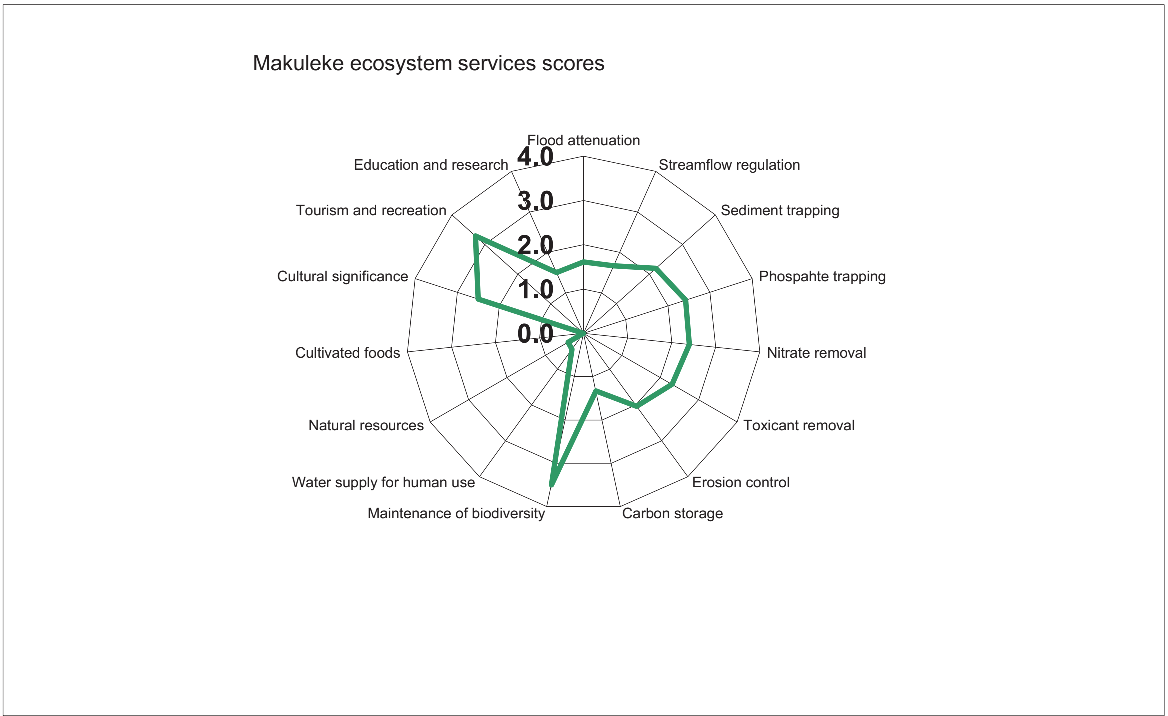


Figure 19: Ecosystem services of the Makuleke Wetlands

5.7 Land use and threats

The Makuleke Wetlands are very dependent on the Luvhuvhu and Limpopo rivers, especially since these rivers flood their banks periodically into the floodplain. Therefore, low flows within these rivers are a serious threat to the wetlands. Already evidence suggests that the Luvhuvhu River has changed from a perennial river to a seasonal flow river due to water abstractions (Venter et al., 1994). This has already affected the river and riparian zone within the KNP, where old fig trees have died off in certain places where the water table has lowered. The lower flows within the Luvhuvhu River have caused the following effects: extended periods of no flow in the river; receding groundwater levels; extensive stretches of river bed (channel) and pools or refugia drying up; and the accretion of sediment.

Additionally, the system is under threat from exotic aquatic plants, such as *Pistia* and *Azolla*, and from potential mining activities that are being investigated in the larger Luvhuvhu catchment. The redistribution of land to the previous owners also poses a risk, as local communities often do not share the conservation philosophy of the management authorities.

Anthrax is endemic to the area, making agriculture less viable. Therefore, the land use that is most suitable, sustainable and viable in the long term is nature conservation and ecotourism. Ecotourism, if managed properly, will impact the least on the biodiversity within the area (Venter et al., 1994). In terms of ecotourism, land use impacts are generally minimal and operators try to be environmentally sustainable.

Land use within the Limpopo and Luvhuvhu rivers is extensive and includes subsistence and commercial agriculture, industries, urban and rural areas. The southern border of the Makuleke Property outside the KNP is sparsely populated and is mainly used for grazing (Deacon et al., 2007). On the northern side of the Limpopo River, land use comprises the Chickwarakwara irrigation project while the rest of the area is tribal land used for subsistence agriculture and stock farming. A small concession area for trophy hunting is also present on the Zimbabwean side (Deacon, 2007).

5.8 Current recreation and tourism

The Makuleke Concession currently has three ecotourism or tourism initiatives: an ecotraining Camp, a wilderness camp on the Luvuvhu River near the main tar road linking Pafuri Gate to Punda Maria gate, and The Outpost Lodge on the Mutale River gorge just upstream of the confluence with the Luvuvhu River.

Tourism activities from the KNP are mostly from day visitors visiting the Luvuvhu picnic site and the confluence of the Limpopo and Luvuvhu rivers at Crook’s Corner. There is no general public accommodation in the concession, apart from three to five huts at Pafuri Gate. Most of the overnight guests are housed within the Makuleke Concession.

5.9 Aquatic biodiversity information

5.9.1 Diatoms

Currently, no published information is available on algae, diatoms or phytoplankton from the Makuleke Wetlands. The field surveys during 2015, in April and September, identified 70 diatom species (Table 21). Each of the different pans had a unique diatom community with around 15–20 taxa identified per pan. Detailed methods and analyses are provided in Appendix D.

Table 21: Diatom species present in the Makuleke Wetlands from two surveys, in April 2015 and September 2015

Species	Date described
Amphora pediculus (Kützing) Grunow	1880
Aulacoseira granulata (Ehrenebrg) Simonsen	1979
Caloneis aequatorialis Hustedt	1962
Cocconeis placentula Ehrenberg	1838
Craticula sp. Grunow	1868
Craticula accomoda (Hustedt) D.G. Mann	1990
Craticula accomodiformis Lange-Bertalot	1993
Craticula cuspidata (Kützing) D.G. Mann	1990
Cyclotella meneghiniana Kützing	1844
Cyclotella ocellata Pantocsék	1902
Cymbella cymbiformis Agardh	1830
Diploneis elliptica (Kützing) Cleve	1891
Discostella pseudostelligera (Hustedt) Houk and Klee	2004
Eolimna subminuscula (Manguin) Moser, Lange-Bert.and Metzeltin	1998
Eunotia formica Ehrenberg	1843
Gomphonema sp. Ehrenberg	1832
Gomphonema exilissimum (Grunow) Lange-Bertalot and Reichardt	1996
Gomphonema insigne Gregory	1856
Gomphonema lagenula Kützing	1844
Gomphonema parvulum (Kützing) Kützing	1849
Gomphonema pseudoaugur Lange-Bertalot	1979
Gomphonema sp. 2	1832
Gyrosigma sp. Hassall	1845
Hantzschia amphioxys (Ehrenberg) Grunow	1909
Navicula sp. Bory	1822
Navicula antonii Lange-Bertalot	2000
Navicula erifuga Lange-Bertalot	1985
Navicula germainii Wallace	1960
Navicula pusilla W.Smith	1853
Navicula radiosa Kützing	1844
Navicula ranomafanensis (Manguin) Metzeltin and Lange-Bertalot	2002
Navicula rhynchocephala Kützing	1844

Species	Date described
Navicula rosenbergii Oestrup	2006
Navicula sp. 1	1822
Navicula veneta Kützing	1844
Nitzschia sp. Hassall	1845
Nitzschia acidoclinata Lange-Bertalot	1976
Nitzschia amphibia Grunow	1862
Nitzschia archibaldii Lange-Bertalot	1980
Nitzschia capitellata Hustedt	1995
Nitzschia dissipata (Kützing) Grunow	1862
Nitzschia etoshensis Cholnoky	1966
Nitzschia filiformis (W.M.Smith) Van Heurck	1896
Nitzschia gracilis Hantzsch	1860
Nitzschia hantzschiana Rabenhorst	1860
Nitzschia intermedia Hantzsch	1880
Nitzschia irremissa Cholnoky	2008
Nitzschia liebetruthii Rabenhorst	1864
Nitzschia linearis (Agardh) W.M.Smith	1853
Nitzschia microcephala Grunow	1878
Nitzschia palea (Kützing) W.Smith	1856
Nitzschia paleacea (Grunow) Grunow	1881
Nitzschia pusilla (Kützing)Grunow	1862
Nitzschia reversa W.Smith	1853
Nitzschia sigma var. diminuta Grunow	1881
Nitzschia sp. 2 Hassall	1845
Nitzschia sp. 3 Hassall	1845
Nitzschia umbonata (Ehrenberg) Lange-Bertalot	1978
Pinnularia subbrevistriata Krammer	2000
Pinnularia viridis (Nitzsch) Ehrenberg	1891
Placoneis placentula (Ehrenberg) Heinzerling	1908
Rhopalodia gibba (Ehrenberg) O.Müller	1895
Sellaphora pupula (Kützing) Mereschkowksy	1902
Sellaphora stroemii (Hustedt) D.G. Mann	2002
Stauroneis anceps Ehrenberg	1843
Surirella abies Cleve-Euler	2010
Tryblionella sp. W. Smith	1853
Tryblionella calida (Grunow) D.G. Mann	1853
Tryblionella hungarica (Grunow) D.G. Mann	1853
Tryblionella levidensis W.M. Smith	1853

5.9.2 Zooplankton

The available information for zooplankton in the Makuleke Wetlands is scarce, with very little published information. Some information is available from Nesbitt (2014) where a very limited study was completed on some selected pans in the area and the invertebrate communities present.

The field surveys of the various Makuleke Wetlands in April and September 2015 identified 15 different zooplankton taxa at the various pans (Table 22). The major groups were found to be Branchiopoda and Copepoda. Most of the pans had between three and seven different taxa present. Detailed results of the zooplankton community can be found in Appendix E.

Table 22: Zooplankton sampled at the selected pans that contained water during the April 2015 sampling survey in the Makuleke Wetlands

Class	FAMILY	GENUS AND SPECIES
Branchiopoda	Streptocephalidae	*Streptocephalus (bidentatus/indistinctus)*
	Bosminidae	*Diaphanosoma* sp. *(excisum)*
	Macrothricidae	*Macrothrix (spinosa)*
		Macrothrix (propinqua)
	Chydoridae	*Eurycercus* sp. *(lamellatus)*
	Daphniidae	*Daphnia laevis*
		Daphnia barbata
	Moinidae	*Moina micrura*
Copepoda	Diaptomidae	*Lovenula falcifera*
		Tropodiaptomus sp.
	Cyclopidae	*Macrocyclops* sp.
		Thermocyclops oblongatus
Ostracoda	Cyprididae	*Cyprididae* sp. A
		Cyprididae sp. B
		Cyprididae sp. C

5.9.3 Macroinvertebrates

The macroinvertebrate communities within the Makuleke Wetlands are not well studied. Some macroinvertebrate data is available from the Luvhuvhu River, where a total of 28 taxa that represented 18 genera were recorded exclusively in the Luvhuvhu River (Moore and Chutter, 1988). A study by Nesbitt (2014) was entitled: “An investigation into pan hydrology and ecology in the Makuleke Concession, Northern Kruger, South Africa”. This study focused on selected pans and determined the hydrology of the pans in terms of sediment grain size, vegetation cover and wetland habitat. A small part of the study also looked at the macroinvertebrates present in the pans selected for the study. However, by the author’s own admission, the work only scratched the surface.

The field surveys of the various pans in the Makuleke Wetlands, in April and September 2015, identified 108 different taxa (Table 23). This data is an indication that the macroinvertebrates in the Makuleke Wetlands are as diverse as expected and it is possible that more species will be sampled with more focused sampling over different hydrological regimes. The detailed data, and interpretation and discussion of the macroinvertebrate data are provided in Appendix E.

Table 23: Macroinvertebrates sampled at the selected pans in the Makuleke Wetlands during the April and September 2015 sampling survey

FAMILY	GENUS AND SPECIES	FAMILY	GENUS AND SPECIES
Dytiscidae	*Copelatus* sp.	Mesoveliidae	*Mesovelia* sp.
	Cybister sp. *A*		*Mesovelia vittigera*
	Cybister sp. *B*	Paraphrynoveliidae	*Paraphrynovelia* sp.
	Derovatellus sp.	Nepidae	*Barborophilus* sp.
	Eretes sp.		*Ranatra* sp.
	Hydroglyphus sp.		*Laccotrephes* sp.
	Hydrovatus sp. *A*	Naucoridae	*Laccocoris* sp.
	Laccophilus sp.	Notonectidae	*Anisops* sp. A
	Philodytes sp.		*Anisops* sp. B
	Rhantaticus congestus		*Anisops* sp. C
Noteridae	*Hydrocanthus* sp.		*Enithares* sp.
Curculionidae	*Neohydronomus affinis*		*Notonecta lactitans*
	Pseudobagous sp.		*Nychia limpida*
Hydraenidae	*Discozantaena genuvela*	Pleidae	*Plea* sp.
	Parathetops nigritus	Gomphidae	*Phyllomacromia* sp.
	Hydraena sp.	Libellulidae	*Brachythemis lacustris*
	Prosthetops grandiceps		*Brachythemis leucosticte*
Hydrophilidae	*Allocotocerus* sp.		*Crocothemis* sp. *(divisa/erythraea)*
	Berosus sp.		*Hemistigma* sp.
	Helochares sp.		*Pantala flavescens*
	Hydrophilus senegalensis		*Parazyxomma flavicans*
	Regimbartia sp.		*Tramea* sp. *(basilaris)*
	Sternolophus sp.		*Trithemis* sp. *(arteriosa ateriosa)*
	Enochrus sp.	Platycnemididae	*Allocnemis leucosticta*
Scarabaeidae	*Rhyssemus* sp.	Coenagrionidae	*Agriocnemis* sp.
Sciomyzidae	Sciomyzid larva		*Enallagma glaucum*
Dolichopodidae	Dolichopodid larva	Lestidae	*Lestes* sp.
Syrphidae	*Eristalis* sp.	Tetragnathidae	*Tetragnatha veriformis*
	Eumeris sp.	Lycosidae	*Pirata* sp. *(Africana)*
Limnichidae	Limnichidae	Pisauridae	*Thalassius massajae*
Ecnomidae	*Ecnomus* sp. *(thomasseti)*	Hydrachnidae	*Hydrachnidae* sp.
Ephydridae	*Ephydra* sp.		*Tetratothyasidae* sp.
Tabanidae	Tabanidae		*Africasia radiata*
Ceratopogonidae	*Bezzia* sp.		Nematoda
	Leptoconops sp.	Lumbriculidae	Lumbriculidae
	Culicoides sp. (larva)		Hirudinea
Chironomidae	Chironominae	Unionicolidae	*Neumania* sp.
	Orthocladiinae	Littorinidae	*Littoraria subvittata*
Culicidae	Culicinae	Thiaridae	*Tarebia granifera*
	Ficalbia sp.	Ancylidae	*Burnupia* sp.

FAMILY	GENUS AND SPECIES	FAMILY	GENUS AND SPECIES
	Culex sp. A		*Ferrissia* sp.
	Eretmapodites sp. (pupa)	Lymnaeidae	*Lymnaea natalensis*
Baetidae	*Cloeon* sp. & *Procloeon* sp.		*Lymnaea truncatula*
	Pseudopannota (maculosa)	Planorbidae	*Bulinus africanus*
Leptophlebiidae	*Euthraulus elegans*		*Bulinus depressus*
Belostomatidae	*Appasus* sp.		*Bulinus forskalii*
Corixidae	*Agraptocorixa* sp. A	Naididae	*Nais* sp.
	Agraptocorixa sp. B	Mutelidae	*Chambardia petersi*
	Stenocorixa sp.	Sphaeriidae	Sphaeriidae
Gerridae	*Halobates* sp.	Nematoda	
	Limnogonus sp. A		
	Naboandelus africanus		
	Neogerris severeni		
	Rhagadotarsus sp.		
	Tenagogonus sp.		
	Gerris sp.		
	Aquaris distanti		
	Eurymetra sp.		

5.9.4 Fish

The Luvhuvhu and Limpopo rivers have a total of 38 fish species that have been recorded in the area. The main fish species found within the wetlands include Hamilton's barb (*Enteromius afrohamiltoni*), straightfin barb (*Enteromius paludinosus*), east coast barb (*E. toppini*), tigerfish (*Hydrocynus vittatus*), various robbers (*Micralestes acutidens* and *Brycinus imberi*), *Labeo rosae*, *Labeo congoro*, *Labeo ruddi*, *Schilbe intermedius* and *Synodontis zambezense*. Fish sensitive to changes in quality and quantity fluctuations that can still be found in the Luvuvhu River, but have become rare or absent in the other tributaries of the Limpopo River, include: Madagascar mottled eel (*Anguilla marmorata*), longfin eel (*Anguilla mossambica*), Limpopo or dwarf rock catlet (*Chiloglanis pretoriae*), Lowveld or bearded catlet (*Chiloglanis swierstrai*), purple labeo (*Labeo congoro*), bulldog (*Marcusenius macrolepidotus*), silver robber (*Micralestes acutidens*), Churchill (*Petrocephalus catostoma*), southern redbreast tilapia (*Tilapia rendalli*), and Hamilton’s barb (*Enteromius afrohamiltoni*).

The fish that were collected during the April 2015 survey were measured, counted and identified at each of the pans where they were present. This data is presented in Table 24 for the various pans. In addition to the diversity of fish within the Makuleke Wetlands, 20 specimens of *Oreochromis mossambicus* and 10 specimens of *Clarias gariepinus* were dissected to perform the fish health assessment index (FHAI). The Limpopo River catchment is known for the wide distribution of *O. niloticus,* which is an invasive alien species. Although identification of these specimens in the field was based on visual characteristics, it was deemed important to establish the genetic structure of these fish within the system.

Table 24: Fish diversity sampled at the Makuleke Wetlands during the April 2015 survey

No.	Fish Name	Banyini	Jachacha	Hapi	Makwadzi	Nhlangaluwe	Hulukulu
1	*Glossogobius giuris*	–	–	76	–	–	–
2	*Enteromius afrohamiltoni*	–	30	53	14	35	12
3	*Oreochromis mossambicus*	6	140	17	28	104	5
4	*Tilapia sparrmanii*	–	–	1	–	–	–
5	*Mesobola brevianalis*	–	–	5	–	–	–
6	*Brycinus imberi*	–	–	1	–	–	–
7	*Labeo molybdinus*	–	9	–	–	–	–
8	*Clarias gariepinus*	6	3	–	–	2	1
9	*Schilbe intermedius*	–	2	–	–	–	–
10	*Synodontis zambezensis*	–	1	–	–	–	–
11	*Oreochromis niloticus*	–	–	–	19	14	–
12	*Coptodon rendalli*	–	–	–	6	–	–
13	*Enteromius toppini*	–	–	–	–	6	–
14	*Enteromius paludinosus*	–	1	1	–	1	–

5.9.5 Amphibians

The Makuleke Wetlands are home to around 33 amphibian species of which 28 are tropical forms (Passmore et al., 1995). These areas also represent the south-western limits of the range of distribution of dune squeakers (*Arthroleptis stenodactylus*). The dune squeaker is an inhabitant of northern Zululand, Mozambique and Zimbabwe. This frog has a limited distribution in South Africa and only occurs in the coastal dune forest at Cape Vidal and in the far northern areas of the Park where it has been collected from Shipudza spring and from Bobomene (Deacon, 2007). The information that is available from the FrogMAP was extracted and included for reference in Table 25 (FrogMAP, 2016).

Table 25: A list of the amphibian species expected to occur within Makuleke Wetlands (from FrogMap).

Species code	Family	Genus	Species	Common name	Red list category
130	Arthroleptidae	*Arthroleptis*	*stenodactylus*	Shovel-footed squeaker	Least Concern
670	Arthroleptidae	*Leptopelis*	*mossambicus*	Brownbacked tree frog	Least concern
160	Brevicipitidae	*Breviceps*	*adspersus*	Bushveld rain frog	Least concern
300	Bufonidae	*Poyntonophrynus*	*fenoulheti*	Northern pygmy toad	Least concern
910	Bufonidae	*Schismaderma*	*carens*	Red toad	Least concern
320	Bufonidae	*Sclerophrys*	*garmani*	Olive toad	Least concern
340	Bufonidae	*Sclerophrys*	*pusilla*	Flatbacked toad	Least concern
550	Hemisotidae	*Hemisus*	*marmoratus*	Spotted shovel-nosed frog	Least concern
590	Hyperoliidae	*Hyperolius*	*marmoratus*	Painted reed frog	Least concern
620	Hyperoliidae	*Hyperolius*	*pusillus*	Water lily frog	Least concern

Species code	Family	Genus	Species	Common name	Red list category
650	Hyperoliidae	*Kassina*	*maculata*	Redlegged kassina	Least concern
660	Hyperoliidae	*Kassina*	*senegalensis*	Bubbling kassina	Least concern
760	Microhylidae	*Phrynomantis*	*bifasciatus*	Banded rubber frog	Least concern
730	Phrynobatrachidae	*Phrynobatrachus*	*mababiensis*	Dwarf puddle frog	Least concern
740	Phrynobatrachidae	*Phrynobatrachus*	*natalensis*	Snoring puddle frog	Least concern
1060	Pipidae	*Xenopus*	*muelleri*	Tropical platanna	Least concern
780	Ptychadenidae	*Ptychadena*	*anchietae*	Plain grass frog	Least concern
800	Ptychadenidae	*Ptychadena*	*mossambica*	Broadbanded grass frog	Least concern
880	Pyxicephalidae	*Amietia*	*delalandii*	Delalande's river frog	Least concern
400	Pyxicephalidae	*Cacosternum*	*boettgeri*	Common caco	Least concern
850	Pyxicephalidae	*Pyxicephalus*	*adspersus*	Giant bull frog	Near threatened
860	Pyxicephalidae	*Pyxicephalus*	*edulis*	African bull frog	Least concern
1020	Pyxicephalidae	*Tomopterna*	*marmorata*	Russetbacked sand frog	Least concern
470	Rhacophoridae	*Chiromantis*	*xerampelina*	Southern foam nest frog	Least concern

5.9.6 Birds

The birds in the Makuleke Wetlands are diverse and a total of over 450 bird species have been identified, with 34 species restricted to the northern area of the KNP (Sinclair and Whyte, 1992). Scarce Pel's fishing owl (*Scotopelia peli*), rare pygmy goose (Nettapus auritus), sparse Böhm's (*Neafrapus boehmi*) and mottled spinetails (*Telacanthura ussheri*), long-tailed wagtail (*Motacilla clara*) and Basra reed warbler (*Acrocephalus griseldis*) are all bird species that are more common in the Makuleke Wetlands than in other parts of the country. The Luvuvhu/Limpopo region is widely acknowledged amongst bird watching enthusiasts as one of the top birding areas in the country (Deacon, 2007).

A full list of the bird species found in the Makuleke Wetlands is presented in Appendix B (SABAP2, 2016). The bird list was based on Southern African Bird Atlas Project 2 data (SABAP2, 2016) gathered by citizen scientists and avid birders, based on quarter degree squares and pentads. The yearly coordinated water bird count data for 2014–2016 was also used for the bird list in Appendix B.

5.9.7 Aquatic mammals and other fauna

Currently no information was found to be available on the aquatic mammals of the Makuleke Wetlands. However, it is known that the hippopotamus (*Hippopotamus amphibius*) is present in at least Makwadzi and Nhlangaluwe

5.10 Conclusion and recommendations

This study was successful in identifying and describing the biodiversity of the aquatic invertebrates from the various pans in the Makuleke Wetlands. It was found that possible anthropogenic activities from the upper catchments of the Luvuvhu and Limpopo River could have a potential effect on the quality of the water and the sediment. Results from this study will be used to update the Ramsar Information Sheet (RIS) regarding the Makuleke Wetlands as well as provide important baseline data on the aquatic integrity of these wetlands.

The following research topics are recommended for future studies:

- Investigate the Makuleke Wetlands during a wet cycle to determine if the aquatic communities within the pans change
- Determine the distribution of Branchiopoda in the Makuleke Wetlands
- Investigate how the succession patterns within floodplain depressions and floodplain depressions with inflow functions
- Determine the origin of anthrax and whether it is linked with the aquatic invertebrates in the sediment.

6 KOSI BAY

6.1 Introduction

The Kosi Bay Ramsar site is an estuary-linked lake system of four interconnected, almost circular lakes (Makhawulani, Mpungwini, Nhlange and Amanzimnyama) with a broad channel leading to an estuary which opens into the Indian Ocean (Green et al., 2006). The freshwater is derived from three permanent rivers and at least two of the four lakes have some form of tidal influence. The principal habitats in the systems comprise swamp and mangrove forest, reedbeds, dune systems with associated woodland and coastal grassland. The Kosi lakes are separated from the ocean by forested sand dunes between 600 and 2 000 m in width. Although the Kosi system has diverse habitat types, the overall nutrient status is low. The Kosi Bay systems support numerous aquatic invertebrate species, fish species, birds, mammals, butterflies and plants. Some of the species found here are endemic, threatened or endangered (Kyle, 1995).

6.2 Site location

The Kosi Bay system is situated in northern KwaZulu-Natal. It has the Mozambican border to the north and the Indian Ocean to the east. The western border is formed by the lakes of the system and the associated swamp forests around the system. The southern border includes the Kosi catchment but the majority of the southern section falls within the iSimangaliso Wetland Park. The system is approximately 470 km north-east of Durban and the nearest town is Manguzi, situated approximately 35 km from the mouth. There is an Ezemvelo KZN Wildlife camp on the western shores of Lake Nhlange. The Kosi system area covers approximately 11 000 ha with a maximum elevation above sea level at 102 m.

Figure 20 shows all of the sites chosen to assess the Kosi system. Sites chosen for this study were picked throughout the system to show comparisons between the different lakes and channels in the system. A total of 12 sites were assessed during three surveys, in July and November 2015 and February 2016. One site was in Lake Amanzimnyama with the Malangeni River flowing into Lake Amanzimnyama (Figure 21 and Figure 22), three sites were in Lake Nhlange, one site was in the channel that connects Lake Mpungwini and Lake Nhlange (Figure 22), one site was in Lake Mpungwini, two sites were in Lake Makhawulani and three sites were selected points throughout the estuary (Figure 23).

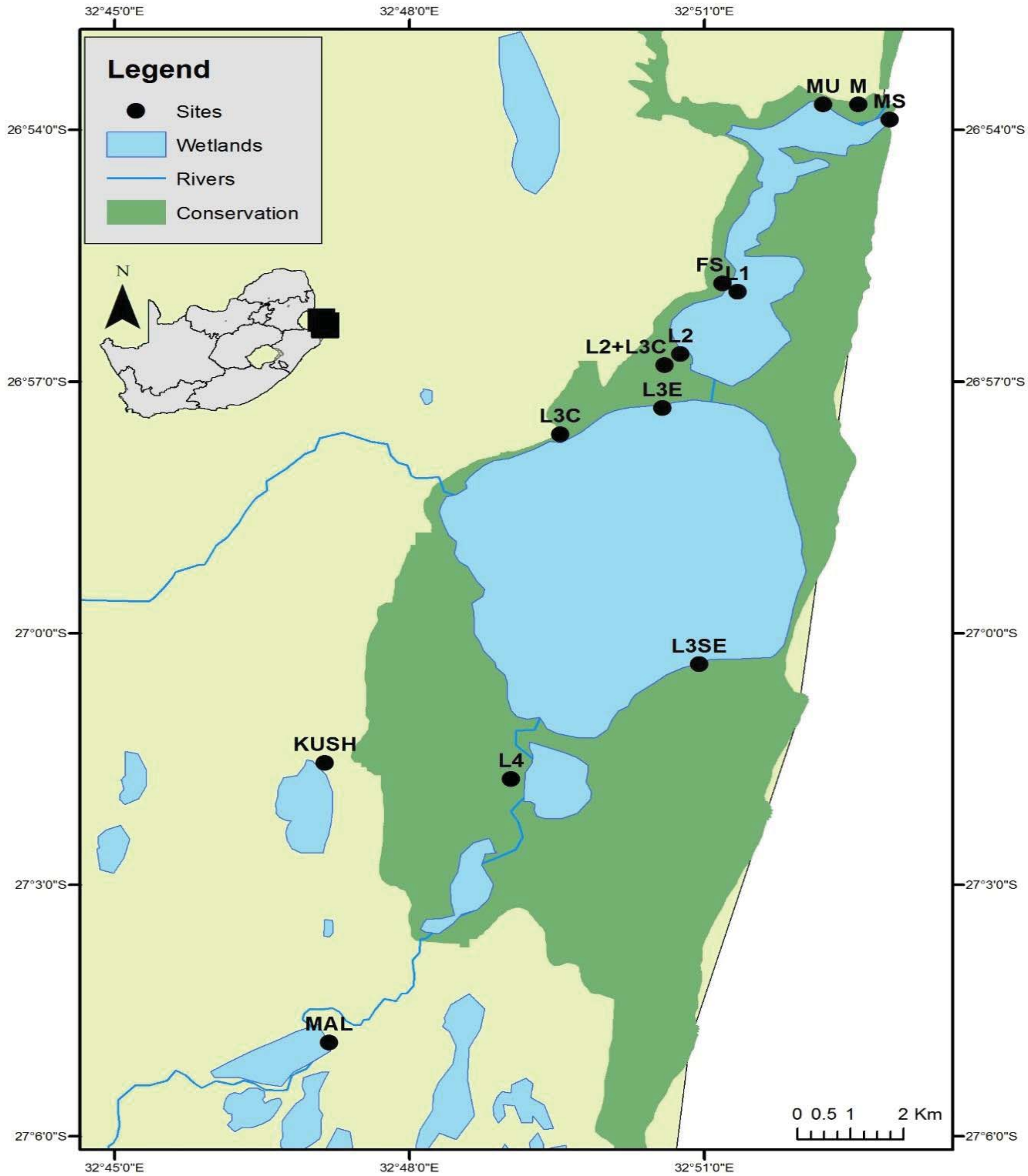


Figure 20: Map of the Kosi Bay system and Kushengeza with the selected sites used during the study

The Kosi Bay system is situated in the Natal Coastal Plain (Category 13.02). The area is situated within the Water Management Area for the Usuthu to Mhlatuze rivers. All of the sub-quaternary catchments in the Kosi Bay system are classified as Freshwater Ecosystem Protected Areas (Driver et al., 2011).

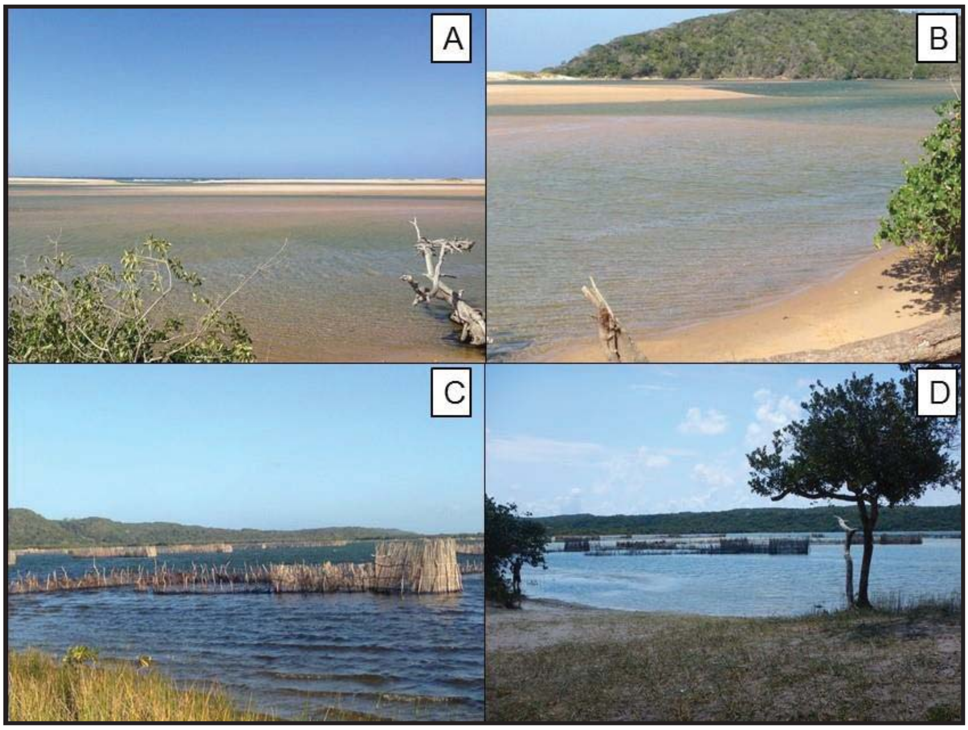


Figure 21: Selected sites sampled in the Kosi Bay system during the August 2015, December 2015 and February 2016 surveys. (A): MS, (B): M, (C): MU, (D): FS.

Figure 22: Selected sites sampled in the Kosi Bay system during the August 2015, December 2015 and February 2016 surveys. (E): L1, (F): L2+3C, (G): L2, (H): L3E.

Figure 23: Selected sites sampled in the Kosi Bay system during the August 2015, December 2015 and February 2016 surveys. (I): L3C, (J): L4, (K): L3SE, (L): MAL.

6.3 Ramsar criteria

The following criteria were met by the Kosi Bay system for inclusion as a Ramsar protected wetland:

<u>Criterion 1</u>: Kosi Bay is one of the largest estuary systems in KwaZulu-Natal and is the least impacted and degraded by anthropogenic impacts. The system supports a diverse fish population as well as numerous other aquatic fauna. The water is also generally less turbid and relatively deeper than other systems in the same area. Kosi Bay is a relatively isolated estuarine system and it is well over 100 km north or south of any other major estuarine systems. This results in no significant transfer of truly estuarine organisms between systems. Kosi Bay probably provides the only recruitment for several species of marine organisms found along the KwaZulu-Natal coast (Bruton, 1980).

<u>Criterion 2</u>: Many rare and threatened animals and plants can be found in the area. One of the distinctive plant species is the giant palm (*Raphia australis*), which only occurs in the Kosi Bay area in South Africa. The palm forests are also important for the occurrence of the palm-nut vulture (*Gypohierax angolensis*), which is dependent on it for nesting and food. The fish population in Kosi Bay is very diverse due to the rocky reef found within the estuary on the southern shores. It is estimated that about 80% of the fish in the Kosi Bay Estuary are only

found on this reef. Breeding crocodiles are also found in small numbers in the Kosi Bay lakes, especially in Lake aManzimnyama. The coastal dune vegetation, mangroves, swamp forests and various dry-land communities are all abundant and many contain rare species.

6.4 Physical features

6.4.1 Climate

Kosi Bay has warm summers and a humid subtropical climate. Average annual rain records of 980 mm (Holbach et al., 2012); variations in rainfall from 1 200 mm in the south-east region to 700 mm in the west region (Green et al., 2006) have been recorded. The rainfall occurs during the summer months, from October to March, with most of the rain falling during February and March. Average maximum temperatures vary from 28°C in January to 22°C in July and average minimum temperatures are 19°C in January and 9°C in July (Kyle, 1995). However, extreme temperatures can reach 43°C and 34°C in January and July, respectively.

There are several thermoclines that develop during the summer because of strong northerly or southerly winds. In the colder season of the year, Lake Nhlange tends to develop a homothermal temperature of 18.5°C to 19°C and exhibits a complex pattern of stratification (Kyle, 1995). Lake Makhawulani and Lake Mpungwini have temperature layering causing bottom temperatures to be significantly warmer than the surface waters of the lake. Water temperatures in the channels of the system do not fall below 20°C in the winter and can reach temperatures of 30°C in the summer months (Kyle, 1995).

6.4.2 Geology

Kosi Bay is part of the Mozambique coastal plain that consists of sandy soils with Cretaceous beds. The coastal dunes of the system are composed of both Holocene and Pleistocene sand deposits. The Kosi Bay system is not a rocky system although some rock ledges, shelves and outcrops occur. There is a vegetated sand dune area over 130 m high on the eastern side of the coast (Walther and Neumann, 2011). There is one rock outcrop near the mouth of the Kosi Bay Estuary which forms a natural reef system inside the estuary rather than in the marine environment (Kyle, 1995).

The bottom sediment in the system is mainly clear white sands caused by tidal influences on the northern side of the system. Silt can be found in deeper waters with thin overlaying sand in certain shallow areas. Sandy substrates in the system have a lack of fine particles and have a low nutrient content. Unconsolidated organic debris collects on the bottom of deeper waters and gradually becomes anoxic with high volatile nutrient values and hydrogen sulphide. These materials collected in the deeper waters originate alongside the marshes and swamps of the system and gravitate towards deeper waters (Kyle, 1995).

6.4.3 Vegetation

Vegetation along the coast of Kosi Bay includes grasslands, mangrove forests, subtropical dune thickets, subtropical freshwater wetlands and timber plantations. The subtropical dune thickets consist of dense shrubs, vines and small trees (Tinley, 1976; Walther and Neumann, 2011). Mangrove forests in Kosi Bay have increased from 59 ha to 60.7 ha in recent years (Rajkaran and Adams, 2011). There are six mangrove species that occur in South Africa (*Avicennia marina, Bruguiera gymnorrhiza, Rhizophora mucronata, Lumitzera racemosa, Ceriops tagel* and *Xylocarpus granatum*), where *Ceriops tagel, Lumitzera racemose* and *Xylocarpus granatum* are only found at Kosi Bay (Rajkaran and Adams, 2011). The mangrove communities are scattered throughout the system but do not extend past Makhawulani (Green et al., 2006). These communities can be damaged by cyclones which cause water levels to rise (Kyle, 1995). The vegetation around Lake Amanzimnyama has very dense and tall coastal palm tree populations (*Raffia* palms, *Raphia australis*).

There are a number of different aquatic vegetation habitats and thus many plant species to note. There are submerged macrophytes (such as *Ceratophyllum demersum* and *Potamogeton pectinatus*), semi-emergent plants (such as *Nymphaea* spp. and *Polygonum* spp.), as well as freefloating aquatics (such as *Lemna* spp.). There are hygrophilous grasslands and sedges covering the lower, partially inundated areas, while swamps (especially papyrus swamps) and marshes are found in areas with more permanent water. This is the home for the largest swamp forest in South Africa (adding more value to the Kosi Bay system) and includes large trees such as *Syzygium cordatum*, *Ficus trichopoda*, *Voacanga thouarsii* and *Rauvolfia caffra*, with *Rapanea melanophleos*, *Myrica serrata* and *Halleria lucida* as sub-canopy (Kyle, 1995).

6.4.4 Hydrology

Kosi Bay obtains most of its freshwater input through local drainage and the high groundwater table that is characteristic of the coastal plain. Surface drainage in the area is low due to the high porosity of the cover sand, with only the Malangeni (Sihadhla) and Swamanzi (Gesiza) Rivers being perennial (Wright et al., 2000). Only 5% of the annual precipitation can be expressed as surface runoff into the Kosi Bay system. The origin of the system is formed by two principal rivers which enter the system. The Malangeni (Sihadhla) River is approximately 30 km long and rises in the Mtombeni pans. This river receives contributions from twelve principal tributary systems and then enters into Lake Amanzimnyama (Figure 20) (Kyle, 1995).

Another river that contributes to the Kosi Bay system is the Swamanzi (Gesiza) River, which is approximately 15 km long and collects water from nine principal tributaries and enters Lake Nhlange (Figure 20). The hydrology of the Kosi Bay system has a fairly strong seasonal inflow of fresh water (Kyle, 1995), and, due to the porous sand in the area, most of the freshwater input into the system is from groundwater inputs (Walther and Neumann, 2011).

The maximum water depths reached in the lakes of Kosi Bay are 3 m in the estuary, 8 m in Makhawulani, 18 m in Mpungwini (Kyle, 1995), 31 m in Nhlange and 3 m in Amanzimnyama (Holbach et al., 2012). Nhlange can be exposed to a surface area of 70% during low tide due to the very shallow tidal basin. The mouth varies in size due to seasonal changes (Kyle, 1995). The estuary mouth is permanently open and subjected to regular tidal movements (Blaber, 1978). The exchange with the sea is of utmost importance to the lake system. The estuary mouth varies in size with every tide and is generally 20–50 m wide and 3 m deep. Tidal variations can be seen in Lake Nhlange occasionally and especially during spring tide in late winter. Outflow towards the sea is greater during summer, and water movements during winter are due to tidal effects. In all cases, outflow speeds exceed inflow speeds (Kyle, 1995).

The Kosi Bay system has mostly clear waters and has a classical transition from sea water that enters at the mouth to fresh water in Lake Amanzimnyama. Due to this connection to the sea, a mixture of sea water and fresh water occurs along a salinity gradient in the system (Harrison, 2002). Salinity levels in the tidal basin come close to salinity levels of the sea and vary naturally with the tides. Salinity levels in the tidal basin can drop remarkably at low tide. Lake Makhawulani and Lake Mpungwini both exhibit salinity layering, whereas Lake Nhlange is not similarly arranged, and is predominantly a freshwater lake

6.4.5 Water quality

The available information on water quality for Kosi Bay was limited to our own research during this project. An increase in the human population has resulted in concerns about increased nutrients entering the Kosi Bay system. The ranges of nutrient concentrations that were found during the three surveys of Kosi Bay that took place in 2015 and 2016 (Table 26) indicated increased nutrient concentrations. More detailed water quality data can be found in the Appendix G.

Table 26: Water quality ranges for selected parameters determined during surveys from 2014 to 2016

Water quality parameter	Unit	Kosi Bay
Nitrate	mg/L	1–15
Nitrite	mg/L	0.01–0.08
Ammonium	mg/L	0.09–0.23
Phosphates	mg/L	0.1–0.7

6.5 Wetland classification

The summary classification for Levels 1 to 3 is provided in Table 27. The Kosi Bay Estuary is situated further towards the ocean as Lake Makhawulani, and is classified as an estuarine system. Lake Makhawulani receives some estuarine fish taxa within the system. Lake Sibaya historically had a connection with the ocean as is evidenced in the unique taxa that are present in the system, but due to no current connection to the Indian Ocean it is also classified as an inland system.

The vegetation grouping (Figure 24) from the NFEPA project (Nel et al., 2011) indicates these systems are in the Indian Ocean Coastal Belt Group 1 and this was determined with high confidence. The ecoregion map (Figure 24) indicates that these two systems are located in the Natal Coastal Plain and this was also established with high confidence. The landscape setting was determined using Google Earth and 5 m contour lines of the area.

Table 27: Summary of the classification of the Kosi Bay system using Levels 1 to 3 of the NWCS (confidence ratings of the classification are given in brackets for each level)

Wetland Name	Level 1	Level 2		Level 3
	System	DWA Ecoregion	NFEPA WetVeg Group/s	Landscape Unit
Kosi Bay system	Estuarine	Natal Coastal Plain (High)	Indian Ocean Coastal Belt Group 1 (High)	Plain

Estuarine classification is less complicated than classifying inland systems in South Africa as the diversity in types is lower. A breakdown of the Estuarine Classification from Level 1 to Level 4 is provided in Table 28 for reference. The table was adapted from SANBI (2009). The SANBI (2009) report can be consulted for more detail on each of the specific estuary types. The Kosi Bay system was classified using Table 28 and the results for Level 1 to Level 4 are provided in Table 29. Kosi Bay is mainly situated within the subtropical zone for the Level 2 classification. At Level 3 of the classification it was deemed from previous studies that Kosi Bay is a permanently open estuary. When classifying Kosi Bay further it is evident that the estuary is an estuarine lake system.

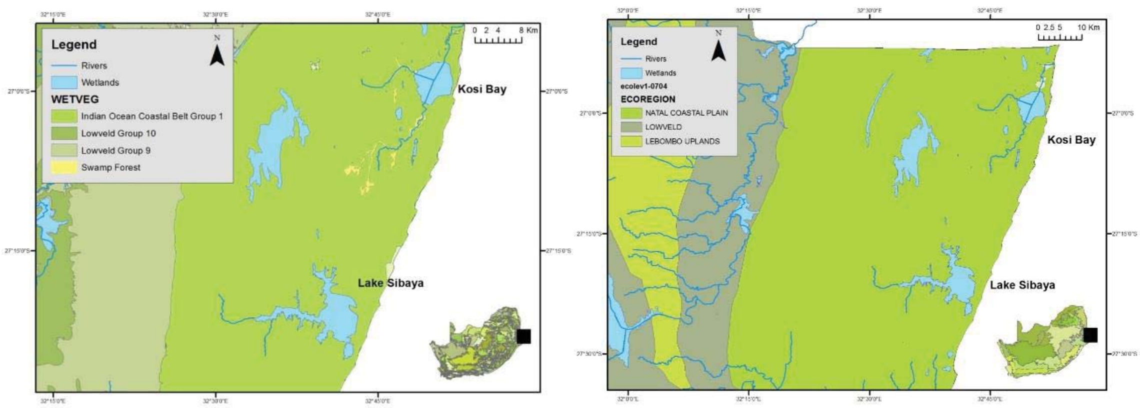
Table 28: The classification structure for estuarine systems in South Africa from Level 1 to Level 4 (adapted from SANBI, 2009)

Level 1: System	Level 2: Regional Setting	Level 3: Subsystem	Level 4: Hydrogeomorphic Unit
Connectivity to the open ocean	*Biogeographic zones*	*Periodicity of connection*	*Landforms and hydrodynamics*
Estuarine	Cool-temperate zone Warm-temperate zone Subtropical zone	Permanently open	Estuarine bay
			Estuarine lake
			Open estuary
			River mouth
		Temporarily open / closed	Estuarine lake
			Closed estuary
			River mouth

Note: The 2nd row of the table provides the criteria to distinguish between the wetland units in each column.

Table 29: Classification of the Kosi Bay system from Level 1 to Level 4

Level 1: System	Level 2: Regional Setting	Level 3: Subsystem	Level 4: Hydrogeomorphic Unit
Estuarine	Subtropical zone	Permanently open	Estuarine lake



A B

Figure 24: (A) NFEPA wetland vegetation group (Nel et al., 2011) for Kosi Bay. (B) Department of Water and Sanitation Level 1 Ecoregion (Kleynhans et al., 2005) for Kosi Bay.

6.6 PES/Ecosystem services

The Kosi Bay Ramsar site has two main river reaches that enter the various lake systems. No PES is available for the lake systems but there is information available for these rivers. The first river is the Swamanzi River that enters from the western side and drains the catchment around Manguzi. This river is Largely Modified in terms of the PES as determined by the PESEIS model (DWS, 2014). The EI for this reach was found to be Moderate while the ES was found to be Very High. The second river is the Malangeni River that runs in a south to north direction entering the Kosi Bay system. The PES for this river reach was found to be Largely Natural with the EI categorised as High and the ES as Very High. The desktop review identified around 38 possible macroinvertebrate taxa that should occur in the riverine sections of the system.

6.7 Land use and threats

The use of the land by the local population has led to some erosion due to the slash-and-burn method of cultivation. This method is often unproductive as the sandy soils in the area are not conducive to agriculture. Cultivation within the swamp forest of crops like bananas often goes along with canals and drying out of the swamps. This leads to a loss of peat soils in the area. Afforestation in the larger catchment is present for the growth of *Eucalyptus* plantations. These plantations threaten the freshwater wetlands and water supply to the lake systems. This will eventually lead to decreased freshwater inflow and a rise in salinity in the lakes and thus a change in the ecological processes in the system.

Increasingly, chemicals and fertilisers are used in the catchment to increase agricultural productivity. Thus far no eutrophication has occurred but with increasing human population and concomitant fertiliser use it is a potential problem. The use of DDT for indoor residual spraying is also a potential problem. One of the most serious problems in Kosi relates to the fact that DDT (DDE and TDE) is apparent in the sediments of Lake Mpungwini and Makhawulani, and present in fish tissues in relatively high levels (Kyle, 1995). The presence of invasive plants, like *Pereskia aculeate*, which are found in the area, is also a potential threat. Another potential problem is the gradual sanding up of the tidal basin. Fish traps contribute to the sanding up of the basin and bank erosion is caused by bow-waves from boats passing through the Mtando channel.

Fish traps have been used by traditional Zulu fishermen in the Kosi Bay system for many generations (Kyle, 2013). Due to population pressure, the fish of the system are being over-fished by fish traps and the use of gill nets that began in 1992 (Kyle, 1995). The use of fish traps over the years has increased dramatically and could lead to a decline in fish populations. A gillnetting scheme allowed the local community to use gillnets in Lake Nhlange on a controlled basis. These gillnets cause massive damage to the fish populations and it is now illegal to use them without a permit. However, they are still being used with no controlled basis (Kyle, 1995). Other factors that are threatening fish are mostly habitat degradation, environmental pollution and ecological process disruption (Whitfield, 1997).

Current management practices allow sustainable yield utilisation of the natural resources within the nature reserve. Tourism is relatively high and continuing efforts are made to increase the benefit to the local community. Currently, around 25% of the gross revenue of the reserve goes to the local community through the tribal or community authority. Labour intensive schemes for the control of noxious weeds such as *Pereskia aculeata* are being carried out both to control the problem and to provide more employment for the local people (Kyle, 1995). Subsistence agriculture is carried out in the form of maize, millet and groundnuts in the dry area and bananas, sugar cane and *madumbis* in the wetter areas. Resources used in the Kosi Bay area by residents and recreational visitors include fish, crabs, shrimps, reeds, sedges, poles, branches, wild fruits, honey, palm wine, grazing, water and firewood.

6.8 Current recreation and tourism

Recreation and tourism activity in the area is extensive, and includes various lodges and camping sites along the various lakes. However, access to the estuarine, mouth and beach sections is restricted to a specific number of cars per day. Recreational activities that are popular in the area are fishing, bird watching, snorkelling and hiking. Hikes and walks can be on the beaches, through virtually undisturbed coastal dune forest and swamp forest, through open grassland and around the lakes. Fishing for optic-feeding game fish (marine) is probably the best in South Africa (except in the open ocean) as the system has low turbidity. Main target species of sport anglers are kingfish (*Caranx* spp.), seapike (*Spyraena* sp.) and rock salmon (*Lutjanus argentimaculatus*). Cultural activities in the area include observing local people in the artisanal fisheries using traditional fish traps and spears to collect fish. Bird watching in the bush and lakes can also be very rewarding although species diversity is lower than at the nearby Ndumu Game Reserve (Kyle, 1995).

6.9 Aquatic biodiversity information

6.9.1 Diatoms

Algal and diatom research at Kosi Bay is limited with only general distribution of taxa available. One of the most common planktonic algae in the Kosi system is *Microcystis* sp. especially in the uKhalwe inlet (Kyle, 1995).

6.9.2 Zooplankton

Currently, no information on zooplankton from Kosi Bay could be found.

6.9.3 Macroinvertebrates

Within the marginal vegetation around Lake Nhlange and in the Mthando channel are several species such as *Musculus virgiliae*, detritus-feeding crustaceans (amphipods, isopods and tanaids) and the crab, *Rhynchoplax bovis*. Penaeid prawns are scarce in the nutrient deficient system; however, there are numerous *Musculus virgiliae* (a lamellibranch) to be found, except in the anoxic bottom of Lake Mpungwini and Makhawulani. These two lakes house *Callianassa kraussi* (sand prawn) which is confined to Lake Mpungwini, Lake Makhawulani and the southern section of the tidal basin. This species is considered a major infaunal organism for the system, despite its confined distribution. Some of the insects found in the area include *Clinotanypus* sp. and *Chironomus* sp. which are important in the benthos, while others, such as the weaver or tailor ant (*Oecophyllum smaragdina*), are more common in the mangroves. The skipper butterfly, *Parnara micans*, is endemic to Kosi Bay (Campbell, 1969) and *Charaxes protoclea azota* (a marginal Red Data butterfly species) only occurs in South Africa in Kosi Bay.

6.9.4 Fish

The fish in the Kosi Bay system are very diverse due to the tropical water temperatures, the close proximity of the estuary to the warm Agulhas current, the absence of heavily silted river systems, and the different physical characteristics of the various lakes. This clear water system is home to a number of marine game fish such as *Caranx ignobilis*, *C. sexfasciatus* (kingfishes), *Sphyraeno jello* (barracuda), and *Scomberoides lysan* (queen fish). These predators feed on several abundant mullet species (Gerreidae and *Rhabdosargus* spp.). A total of 124 marine species has been recorded in Kosi Bay, with 70% of the species present found in the estuary and the reef of the system (Blaber, 1978).

Within the mouth of the estuary, there is a rocky reef which is home to 80% of the species in this system. The fish are typical tropical reef fauna found in the Indo-Pacific including surgeonfishes (Acanthuridae), damselfishes, butterflyfishes (Scorpaenidae) and wrasses (Labridae). Those freshwater fish found within the river include *Enteromius paludinosus*, *Enteromius viviparus*, *Clarias gariepinus*, *Aplocheilichthys johnstonii*, *A. katangae*, *Pseudocrenilabrus philander*, *Oreochromis mossambicus*, *Coptodon rendalli*, *Tilapia sparrmanii*, *Glossogobius giuris*, *Eleotris fusca*, *Eleotris melanosoma*, and *Hypseleotris dayi*.

Kosi Bay is a clear water system with a large variety of fish species (Kyle, 1995). A number of surveys have been undertaken but most have been non-quantitative with limited sampling (Blaber, 1978). These surveys were undertaken during 1975, 1976 and 1977. The aim of these studies was to establish the important characteristics and seasonal variations of the fish fauna of each part of the system (Blaber, 1978). The results indicated a total of 124 species (not including freshwater species), of which 70% are restricted to the estuary and 30% are estuarine resident species. In 1980, a study was designed to investigate the exploitation of the fish resources in the Kosi Bay lakes to determine sustainable levels of fishing (Kyle and Robertson, 1997). Kyle and Robertson (1997) also completed a study to tag fish in the Kosi Bay system to obtain information on fish movements, growth rates, mortality rates and population estimates. A total of 500 *Acanthopagrus berda* were tagged, where 279 of the fish tagged were caught on rod and reel, 157 purchased from local fisherman and the rest caught by seine and gill netting. James et al. (2001) conducted a study which analysed recreational angling within the Kosi Bay system. This study was based on the catch card data that recreational anglers fill out at the Nhlange campsite (James et al., 2001). The recreational catch card data from 1986 to 1999 was analysed to determine total catches, catch composition and seasonality of the catches. Angling outings increased from 510 to a peak of 2 379 in 1994 and then declined to 892 in 1999. Along with fish diversity, characteristics and seasonal variations, the impact of fish traps was also investigated. The number of fish traps increased drastically from 66 traps in 1981 to 158 traps in 2001 (Green et al., 2006). Fish caught in the traps increased from 40 000 fish in 1981 to 93 000 fish in 1993 (James et al., 2001). The rural community of Kosi Bay has been building fish traps in the system for centuries and were using fish traps before the system was declared a Ramsar site (James et al., 2001).

Field surveys for fish were completed during July 2015, November 2015 and February 2016 at the selected sites mentioned in Section 6.2. Water, sediment and fish samples were collected and analysed for metal concentrations. Three fish species (*Oreochromis mossambicus*, *Rhabdosargas sarba* and *Terapon jarbua*) were investigated for their fish health and the potential risk to humans of consuming the fish. The outcome of this assessment indicated that the selected fish were healthy and that only some metal concentrations would pose a risk if the fish were consumed by the local community. The detailed results of these assessments are presented in Appendix G.

6.9.5 Amphibians

The information that is available from FrogMAP was extracted and included for reference in Table 30 (FrogMAP, 2016). A new research project on the frogs of Zululand started at the end of 2015 under the leadership of Prof. Louis du Preez. This project will provide valuable information on the frog community within Zululand.

Table 30: A list of the amphibian species expected to occur within Kosi Bay area (from FrogMAP)

Species code	Family	Genus	Species	Common name	Red list category
130	Arthroleptidae	*Arthroleptis*	*stenodactylus*	Shovel-footed squeaker	Least concern
140	Arthroleptidae	*Arthroleptis*	*wahlbergi*	Bush squeaker	Least concern
670	Arthroleptidae	*Leptopelis*	*mossambicus*	Brownbacked tree frog	Least concern
160	Brevicipitidae	*Breviceps*	*adspersus*	Bushveld rain frog	Least concern
220	Brevicipitidae	*Breviceps*	*mossambicus*	Mozambique rain frog	Least concern
910	Bufonidae	*Schismaderma*	*carens*	Red toad	Least concern
320	Bufonidae	*Sclerophrys*	*garmani*	Olive toad	Least concern
330	Bufonidae	*Sclerophrys*	*gutturalis*	Guttural toad	Least concern
10	Hyperoliidae	*Afrixalus*	*aureus*	Golden leaf-folding frog	Least concern
20	Hyperoliidae	*Afrixalus*	*delicatus*	Delicate leaf-folding frog	Least concern
30	Hyperoliidae	*Afrixalus*	*fornasinii*	Greater leaf-folding frog	Least concern
570	Hyperoliidae	*Hyperolius*	*argus*	Argus reed frog	Least concern
590	Hyperoliidae	*Hyperolius*	*marmoratus*	Painted reed frog	Least concern
600	Hyperoliidae	*Hyperolius*	*microps*	Sharp-headed long reed frog	Least concern
620	Hyperoliidae	*Hyperolius*	*pusillus*	Water lily frog	Least concern
630	Hyperoliidae	*Hyperolius*	*semidiscus*	Yellowstriped reed frog	Least concern
640	Hyperoliidae	*Hyperolius*	*tuberilinguis*	Tinker reed frog	Least concern
650	Hyperoliidae	*Kassina*	*maculata*	Redlegged kassina	Least concern
660	Hyperoliidae	*Kassina*	*senegalensis*	Bubbling kassina	Least concern
730	Phrynobatrachidae	*Phrynobatrachus*	*mababiensis*	Dwarf puddle frog	Least concern
740	Phrynobatrachidae	*Phrynobatrachus*	*natalensis*	Snoring puddle frog	Least concern
1050	Pipidae	*Xenopus*	*laevis*	Common platanna	Least concern
780	Ptychadenidae	*Ptychadena*	*anchietae*	Plain grass frog	Least concern
790	Ptychadenidae	*Ptychadena*	*mascareniensis*	Mascarene grass frog	Least concern
800	Ptychadenidae	*Ptychadena*	*mossambica*	Broadbanded grass frog	Least concern
810	Ptychadenidae	*Ptychadena*	*oxyrhynchus*	Sharpnosed grass frog	Least concern
820	Ptychadenidae	*Ptychadena*	*porosissima*	Striped grass frog	Least concern
830	Ptychadenidae	*Ptychadena*	*taenioscelis*	Dwarf grass frog	Least concern
880	Pyxicephalidae	*Amietia*	*delalandii*	Delalande's river frog	Least concern
850	Pyxicephalidae	*Pyxicephalus*	*adspersus*	Giant bull frog	Near threatened
860	Pyxicephalidae	*Pyxicephalus*	*edulis*	African bull frog	Least concern
940	Pyxicephalidae	*Strongylopus*	*fasciatus*	Striped stream frog	Least concern
1010	Pyxicephalidae	*Tomopterna*	*krugerensis*	Knocking sand frog	Least concern
470	Rhacophoridae	*Chiromantis*	*xerampelina*	Southern foam nest frog	Least concern

6.9.6 Birds

Approximately 247 bird species are reported from the Kosi Bay system, of which only 85 are associated with water, making the majority forest-orientated birds. Some notable water-associated birds include the rare flufftail (*Sarothrura* spp), whitebacked night heron (*Gorsachius leuconotus*) and the crab plover (*Dromas ardeola*). Several bird species are not encountered in any other parts of South Africa, with Kosi Bay being the most southerly limit of their distribution.

A full list of the bird species found in the Kosi Bay area is presented in Appendix B (SABAP2, 2016). The bird list is based on the Southern African Bird Atlas Project 2 data (SABAP2) gathered by citizen scientists and avid birders, based on quarter degree squares and pentads. The yearly coordinated water bird count data for 2014–2016 was also used for the bird list in Appendix B.

6.9.7 Aquatic mammals and other fauna

There are approximately 26 mammal species in this area. The most dominant mammal is the hippopotamus (*Hippopotamus amphibius*) and only the water mongoose (*Atilax paludinosus*) and the clawless otter (*Aonyx capensis*) are located in the estuary.

6.10 Conclusion and recommendations

Kosi Bay is one of the most interesting Ramsar sites in South Africa; however, very little is known about its ecosystem functioning, apart from the fish kraal research available. Scanty water quality or ecosystem data was available and this prevents management measures being implemented to maintain its sustainable use. Natural resource use is very high with subsistence fishing and increased destruction of mangroves having a major impact on the system. Increased boating and recreational uses could also potentially impact on the ecosystem at Kosi Bay.

Overall, Kosi Bay seems to be in a fair condition, although the impacts from anthropogenic activities are visible. These include increased algal growth, reed growth and water grass growth in response to nutrient increase. Anecdotal evidence from recreational fishermen has also indicated a decreased catch for certain species within the Kosi Bay system as a result of the increased subsistence fishing industry.

The following research topics are recommended for future studies:

- Water quality fluxes within the different lakes together with the estuarine and marine environment could shed light on the productivity of the system
- Benthic invertebrate and diatom analyses could indicate trends in the ecosystem condition
- The presence of alien invasive gastropoda is a major concern and a study of the impact on the indigenous gastropoda is needed
- The information on the fish community is up to date due to the catch records that are taken as well as the monitoring of the fish kraals. This monitoring should be continued to ensure the sustainability of the practices.

- A socio-economic study on the reliance on the fish kraals for protein for subsistence versus protein for sale should include a feasibility study on minimising fish kraals to ensure the practice remains sustainable
- The impact of recreational use of Kosi Bay should be studied to determine its sustainability.

7 LAKE SIBAYA

7.1 Introduction

Lake Sibaya is the largest natural freshwater lake in South Africa (Humphries, 2013) and is situated on the coastal plain in KwaZulu-Natal. The lake is separated from the ocean by forested dunes, swamp forest and wet grassland. Lake Sibaya supports numerous reptiles, fish, birds, mammals and plants, with some being endangered or endemic. Numerous species of birds use the area for breeding, while a large population of *Hippopotamus* sp. is also situated here. The lake supports a diverse zooplankton fauna, 15 species of aquatic and 43 species of terrestrial molluscs, as well as flora and fauna unique to South Africa (Ward and Kyle, 1990). The lake provides water for Mbazwane and Vasi. Human activities consist of livestock grazing and cultivation.

7.2 Site location

Lake Sibaya is situated 430 km north-east of Durban (Ward and Kyle, 1990). Lake Sibaya is situated in Zululand on the Maputaland coastal plain (Allanson, 1979; Bruton, 1979; Ward and Kyle, 1990), which commences in Mtunzini (south of Richards Bay) where it broadens out northward into Mozambique and occupies almost half the width of Mozambique (Allanson, 1979). The western side of the lake is very flat making it difficult to define the boundary of the catchment (Ward and Kyle, 1990). High dune forest separates the eastern side of the lake from the ocean (Ward and Kyle, 1990). Lake Sibaya is classified as a coastal freshwater lake, with a surface area of 60–70 km^2 and a total catchment area of 530 km^2 (Bowen, 1979; Bruton, 1979; Ward and Kyle, 1990). The lake has a maximum depth of 43 m, with a maximum altitude of 20 m above sea level (Bowen, 1979; Bruton, 1979; Ward and Kyle, 1990). Offshore marine canyons suggest that a large river once connected the lake to the sea (Ward and Kyle, 1990). This large river is possibly the Phongolo River which is now diverted northwards (Ward and Kyle, 1990).

Lake Sibaya is situated in the Natal Coastal Plain (Category 13.02). The area is situated within the water management area for the Usuthu to Mhlatuze rivers. All of the sub-quaternary catchments in the area around the Lake Sibaya system are classified as Freshwater Ecosystem Protected Areas (Driver et al., 2011).

Four study sites were selected at Lake Sibaya, namely Lake Sibaya 1 (LS1), Lake Sibaya 2 (LS2), Lake Sibaya 3 (LS3) and Lake Sibaya 4 (LS4). Sites were selected based on accessibility, availability of substrata and representivity in terms of the basin sampled. The sites were sampled over three surveys; the first in August 2015, the second in December 2015 and the third in February 2016. Figure 25 indicates the location of all four sites. LS 1 and 2 are located within the main basin of the lake on the eastern side. LS 3 is situated in the southern basin and LS 4 is situated in the western arm.

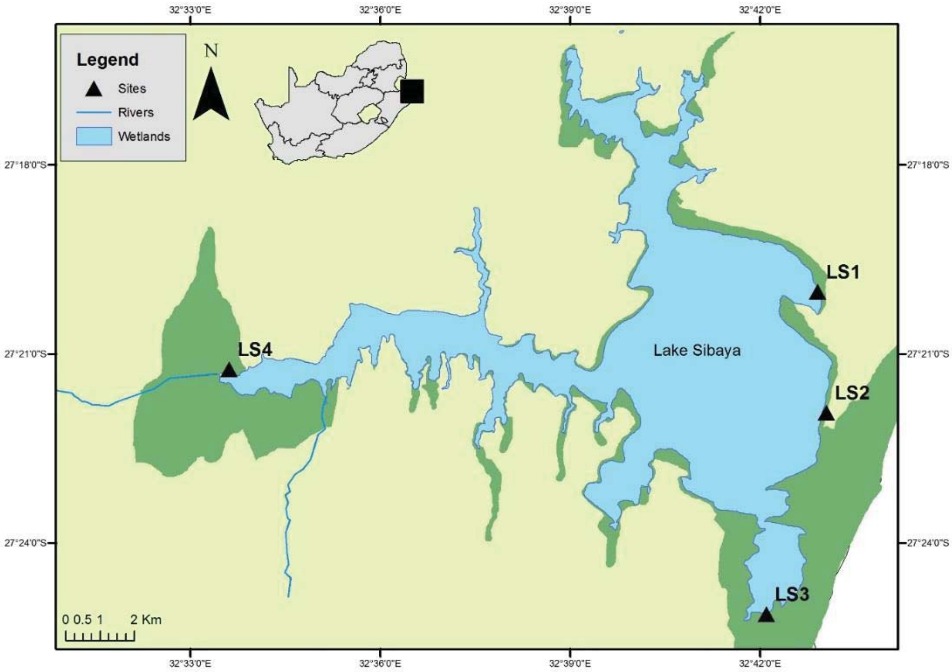


Figure 25: Map indicating the location of the Lake Sibaya Ramsar site, and the sites used to assess the system during 2015 and 2016

7.3 Ramsar criteria

Lake Sibaya was designated a Ramsar wetland based on the following criteria:

1. Firstly, it is the largest, natural freshwater lake in South Africa with many diverse flora and fauna. It is the only permanent water source in the area for animals, with water in the surrounding coastal plains drying up completely in dry years. Lake Sibaya is an important link between Kosi Bay and St Lucia Bay, extending the tropical elements down the east coast.
2. It contains the second largest population of hippopotamus (*Hippopotamus amphibius*) and crocodiles (*Crocodylus niloticus*) in KwaZulu-Natal. Lake Sibaya and its surroundings has the capacity to support almost 250 hippos, hundreds of crocodiles, and other larger mammals. Breeding populations of these hippos and crocodiles, as well as fish eagles (*Haliaeetus vocifer*), reed and whitebreasted cormorant (*Phalacrocorax africanus* and *P. carbo*), herons (*Ardea* spp.), kingfishers (*Halcyon* sp.), weavers and a variety of other waterbirds, are also found on the lake.

3. The freshwater goby, *Silhouetta sibayi*, is thought to be endemic to this region. There are a number of Red Data species also known from this region which would be threatened without this lake.
4. The rare climbing orchid (*Vanilla roscheri*) occurs on the shore of Lake Sibaya and is the only known population of this species.
5. The wetland also supports rural inhabitants in the region, who are often solely dependant on the water and its associated biota.

7.4 Physical features

7.4.1 Climate

The seasonal mean annual precipitation (MAP) of Lake Sibaya for July 2014–June 2015 was 500–2 000 mm and 100–200 mm for July 2015–November 2015 (SAWS, 2016). Furthermore, the MAP decreases over the catchment in a westerly direction (Allanson, 1979). The precipitation decreases from 1 200 mm in the south to only 700 mm in the west (Allanson, 1979). Most of the rain in the area falls between January and March, but rain occurs all year round (Allanson, 1979). Directly on the surface of the lake the annual evaporation of 1 420 mm/yr exceeds the annual precipitation (Allanson, 1979; Ward and Kyle, 1990).

7.4.2 Geology

Tertiary and recent sand make up the coastal plain, with Cretaceous and Palaeocene sediments forming the main rock underlying the coastal plain (Allanson, 1979; Ward and Kyle, 1990). The Cretaceous sediments, according to Allanson (1979), are overlaid with “relatively thin, discontinuous Tertiary shallow marine and beach deposits, with erosive unconformity”. A variety of depositional environments are represented by Quaternary sediments, which postdate the Cretaceous and Palaeocene sediments (Allanson, 1979). Major physiographic elements are constituted by these environments, which include aeolian dune, lagoonal, shore zone, fluviatile and paludal (Allanson, 1979).

7.4.3 Vegetation

A dune forest is situated on the eastern side of the lake, with 147 species found in the forest (Allanson, 1979; Ward and Kyle, 1990). The forested dunes are the coastal plains’ most striking feature as they attain a considerable height, even though they rarely exceed 1 km in width (Allanson, 1979). The dune forest reaches heights of 183 m in the St. Lucia vicinity, while Lake Sibaya’s highest peak is at 134 m (Allanson, 1979). The dune crest, in this area, was most probably fashioned by southerly winds when the sea level was lower and there was an expanse of sand on the ocean side (Allanson, 1979). However, the vegetation of the dune forest is mostly influenced by the north-easterly sea breezes (Allanson, 1979). This is due to salt spray, picked up from sea breezes, that is deposited on the vegetation (Allanson, 1979). This wind and sea salt influences the entire Natal and Zululand vegetation, resulting in deformed bushes and low-growing shrub, all of which has a hedged or uniform canopy (Allanson, 1979). The species occupying the Natal and Zululand regions are the same as at Lake Sibaya (Allanson, 1979). All these species bind to sand and are salt tolerant (Allanson, 1979).

Canopy, sub-canopy, shrub and herb layers and coastline vegetation are the strata which comprise the dune forest (Allanson, 1979). The coastline vegetation plays an important role and is found in relatively unstable sand on a narrow belt between the dune scrub and high tide level (Allanson, 1979). The species that makes up the coastline vegetation are mostly widespread between Natal and Zululand (Allanson, 1979).

7.4.4 Hydrology

Lake Sibaya is found on the Natal Coastal Plain, which is better known as Maputaland. It is a landlocked freshwater lake of around 60–70 km^2 with a rough elevation of 20 m above mean sea level. Water from the lake is mainly lost by evaporation but it is suspected that some water may be lost via seepage to the ocean.

The lake water is clear, with transparency averaging 3.2 m. The pH of the lake varies between 8.2 and 8.3. The main chemical characteristics are an elevated chloride level for fresh water (135 mg/L) and constantly high dissolved oxygen concentrations. The average depth of Lake Sibaya is around 10 m with an average volume of 700 × 106 m^3. Maximum depth is around 41 m.

Lake Sibaya is a vital source of fresh water for the ecology and local community and it is often the only source of water for birds and mammals during drought periods. The lake is an important hydrological feature that has great scientific and economic value. Lake Sibaya is the largest inland freshwater lake in South Africa and it is a popular fishing and diving destination but is often exploited for urban and rural water supply (Allanson, 1979; Meyer et al., 2001). A study by Weitz and Demlie (2014) looked at the water balance and lake levels of Lake Sibaya (Figure 26). Their study, from quantification of a 14-year monthly water balance, showed strong seasonal variation in the various water balance components. In recent years the rate of water abstraction has increased. This, coupled with decreasing rainfall and increasing pine plantations, has resulted in a lower lake level. The decreased lake level could potentially have negative effects on neighbouring ecosystems and cause a potential sea-water invasion of the coastal aquifer (Weitz and Demlie, 2014).

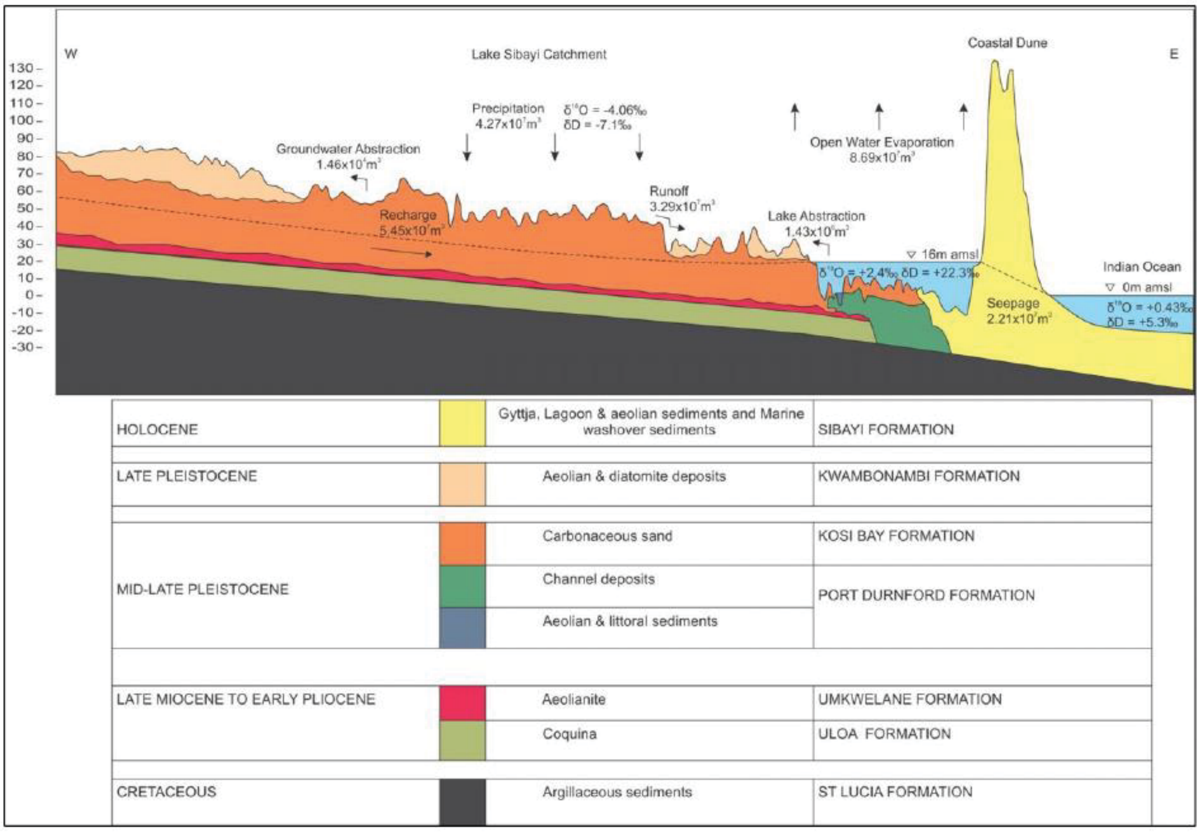


Figure 26: Hydrogeological conceptual model of the Lake Sibaya catchment (from Weitz and Demlie, 2014).

7.4.5 Water quality

The water quality ranges that were measured during the field surveys in 2015 and 2016 were supplemented with a Reserve determination study completed on Lake Sibaya during 2015 (Table 31). It is evident from the water quality data that Lake Sibaya is predominantly a freshwater system; however, the pH is slightly higher due to the different ion concentrations that indicate its estuarine origin. The nutrient concentrations varied during the project and it was found that phosphates have increased significantly in certain sections due to anthropogenic activities.

Table 31: Water quality ranges for selected parameters determined during surveys from 2014 to 2016

Water quality parameter	Unit	Lake Sibaya
Oxygen saturation	%	50–78
pH	-	8–9
Temperature	°C	21–24
Electrical conductivity	µs/cm	540–730
Nitrate	mg/L	0.5–0.85
Nitrite	mg/L	0.003–0.007
Ammonium	mg/L	0.09–0.25
Phosphates	mg/L	0.5–2.2

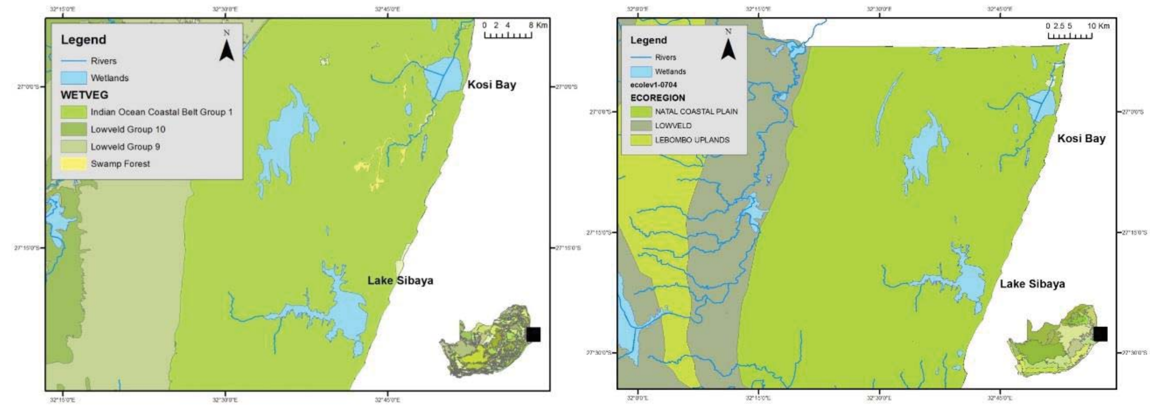
7.5 Wetland classification

The summary classification for Levels 1 to 3 is provided in Table 32. Lake Sibaya is classified as an inland system. Lake Sibaya historically had a connection with the ocean as is evidenced in the unique taxa that are present in the system, but due to no current connection to the Indian Ocean it is also classified as an inland system. The vegetation grouping (Figure 27) from the NFEPA project (Nel et al., 2011) indicates that this system is in the Indian Ocean Coastal Belt Group 1 and this was determined with high confidence. The ecoregion map (Figure 27) indicates that this system is located in the Natal Coastal Plain and this was also established with high confidence.

The classification of Lake Sibaya at Level 3 is all within a plain landscape setting and this was determined with high confidence. However, within the wider Ramsar area there will be some wetland features on slopes (low confidence) and valley floors (low confidence).

Table 32: Summary of the classification Kosi Bay and Lake Sibaya systems using Levels 1 to 3 of the NWCS (the confidence rating of the classification is given in brackets for each level).

Wetland Name	Level 1	Level 2		Level 3
	System	DWA Ecoregion	NFEPA WetVeg Group/s	Landscape Unit
Lake Sibaya	Inland	Natal Coastal Plain (High)	Indian Ocean Coastal Belt Group 1 (High)	Plain (High)



A **B**

Figure 27: (A) NFEPA wetland vegetation group (Nel et al., 2011) for Lake Sibaya. (B) Department of Water and Sanitation Level 1 Ecoregion (Kleynhans et al., 2005) for Lake Sibaya.

The classification of Lake Sibaya for Level 4 is fairly straightforward (Table 33). The classification of the smaller system that was indicated in the previous paragraph will be more difficult. When looking at the classification system for Lake Sibaya, it is evident that it is also a depression (high confidence); however, it is not exorheic as the water in the lake comes from the catchment and does not exit. Thus, the system can be classified as endorheic with a medium confidence level. Similar to the other systems at Kosi Bay, Lake Sibaya also has a channelled inflow into the lake. This was also determined with high confidence.

Table 33: NWCS Level 4 Hydrogeomorphic classification of the various main units present at Kosi Bay and Lake Sibaya.

Wetland Name	Unit	Level 4 : HGM Unit		
		4A	4B	4C
Lake Sibaya	5	Depression (high)	Endorheic (high)	With channelled inflow (high)

7.6 PES/Ecosystem services

A DWS (2015a) report on Lake Sibaya stated that the water quality for most of the system, except the southern basin and western arm, is in a near pristine condition and not severely impacted, based on water quality data alone (not considering sediment data). However, the southern basin (LS 3) and western arm's (LS 4) water quality have been influenced by increased rural development and forestry (DWS, 2015b).

The DWS (2015a) report on the lake indicated the present ecological status (PES) and alternative ecological category (AEC). The PES scores were based on the combined water quality parameters (temperature, electrical conductivity, pH, dissolved oxygen, total carbon, total nitrogen and total phosphorus). The categories are presented in Table 34. The ecological categories are interpreted from A–F, with A indicating a natural system and F indicating a critically modified system (Kleynhans and Louw, 2007).

Table 34: Present ecological status (PES) and alternative ecological status (AEC) for Lake Sibaya.

Zone	Site	PES	AEC
Main Basin	Lake Sibaya 1 and 2	B/C	C
Southern Basin	Lake Sibaya 3	C	C
Western Arm	Lake Sibaya 4	B/C	C

7.7 Land use and threats

Lake Sibaya is particularly susceptible to pollution as it is an endorheic system. The main pollution problems stem from overgrazing, injudicious burning, overexploitation of natural resources and indoor residual spraying with DDT for malaria control. Plans have also been proposed to control gastropoda by molluscacide in order to destroy the various vectors that spread bilharzia. These molluscacides will also be deadly to aquatic invertebrates and small fish species.

A recent survey by Humphries (2013) reported that DDT concentrations at Lake Sibaya represented the highest levels in South Africa, with most sediment samples exceeding guideline values. The potential for bioaccumulation of DDT in breeding fish, bird and crocodile populations is therefore a major possibility.

The current land use in the area is mainly subsistence agriculture, livestock grazing, natural resource use, and nature conservation. To the north and south of Lake Sibaya are large pine plantations at Mbazwana and Manzengwenya.

7.8 Current recreation and tourism

The lake and the surrounding area are good for the development of small wilderness-type camps and lodges. Numerous hiking or walking activities in the relatively undisturbed shore vegetation are also possible. A limited amount of recreational fishing is done but the size of the fish in the system does not encourage most tourists to fish (Ward and Kyle, 1990). The area is scenic with great potential for a greater tourist market. When the Rhodes research station was operational, numerous visiting scientists would frequent this area for research puposes (Allanson, 1979).

7.9 Aquatic biodiversity information

7.9.1 Diatoms

Algal and diatom research at Lake Sibaya is limited with only general distribution of taxa available. Past studies on diatom communities in Lake Sibaya were completed by Archibald (1966) and Allanson (1979). In Allanson (1979), a preliminary list of algae (benthic and planktonic) is presented. An article by Archibald (1966) lists the species identified during his study, including three species recorded in South Africa for the first time and nine new species. The three species recorded in South Africa for the first time included: *Amphora robusta* Gregory, *Navicula cryptolyra* Brockmann and *Stauroneis karstenii* (O. Müller) Hustedt. The nine new species included *Achnanthes breenii* Archibald, *Achnanthes sibayiensis* Archibald, *Amphora lacustris* Archibald, *Cocconeis pusilla* Archibald, *Cyclotella substylorum* Archibald, *Fragilaria exiguissima* Archibald, *Navicula breenii* Archibald, *Navicula sibayiensis* Archibald and *Navicula subpatrickae* Archibald. None of the three new South African records were identified in this study but one of the new species was identified, namely, *Amphora lacustris*. Except for the article by Archibald (1966), the only other reference to this species is that of Sánchez Castillo (1993) at the Twelfth International Diatom Symposium in Renesse, Netherlands. Archibald (1966) identified 107 different species, while in the present study only 59 species were identified (Table 35). Both the present study and Archibald's (1966) made use of aquatic plants as a substrate from which to collect the diatom flora. Some species identified in the present study were not identified by Archibald (1966) or Allanson (1979). This may be due to differences in sampling sites, sampling methods, or due to changes in the aquatic environment between 1966 and 2015/16. A detailed analysis of the diatom species sampled during 2015/2016 can be found in Appendix D.

Table 35: Diatom species present in the Lake Sibaya system during the three surveys in 2015 and 2016.

Species	Date described
Amphora sp. Ehrenberg	1844
Amphora veneta Kützing	1844
Amphora lacustris R.E.M. Archibald	2006
Anomoeoneis sphaerophora (Ehrenberg) Pfitzer	1871
Anorthoneis sp. A. Grunow	1868
Aulacoseira granulata (Ehrenberg) Simonsen	1979
Aulacoseira muzzanensis (Meister) Krammer	1991
Cocconeis pediculus Ehrenberg	1838
Cocconeis placentula (Ehrenberg) Grunow	1884
Cocconeis sp. Ehrenberg	1837
Craticula sp. Grunow	1868

Species	Date described
Cymbella cymbiformis Agardh	1830
Diploneis sp. Ehrenberg	1894
Diploneis ovalis (Hilse) Cleve	1891
Diploneis zanzibarica (Grunow) Hustedt	1937
Discostella pseudostelligera (Hustedt) Houk and Klee	2004
Encyonema minutum (Hilse.) D.G. Mann	1990
Encyonema sp. Kützing	1834
Encyonopsis sp. Krammer	1997
Encyonopsis minuta Krammer and Reichardt	1997
Encyonopsis subminuta Krammer and Reichardt	1997
Epithemia adnata (Kützing) Brébisson	1838
Epithemia sorex Kützing	1844
Fragilaria sp. Lyngbye	1819
Fragilaria ulna Lange-Bertalot	1980
Gomphonema sp. Ehrenberg	1832
Gomphonema insigne Gregory	1856
Gomphonema parvulum Kützing	1849
Gomphonema pseudoaugur Lange-Bertalot	1979
Gomphonema sp. 2 Ehrenberg	1832
Gomphonema sp. 3 Ehrenberg	1832
Gyrosigma acuminatum (Kützing) Rabenhorst	1853
Hantzschia distinctepunctata Hustedt	1921
Karayevia ploenensis (Hustedt) Bukhtiyarova	1999
Mastogloia smithii Thwaites	1848
Mastogloia sp. 1 Thwaites	1848
Mastogloia sp. 2 Thwaites	1848
Mastogloia sp. 3 Thwaites	1848
Navicula sp. Bory	1822
Navicula cryptotenelloides Lange-Bertalot	1993
Navicula interruptestriata Schwabe and Simonsen	1961
Navicula radiosa Kützing	1844
Navicula zanoni Hustedt	1949
Navicymbula pusilla Krammer	2003
Nitzschia sp. Hassall	1845
Pinnularia sp. C.G. Ehrenberg	1843
Pinnularia subcapitata Gregory	1992
Placoneis sp. C. Mereschkowsky	1903
Placoneis placentula (Ehrenberg) Heinzerling	1908
Rhopalodia sp. O. Müller	1895
Rhopalodia gibberula (Ehrenberg) O. Müller	1895
Rhopalodia musculus (Kützing) O. Müller	1899
Sellaphora sp. Mereschkowsky	1902
Sellaphora sp. 2 Mereschkowsky	1902
Sellaphora pupula (Kützing) Mereschkowksy	1902
Seminavis sp. D.G. Mann	1990

Species	Date described
Seminavis strigosa (Hustedt) Danieledis and Economou-Amilli	2003
Tabularia fasciculata (Agardh) Williams and Round	1986
Tryblionella apiculata Gregory	1857

7.9.2 Zooplankton

Lake Sibaya has a diverse zooplankton community that includes the endemic copepod *Tropocyclops brevis*. Major species that make up the community include various other copepods and cladocerans. Rotifers are also common. Various other invertebrates also occur but no recent information is available (Ward and Kyle, 1990). Recent work on macrocrustacea has been completed at Lake Sibaya as a study site (Raw et al., 2015; 2016).

7.9.3 Macroinvertebrates

Benthic invertebrates that occur are various crustacea, molluscs, crabs, and shrimp, while various coelenterates, nematodes, a marine polychoete worm and many insect larvae (mayflies, chironomids, dragonflies, damselflies, water bugs, water boatmen) are also found. Studies have shown that 15 species of molluscs are found at Lake Sibaya while 43 species of terrestrial molluscs can be found in the adjacent dune forest (Allanson, 1979).

7.9.4 Fish

The fish community in Lake Sibaya includes 18 species that are dominated by cichlids (four species) and gobiids (three species). One goby (*Silhouetta sibayi*) has its largest known population in the lake as very few records of it have been received from other localities. The most successful and abundant fishes are Mozambique tilapia (*Oreochromis mossambicus*), southern mouth-brooder (*Pseudocrenilabrus philander*), banded tilapia (*Tilapia sparrmanii*), sharptooth catfish (*Clarias gariepinus*) and tank goby (*Glossogobius giuris*). All of the fish work that has been completed was found in Allanson (1979). A DWA (2015) report to determine the Reserve for Lake Sibaya also completed some fish surveys; the results were similar to Allanson (1979).

7.9.5 Amphibians

The Maputaland area in KwaZulu-Natal has more species of frogs than any other biogeographic area surveyed during the South African Frog Atlas Project in 2004. Surveys recorded 23 frog species including the endangered Pickersgill's reed frog, which is an endemic species (EWISA, 2014). Five species of turtles occur along the adjoining coastline, the most common species being leatherback and loggerhead turtles (Kyle, 1995).

At Lake Sibaya, specifically, 22 species of frogs have been recorded, of which 20 species are tropical forms; one is a Cape form and the other is a transitional species. The information that is available from FrogMAP was extracted and included for reference in Table 36 (FrogMAP, 2016). A new research project on the frogs of Zululand started at the end of 2015 under the leadership of Prof. Louis du Preez from North-West University. This project will provide valuable information on the frog community within Zululand.

Table 36: A list of the amphibian species expected to occur within the Lake Sibaya area (from FrogMAP).

Species code	Family	Genus	Species	Common name	Red list category
130	Arthroleptidae	*Arthroleptis*	*stenodactylus*	Shovel-footed squeaker	Least concern
140	Arthroleptidae	*Arthroleptis*	*wahlbergi*	Bush squeaker	Least concern
670	Arthroleptidae	*Leptopelis*	*mossambicus*	Brownbacked tree frog	Least concern
160	Brevicipitidae	*Breviceps*	*adspersus*	Bushveld rain frog	Least concern
220	Brevicipitidae	*Breviceps*	*mossambicus*	Mozambique rain frog	Least concern
910	Bufonidae	*Schismaderma*	*carens*	Red toad	Least concern
320	Bufonidae	*Sclerophrys*	*garmani*	Olive toad	Least concern
330	Bufonidae	*Sclerophrys*	*gutturalis*	Guttural toad	Least concern
10	Hyperoliidae	*Afrixalus*	*aureus*	Golden leaf-folding frog	Least concern
20	Hyperoliidae	*Afrixalus*	*delicatus*	Delicate leaf-folding frog	Least concern
30	Hyperoliidae	*Afrixalus*	*fornasinii*	Greater leaf-folding frog	Least concern
570	Hyperoliidae	*Hyperolius*	*argus*	Argus reed frog	Least concern
590	Hyperoliidae	*Hyperolius*	*marmoratus*	Painted reed frog	Least concern
600	Hyperoliidae	*Hyperolius*	*microps*	Sharp-headed long reed frog	Least concern
620	Hyperoliidae	*Hyperolius*	*pusillus*	Water lily frog	Least concern
630	Hyperoliidae	*Hyperolius*	*semidiscus*	Yellowstriped reed frog	Least concern
640	Hyperoliidae	*Hyperolius*	*tuberilinguis*	Tinker reed frog	Least concern
650	Hyperoliidae	*Kassina*	*maculata*	Redlegged kassina	Least concern
660	Hyperoliidae	*Kassina*	*senegalensis*	Bubbling kassina	Least concern
730	Phrynobatrachidae	*Phrynobatrachus*	*mababiensis*	Dwarf puddle frog	Least concern
740	Phrynobatrachidae	*Phrynobatrachus*	*natalensis*	Snoring puddle frog	Least concern
1050	Pipidae	*Xenopus*	*laevis*	Common platanna	Least concern
780	Ptychadenidae	*Ptychadena*	*anchietae*	Plain grass frog	Least concern
790	Ptychadenidae	*Ptychadena*	*mascareniensis*	Mascarene grass frog	Least concern
800	Ptychadenidae	*Ptychadena*	*mossambica*	Broadbanded grass frog	Least concern
810	Ptychadenidae	*Ptychadena*	*oxyrhynchus*	Sharpnosed grass frog	Least concern
820	Ptychadenidae	*Ptychadena*	*porosissima*	Striped grass frog	Least concern
830	Ptychadenidae	*Ptychadena*	*taenioscelis*	Dwarf grass frog	Least concern
880	Pyxicephalidae	*Amietia*	*delalandii*	Delalande's river frog	Least concern
850	Pyxicephalidae	*Pyxicephalus*	*adspersus*	Giant bull frog	Near threatened
860	Pyxicephalidae	*Pyxicephalus*	*edulis*	African bull frog	Least concern
940	Pyxicephalidae	*Strongylopus*	*fasciatus*	Striped stream frog	Least concern
1010	Pyxicephalidae	*Tomopterna*	*krugerensis*	Knocking sand frog	Least concern
470	Rhacophoridae	*Chiromantis*	*xerampelina*	Southern foam nest frog	Least concern

7.9.6 Birds

Lake Sibaya and the surrounding areas has a diverse bird fauna with up to 279 species that have been recorded. Of these, 62 species are closely associated with the aquatic ecosystem through breeding, feeding or roosting habitats. The most abundant bird species are cormorants (*Phalacrocorax* spp.), various kingfishers (*Halcyon* spp.), fish eagles (*Haliaeetus vocifer*), and a variety of herons, darters and egrets. Waders include the white-fronted sand plover (*Vanellus* spp.), black-winged stilt (*Himantopus himanto*pus), avocet, greenshank, spoonbills and herons, with jacana, crakes, gallinules and bitterns in sheltered bays.

A full list of the bird species found in the Lake Sibaya area is presented in Appendix B. The bird list is based on the Southern African Bird Atlas Project 2 data (SABAP2, 2016) gathered by citizen scientists and avid birders, based on quarter degree squares and pentads. The yearly coordinated water bird count data for 2014–2016 was also used for the bird list in Appendix B.

7.9.7 Aquatic mammals and other fauna

The most dominant mammal is the hippopotamus (*Hippopotamus amphibius*), the water mongoose (*Atilax paludinosus*) and the clawless otter (*Aonyx capensis*). Studies have shown that there has been a 95–98% decline in crocodile (*Crocodylus niloticus*) numbers at Lake Sibaya (Combrink et al., 2011) with only a few breeding individuals remaining.

7.10 Conclusion and recommendations

The overall condition of Lake Sibaya is variable depending on where you are in the system. Areas in the main basin closer to the ocean are in a better condition than the eastern arm, which is more associated with anthropogenic activities. The completion of the Reserve determination will go a long way in managing any future impacts on the system. However, it must be mentioned that the Reserve determination did not sample extensively in the system and many findings were based on the work of Allanson (1979). Therefore, it is of utmost importance that continuous monitoring of the system is initiated and implemented to ensure the sustainability of the system.

The following research topics are recommended for future studies:

- Further research is needed on the diatom community composition
- Macroinvertebrate sampling was limited during this project and as such a project related only to Lake Sibaya should be initiated

- Ideally, a long-term follow-up study to replicate the work of Allanson (1979) should be initiated to monitor how the system has changed in the last 30–40 years
- The impact of anthropogenic activities on the fish community and fish health should be studied.

8 NTSIKENI NATURE RESERVE

8.1 Introduction

The Ntsikeni Nature Reserve is one of the most conserved and largest high-altitude wetlands in South Africa (> 1700 m). It is named after the Ntsikeni Mountain on the eastern boundary of the nature reserve. This palustrine emergent wetland is dominated by sedges and grasses and is located at the bottom of a valley, within Sisonke District Municipality and Umzimkhulu Local Municipality. Since protective measures were put in place for this nature reserve, little ecological change has occurred to the wetland with no commercial activities within the site. It is recognised as the second most important breeding site in South Africa for the critically endangered wattled crane (*Bugeranus carunculatus*) and threatened Eurasian bittern (*Botaurus stellaris*). It is also home to the endangered long-toed tree frog (*Leptopelis xenodactylus*), oribi (*Ourebia ourebi*), as well as other wetland-dependent mammals. The reserve is under threat, however, from commercial afforestation activities along its outer borders (a major source of alien invasive species). It plays an important ecological role in water storage and regulating water flow to the Ngwagwane and Umzimkulu Rivers. Legislation is necessary (amongst other things) to ensure clean water is available to the surrounding communities downstream, although no specific management plan is in place.

8.2 Site location

The Ntsikeni Nature Reserve is located in the southern part of the KwaZulu-Natal Province, between Franklin and Creighton. Kokstad, situated approximately 45 km from Ntsikeni, is the nearest large town. The protected area is 9 200 ha (a flat area of 9 228.7 ha with an actual surface area of 9 517.6 ha according to GIS), including a wetland of approximately 1 070 ha (Figure 28), and the highest point is 2 321 m (the lowest elevation being 1 580 m).

The Ntsikeni Nature Reserve is classified as a grassland biome within the Drakensberg Foothill Moist Grassland (Vegetation type GS10) as well the Eastern Temperate Freshwater Wetland (Vegetation type AZf3) (Mucina and Rutherford, 2004).

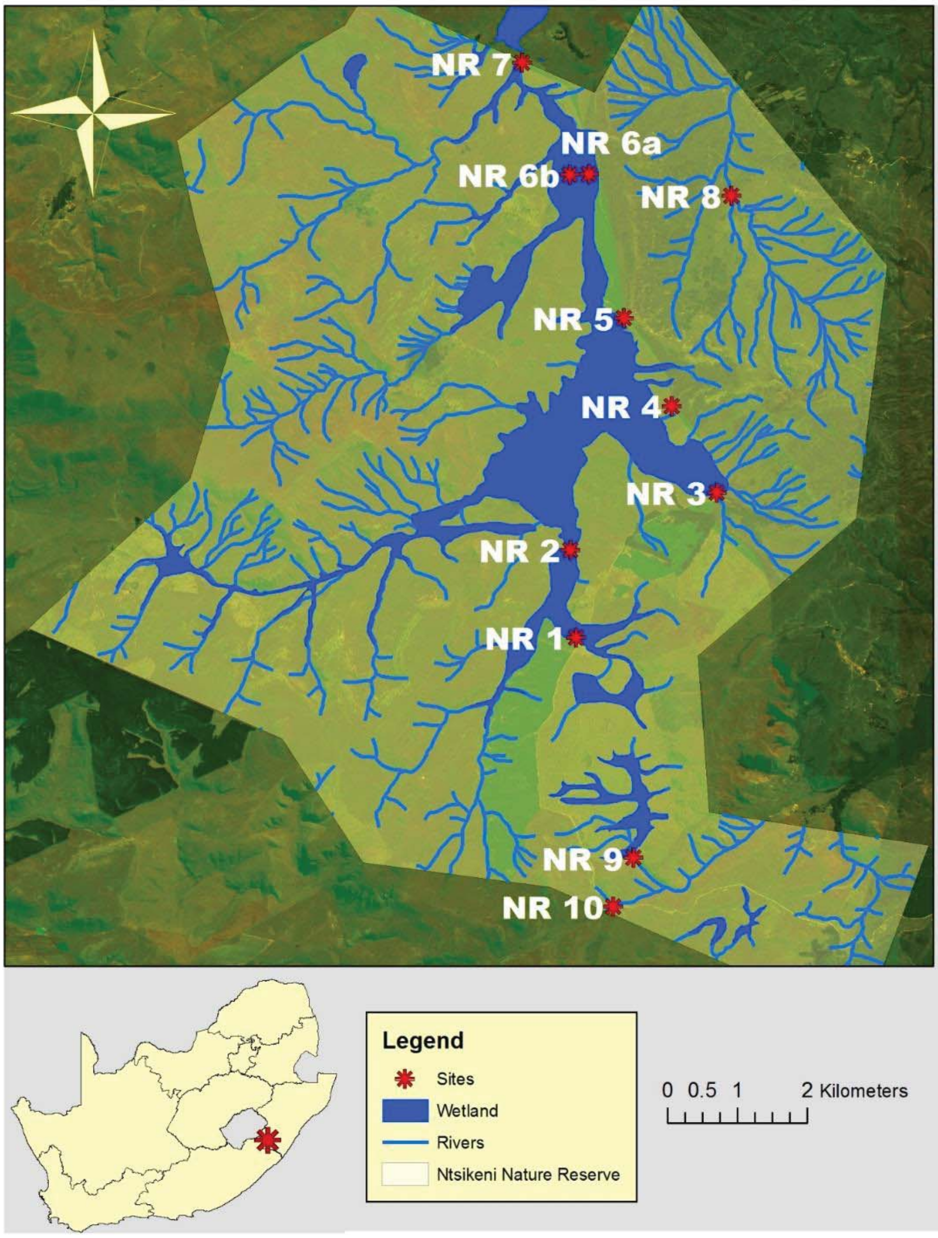


Figure 28: Map of the Ntsikeni Nature Reserve indicating the various sites that were assessed during the sampling surveys in 2015 and November 2016

8.3 Ramsar criteria

The Ntsikeni Nature Reserve was designated a Ramsar wetland based on the following three criteria required for Ramsar status:

Criterion 1: The Ntsikeni Nature Reserve is one of the largest high-altitude wetlands in South Africa, entirely protected within a nature reserve. There are no other Ramsar sites in this 100 km^2 wetland area (on the eastern coastal slope, Drakensberg region), and according to Begg (1988), Ntsikeni was identified as one of Kwazulu-Natal's 28 priority wetlands. Within the wetland-rich area, there are three other major wetlands (the Kromrivier vlei, Cedarville flats wetland and the Franklin vlei), but none have protected status, reinforcing the importance of protecting Ntsikeni, which is the only one with very low levels of hydrological and ecological impact.

Criterion 2: The Ntsikeni wetland has been identified as a very important breeding site for the endangered species, wattled crane (*Bugeranus carunculatus*), which is classified as Vulnerable on the IUCN Red List (Meine and Archibald, 1996). According to Blackmore (2010), two to three pairs (out of 80 active breeding pairs in the country) of these cranes are known to breed in the wetland. The wattled crane is considered to be a conspicuous “flagship species” and the Ntsikeni wetland the second most important breeding site in South Africa for this species. Furthermore, this wetland is thought to be home to the endangered long-toed tree frog (*Leptopelis xenodactylus*).

Criterion 3: This wetland has been identified as the second most important breeding site for the wattled crane in South Africa (second only to Mgeni vlei) and has two to three breeding pairs utilising this site. Ntsikeni therefore supports 3–4% of the South African breeding population of these cranes.

8.4 Physical features

8.4.1 Climate

South Africa receives an average annual rainfall of 450 mm, while the world average is calculated to be 860 mm. This indicates that South Africa is an arid country with only about 1.5% of the country not being classified as arid (De Villiers and De Wit, 2010; Breedt and Dippenaar, 2013). It is calculated that approximately 65% of the country receives less than 500 mm of rainfall annually and that 21% of the country receives less than 200 mm of rain annually (Breedt and Dippenaar, 2013). KwaZulu-Natal (KZN), on the other hand, is considered to have a subtropical climate and experiences summer rainfall of between 900 mm and 1 200 mm per annum (Fairbanks and Benn, 2000). KwaZulu-Natal is responsible for 28.5% of South Africa’s national MAR (Rivers-Moore and Goodman, 2010), thereby highlighting the importance of freshwater conservation in the province. The area receives summer rainfall (911 mm annually), has a mean temperature of 11.5°C (9.5–17.4°C), and often has severe frost and snowfall during the year (Camp, 1998).

8.4.2 Geology

The entire Ntsikeni catchment occurs within the 9 200 ha and is characterised by a central, broad, flat valley bottom made up of alluvial sediments. The valley bottom rises into the grasslands which are underlain with Tarkastad mudstones and sandstones as well as some Adelaide mudrock and sandstone.

8.4.3 Vegetation

Ntsikeni Nature Reserve conserves a representative portion of the Drakensberg Foothill Moist Grassland (EKZN, 2016). The permanently saturated marsh areas of the wetland are dominated by *Carex acutiformis* (Kotze, 2003). The hummocked sedge meadow is dominated by a mixture of grass and sedge species such as *Aristida junciformis* and *Bulbostylis schoenoides* (Kotze, 2003). The remaining areas such as seasonally waterlogged zones, wet grassland transitional zones and surrounding non-wetland areas are all dominated by a mixture of grass species (Kotze, 2003; Blackmore, 2010). Although the reserve is largely clear of alien plants, a small proportion of the wetland's catchment (< 1%) is occupied by invasive tree species (Blackmore, 2010) such as wattles (Kotze, 2003). As part of the rehabilitation programme, wattle and bramble are being cleared (Nxele, 2007).

8.4.4 Hydrology

Ntsikeni Nature Reserve is located in the KZN Province between the towns of Underberg and Kokstad and is situated within the Umzimkhulu catchment on the Lubhukwini River (Nxele, 2007; Blackmore, 2010; EKZN, 2016). The catchment of Ntsikeni vlei (75 km^2) is estimated to supply a MAR of 22 × 106 m^3 (Middelton et al., 1981; Begg, 1989). This vlei is situated high in the Umzimkulu catchment and has low pollutant input as there is a low level of human activity upstream of the wetland. Thus, the primary hydrological value of this wetland is stream flow regulation, and its main benefit is to provide clean water for downstream communities who have no formal bulk water provision.

8.4.5 Water quality

No water quality data for Ntsikeni Nature Reserve was available prior to the three surveys completed during 2015 and 2016 as part of this project. The water quality ranges that were found at the various sites (Table 37) indicated that the water quality is still good. The variability seen within Table 37 relates to seasonality and wetland type rather than impacts. Nutrients in some cases were found to be increasing but this could be related to organic enrichment from plant decay rather than anthropogenic activities.

Table 37: Water quality ranges for selected parameters determined during surveys from 2014 to 2016

Water quality parameter	Unit	Ntsikeni Nature Reserve
Oxygen saturation	%	34–125
Oxygen content	mg/L	2.7–13.42
pH	–	6.6–8.6
Temperature	°C	3–28
Electrical conductivity	µs/cm	23–173
TDS	mg/L	17–81
Nitrate	mg/L	0.25–2.5
Nitrite	mg/L	0.001–0.005
Ammonium	mg/L	0.07–0.45
Phosphates	mg/L	0.09–1.13

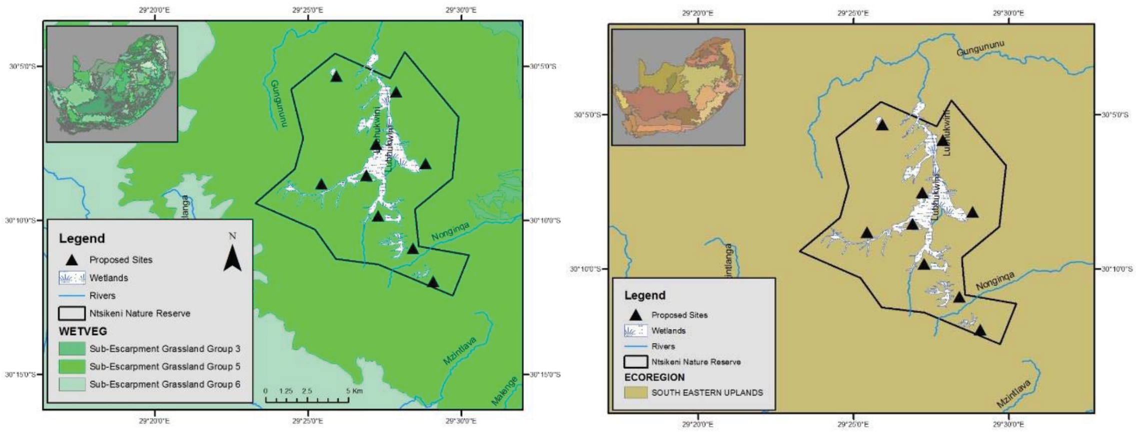
8.5 Wetland classification

The summary classification for Levels 1 to 3 is provided in Table 38. The Ntsikeni Nature Reserve systems are inland systems with elevations above sea level that range from approximately 1 600 m to over 2 300 m at the highest point. The Level 2 regional setting was determined using two GIS layers, the NFEPA WetVeg Group for wetland vegetation (Nel et al., 2011) and the DWS Level 1 ecoregions (Kleynhans et al., 2005). The wetland vegetation was identified mostly as Sub-escarpment Grassland Group 5 (Figure 29) while the DWS ecoregion layer identified the area as situated in the South-eastern Uplands (Figure 29). The ecoregion classification was high confidence while the wetland vegetation classification was medium confidence.

Table 38: Summary of the classification of the Ntsikeni Nature Reserve wetlands systems using Levels 1 to 3 of the NWCS (confidence ratings of the classification are given in brackets for each level)

Wetland Name	Level 1	Level 2		Level 3
	System	DWA Ecoregion	NFEPA WetVeg Group/s	Landscape Unit
Ntsikeni Vlei	Inland	South Eastern Uplands	Sub-escarpment Grassland Group 5 (High)	Slope (high) Valley floor (high) Hilltop (low) Bench (low)

The landscape setting was determined using Google Earth and 5 m contour lines of the area. From the imagery and desktop surveys it was already evident that numerous different types of wetland are present in this Ramsar area. At a Level 3 classification it was evident that wetlands are present on slopes (high confidence) and valley floors (high confidence) while there is a strong possiblility that wetlands will be present on hilltops (low confidence) and benches (low confidence) at Ntsikeni Nature Reserve. The Level 4 classification is summarised in Table 39 together with pictures of the various sites sampled during the project.



A **B**

Figure 29: (A) NFEPA wetland vegetation groups (Nel et al., 2011) present within the Ntsikeni Nature Reserve. (B) Department of Water and Sanitation Level 1 Ecoregion (Kleynhans et al., 2005) present within the Ntsikeni Nature Reserve.

8.6 PES/Ecosystem services

The DWS (2014) PESEIS assessment model was used for each of the Ramsar sites and this model provided the PES, environmental importance (EI) and environmental sensitivity (ES). EI looks at biophysical aspects that are related to capacity to function sustainably. ES considers attributes that relate to the sensitivity of the biophysical components to general environmental changes such as flow, water quality and geomorphological modifications. When the model was designed, the objective was to provide only a desktop model with information on the ecological issues that are important for the protection and management of river reaches. The PESEIS model was specifically designed for rivers and some limited aspects of valley bottom wetlands. In the Ramsar site case, the information within the model is useful to determine a PES and what the current expected biodiversity should or could be. The Ntsikeni Nature Reserve has one main river draining the reserve, namely the Lubhukwini River. Various valley bottom wetlands and seepage wetlands are also present. The PESEIS model indicated that the Lubhukwini River PES is Largely Natural to Natural. The EI and the ES was found to be in the High category (DWS, 2014).

Table 39: Summary of results of the application of Level 4 of the classification system to Ntsikeni wetland as laid out by Ollis et al. (2013) (Confidence rating of the classification of each site at each level given in brackets).

Site No.	Level 4A	Level 4B	Level 4C	Photo showing the structure of the site
NR1	Unchannelled valley bottom wetland (high)	n/a	n/a	
NR2	Channelled valley bottom wetland (high)	n/a	n/a	
NR3	Unchannelled valley bottom wetland (high)	n/a	n/a	

Site No.	Level 4A	Level 4B	Level 4C	Photo showing the structure of the site
NR4	Unchannelled valley bottom wetland (high)	n/a	n/a	
NR5	Unchannelled valley bottom wetland (high)	n/a	n/a	
NR6a	River (high)	Lowland river (low)	Not applied	

Site No.	Level 4A	Level 4B	Level 4C	Photo showing the structure of the site
NR6b	Floodplain (high)	Floodplain depression (medium)	n/a	
NR7	River (high)	Transitional (low)	Not applied	
NR8	River (high)	Upper foothills (low)	Not applied	

Site No.	Level 4A	Level 4B	Level 4C	Photo showing the structure of the site
NR9	Unchannelled valley bottom wetland (high)	n/a	n/a	
NR10	Unchannelled valley bottom wetland (high)	n/a	n/a	

The WET-Ecoservices (Figure 30) indicated that Ntsikeni Nature Reserve is able to provide services relating to tourism and recreation, carbon storage, maintenance of biodiversity and natural resources. The habitat for birding is excellent and potentially a functioning ecotourism industry could be set up here. Currently, the ecotourism present at the site is not sustainable and improved efficiency and usage will attract more visitors.

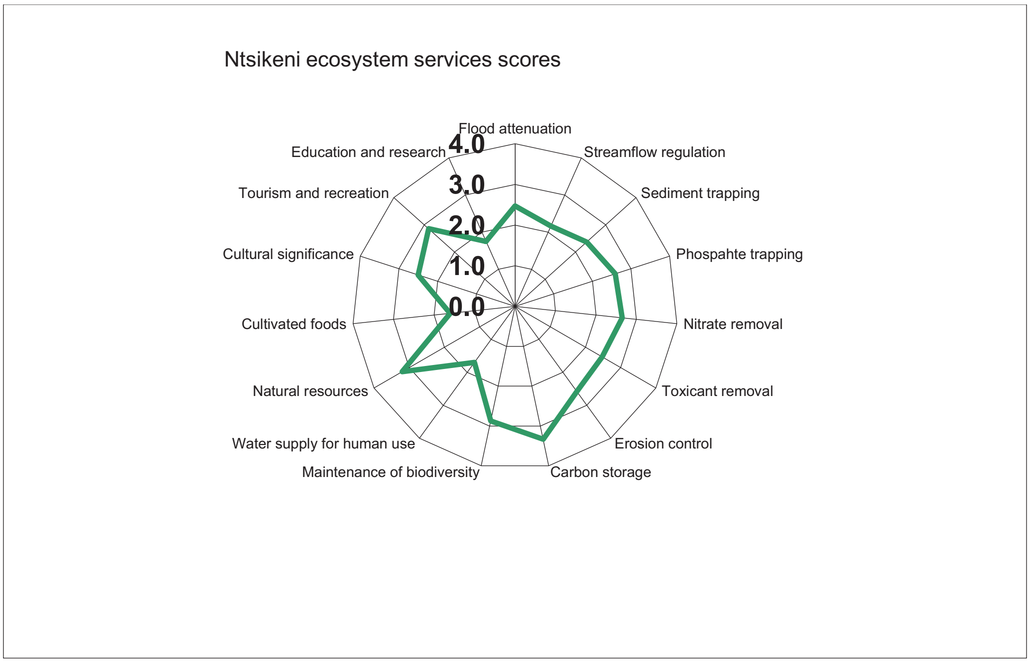


Figure 30: Ecosystem services star graph for Ntsikeni Nature Reserve.

8.7 Land use and threats

During 1998–1999, the Rennies Wetland Project and Eastern Cape Nature Conservation conducted a survey of the Ntsikeni wetland. This survey indicated the presence of abandoned artificial drainage channels in some of the tributaries, most of which were becoming progressively shallower due to the increased vegetation and sediment being trapped. The Department of Environmental Affairs and Tourism (DEAT) funded "Working for Wetlands" to build numerous concrete mass gravity structures and gabions in eroding sections of the wetland from 2000 to 2007 and the hydrological processes are all fully functional now.

Alien invasive trees are absent from the wetland, but some alien trees (*Acacia* spp. and *Eucalyptus* spp.) have invaded some of the drainage lines feeding the wetland. No afforestation, dams or irrigation problems which would affect the water entering the wetland are present. Some localised erosion is present within the wetland and its catchment due to old livestock paths and poorly maintained vehicle tracks, but control of cattle and vehicle movement has improved this situation.

Generally, the ecological state of the wetland has not been, nor will likely be, altered by any major threats. The potential for negative impacts from the surrounding communities is also low as there is a good relationship between the communities and the reserve management; there are strict conservation measures; the wetland does not have a high erosion hazard and is relatively resilient to grazing. However, the commercial afforestation in the surrounding areas serves as a major source of alien invasive plants (such as the American bramble, *Rubus cuneifolius*) and the timber industry is growing in the area, which could lead to increased afforestation adjacent to the protected area. This in turn could result in habitat fragmentation and isolation.

The Ntsikeni Nature Reserve, including the entire wetland and catchment, is currently being used for the reserve. The surrounding area is being used for a mixture of commercial and communal livestock grazing as well as subsistence agriculture and plantation forestry.

8.8 Current recreation and tourism

There are currently two community-owned and community-run lodges in the area. The access road to these establishments was upgraded in 2006, however, 4×4 vehicles are still required. There is not a big tourist market for the nature reserve and most visitors to the area are birders.

8.9 Aquatic biodiversity information

8.9.1 Diatoms

Currently, no information on the diatoms of Ntsikeni Nature Reserve could be found. Diatom samples were collected during three surveys, in July 2015, November 2015 and April 2016. These samples were identified and are listed below (Table 40).

Table 40: Diatom species present in Ntsikeni Nature Reserve from three surveys, in July 2015, December 2015 and April 2016

Species	Date described
Achnanthes linearis (W.Sm.) Grunow	1880
Achnanthes	
Achnanthidium crissum (Hustedt) Potapova & Ponader	2004
Achnanthidium F.T. Kützing	1844
Cocconeis placentula Ehrenberg	1838
Craticula acidoclinata Lange-Bertalot & Metzeltin	1996
Cymbella aspera var. gigas McCall	1933
Cymbella turgidula Grunow	1875
Cymbopleura amphicephala Krammer	2003
Diploneis elliptica (Kützing) Cleve	1891

Species	Date described
Encyonema minutum D.G. Mann	1990
Encyonema neogracile Krammer	1997
Encyonema silesiacum D.G. Mann	1990
Encyonema F.T. Kützing	1833
Eunotia minor (Kützing) Grunow	1881
Eunotia rhomboidea Hustedt	1950
Eunotia C.G. Ehrenberg	1837
Fragilaria parasitica (W.Sm) Grun. *var subconstricta* Grunow	1880
Fragilaria rumpens (Kützing) Carlson	1913
Fragilaria H.C. Lyngbye	1819
Geissleria decussis Lange-Bertalot & Metzeltin	1996
Gomphonema affine Kützing	1844
Gomphonema clavatum Ehrenberg	1832
Gomphonema gracile Ehrenberg	1838
Gomphonema parvulum Kützing	1849
Gomphonema clavatum Ehrenberg	1832
Gomphonema sp. 2 G.C. Ehrenberg	1832
Gomphonema stigma	
Gomphonema venusta Passy, Kociolek & Lowe	1997
Navicula cryptocephala Kützing	1844
Navicula notha Wallace	1960
Navicula ranomafanensis Metzeltin & Lange-Bertalot	2002
Navicula J.B.M Bory	1822
Navicula sp.	1822
Neidium productum (W.M. Smith) Cleve	1894
Nitzschia draveillensis Coste & Ricard	1980
Nitzschia A.H. Hassall	1845
Nitzschia sp. 2 A.H. Hassall	1845
Pinnularia C.G. Ehrenberg	1843
Pinnularia viridiformis Krammer	2000
Planothidium lanceolatum v. bimaculatum	2000
Staurosira pinnata Ehrenberg	1843
Staurosirella D.M. Williams & F.E. Round	1987
Surirella angusta Kützing	1844
Surirella P.J.F. Turpin	1828

8.9.2 Zooplankton

Up to now, no information on the zooplankton of Ntsikeni Nature Reserve was available. However, the field surveys completed in 2015 and 2016 sampled zooplankton from various sites within the nature reserve. The results are presented in Table 41 as a combined species list for all surveys. Detailed analyses and results can be found in Appendix G. The results of the zooplankton indicated that 23 different taxa were sampled at Ntsikeni Nature Reserve during the various surveys.

Table 41: Classification of zooplankton taxa sampled from all sites in Ntsikeni Nature Reserve during all surveys. Surveys occurred in July 2015, December 2015 and April 2016.

Kingdom	Phylum	Subphylum	Class	Order	Family	Species
Animalia	Arthropoda	Crustacea	Branchiopoda	Cladocera	Chydoridae	*Acroperus* sp.
						Alona sp.
						Chydorus sp.
					Daphniidae	*Ceriodaphnia* sp.
						Simocephalus sp.
					Moinidae	*Moina* sp.
			Maxillopoda	Calanoida	Diaptomidae	*Lovenula* sp.
						Metadiaptomus sp.
				Cyclopoida	Cyclopidae	*Ectocyclops* sp.
						Eucyclops sp.
						Macrocyclops sp.
						Microcyclops sp.
						Paracyclops sp.
				Harpacticoida		
			Ostracoda	Podocopida	Cyprididae	*Cypricercus* sp.
						Kapcypridopsis sp.
						Parastenocypris sp.
						Potamocypris sp.
						Stenocypris sp.
						Zonocypris sp.
					Darwinulidae	*Darwinula* sp.
						Vestalenula sp.
					Ilyocyprididae	*Ilyocypris* sp.

8.9.3 Macroinvertebrates

Information on the freshwater macroinvertebrates for Ntsikeni Nature Reserve is scarce and only three studies were available. These mainly looked at family level identification of invertebrates at limited sampling localities (Bok and Cambray, 1996; Burger, 1996; Mangold and de Moore, 1996).

The field surveys completed in 2015 and 2016 sampled macroinvertebrates from various sites within the nature reserve. The results are presented in Table 42 as a combined species list for all surveys. Detailed analyses and results can be found in Appendix G. The results indicated that approximately 115 taxa were sampled during the various surveys at the sites.

Table 42: Aquatic macroinvertebrate taxa sampled from all sites in Ntsikeni Nature Reserve during all surveys (July 2015, December 2015 and April 2016)

Kingdom	Phylum	Subphylum	Class	Order	Family	Species
Animalia	Annelida		Clitellata	Arhynchobdellida	Salifidae	*Salifa africana*
				Rhynchobdellida	Glossiphoniidae	*Batracobdelloides*
						Helobdella stagnalis
						Theromyzon cooperi
			Oligochaeta	Tubificida	Haplotaxidae	*Haplotaxis africanus*
					Naididae	
	Arthropoda	Chelicerata	Arachnida	Acarina	Pontarachnidae	
				Araneae	Lycosidae	
					Pisauridae	
					Tetragnathidae	
		Crustacea	Branchiopoda	Cladocera	Daphniidae	*Ceriodaphnia* sp.
						Scapholeberis sp.
			Malacostraca	Decapoda	Potamonautidae	*Potamonautes sidneyi*
			Malacostraca	Amphipoda	Sternophysingidae	*Sternophysinx* sp.
			Ostracoda	Podocopida	Cyprididae	*Potamocypris* sp.
		Hexapoda	Insecta	Coleoptera	Chrysomelidae	*Donaciasta* sp.
					Curculionidae	*Stenopelmus rufinasus*
					Dytiscidae	*Canthyporus* sp.
						Cybister sp.
						Hydaticus sp.
						Hydroglyphus sp.
						Hyphydrus sp.
						Laccophilus sp.
						Methles sp.
						Philaccolus sp.
						Rhantus sp.
					Elmidae	*Pachyelmis* sp.
					Gyrinidae	*Aulonogyrus* sp.
						Dineutus sp.
						Gyrinus sp.
						Orectogyrus sp.
					Haliplidae	*Haliplus* sp.
					Hydraenidae	*Coelometopon* sp.
						Hydraena sp.
						Parasthetops sp.
					Hydrophilidae	*Berosus* sp.
						Enochrus sp.
						Laccobius sp.
						Regimbartia sp.
					Noteridae	*Hydrocanthus* sp.
					Psephenidae	*Afrobrianax* sp.
						Afropsephenoides sp.
					Ptilodactylidae	
					Spercheidae	*Spercheus* sp.

Kingdom	Phylum	Subphylum	Class	Order	Family	Species
				Diptera	Athericidae	
					Ceratopogonidae	
					Chironomidae	*Paraphaenocladius* sp.
					Culicidae	*Anopheles* sp.
						Culex sp.
						Uranotaenia sp.
					Dixidae	*Dixa bicolor*
						Dixella harrisoni
					Empididae	*Hemerodromia* sp.
					Ephydridae	
					Muscidae	
					Sciomyzidae	
					Simuliidae	*Simulium (Nevermannia)*
					Stratiomyidae	
					Tabanidae	
					Tipulidae	*Antocha* sp.
						Dolichopeza sp.
						Gonomyia sp.
						Limonia (Dicranomyia)
						Tipula sp.
				Ephemeroptera	Baetidae	*Acanthiops* sp.
					Caenidae	*Afrocaenis* sp.
					Heptageniidae	*Afronurus* sp.
					Leptophlebiidae	*Adenophlebia* sp.
						Aprionyx sp.
						Castanophlebia sp.
						Hyalophlebia sp.
					Tricorythidae	*Tricorythus* sp.
				Hemiptera	Belostomatidae	*Appasus* sp.
					Corixidae	*Micronecta* sp.
						Sigara sp.
					Gerridae	*Aquarius* sp.
						Eurymetra sp.
					Naucoridae	*Laccocoris* sp.
					Nepidae	*Laccotrephes* sp.
						Ranatra sp.
					Notonectidae	*Anisops* sp.
						Enithares sp.
						Nychia limpida
					Paraphrynoveliidae	*Paraphrynovelia* sp.
					Pleidae	*Plea* sp.
					Veliidae	*Ocellovelia* sp.
						Rhagovelia sp.
						Xiphoveloidea major
				Lepidoptera	Crambidae	*Nymphula* sp.
				Odonata	Aeshnidae	*Aeshna* sp.
						Anax sp.
					Coenagrionidae	*Ceriagrion* sp.
						Pseudagrion sp.
					Corduliidae	*Phyllomacromia* sp.
					Gomphidae	*Onychogomphus* sp.
					Lestidae	*Lestes* sp.
					Libellulidae	*Notiothemis jonesi jonesi*
					Synlestidae	*Chlorolestes* sp.
				Plecoptera	Notonemouridae	*Aphanicercella* sp.
					Perlidae	*Neoperla* sp.
				Trichoptera	Ecnomidae	*Ecnomus* sp.
					Hydropsychidae	*Cheumatopsyche* sp.
					Hydroptilidae	*Hydroptila* sp.
						Oxyethira sp.

Kingdom	Phylum	Subphylum	Class	Order	Family	Species
					Leptoceridae	*Athripsodes* sp. *Leptecho* sp.
	Mollusca		Bivalvia	Veneroida	Sphaeriidae	*Pisidium* sp.
			Gastropoda	Hygrophila	Planorbidae	*Bulinus* sp. *Ferrissia* sp. *Gyraulus* sp.
					Lymnaeidae	*Lymnaea truncatula*
				Stylommatophora	Succineidae	*Oxyloma* sp.
	Nematoda		Chromadorea	Monhysterida	Monhysteridae	*Monhystera* sp.
	Platyhelminthes		Rhabditophora	Tricladida		

8.9.4 Fish

Currently no information on the fish community of Ntsikeni Nature Reserve is available. The waterfall downstream of the Ntsikeni Vlei is a major barrier for fish and it is expected that no fish, apart from possibly small minnows (*Enteromius anoplus*), are present within Ntsikeni Nature Reserve.

8.9.5 Amphibians

There are a few amphibian species known from the area: *Breviceps verrucosus*, *Cacosternum nanum*, *Strongylopus gray*ii, and *Xenopus laevis*. Only one reptile species is known, namely *Trachylepis striata* (Blackmore, 2010). The information that is available from FrogMAP was extracted and included for reference in Table 43 (FrogMAP, 2016).

Table 43: The amphibian species expected to occur within Ntsikeni Nature Reserve (from FrogMap)

Species code	Family	Genus	Species	Common name	Red list category
270	Brevicipitidae	*Breviceps*	*verrucosus*	Plaintive rain frog	Least concern
660	Hyperoliidae	*Kassina*	*senegalensis*	Bubbling kassina	Least concern
920	Hyperoliidae	*Semnodactylus*	*wealii*	Rattling frog	Least concern
730	Phrynobatrachidae	*Phrynobatrachus*	*mababiensis*	Dwarf puddle frog	Least concern
740	Phrynobatrachidae	*Phrynobatrachus*	*natalensis*	Snoring puddle frog	Least concern
1050	Pipidae	*Xenopus*	*laevis*	Common platanna	Least concern
820	Ptychadenidae	*Ptychadena*	*porosissima*	Striped grass frog	Least concern
1110	Pyxicephalidae	*Amietia*			Not listed
880	Pyxicephalidae	*Amietia*	*delalandii*	Delalande's river frog	Least concern
890	Pyxicephalidae	*Amietia*	*fuscigula*	Cape river frog	Least concern
882	Pyxicephalidae	*Amietia*	*poyntoni*	Poynton's river frog	Not evaluated
110	Pyxicephalidae	*Anhydrophryne*	*ngongoniensis*	Mistbelt or Ngongoni moss frog	Critically endangered
400	Pyxicephalidae	*Cacosternum*	*boettgeri*	Common caco	Least concern
430	Pyxicephalidae	*Cacosternum*	*nanum*	Bronze caco	Least concern
940	Pyxicephalidae	*Strongylopus*	*fasciatus*	Striped stream frog	Least concern
950	Pyxicephalidae	*Strongylopus*	*grayii*	Clicking stream frog	Least concern
980	Pyxicephalidae	*Strongylopus*	*wageri*	Plain stream frog	Near threatened
1030	Pyxicephalidae	*Tomopterna*	*natalensis*	Natal sand frog	Least concern

8.9.6 Birds

The Ntsikeni Nature Reserve is extremely popular as a birding hotspot and many rare birds are present within the wetland. There is unfortunately no research on birds at Ntsikeni and as such all of the information was gathered via citizen science and the SABAP2 programme. A full list of the bird species found in the Ntsikeni Nature Reserve is presented in Appendix B (SABAP2, 2016). The bird list is based on the Southern African Bird Atlas Project 2 data (SABAP2, 2016) gathered by citizen scientists and avid birders, based on quarter degree squares and pentads. The yearly coordinated water bird count data for 2014–2016 was also used for the bird list in Appendix B. These surveys have indicated that more than 200 birds have already been spotted at Ntsikeni Nature Reserve.

8.9.7 Aquatic mammals and other fauna

Currently no information was found to be available on the aquatic mammals of the Ntsikeni Nature Reserve.

8.10 Conclusion and recommendations

The ecological character of Ntsikeni Nature Reserve has not been significantly altered, although some minor alterations are present. It is a high-altitude freshwater wetland with good water quality and very diverse zooplankton and macroinvertebrate communities. The threat of anthropogenic activities is relatively small, taking into account the remoteness of the reserve, but afforestration remains a threat as it is practised on the boundaries of the reserve. Alien infestation of black wattle is common; however, it provides excellent habitat for rare bird species. The major threat to Ntsikeni is mismanagement of the ecotourism aspects that could lead to anthropogenic pressures being increased due to a lack of tourism and visitors to the reserve.

The following research topics are recommended for future studies:

- Surveys at Ntsikeni Nature Reserve should be continued with more sampling trips being conducted over a longer period of time
- Surveys should include other seasons of the year
- Diatoms and algae samples should be collected and analysed
- Amphibians should be studied so as to establish the full extent of the aquatic biodiversity of Ntsikeni Nature Reserve, especially amphibians on the Red Data List that might be present

- Further identification, and molecular identification, of macroinvertebrate and zooplankton taxa is required.

9 BLESBOKSPRUIT

9.1 Introduction

The Blesbokspruit wetland was designated a Ramsar site in 1986 due to the rich diversity of waterfowl that is present ((Van Wyk and Munnik, 1998; Haskins, 1998; Ambani, 2013). The system was formed in the 1930s due to embankments that were constructed across the Blesbokspruit for roads, pipelines and other developments. These developments were exclusively for the gold mining industry. The embankments flooded the adjacent grassland for approximately 20 km upstream and a vast open shallow water was created. The river width was widened to approximately 650 m. The emergent vegetation that grew in the shallow water included beds of *Phragmites australis* and *Typha latifolia.* The shallow habitats were perfect for migrating water birds, which started to visit the system on a seasonal basis.

9.2 Site location

The Blesbokspruit wetland flows through the town of Springs and forms part of its origin (Haskins, 1998; Van der Merwe, 2003). The town of Springs originated during the early 1900s because of mining activities. The Blesbokspruit catchment is a tributary of the Vaal River System and falls within the Upper Vaal catchment management area (Ambani, 2013). The Vaal River catchment is an important river system which the people of Gauteng Province depend on for their water supply. (Grobicki, 2002). Five sites were selected for an aquatic assessment during April and July 2016 (Figure 31). These sites were selected due to their proximity to activities that may alter the state of the wetland, such as wastewater treatment works, mine dumps, water treatment pumps, farming and the Marievale Bird Sanctuary.

9.3 Ramsar criteria

The following Ramsar criteria were used for the designation of the Blesbokspruit site: 1a, 1b, 1c, 1d / 2a, 2b, 2c, 2d / 3a, 3b, 3c / 4a, 4b.

The Blesbokspruit was originally a narrow, meandering non-perennial highveld river or stream that had some associated floodplain features. With the advent of mining in the highveld, it was exposed to human developments and settlements that disrupted the natural stream flow with numerous embankments and river crossings. This resulted in upstream flooding which then became colonised by reed beds. When it was designated a Ramsar site in 1986, Blesbokspruit had become a permanent wetland that was known for its variety and abundance of birds. The wetland is currently maintained in its artificially inundated state by daily inputs of several megalitres of eutrophic water from sewage works, mines and industries (Compaan, 1995).

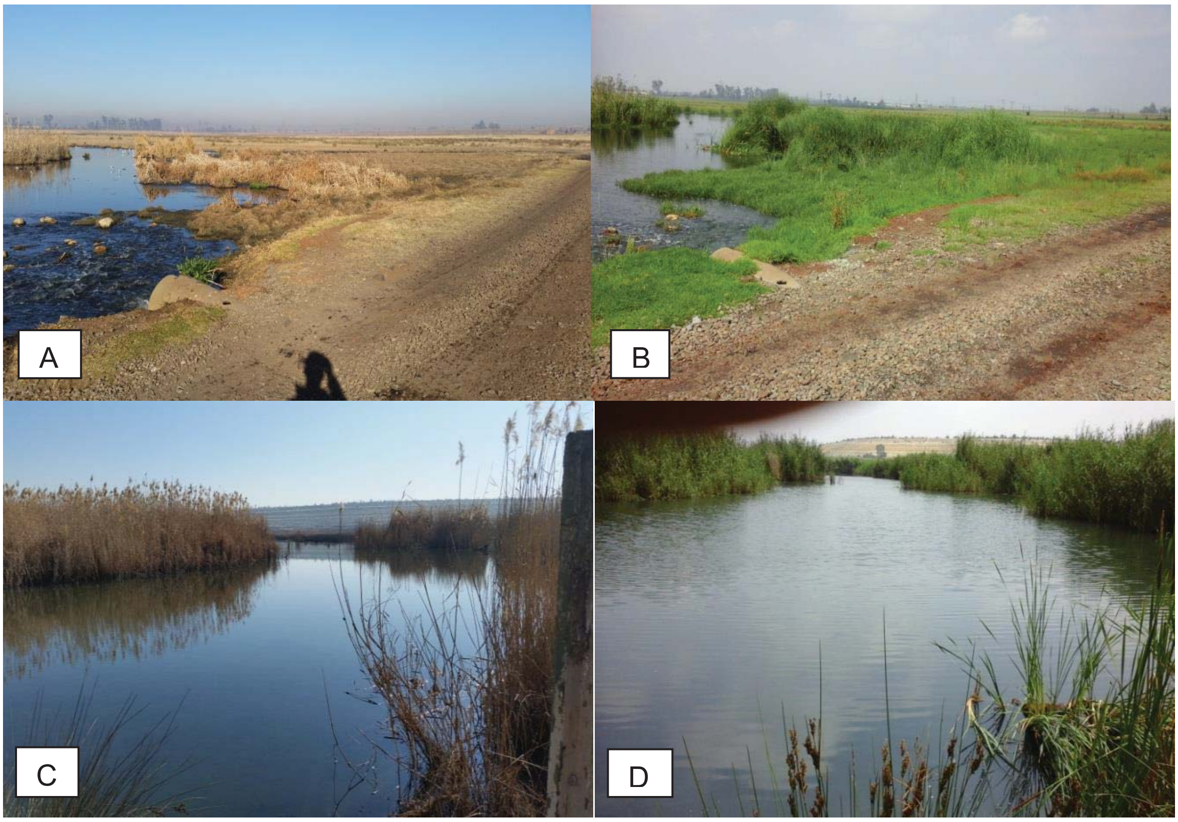


Figure 31: Various sites selected along the Blesbokspruit wetland for aquatic macroinvertebrate monitoring. (Source: Gregg van Rensburg)

9.4 Physical features

9.4.1 Climate

The average rainfall in the Blesbokspruit area is approximately 670 mm for the last 30–40 years. Temperatures vary from −10°C in winter to 35°C in summer. Frost occurs from April through to October. During the coldest months of June and July, ice can occur on the shallow open water. Snow falls on rare occasions. One of the heaviest snowfalls was recorded in July 1964 when a depth of 200 mm was measured and the area was blanketed for three days.

9.4.2 Geology

The geology in the Blesbokspruit catchment is simple with sedimentary rocks of the Karoo and Transvaal age overlying older gold-bearing Witwatersrand formations. All gold mining in the area is underground as none of the reefs appear on the surface. There are Black Reef Quartzite Formations that overlie the Witwatersrand strata. Malmani Dolomites also overlie the Black Reef Quartzites and these form the important natural water reservoirs.

9.4.3 Vegetation

The Blesbokspruit is found in highveld grassland, specifically Cymbopogon-Themeda veld and Bankenveld. The aquatic vegetation consists of *Phragmites australis*, bulrushes *Typha latifolia* and sedges which cover 90% of the water surface. These wetlands cover an area of approximately 85% of the Marievale Bird Sanctuary. The remaining 15% is a grassland which is broadly classified as Bankenveld.

9.4.4 Hydrology

The natural hydrology of the stream has been suppressed by artificial inputs of eutrophic water (from mines, sewage works and various industries). The wetland is thus permanently flooded, whereas before the 1930s the wetland would have been temporary and associated with a small non-perennial stream. The site was however designated as a Ramsar site when it was in its permanently flooded (i.e. artificially supported) state.

9.4.5 Water quality

The water quality of the Blesbokspruit is well analysed and monitored due to the various anthropogenic activities that are present in the system, including mining, agriculture and urban settlements. The ranges for the water quality parameters analysed during 2016 (Table 44) are mainly a snapshot for a specific year. Further details can be found in the Appendix H.

Table 44: Water quality ranges for selected parameters determined during surveys from 2014 to 2016.

Water quality parameter	Unit	High flow	Low flow
Oxygen saturation	%	46–133	
Oxygen content	mg/L	3.3–9.3	
pH	–	4.5–8.5	6.7–7.7
Temperature	°C	21–30	11–17
Electrical conductivity	µs/cm	540–1300	700–2600
TDS	mg/L	360–1200	-
Nitrate	mg/L	0.6–4.3	0.03–1.69
Nitrite	mg/L	0.03–1.14	0.03–0.35

9.5 Wetland classification

The extent of the Blesbokspruit has been changing ever since it was first established due to mining runoff. The extent is also changing due to present impacts in terms of hydrology; however, current land use is fairly stable and not much room is available for the wetland to significantly increase. The Ramsar Information Sheet of the Blesbokspruit indicates that it is between 1 400 and 1 800 ha in size, while the Gauteng C Plan (Version 3) indicates that it is approximately 2 111 ha in size. Figure 32 shows the current Ramsar boundary of the Blesbokspruit compared to the NFEPA wetlands data for wetlands in South Africa. It is evident that additional wetland habitat exists outside of the protected areas of the Ramsar boundary.

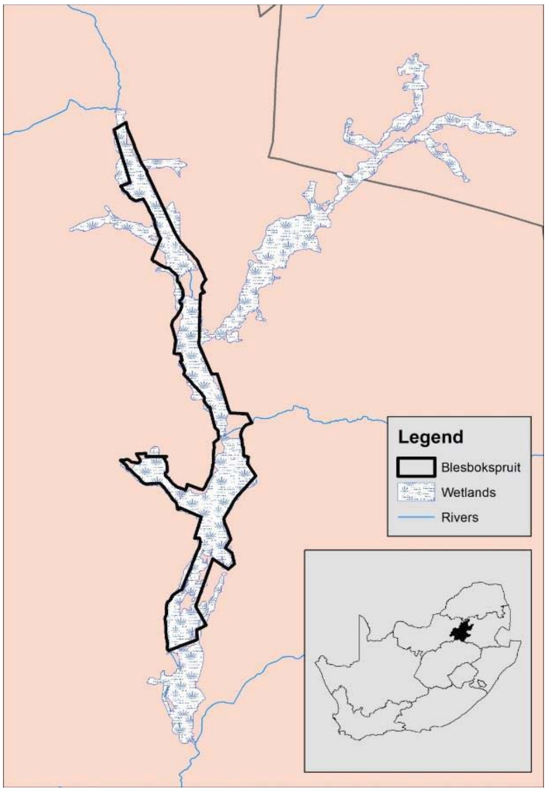


Figure 32: Map of the Blesbokspruit wetland indicating the present Ramsar boundary and the extent of wetlands in the surrounding environment

Regionally, the NFEPA wetlands layer indicated that wetlands within Gauteng comprise around 36 000 hectares while the total wetlands area within South Africa is approximately 3 million hectares. The Blesbokspruit is therefore relatively small in the overall picture although it fulfils an important role within the Gauteng province (Figure 32). The classification system for inland systems indicates that the Blesbokspruit is a floodplain system. However, it is an artificial system making assessment of the system problematic.

Land cover is mostly mining and cultivation, with small areas of natural vegetation potentially still present. Outside of the boundary of the Ramsar site some urban built-up areas also exist in close proximity to the wetland. Numerous bridges also cross the wetland at various points. Thus, 100% of the area is covered with these land covers (Figure 33).

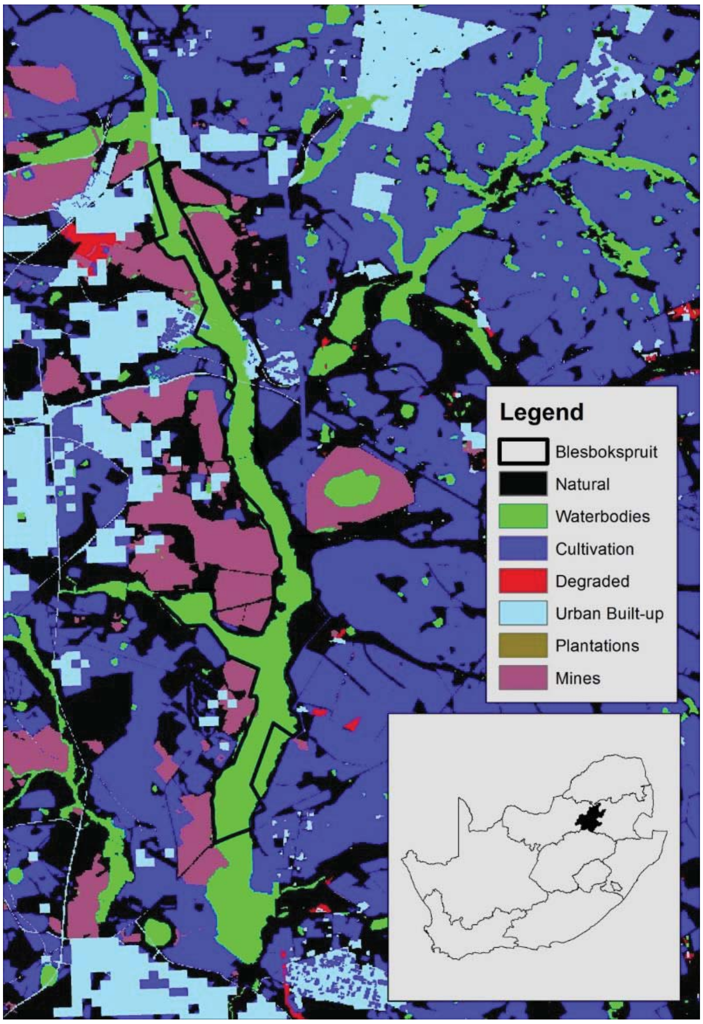


Figure 33: Map of the Blesbokspruit indicating the surrounding land cover

9.6 PES/Ecosystem services

No historical information on the present condition of the Blesbokspruit system is available. The only information that was found was water quality results. Literature did indicate that the wetland is in a degraded condition due to mining and agricultural impacts. The Blesbokspruit is currently still on the Montreux record, which is an indication of impacts present that are a threat to the maintenance of the Ramsar site.

The WET-Ecoservices methodology (Kotze et al., 2008) was used to determine the ecosystem services that the Blesbokspruit provides. The results in Figure 34 indicate that the Blesbokspruit provides carbon storage, erosion control, toxicant removal and tourism and recreation as the main ecosystem services. Other services include streamflow regulation, phosphate trapping, water supply for agriculture and flood attenuation. These ecosystem services are important for the catchment downstream as the system prevents the acid mine drainage that originates within the Blesbokspruit catchment from reaching the Vaal River system. It also provides some form of toxicant removal and regulation of the amount of water that is released from the wetland. As the Blesbokspruit is essentially an artificial system, it provides extremely valuable services at present that should be preserved and improved as much as possible.

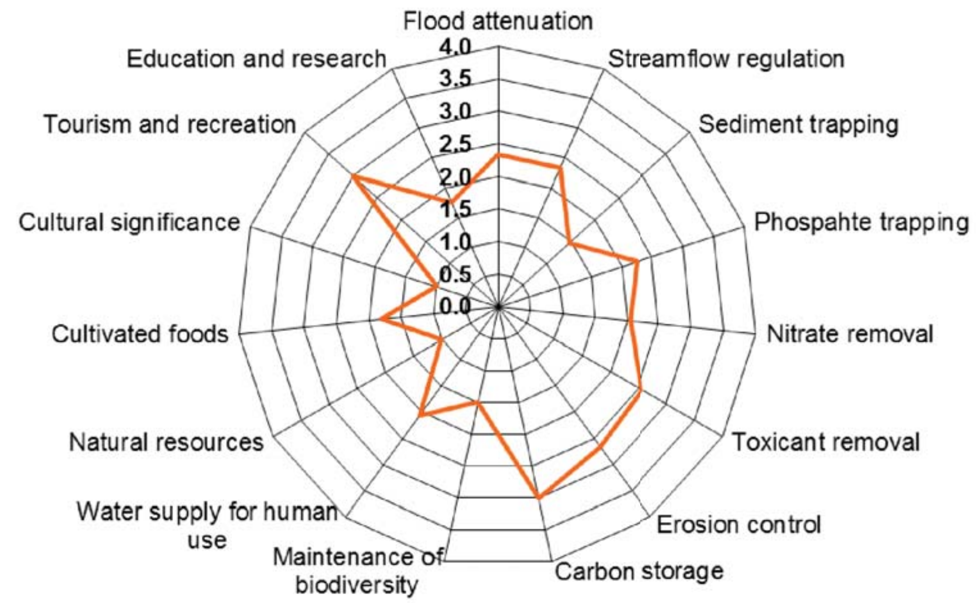


Figure 34: Ecosystem services of the Blesbokspruit.

9.7 Land use and threats

The predominant land uses surrounding the Blesbokspruit are agriculture and mining activities. Agriculture includes mainly maize, vegetables, lucerne, kikuyu grass, fodder and flowers. The major water source for these activities is the Blesbokspruit. Mining is mainly in the form of gold mines, and dewatering of old mine shafts contributes greatly to the poor water quality of the Blesbokspruit. There is a newly built water treatment works that will be able to treat and discharge this water into the Blesbokspruit. The human settlements and developments in the catchment also result in several wastewater treatment works that discharge into the system. The poor quality of this discharge is the main reason for the eutrophic status of the wetland. The impact of these systems is likely to increase in the future as the growing population searches for ways to treat and discharge its waste.

9.8 Current recreation and tourism

The recreation and tourism at the Blesbokspruit is related to its Ramsar status and the promise of a variety and abundance of bird species. The Marievale Bird Sanctuary forms a large part of the total area of the Ramsar site (approximately 1 000 ha) and it is situated in the south of the site. In the north, a conservancy for the wetland has also been established by the Grootvalley Trust and there are numerous bird hides and an educational facility present at the site. There are a few short walking trails in the reserve. The Marievale Bird Sanctuary is a provincial nature reserve and there is some accommodation available for people to overnight. The sanctuary also has some conference facilities available.

9.9 Aquatic biodiversity information

9.9.1 Diatoms

Currently no information on the diatoms of Blesbokspruit is known.

9.9.2 Zooplankton

Currently no information on the zooplankton of Blesbokspruit is known.

9.9.3 Macroinvertebrates

Field surveys for macroinvertebrates in the Blesbokspruit were completed during April and July 2016 at the selected sites indicated previously. The combined macroinvertebrates sampled at the various sites are presented in Table 33. The results indicated that 57 different families were collected during both surveys.

Table 45: Macroinvertebrates sampled at the selected pans in the Blesbokspruit during the April and September 2016 sampling surveys.

Order	Family	Order	Family
Coleoptera	Gyrinidae	Hemiptera	Pleidae
	Dytiscidae		Micronectidae
	Hydrophilidae		Notonectidae
	Helodidae		Belostomatidae
	Psephenidae		Veliidae
	Staphylinidae		Corixidae
	Scirtidae		Gerridae
	Elmidae		Ocheteridae
	Spercheidae	Odonata	Aeshnidae
	Hydraenidae		Platycnemidae
Diptera	Chironomidae		Libellulidae
	Culicidae		Coenagrionidae
	Psychodidae		Lestidae
	Dixidae	Decapoda/ Crustacea	Caridea/ Atyidae
	Tipulidae		Potomonautidae
	Ephydridae	Arachnida	Araneae
	Syrphidae		Hyrachnidae
Mollusca	Physidae		Unionicolidae

Order	Family	Order	Family
	Planorbidae Ancylidae Lymnaeidae		Hydrochnellae Hydrozetidae Tetragnuthidae
Annelida	Hirudinea Oligochaeta		
Ephemeroptera	Baetidae Caenidae		

9.9.4 Fish

The following fish species were expected to occur within the Blesbokspruit: *Enteromius pallidus, Enteromius anoplus, Enteromius trimaculatus, Enteromius aeneus, Labeo capensis, Labeo umbratus, Gambusia affinus, Cyprinus carpio, Micropterus salmoides, Clarias gariepinus* and *Enteromius paludinosus.*

However, recent surveys have indicated that *Austroglanis sclateri*, *Labeo capensis* and *Labeo umbratus* have probably been lost from the reach due to transformation of habitat and deteriorating water quality. In many areas only *Clarias gariepinus* is expected to survive for extended periods. Alien species such as *Gambusia affinis*, *Cyprinus carpio* and *Micropterus salmoides* are expected to have an impact on the indigenous species. Migration barriers in the system are also a driver of impact in the fish community.

9.9.5 Amphibians

The information that is available from FrogMAP was extracted and included for reference in Table 46 (FrogMAP, 2016).

Table 46: A list of the amphibian species expected to occur within the Blesbokspruit area and specifically from the Marievale Bird Sanctuary (from FrogMAP).

Species code	Family	Genus	Species	Common name	Red list category
910	Bufonidae	*Schismaderma*	*carens*	Red toad	Least concern
370	Bufonidae	*Sclerophrys*	*capensis*	Raucous toad	Least concern
330	Bufonidae	*Sclerophrys*	*gutturalis*	Guttural toad	Least concern
660	Hyperoliidae	*Kassina*	*senegalensis*	Bubbling kassina	Least concern
920	Hyperoliidae	*Semnodactylus*	*wealii*	Rattling frog	Least concern
1050	Pipidae	*Xenopus*	*laevis*	Common platanna	Least concern
880	Pyxicephalidae	*Amietia*	*delalandii*	Delalande's river frog	Least concern
890	Pyxicephalidae	*Amietia*	*fuscigula*	Cape river frog	Least concern
400	Pyxicephalidae	*Cacosternum*	*boettgeri*	Common caco	Least concern
850	Pyxicephalidae	*Pyxicephalus*	*adspersus*	Giant bull frog	Near threatened
990	Pyxicephalidae	*Tomopterna*	*cryptotis*	Tremelo sand frog	Least concern
1030	Pyxicephalidae	*Tomopterna*	*natalensis*	Natal sand frog	Least concern

9.9.6 Birds

A full list of the bird species found in the Blesbokspruit wetland is presented in Appendix B (SABAP2, 2016). The bird list is based on the Southern African Bird Atlas Project 2 data (SABAP2) gathered by citizen scientists and avid birders, based on quarter degree squares and pentads. The yearly coordinated water bird count data for 2014–2016 was also used for the bird list in Appendix B.

9.9.7 Aquatic mammals and other fauna

Currently, little information on the mammals or fauna of Blesbokspruit is known. Numerous larger mammals were abundant previously but currently the majority would only be found in the Marievale Bird Sanctuary. Otters, like *Lutra maculicollis* and *Aonyx capensis*, as well as the water mongoose, *Atilax paludinosus,* could possibly still be found within the bird sanctuary.

9.10 Conclusion and recommendations

The Blesbokspruit is an interesting system as the mining in the area has artificially created a wetland that functions extremely well in certain aspects. This is especially true for the creation of habitat for water fowl and other water birds. However, with all the anthropogenic activities in the catchment, and especially the Groot Valley Mine, it has been on the Montreux Record for more than 20 years. With recent improvements in the water quality, due to treatment as well as the closing down of various mines, there has been a drive to remove the Blesbokspruit from the Montreux Record.

Overall, the Blesbokspruit system is still in a modified state due to all of the anthropogenic activities that lead to poor water quality and destruction of the wetland habitat. This project has taken a snapshot of the water quality and the biological diversity at selected sites but it would be ideal if long-term aquatic ecosystem monitoring could be implemented to facilitate the management of the Blesbokspruit.

The following research topics are recommended for future studies:

- Assessment of the zooplankton community should be performed at the various open water sections of the system, especially at Marievale Bird Sanctuary
- The impact of treated acid mine drainage entering the system from the Groot Valley Mine should be investigated in a long-term study, incorporating water quality, sediment quality and biota in the system

- Long-term monitoring of the system is needed to facilitate the removal of the Blesbokspruit from the Montreux Record.

10 SEEKOEIVLEI NATURE RESERVE

10.1 Introduction

The Seekoeivlei wetland is situated in the Free State, just outside of the town of Memel (Youthed, 2014). It is approximately 16 km long, and varies in width from a few hundred metres up to 2 km in places (McCarthy et al., 2010). In terms of wetland type, it is predominantly a floodplain of the Klip River, which is the primary source of water (McCarthy et al., 2010). The Seekoeivlei was declared a Ramsar wetland in 1999 and is considered important in providing ecosystem services such as water purification and flood attenuation. The wetland is further considered to be important because it forms the upper reaches of the Klip River catchment, which is an important tributary of the Vaal River (Youthed, 2014). This wetland also provides food for livestock and game during winter times. Before Seekoeivlei was declared as a nature reserve, the wetland was impacted by artificial drainage channels because of commercial farming. These human interventions have had an impact on wetland geohydrological processes that has led to the decrease in function and integrity of the Seekoeivlei wetland (Youthed, 2014). The site consists of seasonal freshwater lakes, riverine floodplains and seasonally flooded grasslands, marshes and pools and peatlands (Ramsar, 2013).

10.2 Site location

Seekoeivlei Nature Reserve is situated in the north-eastern corner of the Free State close to the town of Memel (Figure 35). The wetland stretches from Memel for approximately 20 km to the Mpumalanga border. The main wetland varies in width from 200 m to 1 000 m at some places. The floodplain is approximately 3 700 ha, with the nature reserve and the floodplain totalling approximately 4 700 ha (Mobara, 2014).

10.3 Ramsar criteria

The following criteria were used to designate Seekoeivlei Nature Reserve as a Ramsar site:

Criterion 1(a): Seekoeivlei is a good representative example and one of the largest natural wetland systems in the grassland biome of South Africa (Du Preez and Marneweck, 1996).

Criterion 1(b): The Seekoeivlei wetland plays a substantial hydrological and ecological role in the natural functioning of the Klip River as well as the upper Vaal River, which is the major water source for the highly industrialised and densely populated Johannesburg area. This high-altitude wetland plays a vital role in regulating flow and in maintaining the highest water quality standards (Du Preez and Marneweck, 1996).

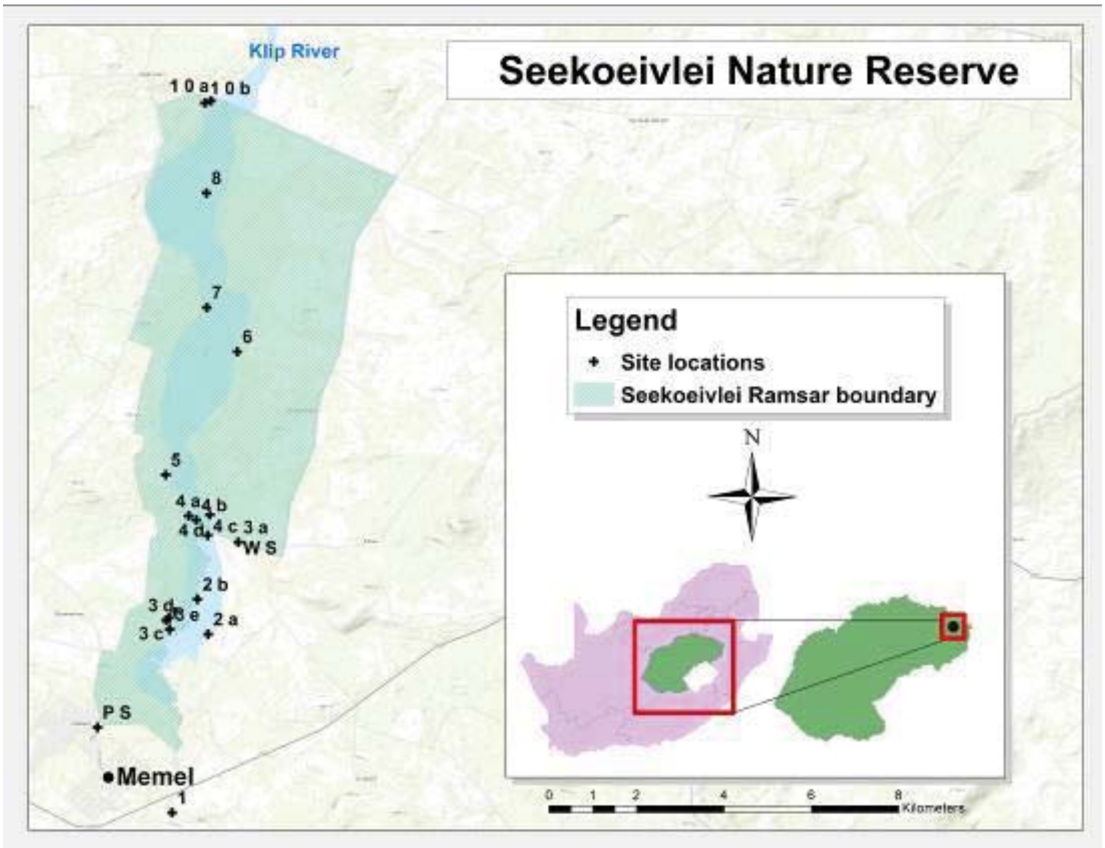


Figure 35: Map of Seekoeivlei Nature Reserve and the selected sampling sites for the surveys during 2016

Criteria 2(a): The area supports an appreciable assemblage of rare, vulnerable or endangered species or subspecies of plants or animals (Du Preez and Marneweck, 1996).

Criteria 2(b): This nature reserve is of great significance for the maintenance and permanent protection of the genetic and ecological diversity on the drier western side of the Drakensberg escarpment (Du Preez and Marneweck, 1996).

10.4 Physical features

10.4.1 Climate

The average annual rainfall for Seekoeivlei Nature Reserve is approximately 800 mm (McCarthy et al., 2010). The Klip River catchment has an annual average flow of 46 million m^3 (Du Preez and Marneweck, 1996). The peak flows in the river are between November and March (McCarthy et al., 2010) while lower flows occur during the winter months (Tooth et al., 2002). The absolute minimum temperature was measured at −15.3 °C and absolute maximum temperature at 37.0°C (FS DTEEA IMP, 2005; Mobara, 2014).

10.4.2 Geology

The Seekoeivlei Ramsar site has sediments of the lower Beaufort and upper Ecca Groups of the Karroo Sequence. There are also mudstones and sandstones that make up the Normandien formation within the Beaufort group. Alluvium has been deposited over a layer of shale (approximately 205 m in depth) and it is made up of unconsolidated grey-coloured fine and clay-rich sand and silt. Numerous dolerite dykes and sills are present throughout the wetland as well. According to McCarthy et al. (2010), the flow and sediment regime have been altered as a result of channel modifications coupled with faunal and floral changes. These changes have initiated major changes to erosional and depositional patterns (Mobara, 2014).

10.4.3 Vegetation

The Seekoeivlei Nature Reserve occurs within the grassland biome generally found within the interior of South Africa (Mobara, 2014). The reserve is almost the only reserve that protects grassland in this region, which occurs between an altitude of 1 700 and 1 850 m (FS DTEEA IMP, 2005). The vegetation in the Seekoeivlei Nature Reserve is generally grassland, woodland and thicket and hygrophilous communities (Du Preez and Marneweck, 1996). The vegetation found on the sandy loam soils can be classified as: *Aristida junciformis–Eragrostis plana* grassland (Mobara, 2014). The floodplains are poorly drained and thus form typical examples of seasonally moist habitats within drier western grasslands (O'Conner and Bredenkamp, 1997). Dominant vegetation is generally *Eragrostis plana,* and *Hyparrhenia hirta* is a prominent species (O'Conner and Bredenkamp, 1997).

10.4.4 Hydrology

The major part of the Seekoeivlei wetland is part of the wider floodplain of the Klip River. There are also a few depressions associated with the floodplain as well as outside of the floodplain. Numerous smaller seeps are also present within the system. However, many years of direct and indirect anthropogenic impacts, faunal and floral changes, and channel modifications have altered the flow and sediment regime of the wetland (Mobara, 2014). These changes have resulted in impacts to erosional and depositional patterns, including promoting rapid headward growth of a new channel and abandonment of a former channel (McCarthy et al., 2010). The floodplains receive water from overbank flooding as well as local rainfall over the system. The floodplain depressions progressively desiccate during winter (dry season) but several of the abandoned channels, oxbows, and backswamps retain water throughout the year (Mobara, 2014).

10.4.5 Water quality

Seekoeivlei Nature Reserve was added into this project during 2016 and the water quality in Table 47 is a snapshot from one survey. Future work is being completed and will be published in the scientific literature. The range of the water quality variables indicated a system that is least impacted by anthropogenic activities even though impacts from Memel are present and visible. The water quality was found to be good with very low electrical conductivity and TDS concentrations. The oxygen concentrations showed a wide variation that is consistent with daily fluctuations.

Table 47: Water quality ranges for selected parameters, determined during surveys from 2014 to 2016.

Water quality parameter	Unit	July	December
Oxygen saturation	%	36–112	40–146
Oxygen content	mg/L	5–12	3–14
pH	–	6.4–8.4	6.7–9.6
Temperature	°C	5–13	19–31
Electrical conductivity	µs/cm	63–185	82–186
TDS	mg/L	44–130	48–131

10.5 Wetland classification

The National Wetland Classification System used in this study (Ollis et al., 2013) distinguishes six levels, where the first four levels distinguish between different types of aquatic ecosystems. Using the above information on Seekoeivlei and the method of classification given by Ollis et al. (2013), it can be concluded that Seekoeivlei wetland can be classified as a floodplain wetland. In many cases the floodplain wetland is further classified as a floodplain depression. One site was also classified as a floodplain flat.

10.6 Land use and threats

The major land uses within the Ramsar site are grazing by animals and mowing of grassland for hay. The surrounding land use in the catchment is similar, with some cultivation in arable areas for maize and wheat. The water supply for Memel is taken from the Klip River. The town of Memel has grown during the last few years and pollution is entering the system through the Pampoenspruit.

One threat to the Ramsar site is from uncontrolled veld fires that can spread into the reserve from adjoining properties. Inappropriate management within the reserve and the surrounding farms and upstream catchments is also a problem. Examples of inappropriate management measures are increased use of fertilisers and increased erosion due to overgrazing or trampling (Du Preez and Marneweck, 1996).

10.7 Current recreation and tourism

The fact that the wetland is a sanctuary that supports large numbers of local and migratory birdlife is well known amongst professional and amateur ornithologists, as well as photographers (Ramsar, 2013). The drawcard of the reintroduction of hippopotamus in the last few years, as well as the introduction of buffalo, has proved important for tourism in the reserve. The construction of new accommodation in the reserve will increase tourism activities in the future and provide valuable support to this reserve.

10.8 Aquatic biodiversity information

10.8.1 Diatoms

Currently, no information on the diatoms of the Seekoeivlei Nature Reserve is known.

10.8.2 Zooplankton

Currently, no information on the zooplankton of the Seekoeivlei Nature Reserve is known.

10.8.3 Macroinvertebrates

Currently, very little information on the macroinvertebrates of the Seekoeivlei Nature Reserve is known. A study in 2014 by Mobara (2014) looked at the nematode diversity within the Seekoeivlei Nature Reserve. That study found a total of 43 genera that belong to 20 families and 7 orders, from three sites at the reserve.

A field survey of the Seekoeivlei Nature Reserve was completed in July 2016 to determine the macroinvertebrate diversity within the Klip River and the various floodplain depressions found within the Ramsar site. The survey identified 29 different families within 16 different sites within the Seekoeivlei Nature Reserve and the surrounding wetland areas of the Ramsar site (Table 48)

Table 48: Macroinvertebrates sampled at the selected pans in the Seekoeivlei Nature Reserve during the July 2016 sampling survey.

Order	Family	Order	Family
Diptera	Chironomidae	**Trichoptera**	Ecnomidae
Lepidoptera	Crambidae	**Arachnida**	Pontarachnidae
Ephemeroptera	Baetidae	**Crustacea**	Daphnia
	Caenidae		Ostrocoda
			Copepoda
Hemiptera	Naucoridae	**Mollusca**	Planorbidae
	Corixidae		Lymnaeidae
	Notonectidae		Ancyliidae
	Belostomatidae		Sphaeridae
	Pleidae		Potamonautidae
	Hebridae	**Hirudinea**	
Coleoptera	Curculionidae	**Odonata**	Libellulidae
	Hydrophilidae		Lestidae
	Dytiscidae		Coenagrionidae
	Haliplidae		

10.8.4 Fish

Eight different fish species have been found within the Seekoeivlei Nature Reserve: *Enteromius anoplus, Enteromius palidus*, *Enteromius paludinosus*, *Tilapia sparrmanii*, *Labeo capensis*, *Labeo umbratus*, *Clarias gariepinus* and *Labeobarbus aeneus* (DWS, 2014).

10.8.5 Amphibians

While at least 47 reptile and 20 amphibian taxa are expected to occur in the reserve (FS DTEEA IMP, 2005), Bates (1997) listed only two reptile and two amphibian taxa. The information that is available from FrogMAP was extracted and included for reference in Table 49 (FrogMAP, 2016).

Table 49: A list of the amphibian species expected to occur within the Seekoeivlei Nature Reserve (from FrogMAP, 2016).

Species code	Family	Genus	Species	Common name	Red List category
370	Bufonidae	*Sclerophrys*	*capensis*	Raucous toad	Least concern
330	Bufonidae	*Sclerophrys*	*gutturalis*	Guttural toad	Least concern
660	Hyperoliidae	*Kassina*	*senegalensis*	Bubbling kassina	Least concern
920	Hyperoliidae	*Semnodactylus*	*wealii*	Rattling frog	Least concern
1050	Pipidae	*Xenopus*	*laevis*	Common platanna	Least concern
880	Pyxicephalidae	*Amietia*	*delalandii*	Delalande's river frog	Least concern

Species code	Family	Genus	Species	Common name	Red List category
890	Pyxicephalidae	*Amietia*	*fuscigula*	Cape river frog	Least concern
400	Pyxicephalidae	*Cacosternum*	*boettgeri*	Common caco	Least concern
950	Pyxicephalidae	*Strongylopus*	*grayii*	Clicking stream frog	Least concern
1030	Pyxicephalidae	*Tomopterna*	*natalensis*	Natal sand frog	Least concern

10.8.6 Birds

Seekoeivlei Nature Reserve is known for its rich birdlife as it supports a large number of local and migratory birds. It provides important habitat for several species of rare or endangered birds (Ramsar, 2013). Two important bird species, the wattled crane and the white-winged flufftail, have been recorded at this Ramsar site. The flufftail lives in high-altitude marshes in between sedges and aquatic grasses in shallow water (Mobara, 2014). This bird has only been found at nine localities in South Africa and its survival depends on effective wetland conservation (FS DTEEA IMP, 2005).

A full list of the bird species found in theSeekoeivlei wetland is presented in Appendix B (SABAP2, 2016). The bird list is based on the Southern African Bird Atlas Project 2 data (SABAP2) gathered by citizen scientists and avid birders, based on quarter degree squares and pentads. The yearly coordinated water bird count data for 2014–2016 was also used for the bird list in Appendix B.

10.8.7 Aquatic mammals and other fauna

Hippopotami (*Hippopotamus amphibius)* were reintroduced into Seekoeivlei Nature Reserve in 1999. Other important mammal species are roan antelope (*Hippotragus equinus*), buffalo (*Syncerus caffer*), and black wildebeest (*Connochaetes gnou*). A total of 31 mammal species are found within the reserve. The introduction of hippopotami has resulted in an extensive networks of trails in some parts of the wetland due to the movement of hippopotami along the channel and from their nocturnal grazing in the grasslands.

10.9 Conclusion and recommendations

The Seekoeivlei Nature Reserve and floodplain of the Klip River are extremely important to the Vaal River as they provide a baseflow of water to users in the Vaal River catchment. If pollution and mismanagement should occur here, it will be felt lower down in the catchment in due course. Currently, it seems that the system is in a good condition following numerous rehabilitation projects that have been completed in the past. These projects were mainly related to the geomorphological structure of the river and floodplain features.

However, no biological information was available for Seekoeivlei and the results presented here are a first for the system. The macroinvertebrate community appears diverse and further field work will potentially increase the known diversity of the system.

The following research topics are recommended for future studies:

- Continous monitoring of water quality and macroinvertebrates at selected sites in the Seekoeivlei Nature Reserve should be implemented
- Surveys should include other seasons of the year
- Diatoms and algae samples should also be collected and analysed
- Amphibians should also be added to future studies so as to establish the full extent of aquatic biodiversity
- Further identification, and molecular identification, of macroinvertebrate and zooplankton taxa is also required.

11 THE TOURISM VALUE OF RAMSAR SITES IN SOUTH AFRICA

11.1 Introduction

The importance of tourism in South Africa is widely acknowledged due to the beauty of our natural environment. Tourism is also one of the fastest growing industries and a leading source of growth and development (Govender, 2013). As such, the direct impact on the economy is extremely important with its contribution totalling over a R100 billion in 2008, which comprised 2.9% of the total GDP. The total tourism spend in 2013 was calculated as R218.9 billion, which was a 9.7% increase from 2012. Domestic tourism visitors contributed 57% of the total and international visitors contributed 43%.

Wetlands and their uniqueness are a significant component within South Africa's tourism industry, especially in developing countries (Khoshkam et al., 2014). It is therefore obvious that wetlands have numerous possibilities for attracting tourists. The quality of the environment is extremely important for tourism as tourists tend to demand places that are unpolluted and free of waste (Secretariat of the Convention on Biological Diversity, 2007).

The following section summarises the available literature in South Africa on the following topics that relate to tourism at our Ramsar sites: tourism value, tourist experiences, potential loss of tourism due to environmental degradation, Ramsar site tourism studies, the environmental impact of tourism activities, and tourism and climate change.

11.2 Literature review

11.2.1 Tourism value

The development of biodiversity conservation is often a difficult prospect as the costs are often carried by the current generation while the full benefits are often only seen during future generations. The time, spatial and generational differences between the costs and benefits of biodiversity conservation make it challenging to raise funds for it (Lochner, 2003).

A study by Turpie et al. (2003) looked at nature-based tourism in the Cape Floristic Region (CFR) and estimated a total worth of R7.4 billion over the nine million hectares of the region. That study used travel cost, contingent and conjoint methods in combination to estimate the use and non-use values of nature-based tourism in the CFR. Previously, Turpie and Joubert (2001) also estimated that the tourism value for the whole Kruger National Park (KNP), spanning 2 million hectares, was around R1 billion.

Corbeira and Conradie (2010) extrapolated these figures for the Agulhas Plain and found that the tourism value should be between R77 and R126 million. The Agulhas Plain is part of the

CFR and spans 153 000 hectares across five tourism centres, i.e. Agulhas, Bredasdorp, Napier and Elim, and two in the Overberg, Gansbaai and Stanford. Corbeira and Conradie (2010) surveyed these tourism centres to determine the tourism value of the area as well as the type of activities that people were participating in. Their surveys indicated that 34% of people interviewed were visiting the region for the nature and biodiversity of the area. This result tied in with research indicating that this area is known as a biodiversity hotspot in South Africa and the CFR (Younge and Fowkes, 2003). The Agulhas Plain has two Ramsar sites, i.e. De Hoop Nature Reserve and the De Mond Nature Reserve. Interestingly, only De Hoop was included in the top ten places people would like to visit in the area, with 32% of interviewees including it in their location preferences (Corbeira and Conradie, 2010).

Their study also quantified the overall tourism value in the Agulhas Plain using various models and then compared it to the studies by Turpie et al. (2003) and Turpie and Joubert (2001). It was found that an "averages approach" yielded a range of R61 million to R110 million, which corresponds well to the R77–R126 million extrapolated from the previous studies (Corbeira and Conradie, 2010). Therefore, if an extrapolation is done for the Makuleke Wetlands in the KNP, the suggested tourism value could have been around R12 million to R19 million in 2003. If this is extrapolated with inflation to current prices, this range could be R24 million to R31 million. However, this is an estimate at best as numerous factors are involved in this estimate.

Currently, there are only three accommodation options within the Makuleke Concession, namely Ecotraining, the Outpost, and the older Wilderness Safaris camp on the banks of the Luvuvhu River, which is under new management. Limited accommodation is available at Pafuri Gate and border post. The other nearest accommodation options are in the Punda Maria area in the KNP or outside Pafuri Gate.

11.2.2 Tourist experiences

Tourist experiences are an important factor to consider that potentially affects tourism value in time. A study by Du Plessis et al. (2012), one of the first of its kind for South African national parks, studied the environmental factors that affect tourists' experiences negatively in South Africa's national parks. As part of their study they summarised previous studies looking at tourists' experiences affected by environmental factors (Table 50).

Table 50: Previous research on environmental factors affecting tourist experiences.

Factor	Effect on tourist experience
Noise pollution (Buultjens et al., 2005; Bresler, 2007; Moore and Polley, 2007)	Disturbs the natural sounds of the environment.

	Reduces satisfaction.
Litter (Tonge and Moore, 2007; Moore and Polley, 2007; Cole and Hall, 2009)	Loss of amenity (losing natural beauty and a calm atmosphere). Interferes with the quality of the experience. Reflects a violation of deeply held norms of western society.
Poor general environmental condition (Shafer and Inglis, 2000; Smith and Newsome, 2002; Tonge and Moore, 2007)	Decreases the quality of the natural environment.
Vegetation loss and trees damaged (Chin et al., 2000; Smith and Newsome, 2002; Deng et al., 2003)	The natural environment is perceived as less satisfying.
Tourist crowding (Smith and Newsome, 2002; Buultjens et al., 2005; Yang and Zhuang, 2006; Moyle and Croy, 2007; Cole and Hall, 2009)	Reduces satisfaction because viewing space is limited. Causes discomfort. Reduces opportunities for solitude.
Inadequate disposal of human waste (Moore and Polley, 2007)	Impacts on the experience negatively. Leads to dislike of the area. Causes discomfort.

The study by Du Plessis et al. (2012) found that five environmental factors had negative impacts on visitor experiences at South African national parks. These five environmental impacts were pollution, tourism activities, park violations, environmental management and tourism impacts. In addition, the study looked at visit frequency and the effect on the five environmental factors identified. The study concluded that increased visits resulted in an increased awareness of the environmental impacts seen within the national parks. This is an important result as it encourages continuous management and improvement of management strategies, as visitors are less forgiving of problems on return visits (Du Plessis et al., 2012). Although this study was completed at a national park, the results are just as applicable for the Ramsar sites in South Africa. Of the 22 Ramsar sites found in South Africa, only the Makuleke Wetlands are located within a national park while all of the other sites are generally provincial nature reserves or protected areas.

11.2.3 Potential loss of tourism due to environmental degradation

One of the first studies in South Africa to look at the economic value of goods and services provided by functioning aquatic ecosystems was completed by Turpie and Joubert (2001) on the rivers of the Crocodile River catchment. The Crocodile River is the southern boundary of the KNP and as such will be affected by upstream water usage that could have an impact on tourism. The study developed methods that could help identify the portion that the rivers within the KNP contributed to tourism and what the effect on tourism would be if the rivers were degraded. The study found that 30% of the total tourism value is attributed to the rivers and if the rivers were allowed to be completely degraded it would lead to a 30% decrease in tourism business (Turpie and Joubert, 2001). The study found that the riverscape appearance was ranked the most influential on the recreational use value and this was followed by waterbird diversity, aquatic megafauna and riparian density. The authors indicated that these attributes could be used in water allocation decision processes to ensure that the tourism value is maintained within the KNP (Turpie and Joubert, 2001).

Not many studies have investigated the cost or value of environmental degradation (Turpie, 2007). A study by Turpie (2007) in Knysna indicated that the majority of the people in Knysna were against development if it would result in negative impacts on the estuary. The results indicated that foreign and domestic tourists would spend, on average, 24% and 32% less time, respectively, in Knysna, if the estuary degraded significantly. This decrease in time spent in Knysna could potentially lead to a R260 million per annum loss. The survey results indicated that 80% of people would like increased estuarine management while 60% would contribute financially to maintain the present conservation status of the Knysna estuary (Turpie, 2007). This willingness could potentially lead to R34 million of revenue per annum (Turpie and Joubert, 2005).

A study by Turpie and Clark (2007) was completed to estimate the potential degradation costs of temperate South African estuaries. This work was completed with several estuarine ecologists and using simple assumptions. This led to a rough calculation that indicated a potential decrease in ecotourism using internet. This translates to a decrease of R413 million per annum or 13% of the estuaries' total value. Turpie and Clark (2007) also indicated that conservation planning of the estuaries that led to partial protection at 80% of the estuaries will actually increase the overall value by 11%. Thus, Turpie and Clark (2007) conclude that the difference between under protection and no protection of 24% would be the real value of protecting the temperate estuaries in South Africa.

Nahman and Rigby (2008) investigated the potential cost associated with the withdrawal of Blue Flag status from Margate Beach due to degradation of the water quality of the estuary. The study found that reduced visits would potentially result in a R17 million to R25 million loss in revenue per annum. The study was a hypothetical study, but, shortly after its completion, the Blue Flag status of Margate Beach was revoked due to reduced water quality (Nahman and Rigby, 2008).

11.2.4 Ramsar site tourism studies

Not many studies are available that focus specifically on South Africa's Ramsar sites and tourism, with the exception of the iSimangaliso Wetland Park where a study was completed by Govender (2013). The iSimangaliso Wetland Park has three Ramsar sites within it, i.e. Kosi Bay, Lake Sibaya and St Lucia. The iSimangaliso Wetland Park is South Africa's first World Heritage Site and has been using ecotourism as a development and conservation strategy since 1999 (Govender, 2013). This has resulted in the park becoming a premier ecotourism destination from what was previously (before 1999) only a fishing destination (Govender, 2013). Govender (2013) evaluated this shift in tourism using visitor characteristics and the behaviour and perceptions of both tourists and tourism businesses over time. The research indicated a shift from "mass" fishermen to more ecologically inclined "niche" tourists. The research also found various forms of ecotourism from basic ecotourism to more dedicated ecotourism, which participates in conservation and sustainable development of the area. Govender (2013) indicated that the changes seen in iSimangaliso could be representative of global tourism trends that are constantly shifting and require constant management interventions.

As part of the Water Research Commission's Wetlands Health and Importance research programme, a study at the Nylsvlei floodplain Ramsar site was carried out by Turpie (2010). The study was based on discussions with key stakeholders and a limited visitor survey. The survey found that the largest use of the floodplain is found within the Nylsvlei Nature Reserve, which only protects around 1 000 hectares of the 16 000 hectares (Turpie, 2010). The study made a rough estimation of the total tourism value based on an averages approach that included on-site and off-site travel expenditure for visits. This estimate was found to be R9 million to R10 million per annum. The reserve was mainly visited for bird watching by domestic visitors living within a few hours' drive. The number of visitors was found to be between 9 000 and 10 000 people per annum (Turpie, 2010).

The promotion of tourism at South Africa's Ramsar sites is of utmost importance as additional revenue and interest will promote conservation and management. A project is in process to visit all the Ramsar sites in South Africa and neighbouring countries to promote tourism via popular magazine articles (Rothman, 2016).

11.2.5 Environmental impact of tourism activities

The uses of wetlands and their ecosystem services are often not environmentally neutral (Kronenberg, 2014). The study by Kronenberg (2014) provides a framework for analysing the environmental impacts of ecosystem service use. The study classified the impacts into five categories: (1) direct impacts; (2) management impacts; (3) impacts relating to accessing the ecosystems to use the services; (4) consumption of products, infrastructure or services required to use the ecosystem service; (5) impacts on the broader society (Kronenberg, 2014).

The involvement of local communities in sustainable tourism management is essential if it is to be successful. A study by Khoshkam et al. (2014) reviewed the relationship between the local communities and their potential contribution in wetland tourism management. One of the main obstacles for sustainability is the training of communities associated with wetlands as well as their limited knowledge of how to make use of the wetland's resources (Khoshkam et al., 2014).

Ecotourism management can often face many challenges but primarily it needs to be profitable and sustainable while also satisfying to the tourists and beneficial to the host community (Lim and McAleer, 2005). A wetland reserve in Australia, Boondall Wetlands Reserve, established a visitor centre to deal with these challenges. This wetland is renowned for its importance as a feeding and resting ground for migratory birds from Alaska, China, Japan, Mongolia and Siberia (Lim and McAleer, 2002). The visitor centre at the wetlands has four aims, namely environmental awareness at a local and regional scale; community education and information about the specific wetland value as well as wetlands in general; hosting of nature-based recreation and tourism; and to serve as an example of the value of wetlands in tourism and ecotourism (Lim and McAleer, 2002; Lim and McAleer, 2005).

A major topic that has originated in recent years in relation to tourism and ecotourism is sustainable tourism. This term is aligned to the wise use of wetlands as used by the Ramsar Convention for Wetlands of International Importance. The idea of sustainable tourism is that it can provide or contribute to the following (Secretariat of the Ramsar Convention on Wetlands, 2012):

- Contribute biodiversity conservation and cultural diversity
- Contribute to local communities and indigenous people
- Include educational experiences
- Ensure that tourists and tourism industries are responsible
- The scale of the tourism venture should be appropriate for the environment
- Use non-renewable resources as little as possible

- Respect the carrying capacities of the environment – physical as well as social
- Minimal repatriation of revenue
- Locally owned and operated either through participation, ownership or business opportunities for local communities (Millennium Ecosystem Assessment, 2005).

11.2.6 Tourism and climate change

Another important consideration for tourism at Ramsar sites is the potential influence of climate change on these sites. Predictions are that an average 2–3°C increase will occur by 2100 (Gössling, 2010). This will obviously have an effect on the tourism assets at the Ramsar sites, i.e. lakes, rivers, snow and freshwater. Many tourism activities and locations, especially the Ramsar sites, are dependent on the availability and quality of the marine or freshwater resources where they are located (Orams, 1998; Garrod and Wilson, 2003). The lakes or rivers located at the Ramsar sites are an extremely important element of the landscape that the tourists are visiting (Hall and Härkönen, 2007). If these disappear or are less frequent, it will affect tourism. This was also shown by Turpie and Joubert (2001) in their study of the Kruger National Park that would achieve, hypothetically, 30% less revenue if the associated rivers should become severely degraded or cease to flow.

Literature has shown that climate change will affect tourism directly and indirectly with the following effects expected (Gössling, 2010):

- increased water scarcity in some areas
- declining water quality
- more intense precipitation events
- loss of water-related tourism assets like glaciers (not in South Africa) and snow
- increased runoff that impacts on the tourism opportunities at lakes and rivers
- impacts on food availability and costs
- impacts on infrastructure – human as well as ecological infrastructure.

Thus, the tourism industry needs to take note of the importance of water and the mostly negative impacts that could be expected should water become increasingly scarce (Gössling, 2010). Tourist businesses should continuously try to use cost-efficient and sustainable technologies that will help reduce their energy use and water consumption (Gössling, 2010). It is important to realise that sustainable tourism should consider the quantity as well as the quality of the water they rely on to be sustainable (Orams, 1998; Garrod and Wilson, 2003; WWF, 2004). Although many of South Africa's Ramsar sites are wildlife and birdlife orientated, recreational activities are present at certain sites. These activities, like swimming, sailing, kayaking, canoeing, diving or fishing, are directly dependent on the water resource and this will be negatively affected by decreasing water quality. Examples are increased algae or microorganisms like amoeba or *E. coli* in the water, making it unsuitable for swimming and often other activities as well (Heggie, 2010).

12 CONCLUSION AND RECOMMENDATIONS

The project aimed to provide a consolidated database of information on the aquatic ecosystems at selected Ramsar wetlands in South Africa. This was achieved by carrying out extensive literature searches and a range of aquatic ecosystem assessments. The nine selected Ramsar wetlands for the project were: Barberspan Bird Sanctuary, De Hoop Nature Reserve, De Mond Nature Reserve (Heuningnes Estuary), Makuleke Wetlands, Kosi Bay, Lake Sibaya, Ntsikeni Nature Reserve, Blesbokspruit and Seekoeivlei Nature Reserve.

The project was completed between 2014 and 2016, and numerous field surveys were completed at all the selected Ramsar sites. Details of these visits can be found in each of the specific sections as well as in the appendices. The field surveys were based on the specific Ramsar sites that were visited as each one had different components of importance. However, in general, the aquatic assessments included water quality, sediment quality, diatoms, zooplankton, macroinvertebrate and fish assessments. Literature was used to establish the occurrence of frogs and birds at the respective Ramsar sites.

Assessment of the general ecosystem condition was problematic as many of the methods available to assess the PES in wetlands and riverine systems did not fully apply to each Ramsar site. However, based on the assessments and the literature it was found that many of the Ramsar sites sampled indicated that although there were impacts presenton the systems, all of the systems were still functional and providing ecosystem services.

The aquatic ecosystem component results indicated that the Ramsar sites are unique or have specific features that make assessment of the sites difficult. The diatom and macroinvertebrate communities within the Makuleke Wetlands are an example as the assessment indicated that each depression (pan) was unique and contributes to the overall diversity of the system. If one depression (pan) is degraded, it could impact on the overall diversity within the Ramsar wetland. The uniqueness of the Ramsar sites is then also the reason why many of them are eligible to be a Ramsar site. The conclusion from this is that management of the systems should be site-specific and no single monitoring programme would appropriately suit the uniqueness of each Ramsar site.

Anthropogenic impacts on the selected Ramsar sites were present in most of the systems, mainly due to the increased human population in many of the areas. Therefore, these systems in some way or another are threatened by some form of anthropogenic activities. These threats can be summarised as habitat loss, nutrient enrichment, numerous pollutants, urban and rural encroachment, alien invasive species, poor land use practices, and organic enrichment. All of these could pose a significant threat to the Ramsar sites presently as well as in the future. Management and proper monitoring will be the only effective tool to track and provide an early warning for the degradation of these Ramsar wetlands.

The results of this project will be valuable for future monitoring of the aquatic ecosystems at the specific Ramsar wetlands. The results gathered here provide a current baseline for monitoring while the detailed information provided for many aspects in the appendices would form the baseline for monitoring programmes. This data will also be valuable to the management authorities in order to update the RIS that form part of the requirements of the Ramsar Convention. If all of the RIS sheets for these nine selected Ramsar wetlands could be updated using the information from this study, it will potentially enhance the standing of South Africa within the Ramsar wetlands community.

The tourism assessment indicates that ecotourism at the Ramsar wetlands could be invaluable in generating income for the specific sites. However, it was obvious that the ecotourism potential of many of the Ramsar wetlands was still underutilised. Thus, there is significant potential to develop sustainable ecotourism and education initiatives at many of South Africa's Ramsar wetlands. The potential should be realistically assessed, taking into account the potential impact that tourism could have on the environmental condition at the Ramsar site (both good and bad). Thus, detailed studies should be carried out at each Ramsar wetland to assess the viability of ecotourism as well as the extent to which it will benefit the Ramsar site and not be detrimental to the environment.

Detailed recommendations and potential research topics for each Ramsar site are included in each section. The following general recommendations and potential research questions have emerged from this study:

- Currently there are no monitoring programmes running (in terms of aquatic ecosystem monitoring) at any of the Ramsar wetlands. In some cases, water quality assessments on riverine reaches are completed on a regular basis. It is of utmost importance to monitor ecosystem changes in these selected Ramsar wetlands.
- It is essential that the correct components for each Ramsar wetland be monitored. These should be selected based on the information available, protocols that align with the proposed National Wetland Monitoring Programme and communication with local stakeholders that rely on resources from the system.
- At a minimum, monitoring should be completed on components of the Ramsar sites that align with or are directly attributed to the Ramsar criteria used for designating the specific site a Ramsar site. For example, if a site was designated as a nursery habitat for marine fish species, it is obvious that this function should be monitored regularly to ensure the site

remains viable for this specific reason. Thus, monitoring programmes will be unique to each system or possibly group of systems.

- This project has shown that monitoring for water quality, diatoms and aquatic macroinvertebrates should be priority at many of the freshwater Ramsar sites.
- It is recommended that all the monitoring and research that is being completed at South Africa's Ramsar sites should be stored at and monitored from a single institution to ensure that all the data aligns with the monitoring and reporting requirements for the Ramsar Convention.
- It is recommended that a similar project should be initiated at other Ramsar sites that were not included in this study and are under-studied in the scientific literature.
- Lastly, an understanding of each of these unique ecosystems is extremely important for the continuation of their Ramsar status.
- Further identification, and specifically molecular identification, of macroinvertebrate and zooplankton taxa is required in many of the Ramsar sites to adequately determine the aquatic biodiversity.

13 LIST OF REFERENCES

A list of references is provided here for each section presented previously. In some cases the references are not provided in the text as they form background information for the Ramsar sites but were included for reference here.

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APPENDIX A: **Barberspan aquatic assessment results.**

APPENDIX B: **Bird lists of selected Ramsar sites in South Africa based on SABAP2 data.**

APPENDIX C: **Aquatic assessments of De Hoop Vlei and De Mond Nature Reserve**

APPENDIX D: **Diatom diversity and response to water quality within the Makuleke Wetlands and Lake Sibaya.**

APPENDIX E: **Macroinvertebrate Diversity within the Makuleke Wetlands in the Pafuri Region of Kruger National Park.**

APPENDIX F: **Diversity and distribution of aquatic macroinvertebrates within the Ntsikeni Nature Reserve.**

APPENDIX G: **Health assessment of selected fishes from coastal lakes on the East Coast of South Africa.**

APPENDIX H: **An assessment of the ecological condition of the Blesbokspruit wetland using water quality, sediment and macro-invertebrates community structure.**

APPENDIX I: **Seekoeivlei Nature Reserve.**

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