South African Journal for Science and Technology
ISSN: (Online) 2222-4173, (Print) 0254-3486

Ramsar wetlands in South Africa: Historic and current aquatic research

Author:
W Malherbe

Affiliations:
Water Research Group, Unit for Environmental Science and Management, North-West University, Private Bag X6001, Potchefstroom, 2520, South Africa

Corresponding author:
Wynand Malherbe
malherbewynand@gmail.com
+27 83 739 6911

Dates:
Received: 05/12/2017
Accepted: 14/08/2018
Published:

How to cite this article:
Malherbe W., Ramsar wetlands in South Africa: Historic and current aquatic research, Suid-Afrikaanse Tydskrif vir Natuurwetenskap en Tegnologie 37(1) (2018)

'n Afrikaanse vertaling van die manuskrip is aanlyn beskikbaar by http://www.satnt.ac.za/index.php/satnt/article/view/667

Wetlands provide numerous goods and services and therefore they should be protected from anthropogenic impacts. The Ramsar Convention on Wetlands of International Importance was approved as part of legislation in South Africa during 1975 and currently approximately half a million hectares are protected at 23 sites. The Ramsar Convention was created to protect wetlands from degradation and loss of biodiversity, especially the maintenance of bird habitats. However, many of the Ramsar wetlands in South Africa lack aquatic diversity and present ecological state information, specifically fish, macroinvertebrate and diatoms, and in cases where there is information it is often outdated. Therefore, this study was initiated to increase the available aquatic information of Ramsar sites. The Ramsar sites that have been selected include Kosi Bay, Lake Sibaya, Makuleke Wetlands, Barberspan, De Hoop Vlei, Heuningnes Estuary, and Ntsikeni Nature Reserve. The project embarked on numerous surveys from 2014 to 2016. The project outcome provided updated aquatic biodiversity information for diatom, zooplankton, macroinvertebrate and fish communities at these sites together with the historic research that has been completed. The results also reflected the uniqueness of each of these systems, thereby highlighting the need for monitoring programmes suitable for each system. The results from this project will be able to support the information requirements that are specified within the Ramsar Convention.

Ramsar-vleilande in Suid-Afrika: Historiese en huidige akwatiese navorsing: Vleilande verskaf 'n verskeidenheid van goedere en funksies en dus moet die vleilande wat nog natuurlik is, beskerm word. Die Ramsar-konvensie vir vleilande van internasionale belang is al vanaf 1975 in werking in Suid-Afrika en omtrent 'n half miljoen hektaar word beskerm by 23 lokaliteite. Die konvensie is daar om biodiversiteit te bewaar en veral waadvoëlhabitat te beskerm. in Suid-Afrika is baie van hierdie lokaliteite swak bestuur en min inligting oor die akwatiese biodiversiteit is beskikbaar. Waar daar wel inligting beskikbaar is, is die inligting verouderd en geen nuwer inligting is beskikbaar nie. Om hierdie rede is daar 'n studie geloods om te bepaal watter historiese inligting beskikbaar is vir die Ramsar-lokaliteite en om dan van hierdie gapings in die literatuur aan te vul. Die Ramsar-lokaliteite wat gekies is vir hierdie projek was Kosibaai, Sibaya-meer, Ntsikeni-natuurreservaat, Barberspan, De Hoop Vlei, Heuningnesgetyrivier en die Makuleke-vleilande. Verskeie veldopnames is gedoen by die lokaliteite vanaf 2014 tot 2016 tesame met 'n studie van die beskikbare literatuur. Die resultate van die projek het gelei tot nuwe inligting oor die biodiversiteit en verspreiding van diatome, soöplankton, makroinvertebrate en visgemeenskappe by die verskeie Ramsar-lokaliteite. Hierdie inligting is nou beskikbaar om die inligting wat die Ramsar-konvensie vereis, op te dateer en ook om bestuursplanne aan te pas. Die resultate het getoon dat baie van die gemeenskappe uniek is of unieke eienskappe het, wat maak dat daar gepaste moniteringsprogramme vir elke lokaliteit benodig word.

Introduction

There are several definitions of wetlands but in the South African context, the National Water Act (No. 36 of 1998) provides the most important one. It describes a wetland as the "transition area between the terrestrial and aquatic environment where the water table is usually at or near the surface, or the soils are periodically covered with shallow water and that the environment under normal conditions maintains or can maintain vegetation adapted to survive in water-saturated soil". However, the definition of a wetland according to the Ramsar Convention is much broader, and describes wetlands as areas of swamp, peat, or water, natural or artificial, permanent or temporary, with standing water or flowing water, fresh, brackish or saltwater and that includes saltwater to a depth of six meters below the low-water mark (Malherbe et al. 2017).

Wetlands are considered to be important ecosystems worldwide as they provide various ecological services, depending on the type of wetland (Davies and Day 1998). These services include, *inter alia,* the habitat for wetland-associated animals and plants, biodiversity between terrestrial systems or along river systems, base flow for rivers, flood attenuation, improvement of areas where anthropogenic impacts such as nutrients and sediments are found in surface water, and the provision of areas that have value for tourism or recreational activities (Day and Malan 2010).

The survival of wetlands worldwide is threatened by human activities. In rural areas, wetlands are threatened by agricultural activities such as the cultivation and drainage of wetlands to create additional areas for agriculture. Water is also canalised away from wetlands. It is used extensively from boreholes, which leads to a loss of water in wetlands, while the creation of roads and bridges leads to erosion of wetlands. Nutrient content can also be increased in wetlands by livestock waste and the return flows of agricultural lands that are potentially loaded with fertilisers and pesticides (Day and Malan 2010). Industrial impacts can also lead to a loss of wetlands through contaminated water, drainage of wetlands and many other activities from industrial plants. The impacts of urban areas also impact on wetlands and wetland conditions such as filling, flow spreading, drainage and channelling so that additional space for industrial or urban developments can be developed.

The realisation that wetlands are being systematically destroyed worldwide, has led to the emergence of various actions to protect wetlands (Breedt and Dippenaar 2013). The origin of the Ramsar Convention for Wetlands of International Importance in the 1970s was one of the first international conventions for environmental protection (Ramsar Secretariat 2016). The Ramsar Convention is a treaty between various countries that provides a framework for national actions and international cooperation to protect wetlands, but also to ensure the associated natural resources can be used sustainably (Ramsar Secretariat 2016). Currently, there are 169 countries that have signed the convention and there are 2 234 localities registered under the Ramsar Convention. The area it covers in terms of wetland protection is approximately 215 million hectares (Ramsar Secretariat 2016).

Ramsar wetlands in South Africa

South Africa became part of the Ramsar Convention in 1975 with the designation of the De Hoop Nature Reserve and Barberspan Nature Reserve as Ramsar wetlands of international importance (Ramsar Secretariat 2017). South Africa was the fifth country that signed the International Convention (Cowan 1995), with the aim of protecting wetlands and water birds across international borders as their habitats usually cross national borders (Breedt and Dippenaar 2013). Furthermore, the purpose of the treaty was to reduce wetland losses, encourage the wise use of wetlands, increase the protection of wetlands, encourage further skills development, and encourage stakeholders to fulfil the responsibilities of the Ramsar Treaty (Cowan 1995).

Currently, there are 23 different areas falling under the protection of the Ramsar Convention in South Africa (Figure 1). The latest additions to South Africa's Ramsar sites have been the False Bay Wetland Park (April 2015) and Bot-Kleinmond Estuary (March 2017). These additions bring the total area of Ramsar areas in South Africa to approximately 556 000 hectares. It is a relatively small area compared to the total size of wetlands in South Africa, which have been estimated at 3.5 million hectares. When looking at the distribution of Ramsar sites in South Africa, there is at least one locality in each province, except for the Eastern Cape Province. Furthermore, there are five locations on the east coast near the Mozambique border, including Kosi Bay, St Lucia, Ndumu Game Reserve, Lake Sibaya and the Pondoland Coast turtle beaches. Currently, all 23 Ramsar sites are preserved as national or provincial protected areas (Figure 1).

Unfortunately, many of the catchment areas for these locations fall outside the protected areas and thus there are potential impacts that can occur in the aquatic environment. In several cases, the Ramsar sites are wetlands that are not currently covered by any national monitoring programme, with the exception of the National Estuary Monitoring Programme that has recently been initiated. Thus, the ecological state of wetlands is rarely monitored on a national scale. Detailed research on the Ramsar wetlands is also limited except for some of the more prominent wetlands, as in the case of St Lucia. In other cases, such as the Barberspan Nature Reserve, no aquatic research has been carried out since the early 1970s.

For South Africa to fulfil its obligation to the Ramsar Convention, the current ecological state of every Ramsar site must be updated every six years. This is to determine if the wetland is still of international importance or not. As much of the Ramsar Wetland information on the current conditions is unknown, there is a need to determine the current ecological state in these wetlands. However, the present conditions are difficult to determine if there is no reference information or framework available. Thus, the purpose of this study was to review the available information of certain Ramsar wetlands in South Africa, briefly evaluate the research already completed on these selected wetlands, and identify gaps in our knowledge regarding these wetlands.

Barberspan Nature Reserve

The Barberspan Nature Reserve was one of the first two sites in South Africa designated as a Ramsar protected site in 1975. Barberspan is one of the few permanent waterbodies in the western highveld (North West province) during the dry winter months (Swart and Cowan 1994). Originally, Barberspan was a temporary depression (pan), but in 1918, a connection to the Harts River was created that changed the system into a perennial system. The change in hydrology has resulted in an excellent habitat for water birds as well as the recreational fishing community. The perennial nature of the system provides food and shelter for large numbers of water birds during the dry winter months when most of the water sources dry up in the area. Barberspan also hosts many migratory birds that use the reserve as a stopover or overwintering location. Approximately 365 bird species have been identified in the reserve, of which about 60 are migratory species (SABAP2 2016).

Barberspan had a research station on waterfowl during the 1970s and 1980s, but unfortunately the research station no longer exists. Research at Barberspan was therefore primarily focused on the birds (and more specifically water birds) and little information is available on the aquatic ecosystem. Unpublished studies in the 1960s regarding the nutritional habits of fish (Enslin 1966; Schoonbee 1969) and aquatic invertebrate communities (Roode 1967) are available. Current research is still mostly focused on bird communities with little attention paid to the aquatic environment, as well as the impact or potential impact of poor water quality from the Harts River. This poor water quality is derived from effluents released from sewage works as well as agricultural activities in the catchment area (Golder Associates 2011).

When looking at different groups of aquatic organisms at Barberspan, it can be seen that no algal research has been completed except for a study on desmids from 1928 (Levanets and van Rensburg 2011). A study on zooplankton was completed by Combrinck (1966) in 1966, but no other invertebrate studies were available until research by Henri et al. (2014), Foster et al. (2015) and de Necker et al. (2016). Henri et al. (2014) investigated the number of Branchiopoda taxa which could hatch from dried sediment, while de Necker et al. (2016) sampled invertebrates and zooplankton in a study focused on temporary pans in the Delareyville area. This research found that there were about 19 different macroinvertebrate taxa in Barberspan. The latest studies on Barberspan (Malherbe et al. 2017) completed various surveys from 2014 to 2016 for diatoms, zooplankton, and macroinvertebrate diversity. These studies found that 22 different diatom species, 12 zooplankton taxa, and 48 macroinvertebrate taxa occurred at Barberspan (Malherbe et al. 2017) (Table 1).

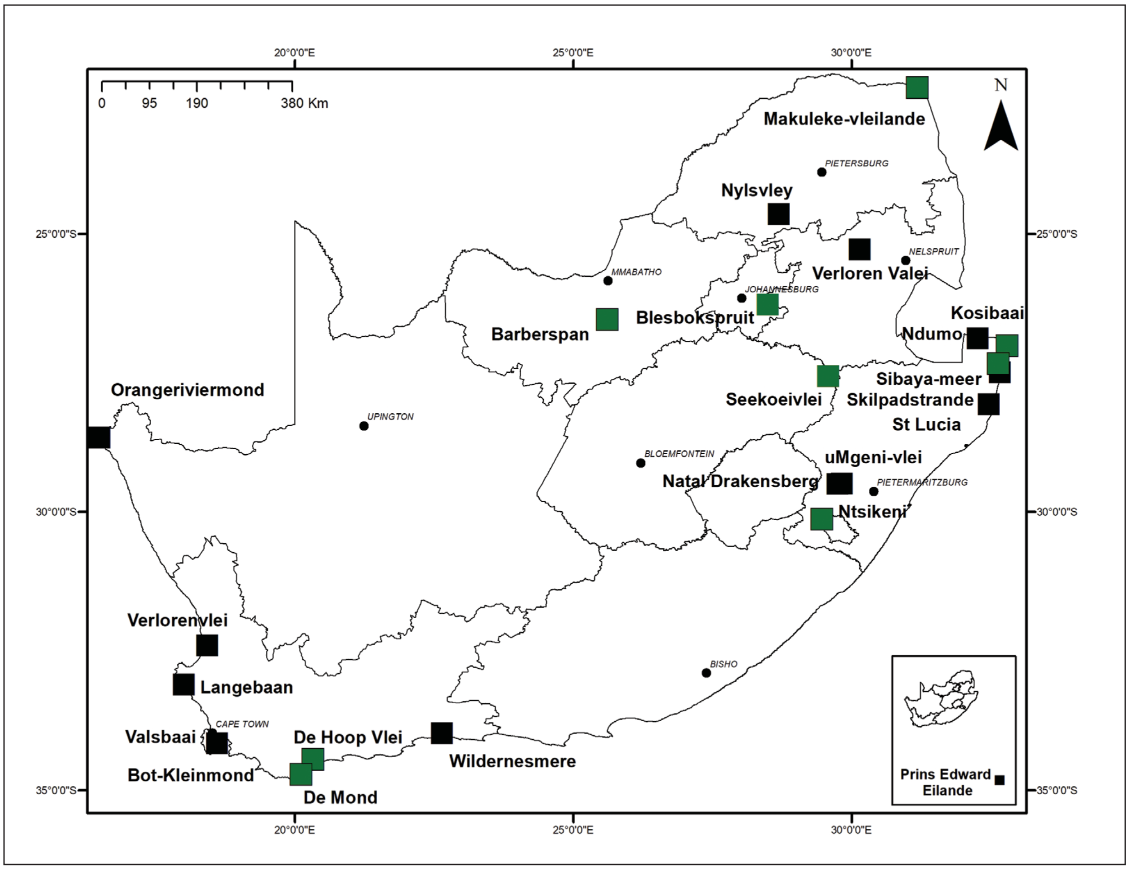

Figure 1: Map of the 23 different locations in South Africa that have been declared as Ramsar wetlands of international importance. Green squares indicate the different sites included in the present review and study.

The fish community of Barberspan consists of the following ten species: *Labeobarbus aeneus*, *Labeo umbratus*, *L. capensis*, *Cyprinus carpio* (exotic), *Pseudocrenilabrus philander*, *Tilapia sparrmanii*, *Gambusia affinis* (exotic), *Enteromius paludinosus*, *E. anoplus* and *Clarias gariepinus*. The available information on the fish community dates back to studies in the 1960s by Goldner (1967) and Enslin (1966), which were completed at the then Potchefstroom University (now North-West University). These studies focused on the population structure of the fish community (Goldner 1967) and a functional nutrition study of various fish species (Enslin 1966; Schoonbee 1969).

More recent fish information can only be found for the nearby Leeupan in the form of a fish kill study after a major fish kill in November 2013 (Grant 2013). During this study, the cause of death of mostly *Cyprinus carpio* in Leeupan was investigated as it presented a risk of botulism in birds. The study found that extremely high diatom populations were present in the system that then led to an oxygen deficiency in the fish (Grant 2013).

Since there are several sources indicating that Barberspan is contaminated with metals, samples of *C. gariepinus* and *L. capensis* were collected during 2014 to determine whether metal levels were high in the muscle tissue (Malherbe et al. 2015). The results showed that selected metals (chromium, copper, nickel and zinc) were similar to other studies in the Vaal River system for *C. gariepinus* and *L. capensis*. The latest study available for Barberspan focused on metal pollution in the eggs of certain bird species. The research showed that the blue heron eggs had high concentrations of gold (Au), uranium (U), thallium (Tl) and platinum (Pt) at Barberspan (Van der Schyff et al. 2016). The study concluded that the selected metals did not come from the Barberspan catchment area, but rather from nearby areas to the east where the birds feed before migrating to Barberspan to breed.

Recently, the metazoan fish parasites of *Enteromius paludinosus* and *Pseudocrenilabrus philander* from Baberspan were reported (Truter et al. 2016). The study showed *P. philander* was parasitised by the copepod *Lernaea cyprinacea*, the monogenean *Gyrodactylus thlapi*, and four gryporhynchid metacestode (Cyclophyllidea) species: *Paradilepis scolecina*, *P. maleki*, *Neogryporhynchus lasiopeius* and *Valipora campylancristrota*. *Enteromius paludinosus* was found to be infected with the monogenean parasites *Dogielius intorquens* and *Dactylogyrus teresae*, as well as three unidentified *Dactylogyrus* spp. (Truter et al. 2016).

Makuleke Wetlands, Kruger National Park (KNP)

The Makuleke Wetlands are located in the northern part of the Kruger National Park in the floodplains of the Limpopo and Luvhuvhu rivers. The Ramsar area extends from the western KNP border to the Mozambique border on the Limpopo River and from Lanner Gorge on the Luvhuvhu River until the confluence with the Limpopo River at Crooks Corner (Deacon 2007). The wetland area is about 7 700 ha, while the various depressions cover about 350 ha (Deacon 2007). The Ramsar area consists of about 30–31 floodplain depressions (or pans) that are seasonally filled from the rivers. Some of these pans have their own catchment area and are fed by various streams. The pans are important for the breeding and feeding of various animals and birds that occur within the Makuleke Wetlands. Furthermore, the pans serve as a stopover for several migratory bird species, especially in the Limpopo River's floodplains where the pans hold water longer than in the Luvhuvhu River. The largest pan in the Ramsar area is Banyini, which consists of an area of approximately 162 ha.

The available information for the various aquatic organisms found in the Makuleke Wetlands is extremely limited. It is mostly for the Luvhuvhu and Limpopo rivers and not the actual wetlands and includes various studies on the tigerfish *Hydrocynus vittatus* in the Luvhuvhu River (Smit et al. 2013; Gerber et al. 2016), as well as river health (Smit et al. 2013). The most recent reports on river health of the Luvhuvhu and Limpopo rivers indicate that the river sections in the KNP are largely natural (DWS 2014). However, other publications (Smit et al. 2013; Gerber et al. 2015) have indicated that there are problems with water quality in the Luvhuvhu River. The river health information (DWS 2014) showed that the rivers contain at least 56 macroinvertebrate families and 36 fish species.

Until recently, the available data from the Makuleke pans and surrounding rivers did not include any information on diatoms. Surveys in April and September 2015 showed that 70 different diatom species were found in about ten different sites, taking into account the drought conditions experienced during 2015 (Malherbe et al. 2017). An interesting phenomenon was that each pan's diatom community was unique and that only between 15–20 species per pan was identified (Kock 2017; Malherbe et al. 2017). The diatom community in 2015 indicated in many cases that the water quality could be classified as eutrophic due to the nutrients found in the system.

The zooplankton and macroinvertebrate communities of the Makuleke pans were previously only reported by Nesbitt (2014). The study focused on the hydrology and ecology of the pan, and more specifically the sediment particle spread, vegetation and wetland habitat. The macroinvertebrates were collected in one survey and identified to family level (Nesbitt 2014). Recent studies showed that the zooplankton from ten pans (during surveys in April and September 2015) consisted of approximately 15 different taxa (Table I) (Dyamond 2017; Malherbe et al. 2017). The main groups found in these studies were Branchiopoda and Copepoda, with each pan containing about 3–7 taxa.

Information on the macroinvertebrate communities of the various pans in the Makuleke Wetlands is also scanty. The Nesbitt (2014) study looked into the macroinvertebrates in certain pans but the study was superficial and identified few taxa. There are data available from the Luvhuvhu River, where 28 taxa were identified from 18 genera (Moore and Chutter 1988). The recent study by Dyamond (2015) led to the identification of 108 taxa at the various Makuleke pans (Table 1). The macroinvertebrate communities were very diverse, but 2015 was a dry year and therefore it is expected that more taxa could possibly occur in wetter years. Dyamond (2017) also found that the invasive snail, *Tarebia granifera*, occurred in certain pans in high densities; as many as 2 000–4 000 individuals were gathered with the sweep nets at certain pans. This can cause major impacts on the trophic structures of this ecosystem.

There is only one published article about the fish community of the Makuleke Wetlands. This study investigated the Mozambique tilapia (*Oreochromis mossambicus)* and sharptooth catfish (*Clarias gariepinus*) species and how these fish used the wetlands for breeding and feeding purposes (Van der Waal 1998). A total of 38 fish species are known to occur in the Limpopo and Luvhuvhu Rivers (Skelton 2001), but the species that are mainly found in the wetlands are *Brycinus imberi, Coptodon rendalli*, *Enteromius afrohamiltoni*, *E. paludinosus*, *E. toppini*, *Hydrocynus vittatus*, *Labeo rosae*, *L. congoro*, *Micralestes acutidens, Oreochromis mossambicus*, *Schilbe intermedius*, and *Synodontis zambezensis*.

Surveys of the fish communities conducted in 2015 (April, September and October) found that 15 fish species were present in the different pans (Malherbe et al. 2017). The most prominent species were *C. gariepinus*, *Enteromius afrohamiltoni, Enteromius paludinosus*, and *Oreochromis mossambicus*. There were also several individuals of *Oreochromis niloticus*, which is an alien fish species in South Africa. As 2015 was a dry year, there is the possibility that more species would be found in years with higher rainfall. The fish health of 20 individuals of *O. mossambicus* and 10 of *C. gariepinus* was also determined using the fish health assessment index (FHAI). The results for both fish species showed that fish were mostly in a good condition. Changes in liver morphology were one of the more striking variations observed (Malherbe et al. 2017).

There are approximately 33 different amphibian species in the Makuleke Wetlands, of which 28 are tropical species (Passmore et al. 1995). There is a possibility that more species can be found with further studies as the area is very close to the southern distributions of various amphibians and not many extensive surveys have been completed in the wetlands. One example is the dune squeaker (*Arthroleptis stenodactylus*) that occurs only in northern KwaZulu-Natal, Mozambique and Zimbabwe, and then in two places in the north of the Kruger National Park, namely Bobomene on the Luvhuvhu River and the Shipudza fountain (Deacon 2007).

Makuleke Wetlands is one of the top birdwatching areas in South Africa. There are approximately 450 species found there (Sinclair and Whyte 1992), with Pel's fishing owls (*Scotopelia peli*), Pygmy goose (*Nettapus auritus*), Bohm's spinetail (*Neafrapus boehmi*), mottled spinetail (*Telacanthura ussheri*), mountain wagtail (*Motacilla clara*) and Basra reed warbler (*Acrocephalus griseldis*) being more common in the area than in other parts of South Africa (Deacon 2007). The various pans also have several hippos (*Hippopotamus amphibius*) and crocodiles (*Crocodylus niloticus*), especially in the pans that hold water during the drier winter seasons.

Ntsikeni Nature Reserve

The Ntsikeni wetland in the Ntsikeni Nature Reserve is one of the highest altitude wetlands in South Africa, at more than 1 900 m above sea level. The wetland is located in the southern part of the KwaZulu-Natal province between Franklin and Creighton. Kokstad is about 45 km south of Ntsikeni and is the largest town in the vicinity. The reserve is approximately 9 200 ha, while the wetland covers about 1 070 ha.

The wetland is named after the Ntsikeni Mountain located on the eastern boundary of the nature reserve and is about 2 321 m above sea level (Blackmore, 2010). It is mostly an unchannelled valley-bottom wetland, but parts of the wetland have floodplain features especially to the northern side of the reserve. The reserve houses breeding pairs of the critically endangered wattled crane (*Bugeranus carunculatus*) as well as the Eurasian bittern (*Botaurus stellaris*), and is therefore incredibly important in South Africa for the survival of these bird species. Furthermore, there are records of the endangered long-toed tree frog (*Leptopelis xenodactylus*) that occur in the reserve. The wetland is important for the storage of water and river regulation of the Lubhukwini and Umzimkulu rivers so that the communities can be assured of clean water as well as sufficient volumes of water.

The available river health information (DWS 2014) shows that the Lubhukwini River flowing out of the reserve is near-natural to natural, while the importance and sensitivity of the river is also considered to be high. The reserve was previously used only as grazing and for subsistence farming, and thus there are relatively few impacts on the system. Around the reserve there are large cultivated plantations of pine trees, while black-wattle (*Acacia mearnsii*) forests occur in the reserve.

The Ntsikeni wetland has been poorly studied, with only one study on the macroinvertebrates in the then Transkei (Bok and Cambray 1996; Burger 1996; Mangold and De Moore 1996). This report only provided family-level data for the rivers in the area, with little or no research on the Ntsikeni wetland as such. There was no available information on diatoms or algae in the Ntsikeni Nature Reserve before this study was initiated. Diatom samples collected during July 2015, December 2015 and April 2016, showed that approximately 45 diatom species were found at the various sites. There was also no information about zooplankton available for the reserve; however, Bester (2017) identified 23 different taxa at the different sampling sites (Table I). During the current study on the Ntsikeni Wetland, 115 macroinvertebrate taxa were identified in the Ntsikeni Ramsar area. There is no fish information available for the reserve and no fish were collected during the 2015 and 2016 surveys. This is most likely due to the high altitude and catchment area. The Ntsikeni Falls, located just outside the reserve, is a major obstacle to any migrations of fish from lower altitudes. The only fish species that could possibly be found are small minnows (*Enteromius* sp.).

Several amphibians were found in the reserve, such as *Amietia angolensis*, *Breviceps verrucosus*, *Cacosternum nanum*, *Strongylopus grayii* and *Xenopus laevis*. The total amphibian species in the reserve are estimated to be 19 species (FrogMap 2016). There is a possibility that the endangered long-toed tree frog (*Leptopelis xenodactylus*) occur there (Blackmore 2010).

The main attraction of the Ntsikeni Nature Reserve is the bird population that occurs there, especially species such as the cranes, white-winged flufftail (*Sarothrura* spp), and the Eurasian bittern (*Botaurus stellaris*). All four different cranes found in South Africa can regularly be seen here, one of few places in the country where it is still possible. The cranes also use the reserve as a breeding ground, especially the wattled crane, *Bugeranus carunculatus*. According to the SABAP2 surveys, more than 200 species have been identified in the Ntsikeni Nature Reserve (SABAP2 2016).

Kosi Bay

The Kosi Bay Ramsar site (part of the iSimangaliso Wetland Park) is an estuary and coastal lake system consisting of four connected lakes connected by a broad channel to the Kosi Bay Estuary that flows into the Indian Ocean. The system is located approximately 470 km north of Durban with the nearest town, Manguzi, about 35 km from the mouth. The entire Kosi Bay system covers approximately 11 000 ha while certain sand dunes are 102 m above sea level (Kyle 1995).

There are three rivers flowing into the system and at least the first two lakes (Makhawulani and Mpungwini) are influenced by daily tides. The third and fourth lakes (Amanzimnyana and Nhlange) are less affected by the tidal changes and usually contain more freshwater (Harrison 2002). The habitat in the systems is mostly swamp and root forests, reeds, sand dunes, bushveld and coastal grassland. The sand dunes between the different Kosi lakes range from 600 m to 2 000 m in diameter and are mostly surrounded by coastal forest vegetation. The system is relatively low in nutrients as the freshwater influx is limited.

The ecosystem health of the two rivers that flow into the system varies from near natural in the Malangeni River, which flows into the southern parts, while the Swamanzi River, which flows from the west, has various impacts and major deviations from the natural conditions (DWS 2014). The ecological importance and sensitivity of both systems are considered very important. Previous studies in the river systems indicated that about 38 macroinvertebrate taxa occur in these rivers (DWS 2014).

The human population beyond the boundaries of the iSimangaliso Wetland Park grows exponentially, leading to various impacts being present in Kosi Bay. Chemicals and fertilisers are used to increase agricultural productivity in the area. So far, this increase in use has not led to eutrophication of the Kosi Bay lakes, but it is a risk to the system. The use of DDT for indoor residual spraying is also a source of concern. Previous studies have shown that DDT (DDE and TDE) were found in the sediment of Mpungwini and Makhawulani, as well as in the fish tissue (Kyle 1995; Humphries 2013). There are also a multitude of invasive species already found in the system, especially with the exponential increase of *Eucalyptus* sp. which has a direct effect on the water table of the lakes' catchment (Roeder 2014; Grundling et al. 2017). Other factors that threaten the area are habitat loss, pollution and the interruption of ecological processes (Whitfield 1997). The use of gillnets by the local communities in Nhlange was originally implemented on a controlled basis, but it did unbelievable damage to the fishing community and is thus only used illegally now (Kyle 1995).

Kosi Bay maintains various aquatic invertebrate species, fish species, birds, mammals, butterflies and vegetation. Certain species found here are endemic, threatened or at risk of extinction (Kyle 1995). Kosi Bay has two major attractions for tourism: one is the unique rocky reef in the estuary that houses a large variety of fish species; and two are the fish kraals used by the community to catch fish (Kyle 1995; 2013). Algae and diatom research in Kosi Bay is limited and only the general taxa are known. The most common algae in the system is the phytoplankton *Microcystis* sp. which occurs mainly in the uKhalwe inlet (Kyle 1995). The zooplankton community in the Kosi Bay system is made up of marine and freshwater forms. The marine species occur in the tidal reaches, and even into Mpungwini depending on the influence of the tidal reach. The highest zooplankton density was found in Makhawulani's eastern banks where the water is retained the longest in the system. The majority of the zooplankton consists of *Pseudodiaptomus hessei*, but up to 50 taxa have already been recorded (Kyle 1995). However, in general, the zooplankton community is poor because of low food and nutrient levels.

The benthic macroinvertebrates of Kosi Bay consist of approximately 30 taxa, but this excludes Mpungwini and Makhawulani taxa. Species such as *Callichirus kraussi*, *Brachidontes virgiliae* and *Neorhynchoplax bovis* are known to occur in the system. The Kosi Bay system is known for its low diversity of shrimps, due to nutrients and silt levels in the system being low. The Insecta group is diverse in the system, and many are important in the benthic environment, such as the *Chironomus* spp. and *Clinotanypus* spp. Species that are important to the mangroves include the weaver ant (*Oecophylla longinoda*).

Recent studies on the macroinvertebrates have focused on invasive species as well as the Odonata group. One study looked at the indigenous and alien Gastropoda in several coastal lakes in the iSimangaliso Wetland Park and one of the localities was Kosi Bay (Miranda and Perissonotto 2012). The study used stable isotopes to determine whether the diet of alien and native snails overlaps and focused specifically on the *Tarebia granifera* originating from South East Asia. This snail has flourished in many southern African aquatic systems where it dominates the invertebrate communities in the shallow waters (Miranda and Perissonotto 2012). A study on the Odonata in the iSimangaliso Wetland Park by Hart et al. (2014) also used Kosi Bay as a study location. The survey identified 49 Odonata during surveys conducted in February 2011. The surveys focused mainly on the adult Odonata and did not take into account the aquatic stages. Of all the sampling locations in the study, most of the Odonata taxa were found at Kosi Bay (Hart et al. 2014).

The fish community in the Kosi Bay system has been studied relatively more than any other group, as they are so important to the communities' fishing practices. The Kosi Bay system is a very important area for juvenile fish species from the marine environment to grow before migrating back to the sea. A study by Blaber (1978) indicated that there are 133 fish species found in the Kosi Bay. These species consist of approximately 86 marine species, 39 tidal species and nine freshwater species. There is also a long-term study implemented since 1980 on the use of the fish resources in the system to ensure that levels of use are sustainable (Kyle and Robertson 1997). Kyle and Robertson (1997) also tagged fish species in the lakes to study fish movements, growth rates, mortality and population sizes. During the study, the 500 tagged *Acanthopagrus berda* were collected using fishing rods, local fishermen, as well as seine nets and gill nets.

Several other studies focused on the sustainability of the fish kraals and the recreational fisheries in the system. James et al. (2001) looked specifically at the recreational fishermen and the particular species caught by them, using the catch records that were reported at the Kosi Bay camp on Lake Nhlange. The data from 1986 to 1999 were analysed to identify fish diversity, community structures and seasonal variations, as well as the impact of the fish kraals on the system. The fish kraals in the system increased from 66 in 1981 to 158 in 2001 (Green et al. 2006), and this led to an increase in fish from 40 000 in 1981 to 93 000 in 1993. Ezemvelo KZN Wildlife regularly monitors the fish kraals and their catches, and the results of this programme over the last 30 years have been described by Kyle (2013). Kyle observed a definite decline in fish abundance over the last 30 years, ascribed to the number of fish kraals as well as the 'state-of-the-art' material used in newer fish kraals (Kyle 2013). Recently, a study focused on the fish health of three species, namely *Oreochromis mossambicus*, *Rhabdosargas sarba* and *Terapon jarbua*. This study showed that the fish were in good condition and no changes in organ appearance were observed (Beukes 2017). Holbach et al. (2012) looked at the otolith chemistry of various fish species to determine their migration patterns.

The amphibian population in Maputaland area in Kwazulu-Natal has more species than any other biographical area investigated in the South African Frog Atlas Project in 2004. It has been found that there are 23 frog species, including the indigenous and threatened Pickersgill reed frog (Kyle 1995). There are also five sea turtles that appear on the coast along Kosi Bay, the most common being the leatherback turtles (Kyle 1995).

Most bird species found in the Kosi Bay area are forest species and not necessarily wetland or tidal species. There are approximately 250 bird species, of which about 85 species can be associated with the estuary and coastal lakes. The Kosi Bay system is also the southern distribution limit for certain bird species on the bird atlas, and thus this is the only area in South Africa where they can be viewed. Some of the rarer species include the white-winged flufftail (*Sarothrura* spp), the white-backed night heron (*Gorsachius leuconotus*) and the crab plover (*Dromas ardeola*).

Lake Sibaya

Lake Sibaya is the largest natural freshwater lake in South Africa and is located on the coastal plain in KwaZulu-Natal. The lake is separated from the sea by a sand dune forest, swamp forest and wet grasslands. It is located in the iSimangaliso Wetland Park in northern KwaZulu-Natal about 430 km north-east of Durban. The lake is located between the Manzengwenya and Mbazwane plantations and the Mseleni plantation in the west. The estimated catchment area is about 530 km^2, and the lake is approximately 60–70 km^2 in size. The maximum depth has been measured up to 43 m (Bowen 1979; Bruton 1979; Ward and Kyle 1990). Research completed in the immediate marine environment indicates that a large river historically flowed into the ocean at Sibaya (Ward and Kyle 1990). The river was probably the Phongolo River, which presently flows northwards and into Maputo Bay in Mozambique. The lake supplies water to Mbazwane, and human activities are mainly grazing of livestock and agricultural activities, mostly for personal use. A hydrogeological study of the Lake Sibaya catchment area was also recently completed (Weitz and Demlie 2015).

Most of the available research on Lake Sibaya was from 1960 to 1970, when Rhodes University had a research station on the lake. The research focused on a wide range of aspects including hydrology, habitat structure, water quality, productivity, aquatic plants, zooplankton, macroinvertebrates, fish, amphibians, reptiles, birds and mammals (Allanson 1979).

The research station closed down in the 1980s and since then relatively little research has been completed on the lake. The research that is available reports on the presence of invasive snails (Peer et al. 2015; Raw et al. 2016), the concentrations of DDT in the sediment (Humphries 2013), as well as the accumulation of nutrients in the sediment (Humphries and Benitez-Nelson 2013). An investigation by Humphries (2013) showed that the DDT concentration at Lake Sibaya is of the highest values for sediment in South Africa and most of the guidelines for sediment are exceeded. Thus, there is potential for DDT to accumulate in fish, bird and crocodile communities.

No collective research is available regarding the overall condition of the lake and the impacts of human activities in the catchment area. These days, the catchment area is more densely populated, especially on the west side, which is located outside the iSimangaliso Wetland Park. A report in 2015 showed (DWS 2015a; 2015b) that the water quality of Lake Sibaya is mostly natural except for the western arm and the southern bowl. Both these areas are being impacted by the growing population, as well as the various pine plantations occurring in the areas. The water quality status was based on temperature, electrical conductivity, pH, dissolved oxygen, total carbon, total nitrogen and total phosphorus.

Lake Sibaya has numerous birds, reptiles, mammals and plant species that are endangered or endemic to the lake. It maintains crocodiles (*Crocodylus niloticus*) and hippopotami (*Hippopotamus amphibius*) populations as well. Studies have shown that there is a decrease of 95–98% in the crocodile numbers in Lake Sibaya, and only a small number of reproducible individuals are surviving (Combrink et al. 2011).

The available diatom information from Lake Sibaya is limited and is derived from Archibald (1966) as well as research conducted at the Rhodes research station in the 1970s (Allanson 1979). Archibald's work (1966) identified three species found for the first time in South Africa, as well as nine new species. Diatoms were collected in August 2015, December 2015 and February 2015, and only one of the new species found by Archibald (1966) was found again, namely *Amphora lacustris*. The only other reference to this species in the literature is by Sánchez Castillo (1993) at an international diatom symposium in the Netherlands. Archibald (1966) identified 107 different species, while the 2015 study found only 59 species (Kock 2017; Malherbe et al. 2017). Certain species were also found in the latter study that had not been previously found by Archibald (1966) or Allanson (1979). The difference in diversity is possibly due to the different locations, collection methods and potentially the changing environmental conditions from 1966 to 2015.

The lake maintains a diverse community of zooplankton, 15 aquatic molluscs and many other species unique to South Africa (Ward and Kyle 1990). The zooplankton of Lake Sibaya are a diverse community that includes the copepod *Tropocyclops brevis*. Dominant species in the community are mostly Copepoda and Branchiopoda of the Cladocera group, and Rotifera is also common (Ward and Kyle 1990). No newer information from the zooplankton was available, except for research on the larger zooplankton species where Lake Sibaya was one of the study sites (Peer et al. 2015; Raw et al. 2016). The benthic macroinvertebrates found in the lake are characterised by crustaceans, snails, crabs and shrimps, as well as polychaetes and nematode worms. Insecta are represented by several families, but no research has been done on this group since the 1960s and 1970s. These studies have shown that 15 Mollusca species have been found in Lake Sibaya, and 43 terrestrial Mollusca were found in the dune forest on the southern shore (Allanson 1979).

The fish community in Lake Sibaya consists of 18 species dominated by cichlids (four species) and gobies (three species). One of the gobies (*Silhouetta sibayi*) has its largest known population in Lake Sibaya, as few records exist at other places. The most abundant species in the lake are *Clarias gariepinus* (sharp tooth catfish), *Glossogobius giuris* (Ward and Kyle, 1995), *Oreochromis mossambicus*, *Pseudocrenilabrus philander*, and *Tilapia sparrmanii* (banded tilapia).

Lake Sibaya and the surrounding area has a diverse bird fauna with up to 279 species already recorded. Of these, 62 species directly require a water habitat for breeding, feeding or nesting habitats. The most abundant bird species are cormorants, kingfishers, fish eagles (*Haliaeetus vocifer*), and a variety of darters and herons. Wading birds include plovers, black winged stilt (*Himantopus himantopus*), avocet, greenshank, spoonbills and herons, while crakes and African crakes can be found in sheltered bays.

De Hoop Nature Reserve

The De Hoop Vlei was one of the first two wetlands, together with Barberspan, declared as a Ramsar locality in South Africa in 1975. The De Hoop Vlei is located in the De Hoop Nature Reserve, about 56 km from Bredasdorp in the Western Cape Province (Figure 1). The De Hoop Nature Reserve is one of the largest natural areas managed by Cape Nature. The terrestrial reserve covers approximately 355 km^2, while the marine part covers about 253 km^2.

Historically, the De Hoop Vlei was a lagoon, but over time, dune activity has pushed the mouth closed. It is approximately 18 km long and 500 m wide, and can cover a total area of 6.2 km^2 when it is full. The maximum depth varies, but during floods it can be around seven meters deep, whilst in dry times the vlei can completely dry up (at least once in the last century) (Butcher 1984). During events of extensive floods, which occurred only twice this century (1906 and 1957) (Butcher 1984), an area of up to 3 000 ha on the plain south of De Hoop Vlei flooded to a depth of three meters. The water gradually retreated after the 1957 flood and provided very favourable conditions for a variety of wetland-dependent birds for up to ten years afterwards. Currently the altitude is 4–11 m above the average sea level.

The Salt River and the Potteberg River are the two most important rivers that supply the De Hoop Vlei with water. There are also fountains in the northern part of the Vlei that have led to less brackish water in these sections. The catchment area of the Salt River falls outside the De Hoop Nature Reserve, mostly in private ownership, and is used for various agricultural purposes (Butcher 1984). Available information for the catchment area indicates that it is near natural with few changes in quality (DWS 2014).

The aquatic research at De Hoop Vlei is scanty, considering its Ramsar status, which has been valid since 1975. No published information about algae, diatoms or phytoplankton of the De Hoop Vlei is available. Similarly, no available and published information about zooplankton could be found. Conversations with Cape Nature also indicated that no current monitoring of the biological components of the ecosystem is being completed.

In addition to a study on Arachnida found in wet zones of the wetland (Haddad and Dippernaar-Schoeman 2009), there is no published information on invertebrates in the De Hoop Vlei. Data from the River Health Programme from 2000 to 2005 indicated that around 5–15 families were found on various sampling occasions in the Salt River. A survey in March 2015 found 17 different families from De Hoop Vlei (Malherbe et al. 2017). The survey also included an isolated temporary depression, which had kept water from the previous rainy season, containing 11 invertebrate families. The dominant families in the study were mostly Pomatiopsidae, Chironomidae and Corixidae. These taxa are usually generalist taxa that are adapted to occur in a wide range of aquatic ecosystems.

The fish community in De Hoop Vlei contains only one native fish species, *Sandelia capensis* (Siegfried 1963). However, it is possible that *Galaxia zebratus* occurs in the Salt River, and possibly also in the course of De Hoop Vlei. The native *Oreochromis mossambicus*, which naturally occurs in northern South Africa, was translocated to the De Hoop Vlei in the 1960s (Van Rensburg 1966; Scott and Hamman 1988). It now appears in large numbers in the system and dominates the fish biomass in the system, possibly at the expense of the indigenous Cape kurper, *Sandelia capensis*. A study on the parasites of *S. capensis* showed that nematodes, as well as metacercariae, were present on the fish. Moravec et al. (2016) identified the nematode as *Contracaecum* sp., while Van Rensburg and Moravec (2016) identified the metacercariae as part of the Clinostomidae family.

The platanna, *Xenopus laevis*, is the most common amphibian found in the De Hoop Vlei. In the 1960s, terrapins (*Pelomedusa subrufa*) were also present in large numbers (Brand 1961), but in the 1980s it was considered a rarity (Butcher 1984). No information is available about the current state of the community. The amphibian species list for De Hoop Vlei currently stands at ten species (FrogMap 2016).

The bird community of De Hoop Vlei has been studied relatively well, but most information regarding species and distribution is available from the Southern African Bird Atlas Project 2 data (SABAP2 2016). The data show that 233 bird species of the 370 species found in the South Western Cape were recorded at De Hoop Vlei (Hëyl 1983). According to Hëyl (1983), approximately 259 bird species were identified in De Hoop Vlei in 1983. The coordinated waterfowl count (CWAC) is also completed at De Hoop Vlei every year, showing that between 50 and 75 wetland-dependant species frequent this area. The number of bird species that can be seen at De Hoop Vlei is attributed to the habitat diversity in the area (Uys and Macleod 1987).

Heuningnes Estuary (De Mond Nature Reserve)

The Heuningnes Estuary is located on the south coast, about 25 km from Bredasdorp in the Western Cape Province, between Arniston and Struis Bay. The estuary is located in the De Mond Nature Reserve and borders various agricultural areas to the north. The wetland consists of the estuary, the sand dunes, and the salt marshes found in the reserve. The area is very important for various bird species that breed there, especially migratory water birds. There is also habitat within the estuary for seahorses from the genus *Hippocampus* (Western Cape Forest Region 1986).

The Heuningnes Estuary is the southernmost estuary in Africa, and is very important for science as it contains the most southern distribution records for various species, including three tropical species. These species are the ginger prawn (*Penaeus japonicus*), the large mud crab (*Scylla serrata*), and the nerite gastropod *Nerita albicilla*. The Heuningnes Estuary is one of the top 25 important estuaries in South Africa in terms of conservation importance based on size, habitat, rarity and biodiversity (Turpie et al. 2002). A study by Turner (2012) showed that the various ecological components of the estuary vary between good and very good when ecological status is used as a benchmark.

The Heuningnes Estuary and the Heuningnes River are fed by the Kars River as well as Zoetendalsvlei, which receives water from the Nuwe Jaars River. The Nuwe Jaars River current state is largely modified from the natural conditions

(DWS 2014). No information is available for the Kars and Heuningnes Rivers. The Heuningnes system is mostly under pressure due to changes in freshwater inflow, pollution, fishing, bait collection and habitat loss (Turner 2012).

The available aquatic information of the Heuningnes Estuary is quite sparse, but in some aspects, more is known here than at other Ramsar locations in South Africa. No information is available about the diatoms in the system; however, mention has been made that green algae (*Enteromorpha linga* and other *Enteromorpha* spp.), *Ulva* sp. as well as *Arthrocarcia* spp., occur in the area (Mehl 1973).

Zooplankton research in the estuary is also fairly limited, but a study by Montoya-Maya and Strydom (2009) looked at the composition, distribution and numbers of zooplankton in the estuary. They found that the dominant groups consisted mostly of Copepoda (81%), Amphipoda (6.1%) and Cladocera (5.1%). The dominant taxa were *Pseudodiaptomus hessei* (44.1%), Cyclopoida (22.3%) and Harpacticoida (8.5%).

The Heuningnes Estuary may have a tidal influx of up to 12 km, especially since the mouth has been artificially kept open since 1976. This causes a very strong marine impact on the aquatic communities. Macroinvertebrate communities in the source rivers are relatively low with a maximum number of families of 13 found by the River Health Programme between 2004 and 2013. The average family diversity was approximately seven at the various freshwater monitoring sites. Other studies of invertebrates included a study by Hodgson (2010) on the reproductive seasonality of the southern African coast and estuary invertebrates where the Heuningnes Estuary formed part of the study area. The Heuningnes Estuary was also used in a study on seagrass ratios in temperate South African estuaries (Kallen et al. 2012). In a field survey in March 2015, several benthic samples were taken to obtain macroinvertebrates from the mouth along the tidal influx of the Heuningnes Estuary (Malherbe et al. 2017). The results showed that approximately 50 taxa were found at the various sites and this list included Polychaeta, Bivalvia, Hirudiniae, Decapoda, Amphipoda, Mollusca, Gastropoda and Isopoda.

The fish community in the Heuningnes system is divided into freshwater and marine taxa. Cambray and Stuart (1985) conducted a study on the red fin minnows in the Breede River system, which found that the species *Pseudobarbus burchelli* is endemic to the Heuningnes River. In 2007, the Western Cape Province mentioned in a report on the state of biodiversity that the Heuningnes River red fin is critically endangered, as it occurs only in one catchment area and is under extreme risk of extinction. The Agulhas *Galaxia* sp. is also a species where the risk of being eradicated is large as it occurs only in the Heuningnes and Nuwe Jaars rivers (Cape Nature 2007). A further study on the phylogeny and biogeography of the genus *Pseudobarbus* (Cyprinidae) from the Heuningnes River was also completed by Swartz et al. (2009).

A study on the ecology, osmoregulation and reproductive biology of the white steenbras (*Lithognathus lithognathus*) was conducted in the Heuningnes Estuary (Mehl 1973). The study showed that the estuary provides an abundant and varied diet for white steenbras, which occur in large numbers throughout the river, and the estuary provides an ideal habitat for the maturation of juvenile fish. A larval fish study of the Heuningnes River (Montoya-Maya and Strydom 2009) found that 18 species were captured from 11 families. The dominant families were Gobiidae with 89.4%, Atherinidae with 4.2% and Blenniidae with 3.4% of the total catch. The dominant species were *Caffrogobius gilchristi* with 72.9%, *Psammogobius knysnaensis* with 12.5% and *Atherina breviceps* with 4.2% of the total catch (Montoya-Maya and Strydom 2009). The spread and biogeography of South African tributaries was done during the 1990s and one of the study localities was the Heuningnes Estuary. Harrison (1999) found that 24 species of fish occurred in the Heuningnes during those surveys. Of these species, two were freshwater species (*Sandelia capensis* and *Galaxia zebratus*), five were estuarine species, 14 were estuary-dependent marine species, and three were marine fish species.

The bird community of the Heuningnes Estuary has been studied relatively well, but most species and distribution information is available from the Southern African Bird Atlas Project 2 data (SABAP2 2014). The data showed that about 246 bird species (of the 370 species that occur in the southern Western Cape) were recorded at the De Mond Nature Reserve (Hëyl 1983). The coordinated waterfowl counts (CWAC) are also completed each year, indicating that approximately 26 species have occurred that are dependent on wetlands. Bird species that frequently make nests in the sand dunes of the reserve include *Larus dominicanus*, giant stars (*Hydroprogne caspia*), the African oystercatcher (*Haematopus moquini*), the blue crane (*Anthropoides paradisea*), the Karoo prinia (*Prinia maculosa*), the Kittlitz plover (*Charadrius pecuarius*) and the Egyptian goose (*Alopochen aegyptiacus*) (Underhill 1984). The pied kingfisher *Ceryle rudis* also regularly breeds in the area.

Discussion

The current aquatic information of many Ramsar sites in South Africa is limited and only certain sites (e.g. St Lucia Lake in iSimangaliso Wetland Park) have been well studied. There are also various levels of detail and components studied in the various locations (Table 1). The bird communities are well known in most cases, but other components such as water quality, diatoms, algae, zooplankton, macroinvertebrates and fish communities have been poorly studied. In the case of Barberspan and Lake Sibaya, the systems were well studied as research stations in the 1960s and 1970s existed at these locations, but unfortunately those stations have been closed down and newer information is therefore limited.

Table 1 illustrates the overall biodiversity (in terms of taxa richness) found during recent studies at selected Ramsar wetlands in South Africa. It is clear that there are still gaps in the available information for these sites. Current studies have shown that the Ramsar wetlands in many cases have unique characteristics. One example was the Makuleke Wetlands where each pan had a unique composition of diatoms and macroinvertebrates. It also means that each pan increases overall diversity, so every pan must be protected as far as possible. Should only one of these specific pans be degraded by human activities, the risk of losing biodiversity in these pans increases.

The biodiversity of all the Ramsar sites is important information that is needed to protect these systems so that sufficient management plans can be developed for each location. These management plans are essential as all the sites in this study have experienced impacts due to human activities. In some cases, the impact was minimal, but in other locations, the impact was much greater. The most common threats to the Ramsar sites were habitat loss, nutrient increase, pollutants, rural and urban intrusion, invasive species (including invasive parasites [Smit et al. 2017]), and poor land use management. Management and monitoring of the Ramsar sites is the only strategy to monitor these impacts and to send an early warning if the risk increases.

Newer data and monitoring of South Africa's Ramsar sites is critical to create a good basis for future monitoring of potential ecosystem changes due to human activities. Data of the sites should be updated every six years as required by the Ramsar Convention. This study of Ramsar sites in South Africa has found that there are several gaps in the current aquatic information, and from this, several potential research recommendations have been made. Firstly, a national monitoring programme is required to monitor all of these different sites for adverse human impacts. Secondly, more detailed studies will be required to determine which components will be the best reflections of environmental conditions and will also be the best indicators for each location. Thirdly, water and sediment quality, diatoms, macroinvertebrates, and fish are essential for monitoring these Ramsar systems. Fourthly, only seven of the 23 sites in South Africa were surveyed in this study and follow-up work is urgently needed for some of the other Ramsar sites. Lastly, newer molecular identification techniques are needed to determine the aquatic biodiversity accurately, especially with regard to the diatoms, zooplankton and macroinvertebrates.

Acknowledgements

The author would like to acknowledge the Water Research Commission for their sponsorship of the funds to complete the project (K5/2352). The Suid-Afrikaanse Akademie vir Wetenskap en Kuns as well as the PUK Kanselliers Trust are also thanked for their financial contribution to the study. Recognition also goes to Dr Kerry Hadfield Malherbe for her assistance throughout this study. The following persons also contributed during the project: Dr M Ferreira, Dr R Gerber, A Kock, J Beukes, E Bester, E Lubbe, A Greyling, L Erasmus, C Builder, H Coetzee, G Stander, M Truter, K Dyamond, L Hermann, P Garzia, Dr K McHugh, Dr I Prykrilova, Dr R Greenfield, Prof JHJ van Vuren, Prof V Wepener and Prof NJ Smit. Prof K de Kock and Prof A Combrinck are also thanked for their proofreading of the manuscript.

Declaration of interests

The author hereby declares that he has no financial or personal relationship with any party that could have had an adverse or beneficial effect on the writing of this article.

References

Allanson, B.R. 1979. Lake Sibaya. Monographiae Biologicae 36, 1–364, W. Junk, The Hague.

Archibald, R.E.M. 1966. Some new and rare diatoms from South Africa 2. Diatoms from Lake Sibayi and Lake Nhlange in Tongaland (Natal). *Nova Hedwigia* 12, 476–498.

Bester, E. 2017. Diversity of zooplankton and aquatic macroinvertebrates in the Ntsikeni Nature Reserve. Unpublished MSc dissertation, North-West University.

Beukes, J. 2017. Health assessment of fishes from coastal lakes on the east coast of South Africa. Unpublished MSc dissertation, North-West University.

Blaber, S.J.M. 1978. Fishes of the Kosi system. *Lammergeyer* 24, 28–41.

Blackmore, A. 2010. Information sheet on Ramsar wetlands (RIS) – 2006 - 2008 version; 2010. https://rsis.ramsar.org/RISapp/files/RISrep/ZA1904RIS.pdf?language=en [Accessed 25 Jan 2015].

Table 1: Summary table of the species richness found from the recent studies (2014–2017) for the various organisms at the selected Ramsar sites. As far as possible, the species richness refers to species level identification, but some taxa were only identified to genus or order level. Details on this can be found in Malherbe et al. (2017).

Wetland	Taxa found within the selected Ramsar wetlands					
	Diatoms	Zooplankton	Macroinvertebrate	Fish	Amphibians	Birds
Barberspan	22	12	48	10	8	365
Makuleke	70	12	108	15	33	450
Ntsikeni	45	23	115	–	19	200
Kosi Bay	NA	50	30	133	23	250
Lake Sibaya	59 – 107	NA	NA	18	22	279
De Hoopvlei	NA	NA	17	2	10	233
Heuningnes Estuary	NA	NA	50	24	NA	246

NA – not available

Bok, A., Cambray, J. 1996. Report on fish fauna of selected freshwater areas of Transkei in October 1996. In: Bok, A., 1966. Survey of freshwater biota, amphibians and reptiles of selected areas in ex-Transkei. Department of Economic Affairs, Environment and Tourism. Province of the Eastern Cape.

Bowen, S.H. 1979. A nutritional constraint in detritivory by fishes: The stunted population of *Sarotherodon mossambicus* in Lake Sibaya, South Africa. *Ecolological Society of America,* 49(1), 17–31.

Brand, D.J. 1961. A comparative study of the Cape teal (*Anas capensis* Gmelin) and the Cape shoveller (*Spatula capensis* Eyton) with special reference to breeding biology, development and food requirements. Unpublished Ph.D. Thesis, UNISA.

Breedt, N., Dippenaar, M.A. 2013. A summary of wetland legislation in South Africa over the past fifty years. Pretoria: University of Pretoria.

Bruton, M.N., Cooper, K.H. 1980. Studies on the Ecology of Maputaland. Rhodes University and Natal Branch of the Wildlife Society of Southern Africa.

Burger, M. 1996. Report on a herpetofaunal survey conducted in the former Transkei region. In: Bok, A., 1996. Survey of freshwater biota, amphibians and reptiles of selected areas in ex-Transkei. Department of Economic Affairs, Environment and Tourism. Province of the Eastern Cape.

Butcher, S.E. 1984. Environmental factors and the water regime of De Hoop Vlei. School of Environmental Studies Report No. 45, University of Cape Town.

Cambray, J.A., Stuart, C.T. 1985. Aspects of the biology of a rare redfin minnow Barbus burchilli (Pisces, Cyprinidae), from South Africa. *African Zoology*, 20(3), 155–165.

Cape Nature, 2007. Western Cape Province state of biodiversity. Cape Nature Scientific Services.

Combrinck, J.J. 1966. 'n Kwantitatiewe en kwalitatiewe ondersoek van die plankton van Barberspan. Unpublished M.Sc. dissertation. Potchefstroom Universiteit vir Christelike Hoër Onderwys.

Combrink, X., Korrûbel, J.L., Kyle, R., Taylor, R., Ross, P. 2011. Evidence of a declining Nile crocodile (*Crocodylus niloticus*) population at Lake Sibaya, South Africa. *South African Journal of Wildlife Research*, 41(2), 145–157. doi:10.3957/056.041.0201.

Cowan, G.I. 1995. Wetlands of South Africa. Pretoria: Department of Environmental Affairs and Tourism.

Davies, B., Day, J. 1998. Vanishing Waters. UCT Press, University of Cape Town, P/B Rondebosh, Cape Town.

Day, E., Malan, H. 2010. Tools and metrics for assessment of wetland environmental condition and socioeconomic importance: handbook to the WHI research programme. WRC Report No TT433/09.

Deacon, D.A.R. 2013. Information Sheet on Ramsar Wetlands (RIS) - 2007. http://www.ramsar.org/ris/key_ris_index.htm. [Accessed 5 Jan 2013].

de Necker, L., Ferreira, M., van Vuren, J.H.J., Malherbe, W. 2016. Aquatic invertebrate community structure of selected endorheic wetlands (pans) in South Africa. *Inland Waters* 6(3), 303–313.

Department of Water and Sanitation (DWS), 2014. A Desktop Assessment of the Present Ecological State, Ecological Importance and Ecological Sensitivity per Sub-Quaternary Reaches for Secondary Catchments in South Africa. Secondary: [W5] (example). Compiled by RQIS-RDM: https://www.dwa.gov.za/iwqs/rhp/eco/peseismodel.aspx

Department of Water and Sanitation (DWS), 2015a. Resource directed measures: Reserve determination study of selected surface water and groundwater resources in the Usuthu/Mhlanthuze water management area. Lake Sibaya – EWR specialist reports. Report produced by Tlou Consulting (Pty) Ltd. Report no: RDM/WMA6/CON/COMP/1813.

Department of Water and Sanitation (DWS), 2015b. Resource directed measures: Reserve determination study of selected surface water and groundwater resources in the Usuthu/Mhlanthuze water management area. Lake Sibaya – Intermediate EWR assessment report. Report produced by Tlou Consulting (Pty) Ltd. Report no: RDM/WMA6/CON/COMP/1713.

Dyamond, K.S. 2017. Macro-Invertebrate Diversity within the Makuleke Wetlands in the Pafuri Region of the Kruger National Park. Unpublished MSc dissertation, University of Johannesburg.

Enslin, J.M.N. 1966. 'n Vergelykende studie van die gewoontes van sekere varswatervisse in Barberspan, Wes-Transvaal. Unpublished M.Sc dissertation, Potchefstroom University for Christian Higher Education.

Foster, L., Malherbe, W., Ferreira, M., van Vuren, J.H.J. 2015. Macroinvertebrate variation in endorheic depression wetlands in North West and Mpumalanga provinces, South Africa. *African Journal of Aquatic Science* 40(3), 287–297. do i:10.2989/16085914.2015.1074060.

Frogmap, 2016. The Atlas of African Frogs. http://frogmap.adu.org.za/index.php. [Accessed 20 Novr 2016].

Gerber, R., Smit, N. J., Vuren, J. H. J. Van, Nakayama, S. M. M., Yohannes, Y. B., Ikenaka, Y., Wepener, V. 2016. Bioaccumulation and human health risk assessment of DDT and other organochlorine pesticides in an apex aquatic predator from a premier conservation area. *Science of the Total Environment 550*, 522–533.

Gerber, R., Wepener, V., Smit, N.J. 2015. Application of multivariate statistics and toxicity indices to evaluate the water quality suitability for fish of three rivers in the Kruger National Park, South Africa. *African Journal of Aquatic Science* 40(3), 247–259.

Golder Associates, 2011. Risk Assessment of the Barberspan Bird Sanctuary. Golder Associates Report Number 12598-9730-1.

Goldner, H.J. 1967. A population study of freshwater fish in the Barberspan, Western Transvaal. Unpublished MSc. Potchefstroom University for Christian Higher Education; 1967.

Grant, B. 2013. Leeupan Fish Kill Event, North West Province: 15 November 2013. Final Investigation Report. Strategic Environmental Focus (SEF) Report Number 504283.

Green, A.N., Garland, G.G., Uken, R., 2006. Geomorphological and managerial implications of fish trapping in the Kosi Bay Estuary, KwaZulu-Natal, South Africa. *African Journal of Marine Science* 28(3-4), 617–624. doi:10.2989/18142320609504211.

Grundling, P.L., Grundling, A.T., Pretorius, L., Mulders, J. & Mitchell, S. 2017. South African peatlands: ecohydrological characteristics and socio-economic value. WRC Report no.: 2346/1/17, Water Research Commission, Pretoria.

Haddad, C.R., Dippenaar-Schoeman, A.S. 2009. A checklist of the non-acarine arachnids (Chelicerata: Arachnida) of the De Hoop Nature Reserve, Western Cape Province, South Africa. *Koedoe* 51(1), 9 pp. doi:10.4102/ koedoe. v51i1.149.

Harrison, T.D. 2002. Preliminary assessment of the biogeography of fishes in South African estuaries. *Marine and Freshwater Research* 53(2), 479–490. doi:10.1071/MF01121.

Harrison, T.D. 1999. A preliminary survey of the estuaries on the South coast of South Africa, Cape Agulhas—Cape St Blaize, Mossel Bay, with particular reference to the fish fauna. *Transactions of the Royal Society of South Africa* 54(2), 285–310, DOI: 10.1080/00359199909520629.

Hart, L.A., Bowker, M.B., Tarboton, W., Downs, C.T. 2014. Species composition, distribution and habitat types of Odonata in the iSimangaliso Wetland Park, KwaZulu- Natal, South Africa and the Associated Conservation Implications. *PLoS One* 9(3), e92588. doi:10.1371/journal.pone.0092588.

Henri, A.J., Ferreira, M., Malherbe, W., De Necker, L., Wepener, V., van Vuren, J.H.J. 2014. The hatching success of egg banks of selected endorheic wetland (pan) fauna and a suggested water quality classification of pans. Water Research Report No. Pretoria: WRC.

Heÿl, C.W. 1983. Voëllewe van die De Hoopse omgewing en die moontlike impak van ontwikkeling deur Krygkor. In Anon (ed.). The ecology of De Hoop Nature Reserve and environs/Die ekologie van De Hoop-natuurreservaat en omgewing. Vol. II. Unpubl. Report. Cape Dept of Nature & Environmental Conservation, Environmental Impact Assessment Committee.

Hodgson, A.N. 2010. Reproductive seasonality of southern African inshore and estuarine invertebrates – a biogeographic review. *African Zoology* 45(1), 1–17.

Holbach, A., Cowley, P.D., Kramar, U., Neumann, T. 2012. Otolith chemistry of fishes from Kosi Bay, South Africa: A preliminary multiple analytical methods approach to reconstruct fish migrations. *Estuarine and Coastal Shelf Science* 109, 30–40. doi:10.1016/j.ecss.2012.05.027.

Humphries, M.S. 2013. DDT residue contamination in sediments from Lake Sibaya in northern KwaZulu-Natal, South Africa: Implications for conservation in a World Heritage Site. *Chemosphere* 93(8),1494–1499. doi:10.1016/j.chemosphere.2013.07.047.

Humphries, M.S., Benitez-Nelson, C.R. 2013. Recent trends in sediment and nutrient accumulation rates in coastal, freshwater Lake Sibaya, South Africa. *Marine and Freshwater Research* 64(11), 1087–1099.

James, N.C., Beckley, L.E., Mann, B.Q., Kyle, R. 2001. The recreational fishery in the Kosi estuarine lake system, South Africa. *African Zoology* 36(2), 217–228. doi: 10.1080/15627020.2001.11657140.

Källén, J., Muller, H., Franken, M.L., Crisp, A., Stroh, C., Pillay, D., Lawrence, C. 2012. Seagrass-epifauna relationships in a temperate South African estuary: interplay between patch-size, within-patch location and algal fouling. *Estuarine and Coastal Shelf Science* 113, 213–220. doi:10.1016/j.ecss.2012.08.006.

Kock, A. 2017. Diatom diversity and response to water quality within the Makuleke Wetlands and Lake Sibaya. Unpublished MSc dissertation, North-West University.

Kyle, R. 1995. Information Sheet on Ramsar Wetlands (RIS); 1995. http://ramsar.wetlands.org/. [Accessed 20 Feby 2014].

Kyle, R. 2013. Thirty years of monitoring traditional fish trap catches at Kosi Bay, KwaZulu-Natal, South Africa, and management implications. *African Journal of Marine Science* 35(1), 67–78. doi:10.2989/1814232X.2013.769905.

Kyle, R., Robertson, W.D. 1997. Preliminary estimates of population size and capture rates of mature *Acanthopagrus berda* in the Kosi lakes system, South Africa, using mark-recapture methods. *South African Journal of Zoology* 32(4), 124–128. doi:10.1080/02541858.1997.11448443.

Levanets, A., van Rensburg, L. 2011. Desmids of southern Africa: An annotated and illustrated list. *And Cork Publishers, Potchefstroom, Republic of South Africa*: 1–332.

Malherbe, W., Beukes, J., Smit, N.J. 2015. Chromium, copper, nickel and zinc accumulation within selected fish species from a Ramsar site in Southern Africa. In 7th International Toxicology Symposium in Africa (p. 26); August 2015.

Malherbe, W., Ferrreira, M., van Vuren, J.H.J., Wepener, V. Smit, N.J. 2017. The aquatic biodiversity and tourism value of selected South African Ramsar wetlands. Water Research Commission Report No. K5/2352. WRC report.

Mangold, S.T., de Moor, F.C. 1996. A preliminary survey of the macroinvertebrate fauna of the rivers of the former Transkei region with notes on freshwater snails (Mollusca), freshwater prawns (Decapoda), mayflies (Ephemeroptera), caddisflies (Trichoptera) and blackflies (Diptera: Simulidae). In: Bok A, 1996. Survey of freshwater biota, amphibians and reptiles of selected areas in ex-Transkei. Department of Economic Affairs, Environment and Tourism. Province of the Eastern Cape; 1996.

Mehl, J.A.P. 1973. Ecology, osmoregulation and reproductive biology of the White Steenbras, *Lithognathus lithognathus* (Teleostei: Sparidae). *Zoologica Africana* 8(2), 157–230. doi:10.1080/00445096.1973.11448513.

Miranda, N.A.F., Perrissinotto, R. 2012. Stable isotope evidence for dietary overlap between alien and native gastropods in coastal lakes of northern KwaZulu-Natal, South Africa. PLoS One 7(2), e31897. doi:10.1371/journal.pone.0031897.

Montoya-Maya, P.H., Strydom, N.A. 2009. Description of larval fish composition, abundance and distribution in nine south and west coast estuaries of South Africa. *African Zoology* 44(1), 75–92. doi:10.1080/15627020.2009.11407441.

Moore, C.A., Chutter, F.M. 1988. A survey of the conservation status and benthic biota of the major rivers of the Kruger National Park. Final Report. Pretoria: CSIR; 1988.

Moravec, F., van Rensburg, C.J., Van As, L.L. 2016. Larvae of *Contracaecum* sp. (Nematoda: Anisakidae) in the threatened freshwater fish *Sandelia capensis* (Anabantidae) in South Africa. *Dis Aquat Org* 120:251-254. https://doi.org/10.3354/dao03033.

Nesbitt, K. 2014. An investigation into pan hydrology and ecology in the Makuleke Concession, Northern Kruger, South Africa. Unpublished MSc dissertation, University of the Witwatersrand.

Passmore, N.I., Carruthers, V.C. 1995. South African Frogs: a complete guide. Revised edition. Witwatersrand University Press, Southern Book Publishers. 322 pp.

Peer, N., Perissinotto, R., Miranda, N.A.F., Raw, J.L. 2015. A stable isotopic study of the diet of *Potamonautes sidneyi* (Brachyura: Potamonautidae) in two coastal lakes of the iSimangaliso Wetland Park, South Africa. *Water SA* 41(4), 549–558.

Ramsar Secretariat (RCS), 2016. An Introduction to the Convention on Wetlands (previously The Ramsar Convention Manual). Ramsar Convention Secretariat, Gland, Switzerland.

Ramsar Secretariat, 2017. Country Profile – South Africa. Retrieved from: http://www.ramsar.org/wetland/south-africa (27.01.2017).

Raw, J.L., Perissinotto, R., Miranda, N.A.F., Peer, N. 2016. Diet of *Melanoides tuberculata* (Müller, 1774) from subtropical coastal lakes: Evidence from stable isotope (δ 13 C and δ 15 N) analyses. *Limnologica-Ecology and Management of Inland Waters 59*, pp.116–123.

Roeder, M. 2014. The impact of Eucalyptus plantations on the ecology of Maputaland with special reference to wetlands. MSc dissertation, Technical University of Munich.

Roode, M.C., van Eeden, J.A. 1970. ʻn Kwantitatiewe en kwalitatiewe ondersoek van die bentos in Barberspan, Transvaal. Wetenskaplike bydraes van die PU vir CHO; Reeks B Natuurwetenskappe no. 18; 1970.

Sánchez Castillo, P.M. 1993. *Amphora margalefii* Tomás var. *lacustris* P. Sánchez var. nova, a new brackish water diatom. In: (Eds) H. van Dam. Twelfth International Diatom Symposium, pp. 269-270. Kluwer Academic Publishers, Belgium.

Schoonbee, H.J. 1969. Notes on the food habits of fish in Lake Barberspan, Western Transvaal, South Africa. Verhandlungen der Internationalen Vereinigung für Limnologie 17, 689–701.

Scott, H.A., Hamman, K.C.D. 1988. Recent fish records from De Hoop Vlei, a southern Cape coastal lake. *Bontebok* 6, 30–33.

Siegfried, W.R. 1963. Observations on the reproduction and feeding of the Cape kurper *Sandelia capensis* (C. and V.) in De Hoop lake, Bredasdorp. Investigational Report 3; 1963. Cape Department of Nature Conservation. 12 pp.

Sinclair, I., Whyte, I.J. 1992. Field guide to the birds of the Kruger National Park. Struik, Cape Town; 1992. 251 pp.

Skelton, P. 2001. A complete guide to the freshwater fishes of southern Africa. Cape Town: Struik.

Smit, N.J., Malherbe, W., Hadfield, K.A. 2017. Alien freshwater fish parasites from South Africa: Diversity, distribution, status and the way forward. *International Journal for Parasitology, Parasites and Wildlife* 1–16.

Smit, N.J., Wepener, V., Vlok, W., Wagenaar, G.M., van Vuuren, J.H.J. 2013. Conservation of tigerfish, *Hydrocynus vittatus*, in the Kruger National Park with the emphasis on establishing the suitability of the water quantity and quality requirements for the Olifants and Luvuvhu Rivers. Water Research Commission. Pretoria. WRC Report No. 1922/1/12.

Southern African Bird Atlas Project 2 (SABAP2), 2016. South Africa, Lesotho, Botswana, Namibia, Mozambique, Swaziland, Zimbabwe, Zambia. Animal Demography Unit, University of Cape Town and South African National Biodiversity Institute (SANBI). [Accessed 25 Nov 2016].

Swart, D.R., Cowan, G.I. 1994. Information Sheet on Ramsar Wetlands (RIS). [Online] Available at: http://ramsar.wetlands.org/; 1994. [Accessed 20 Feb 2014].

Swartz, E.R., Skelton, P.H., Bloomer, P. 2009. Phylogeny and biogeography of the genus Pseudobarbus (Cyprinidae): shedding light on the drainage history of rivers associated with the Cape Floristic Region. *Molecular Phylogenetics and Evolution* 51(1), 75–84. doi:10.1016/j.ympev.2008.10.017.

Truter, M., Přikrylová, I., Malherbe, W., Smit, N.J. 2016. First report of metazoan parasites from the cichlid *Pseudocrenilabrus philander* and the cyprinid *Enteromius paludinosus* in a South African Ramsar wetland. *African Journal of Aquatic Science* 41 (4).

Turner, A.A. 2012. Western Cape Province State of Biodiversity 2012. Stellenbosch: Cape Nature Scientific Services; 2012. ISBN: 978-0-621-41407-3.

Turpie, J.K., Adams, J.B., Joubert, A., Harrison, T.D., Colloty, B.M., Maree, R.C., Whitfield, A.K., Wooldridge, T.H., Lamberth, S.J., Taljaard, S. 2002. Assessment of the conservation priority status of South African estuaries for use in management and water allocation. *Water* SA 28(2):171–196. doi:10.4314/wsa.v28i2.4885.

Underhill, L.G., Cooper, J. 1981. Counts of waterbirds at coastal wetlands in southern Africa 1978-1981. Percy Fitzpatrick Institute of African Ornithology report; 1982. 253 pp.

Uys, C.J., Macleod, J.G.R. 1967. The birds of the De Hoopvlei Region, Bredasdorp, and the effect of the 1957 inundation over a 10-year period (1957–66) on the distribution of species. *Ostrich* 38(4), 233–254. doi:10.1080/00306525.1967.9634712.

Van der Schyff, V., Pieters, R., Bouwman, H. 2016. The heron that laid the golden egg: metals and metalloids in ibis, darter, cormorant, heron, and egret eggs from the Vaal River catchment, South Africa. *Environmental Monitoring and Assessment* 188(6), 372–377. doi:10.1007/s10661-016-5378-0.

Van der Waal, B.C.W. 1998. Survival strategies of sharptooth catfish *Clarias gariepinus* in desiccating pans in the northern Kruger National Park. *Koedoe*, 41(2), 131–138.

Van Rensburg, C., Moravec, F. 2016. Clinostomid metacercariae and larval *Contracaecum* sp. infecting the Cape kurper *Sandelia capensis* Cuvier, 1831 The 45th Annual Conference of the Parasitological society of Southern Africa. 28 – 31 August 2016. Lagoon Beach Hotel, Cape Town.

Van Rensburg, K.J. 1966. Growth of *Tilapia mosssambica* (Peters) in the De Hoop Vlei and Seekoei Vlei. Dept of Nature Conservation Investl. Rep. 9; 1966. 7 pp.

Ward, M.C., Kyle, R. 1990. Lake Sibaya: Information Sheet on Ramsar Wetlands (RIS). http://ramsar.wetlands.org/ [Accessed 20 Feb 2014].

Weitz, J., Demlie, M. 2015. Hydrogeological system analyses of the Lake Sibayi Catchment, north-eastern South Africa. *South African Journal of Geology* 118(1), 91–107. doi:10.2113/gssajg.118.1.91.

Western Cape Forest Region, 1986. Heuningnes Estuary (De Mond Nature Reserve). Information Sheet on Ramsar Wetlands (RIS). http://ramsar.wetlands.org/ [Accessed 20 Feb 2014].

Whitfield, A.K. 1997. Fish conservation in South African estuaries. *Aquatic Conservation* 7(1), 1–11. doi:10.1002/(SICI)1099-0755(199703)7:1<1::AID-AQC213>3.0.CO;2-8.