Trajectories of change in wetlands of the Fynbos Biome from the late 1980s to 2014

Report to the
Water Research Commission

by

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PREFACE

This report emanates from WRC Project no. K5/2183 "*Trajectories of change in wetlands of the Fynbos Biome*". In this report (referred to as Vol:1), the general trends across the set of wetlands are discussed. The details for individual wetlands are given in "Wetland Status Report" which forms an addendum to this document (referred to as Vol:2) and is available on the enclosed CD.

EXECUTIVE SUMMARY

INTRODUCTION

In this project, a set of 65 wetlands originally sampled during the late 1980s in the Western Cape (Silberbauer and King 1991a & 1991b) were revisited. For each wetland, a rapid habitat assessment was carried out and the current land-use within and around the wetland examined. Water chemistry was assessed by taking *in situ* measurements and extracting water samples for laboratory analysis. Biological samples in the form of diatoms, plants and invertebrates were also collected. The results of these assessments were used to derive the overall environmental condition (expressed as the Present Ecological State) and were compared to the likely condition during the time of the original survey. From the above results, the type and extent of threats that wetlands of the Fynbos Biome have been exposed to over the past 25 years were identified.

AIMS OF THE PROJECT

The major thrust of this project was to better understand the factors leading to wetland degradation and through this to facilitate their conservation. The specific aims of the project are listed below:

1. To revisit a set of wetlands previously surveyed by King and Silberbauer in the late 1980s.

2. To establish the present ecological state (environmental condition) of those wetlands based on a rapid habitat assessment and on water quality data and to compare this with their historic condition.

3. To identify the factors contributing to wetland loss, alteration in wetland character or degradation, or conversely to an improvement in environmental condition.

4. To compare the present plant communities with those recorded in the 1980s.

5. To identify the land-use and other factors contributing to the loss of (or increase in) biodiversity and changes in plant assemblages.

6. To add to our understanding of correlations between wetland habitat condition, water quality and biological response in diatoms.

7. To expand the presently inadequate inventories of wetland biodiversity for wetlands of the Fynbos Biome.

8. To inform the development of techniques needed for a national Wetland Monitoring Programme required by the National Water Act of 1998.

SURVIVAL OF THE WETLANDS

On re-visiting the study wetlands, the following situation was encountered:

- Pinelands crossing, Yzerfontein Inflow and a very small artificial wetland (Soetendalsvlei ditch) are no longer in existence. Areas of the following wetlands have also been lost: Platdrif (the upper part), Kluitjieskraal (the lower, Verrekyker area), and the lower part of Belsvlei.
- Lake Michelle (formerly Noordhoek Salt Pan) and Rooipan still exist but have changed markedly in ecological character. Formerly a degraded seasonal saline pan, Lake Michelle is now a permanently inundated freshwater lake/depression surrounded by residential development. Rooipan on the other hand was being

mined for gypsum at the time of the historical sampling programme and was probably a seep area but now consists of three seasonal pans.

- Cape Corps, Peters Bog, and Groot Hagelkraal wetlands could not be located, although they are still likely to exist.
- Sederhoutkop, Donkerkloof tributary in the Cederberg and Pearly Beach C on the Groot Hagelkraal River could not be sampled because of snow and flooding respectively, but from Google Earth and other information, both of the Cederberg wetlands are still there and in the same ecological condition. The wetland "Pearly Beach C" is also still there and may have increased in extent due to restriction of outflow arising from road construction.

IMPORTANCE AND BENEFITS OF THE WETLANDS

The importance of the wetlands in terms of the ecosystem services or benefits that they currently supply was scored using the approach of Rountree *et al*. (2012).

- The study wetlands differed in the benefits they supplied, depending on the hydrogeomorphic (HGM) type and the opportunity for providing the service.
- The Ecological Importance and Sensitivity was the highest contributor to the overall wetland importance and benefit score. This is because many of the wetlands are situated in un-impacted areas in vegetation types of high importance.
- Direct Human Benefit scores (DHB) were fairly low amongst the study wetlands, probably due to the low levels of subsistence use in the Western Cape and the fact that the wetlands were mostly located on private land or in conservation areas. Many of the wetlands do contribute to DHB through provision of opportunities for tourism (especially avitourism) and by increasing the municipal rating value of adjacent property.
- The use of data on waterbirds (CWAC and SABAP2) to infer the importance of a wetland for avifauna was explored (Appendix A).

PRESENT WATER CHEMISTRY

In situ measurements and laboratory samples were taken from the water column and the results presented below:

Electrical conductivity

- Electrical conductivity (EC) in the present project varied from roughly 2 mS/m for Silvermine Dam inflow to 17170 mS/m for Koekiespan, although the EC for 80% of the wetlands lay between 5 and 4250 mS/m with a median EC of 57 mS/m.
- The results support the findings of Malan and Day (2012), namely that seeps exhibited the lowest EC followed by valley bottom systems, with depressions (specifically endorheic "pans") exhibiting the highest.
- There was little correlation of EC with the Present Ecological State (PES) of the wetland.

pH and water colour

- The wetlands were divided into three broad bands of "acidic" (pH<6), "circum-neutral" (pH 6-8) and "alkaline" (pH>8). The majority of wetlands were in the circum-neutral group with roughly 25% of the wetlands being acidic and 10% being alkaline.

- All of the acidic wetlands were located in largely natural fynbos vegetation, or fed by water from such a system. The alkaline wetlands (excluding Witzand, which derives its water from effluent) are mostly saline depressions – such as Vispan, Rooipan and Vermont Pan.
- As expected, the highest values of water colour were linked with the most acidic wetlands. The wetland systems that had the highest level of water colour were those associated with the Groot Hagelkraal River (including Pearly Beach), Salmonsdam and Hemel-en-Aarde.
- The saline, alkaline pans, *e.g.* Melkbospan, Vispan and Koekiespan often recorded low levels of water colour.

Phosphorus

- Water column phosphate concentrations ranged from below detection to a maximum value of 3.05 mg P/L (for Kiekoesvlei). The median phosphate concentration was 0.01 mg P/L and 25% of wetlands had phosphate concentrations below 0.005 mg P/L.
- There was a trend of increasing phosphate concentration with elevated levels of impact, but this was not clear-cut. The exorheic seeps and valley-bottom wetlands located in the mountains tended to record low phosphate levels. At the other end of the scale are the most impacted systems, which were often endorheic. The Khayelitsha Pool (impacted by extensive upstream urban development) had the highest levels of phosphate.

Nitrogen

- Total Inorganic Nitrogen (TIN) varied from less than 0.01 mg N/L (Driehoek, Kenilworth Racecourse, Silvermine Dam inflow), to more than 1.0 mg N/L (Koekiespan, Khayelitsha Pool, Witzand Aquifer Recharge, Platdrif and Die Vlakte). The median TIN value was 0.083 mg N/L.
- In general, high TIN levels could be explained by surrounding land-use. The wetlands that had low TIN values were usually (but not always) mountain seep/valley bottom systems located in natural vegetation.

CHANGES IN WATER QUALITY (WQ) OVER THE INTERVENING 25 YEARS

The likely change in water chemistry since the historical project was recorded as; “Same” (*i.e.* WQ unlikely to have changed from the historic condition), “Slight deterioration” (one WQ variable has increased in the present condition relative to the historic), “Deteriorated” (indicated by significant increases in one or more variables), and “Improved” (present measurements of WQ variables considerably lower than those recorded by King and Silberbauer). The variables used to assess WQ were EC, phosphate, TIN (or individual species of N, *e.g.* ammonium, nitrate, nitrite, as determined by the availability of data). The results should be interpreted with caution as they are, in the great part, based on only two data points.

On comparing WQ for each study wetland during the historical project and the present, it was found that in terms of water quality:

3% of the wetlands have **improved**
17% of the wetlands are the **same**
9% of the wetlands **likely to be the same (**but data are lacking)

9% of the wetlands have **deteriorated** (significantly)
17% of the wetlands show a **slight deterioration**
6% of the wetlands have **possibly deteriorated** but data are too limited to be conclusive.

The change in WQ for the remaining **39%** could not be determined due to lack of either historical or present day data.

- Of the wetlands that show a significant deterioration in WQ the most marked is the Blinde River where the level of EC in the river has increased 100 fold.
- Deterioration of WQ frequently took the form of increased levels of either (or both) nitrogen or phosphorus. General nutrient enrichment could usually be predicted from the change in land-use.

CHANGES IN PLANT COMMUNITIES

- Differences in sampling intensity and approach between the 1988/89 and 2012/13 surveys may have resulted in some inconsistency in vegetation sampling and may therefore have complicated the interpretation of results. It can be concluded for the study wetlands, however, that although hydrogeomorphic (HGM) types cannot be identified by plant communities, plant communities can be used to describe HGM units. Several HGM units can be recognized, each with characteristic plant communities and indicator species.
- Analysis of the plant species data identified four main plant community groups historically and five in the present-day study. The main change seems to have been an increase in dominance of the reed *Phragmites australis* in several of the wetlands showing increased disturbance.
- Differences in species composition over time seem to be tied to changes in land-use although these changes were not strongly related to differences in the measured environmental variables. As such, the trajectories of change are not readily predictable from changes in simple physical and chemical attributes. The lack in most cases of the relationship between nutrient concentrations and plant communities was unexpected but similar results have been found in certain wetlands elsewhere.
- The majority of wetlands whose plant communities have changed are depressions, perhaps because depressions are often located in areas vulnerable to human disturbance and because depressions tend to retain water and nutrients draining from their surroundings.

DIATOMS

- Strong correlations exist between certain, but not all, water quality variables and the diatom-based indices calculated during this study.
- Despite the once-off sampling regime and the almost complete lack of knowledge of the diatom flora of the south-western Cape wetlands, the wetlands could be separated into water quality classes based on an analysis of their diatom floras. Bioassessment using diatoms therefore represents a potential tool for assessing the ecological condition of wetlands of the south-western Cape. The feasibility of using diatoms as a national tool for monitoring wetland water quality needs to be investigated objectively in conjunction with other potential biotic indicators.
- The SPI (Specific Pollution Sensitivity Index) showed potential for describing water quality in freshwater wetlands but caution should be used in interpreting

results for naturally occurring saline pans. A new index system may need to be developed for these systems.

- It seems that the species identified in this study as “European” do respond in the same way to water quality variables, suggesting that they are cosmopolitan.
- While diatom samples from different substrata gave similar results, further investigations are needed into the effect of substratum on the “ecological condition” or water quality classes identified from diatom analysis.

ASSESSMENT OF CHANGES IN ECOLOGICAL HEALTH

The Present Ecological State (PES) of the wetlands was assessed using the method of Duthie (1999) since it is applicable to all wetland types and is reasonably rapid, simple, flexible and transparent.

- “Historical ecological health scores” were estimated for the study wetlands based on all available information, but are likely to be an educated guess. At the time of the historical survey, the majority of the wetlands (roughly two thirds) were in a natural/slightly impacted condition (*i.e.* A or B category). Some wetlands were already significantly impacted, however, and probably in a “C” or “D” category in terms of ecological heath. The most impacted of all the wetlands was probably Rooipan (“D/E” score).
- With regard to the present ecological condition of the wetlands, 25% of the wetlands are in a natural (“A” category); 24% are in a “B” or slightly impacted category. A further 24% are fairly seriously modified (categories B/C, C and C/D) and 6% are in a “D” category or lower. Almost all of the wetlands in a natural condition included, unsurprisingly, wetlands in conservation areas such as the Cederberg, Table Mountain National Park, or the Agulhas National Park.
- The wetlands currently in the worst condition are Khayelitsha Pool (C/D), Kiekoesvlei (D) and Koekiespan (D). The former is affected by extensive urban development in the upper catchment and the latter two by agriculture.

CHANGE IN CONSERVATION STATUS

It was found that for the study wetlands the conservation status of:

51% of the wetlands have improved
38% of the wetlands are the same
2% wetlands have deteriorated

For the remaining **9%** the change in conservation status is either unknown or not applicable (wetland no longer in existence).

- The establishment of new conservation areas namely; the Table Mountain National Park and the Agulhas National Park and at a more local level, Khayelitsha Wetland Park, Kenilworth Conservation Area, Witzand Aquifer Recharge area, Silvermine River (floodplain) and Vermont Pan Conservation areas has resulted in improved protection for wetlands.
- Initiatives from private land-owners noticeably the Nuwejaars Special Wetland Management Area, and the conservancy agreement due to be formalised between private landowners, CapeNature and the Worcester Municipality for Papkuils (Bokkekraal) wetland have also resulted in improved protection for some wetlands.

CHANGE IN ECOLOGICAL HEALTH

An analysis of the change in environmental condition for the study wetlands for which an ecological health score could be assigned over the past 25 years shows that:

29% wetlands are in a **better/slightly better** category
24% wetlands are in the **same** condition
8% wetlands show a **slight deterioration**
23% wetlands have **deteriorated significantly**

For the remainder of the wetlands (**16%**), the change in ecological health either could not be determined or the wetland is no longer in existence. The results from this study investigating changes in ecological health of the study wetlands are quite mixed. Although some wetlands have been lost, the small number out of a total of ±65 wetlands is lower than was expected.

Impacts that have caused deterioration

With regards to the impacts facing wetlands in the Fynbos Biome, there are few surprises and these include: invasion by alien plants (acacias, pines, eucalypts), urban development, and agricultural development.

Factors that have cause an improvement in ecological health

Improvement in ecological health has arisen from protection of some wetlands within new conservation areas – both at the national level and at the local level involving both state institutions and private landowners.

RECOMMENDATIONS FOR THE NATIONAL WETLAND MONITORING PROGRAMME AND FOR THE NEXT 25 YEARS

An important output of this study was that the challenges and practical considerations arising during the project be documented so as to inform the proposed National Wetlands Monitoring Programme (NWMP). Issues and recommendations that have emerged are discussed below.

General

- It is important to always keep the reason for sampling in mind. The purpose should guide the entire sampling programme and determine exactly what is sampled, how often and where.
- Depending on the answer to the above questions, rather than sampling biotic aspects such as diatoms, plants or invertebrates which can vary across a wetland (in addition to varying temporally) it may be better to rather monitor macro-changes in and around the wetland, such as changes in land-use which can be monitored remotely.
- Ideally, as many aspects as possible should be monitored, but there will always need to be a balance between the financial cost and sampling effort and what yields the most useful and relevant information.
- It would be best to have an initial in-depth assessment of each wetland to prepare the baseline information. Any specific issues, such as threats to the environmental condition need to be highlighted for future monitoring. For each wetland a tailor-made sampling strategy should be prepared. This would include sampling of basic aspects (*e.g.* some water quality parameters, land-use change) and any specific

issues (*e.g*. encroachment of reeds) that are relevant for that particular wetland and likely to pose a threat to the future ecological health.

- Careful attention needs to be paid in the NWMP, to archiving not just the sampling results but other background information that might be of use in the future the exact nature of such needs cannot always be anticipated.
- It was difficult to find out what work has already been done on a given wetland especially if the information is not on the Internet, if it is in the “grey literature“, or lodged as institutional records. It is important that the data obtained through the NWMP be easily available to wetland scientists, managers and interested parties. A database (the “National Wetlands Inventory”) will be required to store the data collected through the NWMP, but in addition the database should also act as a repository for existing data and have links (where possible) to the available literature for a given wetland.

Packaging and disseminating the sampling results

- It is important that information (*e.g.* species lists, WQ data) collected during the sampling programme is made freely available to landowners. It is not just the data *per se* that is important but also the interpretation of the data. This needs to be in a format that can be understood by lay-people. If budget allows, the information should be "packaged" in different ways and in different languages.
- It is important not to under estimate the role and importance of the landowner in planning a sampling programme. Attention needs to be given to development of “citizen science” initiatives in wetlands. This will ensure that the landowners gain a better understanding of the wetlands that they “own” and will hopefully value and conserve them.
- There is a need to have simple “how to sample” guides for the different elements (*e.g.* sampling invertebrates, water quality, plants, *etc*.) so that the sampling effort is standardized.

Assessment of the wetland Present Ecological State

- It is important before starting any assessment of the Present Ecological State that the reference state of the wetland be described because this is the basis against which any changes or impacts are assessed.
- It is important that the NWMP considers not only once-off assessment of wetland environmental condition (as is usually carried out) but also the on-going monitoring of environmental condition.
- Allied to the assessment of wetland environmental condition is the problem of how to assess artificial wetlands or those highly modified from the original condition.

Assessment of wetland Importance and Benefits

- The importance of the wetland and the benefits it provides need to be assessed and monitored. There is a tendency sometimes for these aspects to be left out and only environmental condition defined. Frequently, wetlands are artificial or radically changed from the reference state and so it is difficult to establish the Present Ecological State and yet they provide critical benefits for people and they should not be under-valued.

Sampling the biota

- Vegetation surveys for reference-site data should be based on more than presence/absence data. At the very least, once-off intensive sampling of wetland vegetation should be done. The use of permanent quadrat sampling allows for representative field data collection across subsequent years for monitoring purposes. Using quadrats, comprehensive plant species lists should be made including a record of rare, vulnerable and threatened species. The extent of cover, abundance and vegetation structure should also be determined.
- Sampling should be planned to coincide with spring and/or early summer months as it makes identification much easier for a non-specialist. Suggested standardised methods for sampling are given in Chapter 8.
- Soil samples for emergent vegetation, and water samples for floating and submerged vegetation, should be collected at each plot and/or site for analysis of associated environmental variables. Site descriptions of land-use should also be noted.
- Vegetation monitoring results should be fed into the National Wetland Database (Sieben 2011) or a central wetland attribute database. Such an objective will contribute to and increase the knowledge of wetland vegetation.
- Diatoms show potential as bio-indicators of wetland water quality but more research is first required into various aspects including the effect of substrate and salinity on the presence of diatom communities.

CONCLUSION

The overall conclusion from this project is that although good progress has been made with regard to the management and protection of wetlands, there is no room for complacency and the future of many wetlands located on private land is uncertain. There is an urgent need in this country to investigate ways of incentivising land-owners to protect wetlands on their property in addition to educating them with regard to the benefits wetlands supply. Thus approaches using “citizen-science” need to be explored and developed. Ultimately, landowners need to understand the importance of these systems in the environment. Involving land-owners in the monitoring process, and providing them with rapid feed-back, should encourage them to regard wetlands as important and beneficial features of the landscape.

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ABBREVIATIONS AND ACRONYMS

ASPT	Average Score Per Taxon
BDI	Biological Diatom Index
CCA	Canonical Correspondence Analysis
CCR	Core Cape Region
CFR	Cape Floristic Region
DAFF	Department of Agriculture, Fisheries and Forestry
dbRDA	Distance-based Redundancy Analysis
DHB	Direct Human Benefit
DistLM	Distance-based Linear Modelling
DL	Detection limit
DO	Dissolved oxygen
d/s	Downstream
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
EC	Electrical conductivity
EIS	Ecological Importance and Sensitivity
GCFR	Greater Cape Floristic Region
GDI	Generic Diatom Index
GIS	Geographical Information System
ha	Hectares
HGM	Hydrogeomorphic
LHS	Left hand-side
masl	Metres above sea level
MDS	Multi-dimensional Scaling
Na	Sodium
NCMP	National Chemical Monitoring Programme
ND	Not determined
NGO	Non-governmental organisation
NH4	Ammonium
NMMP	National Microbiological Monitoring Programme
NMMU	Nelson Mandela Metropolitan University
NO3+NO2	Nitrate plus nitrite
NWMP	National Wetland Monitoring Programme
PD	Present day
PES	Present Ecological State
PO4	Phosphate
%PTV	% Pollution Tolerant Valves
QGIS	Quantum Geographic Information System
RC	Reference condition
RD	Red Data
RHP	River Health Programme
RHS	Right hand-side
RQS	Resource Quality Services (Dept. Water and Sanitation)
SAI	South African Infantry

SANBI	South African National Biodiversity Institute
SANParks	South African National Parks
SASS	South African Scoring System
SAWS	South African Weather Service
SO4	Sulphate
SPI	(Diatom) Specific Pollution Sensitivity Index
SRP	Soluble Reactive Phosphorus
TIN	Total inorganic nitrogen
TP	Total phosphorus
UCT	University of Cape Town
UKZN	University of KwaZulu-Natal
u/s	Upstream
WfW	Working for Wetlands
WMA	Water Management Area
WMS	Water Management System
WQ	Water quality
WRC	Water Research Commission
wrt	With regard to
WWTW	Waste Water Treatment Works

CHAPTER 1
INTRODUCTION

1.1 RATIONALE FOR THE PROJECT

It is commonly reported in the literature that at least 50% of wetlands in South Africa have been lost and many more are seriously degraded (*e.g.* RHP 2001; Macfarlane *et al*. 2009) and yet it is difficult to establish the veracity of this statement (Nel *et al.* 2011). Undoubtedly, wetlands appear to be increasingly under threat due to the spread of urban infrastructure and expanding agricultural activities. Adding to the uncertainty around the threat to wetlands is the fact that in general, up until the last decade, wetlands in South Africa were neglected and only recently has research been focused on them. There are, however, some notable exceptions to this statement, for example, the seminal work of Silberbauer and King (1991a and 1991b) who surveyed around 100 wetlands (Section 1.2) in the Western Cape from 1987 to 1989. As part of that survey, the wetlands were photographed, water chemistry parameters were measured and plant and invertebrate samples taken (although sadly, due to a change in strategy of the funding organisation, the project was prematurely terminated and the biological data have never been published: Prof. Jackie King, Water Matters, *pers. com*., June 2011).

In this present project the above set of wetlands was revisited. For each wetland, a rapid habitat assessment was carried out and the current land-use both within and around the wetland examined. Water chemistry was assessed by taking *in situ* measurements and extracting water samples for laboratory analysis. Biological samples in the form of diatoms, plants and invertebrates were also collected. The results of these assessments were used to derive the overall environmental condition (expressed as the Present Ecological State) and were compared to the likely condition during the time of the original survey[1]. From the above results, a picture is emerging of the type and extent of threats that wetlands of the Fynbos Biome have been exposed to over the past 25 years. This can be used to advise the future conservation of wetlands both in the Western Cape and for the entire country.

Although the major thrust of this project was, as outlined above, to identify the trends in wetland condition over the past 25 years, there were several other motivations for undertaking the work.

- To improve our knowledge of the species of plants, diatoms and (ultimately) the invertebrates found in the wetlands of the Western Cape. This is particularly important in the light of the fact that the original type specimens from the National Diatom Collection for the Western Cape have been lost (Dr Jonathan Taylor, North West University, *pers. com*. July 2012).
- To correlate the species of plants and, in particular, diatoms with habitat condition and water quality in order to strengthen our understanding of the responses of these two biotic groups to environmental stressors. Diatoms show potential as bioassessment tools for wetlands and this work will help further the development of those tools.

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[1]In this report, results or issues pertaining to the original project undertaken by and King and Silberbauer from 1987-1989 will be referred to as “historical” and those arising from the current project as “present”.

- Through this project, unpublished data collected by King and Silberbauer on wetland vegetation and invertebrates, have been written up (Section 1.4). The vegetation data are incorporated into two papers about to be submitted for publication, and in a thesis (Ramjukadh 2014). Invertebrate studies were not funded in the current project so, although material was collected, a paper on invertebrates will have to wait until an opportunity presents itself.
- The experience gained during the rapid assessment of a large number of wetlands will be invaluable in the formulation of a National Wetland Monitoring Programme in the future. Recommendations to this end are reported in Chapter 9.

1.2 SCOPE, LIMITATIONS AND CHALLENGES OF THE PROJECT

From unpublished material discovered during the course of this project, it was found that in total over 100 wetlands had been visited by King and Silberbauer from 1987-1989, rather than the (±74) listed in Silberbauer and King (1991b). Because of the premature termination of the project, the level of sampling intensity varied for the 100 wetlands in the historical investigation. For example, ± 25 wetlands were visited only briefly and detailed species lists were not prepared. In addition, 8 of the above wetlands are located in the Karroo, not in the Fynbos Biome. In the present project, only wetlands located within the Fynbos Biome which had been fully sampled in historical project were revisited. This was a total of 65 wetlands.

Because of the nature of the project, from the start it was acknowledged that there was a major constraint with regard to the comparison of biological samples between wetlands. Classification (in the sense of the typing of wetlands) was in its infancy during the original sampling programme, although efforts were made by King and Silberbauer to classify the wetlands according to the system of Cowardin *et al*. (1979). A wide range of wetland types were sampled including estuaries, valley bottom wetlands (both channelled and un-channelled), artificial ponds, dams and even one (and possibly two) ditches. This range in wetland types, plus the fact that the wetlands cover a wide geographical area varying in altitude, climate, soil type and vegetation, means that there is high underlying “natural variation”. Superimposed on this are the varying land-uses and impacts that the wetlands and their surrounding catchments are subjected to. As a consequence of this variation it was impossible to rigorously compare, in particular vegetation, but also diatoms and invertebrates, because the number of comparable wetlands was usually too small for statistical testing. Nevertheless, it was possible to identify general patterns across wetlands and to address the primary focus of the project, namely a comparison of the historical and present day condition of individual wetlands in terms of environmental condition and plant, species assemblages. Because invertebrate studies were not funded in the current project, samples were collected, curated.

1.3 AIMS OF THE PROJECT

The major thrust of this project was to better understand the factors leading to wetland degradation and through this to facilitate their conservation. The specific aims of the project are listed below:

1. To revisit a set of wetlands previously surveyed by King and Silberbauer in the late 1980s.

2. To establish the present ecological state (environmental condition) of those wetlands based on a rapid habitat assessment and on water quality data and to compare this with their historic condition.

3. To identify the factors contributing to wetland loss, alteration in wetland character or degradation, or conversely to an improvement in environmental condition.
4. To compare the present plant communities with those recorded in the 1980s.
5. To identify the land-use and other factors contributing to the loss of (or increase in) biodiversity and changes in plant assemblages.
6. To add to our understanding of correlations between wetland habitat condition, water quality and biological response in diatoms.
7. To expand the presently inadequate inventories of wetland biodiversity for wetlands of the Fynbos Biome.
8. To inform the development of techniques needed for a national Wetland Monitoring Programme (equivalent to the existing River Health Programme), which is required by the National Water Act of 1998 but is not yet under way.

1.4 LIST OF PRODUCTS ARISING FROM THIS PROJECT

The results of this project have been captured in two reports, namely this document (Volume I) which records trends across the set of wetlands and a "Wetland Status Report" (Volume 2). The latter presents a description of each individual wetland that was sampled, including photographs and the results for land-use change, evaluation of environmental condition (expressed as the Present Ecological State), and assessment of the importance of, and the ecoservices (benefits) supplied by each wetland. The water quality, diatom and plant results are also given. Each wetland is reported separately and the entire document is available electronically.

Volume I (this document) details the more scientific aspects and provides a synthesis of the overall results and trends across the wetlands. Firstly, a discussion of the aims, scope and limitations of the project is presented (Chapter 1). Overall characteristics of the wetlands are summarised in Chapter 2. This is followed by a discussion of changes in the abiotic drivers, namely: rainfall (Chapter 3) and water chemistry (Chapter 4). The responses of the wetlands in terms of vegetation (Chapter 5) and diatoms (Chapter 6) are reported. The preceding information is summarised in terms of changes in overall ecological health and the factors causing these changes (Chapter 7). The major findings of the project and conclusions are listed in Chapter 8. Chapter 9 presents recommendations for the National Wetland Monitoring Programme and the way forward. Various appendices are attached. Of note is Appendix A (by Doug Harebottle) which gives a brief assessment of the waterbirds at the wetlands and was used in the assessment of ecological importance of each wetland.

CHAPTER 2

A FIRST LOOK AT THE WETLANDS

2.1 THE GENERAL APPROACH USED

The general approach that was used in this study is described below. In each of the relevant sections, more detailed information is given pertaining to specific aspects (*e.g.* sampling of water chemistry, surveying of vegetation).

1. The set of study wetlands was mapped in Google Earth. Topographic maps, historic and current aerial photographs for each wetland and the immediate surrounding catchment were obtained.
2. The wetlands were screened according to their probable hydrological regime, the period of the year in which they are most likely to be inundated and the month in which they were surveyed by King and Silberbauer. Using this information, a sampling programme was drawn up. As far as possible, each wetland was sampled the same month as historically. A few wetlands were dry during the original sampling programme and therefore in the present project were sampled during the wet season. In some cases, due to logistical reasons the wetlands had to be sampled another month. A comparison was made of the degree of inundation at the time of the historic compared to the present sampling (Chapter 3).
3. Available historical information, including photographs, datasheets, anecdotal information, etc. from the original survey was collated and many, although not all, of the original resources were found (Section 2.2).
4. A brief literature search was carried out for each wetland. Because of the large number of wetlands to be sampled, however, this search was of necessity, superficial.
5. Each wetland was visited once during the course of the project. The list of wetlands, wetland code, sampling dates, historic geographical coordinates and the coordinates of the sampling site from the present project are listed in Appendix B. A note here on the wetland code – this originated from the historical project and is based on the drainage region, the project wetland number, sampling site and number of visits (Silberbauer & King 1991b). It should not be confused with a similar Department of Water and Sanitation[2] coding system used for dam safety records (Dr Mike Silberbauer, DWS, *pers. com.* Nov 2014). Where possible, samples were taken at the same place as the historical project. For some wetlands, however, the original field datasheet was missing and it was difficult to ascertain exactly where the original sampling site was located. This is discussed further in Section 2.3.
6. If possible (*i.e.* if available/willing) the landowner for each wetland was interviewed. Information concerning the management history, the hydrology, the presence of charismatic or Red Data species, etc. was solicited.
7. Land-use in the area surrounding the wetland and any visible impacts to the wetland itself were noted (Chapter 5). These were used to inform the assessment of the “ecological health” or condition of the wetland (Chapter 7).
8. *In situ* physico-chemical parameters of the water, *i.e.* pH, electrical conductivity, dissolved oxygen, water colour, temperature and turbidity were measured in the field (Chapter 4).

[2] The name of the government department responsible for water changed during the course of the current project from the Department of Water Affairs (DWA) to the Department of Water and Sanitation (DWS).

Water samples were collected and analysed for nutrients. Two sets of laboratory samples were taken, one for analysis by the DWS and one for analysis at the Department of Oceanography, UCT.

9. A photographic record was made of the plant species present. Where identification was uncertain, samples were verified at the Bolus Herbarium, UCT. Samples of invasive alien species were taken for the "Alien Plant Species Barcoding Project" of SANBI. The vegetation sampling protocol followed the same procedure used by King and Silberbauer (unpublished). Vegetation was evaluated in terms of the current "dominant" or "most obvious" species, and the extent of alien vegetation. The findings were then compared with the presence/absence data collected during the original study. A database was developed to house the vegetation data both from the historical sampling and the present project (Chapter 5).

10. Diatom samples were collected from various substrates depending on what was present at each site – including emergent, free-floating or rooted macrophytes, sediment, rocks and man-made objects such as pipes. A maximum of three substrates per site were sampled, (Chapter 6).

11. Aquatic invertebrates were sampled in a semi-quantitative manner from all available biotopes (usually open water, submerged vegetation and emergent vegetation) using the method of Bird *et al*. (2014).

12. An assessment of the ecological importance and sensitivity (EIS) of the wetland and the benefits (ecosystem services) that it supplies was carried out using the method of Rountree *et al*. (2012) – see Section 2.5.

13. A rapid habitat assessment was carried out using the method of Duthie (1999) to establish the Present Ecological State (Chapter 7). Using all available information including, historical aerial images, ortho-photos, photos and information from the historical field datasheet (if available), an estimate of the environmental condition of the wetland during the original survey (1987-1989) was formulated. The historical survey did not formally assess environmental condition and thus only a subjective estimate was possible. A description of the wetland in its current condition was compiled, including the hydrogeomorphic type(s), which was previously unrecorded. The Present Ecological State (in other words, the environmental condition) for each wetland was established based on the results of the habitat assessment and the water quality results and was compared with the historic environmental condition (which may, or may not have been reference/pristine). Factors that may have led to worsened or improved environmental condition were identified.

14. Water quality data and Present Ecological State (PES) results were entered into the Wetlands Water Quality database.

15. A summary of the information was prepared and sent to the landowner of each wetland (Wetland Status Reports).

2.2 HISTORICAL DOCUMENTS AND OTHER RESOURCES

One of the first steps in the project was to collate all surviving records from the original sampling survey carried out by King and Silberbauer. This proved to be quite a large job since the documentation was scattered in various store-rooms at the University of Cape Town, lodged with the original researchers or with researchers who had subsequently worked on the data. We serendipitously found historical field-notes behind water pipes, when clearing out the laboratory of the Freshwater Research Unit! Most of the original results (*e.g.* water chemistry measurements, plant and invertebrate species lists) had been entered into an electronic database by Dr Silberbauer[3] which was of inestimable help to this project. Other data sources, such as photographs, field sheets, letters and videos also survived. Usefully, maps and ortho-photographs from the project had been stamped to identify them as belonging to the research programme. The original researchers are to be commended on their foresight in preserving the documentation in the intervening 25 years and without their diligence much more of the original documentation would have been lost and the present project would have been impossible. Nevertheless, some documentation from the historical sampling programme has been lost over the years. Table 2-1 shows a list of the wetlands and for each one, what historical information has survived. We managed to locate roughly 75% of the original field sheets and over 60% of the ortho-photographs (although not all of these are annotated). These documents were of inestimable value in locating the wetlands. For the current project but also for others, including the NWMP when instigated, careful attention needs to be paid to archiving not just the sampling results but other background information that might be of use in the future. The exact nature of such needs cannot always be anticipated and because of this, as much information as possible needs to be preserved.

2.3 LOCATING THE WETLANDS

In order to facilitate comparison of the historic and contemporary condition, a particular objective of the sampling programme was not only to re-visit the wetlands but also if possible, to sample at the exact site(s) as historically. The geographical coordinates for the sampling sites in the original project had been taken manually from 1:50 000 maps (this was before the help of GPS and Google Earth) – and so there is a considerable degree of error. This meant that pin-pointing the exact sampling site or even sometimes the wetland itself was not always easy. Ortho-photos with annotations made by King and Silberbauer, showing amongst other information, the sampling site and location of plant species were of inestimable value in this project. Also, the original office/field sheets were very useful because they often included a description of how to get to a site and valuable insights into, for example the flora, fauna, comments by land-owners or other aspects noted during sampling. Any obvious impacts to the wetlands were often recorded by the samplers and in conjunction with photographs and video footage these were used to estimate the change in ecological health (Chapter 7). The list of wetlands, geographical coordinates and sampling date(s) from the historical project and the coordinates and sampling date for the present project are given in Appendix B. A map showing the location of the wetlands is shown in Figure 2-1.

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[3]The platform used was a simple DOS-based relational database using dBase under PC-File (Button 1988). DWS has since captured the chemical data on the WMS water quality database at RQS. Note that the original database was on 5 ¼” floppy disks, and was only accessible because MS had kept a copy on his computer hard drive.

Figure 2-1: A Google Earth map showing the distribution of the wetlands sampled in this project.

Overall, the location of the original wetlands in this project was fairly successful and the large majority were re-sampled, usually close to the original sampling spot (although this could not always be confirmed). Table 2-1 shows for each of the wetlands how successful we were in locating firstly, the wetland itself and secondly, the sampling site. This last aspect is important, because we are trying to compare “what the wetland was like” in the late 1980s with its condition now and it is important that the sampling site is more-or-less the same, particularly for the larger wetlands. Water chemistry, for example, can vary across a wetland especially if it is a large system. In the case of vegetation where only a rapid assessment both in the historic and present projects was done (Chapter 5), it was especially important that the same area be re-surveyed.

Table 2-1: List of wetlands sampled in the project and the availability of historical information.

	Wetland Name and area	Wetland Code	Availability of historical resources					Same as historical project?		Comments
			Data Sheet?		Ortho-photo?	Photos?	Video?	Wetland	Sampling site	
			Office	Field						
Greater Cape Town	Cape Corps	G204/01A1	No	No	Yes (blacked out)	No	No	Could not locate this wetland		South African Cape Corps Battalion, now 9 SAI. Not visible on Google-Earth. Probably still there because undeveloped land? Likely to be small and part of a wetland mosaic.
	Groot Rondevlei (Cape Point)	G203/04A1	No	No	Yes (some annotations)	1	No	Yes	Unknown – likely to be close	Unclear exactly where sampled historically, but very small wetland and so site likely to be close-by.
	Kenilworth Race Course	G203/13A1	Yes	Yes	Yes	No	No	Yes	Unknown – likely to be close	Mosaic of small wetlands. Without the annotated ortho-photo and commentary we could not have found the exact wetland again.
	Khayelitsha Pool	G204/02A2	No	Yes (short)	Yes (no annotations). Series of 1:50 000 topo maps	No	Yes? (and aerial footage of general area)	Yes	Yes	Fairly confident that we sampled at more or less the same place because of description on data sheet "East of embankment of road between Khayelitsha and Cape Corps".
	Klaasjagers Estuary	G203/05A1	No	No	Yes but no annotations	Yes? (untitled)	No	Yes	Unknown but likely to be same general area	We sampled at the estuary. Unclear where historic sampling site was, but from photograph likely to be close-by?
	Kleinplaas Dam/Kleinplaats West	G203/01A1	No	No	Yes (no useful annotations)	No	Yes	Yes – fairly certain	Same general area	Wetland is a seepage area to west of Kleinplaats Dam but coordinates inexact. Unclear if WQ sample was taken from Kleinplaats itself or not. There is a minor sampling site called Kleinplaats East = wetland d/s of dam presumably.
	Lake Michelle/Noord-hoek Salt Pan	G203/12A2	Yes	Yes	Yes	No	No	Yes	Yes	Same wetland, but now changed completely in ecological character. . K&S sampled "shore on east end". Site indicated on ortho-photo.
	Silvermine Dam inflow	G203/18	Yes	Yes (two)	Yes annotated	No	No	Yes	Same general area, but probably downstream of historic site	Says on office data sheet "Sampling point about 100 m upstream of full supply level in main inflow". Field sheet says "Just below jeep track main trib. of Silvermine R." Not sure exactly where this is. We sampled approx. 5 m upstream of dam (on wooden bridge) because vegetation impenetrable further u/s.
	Silvermine River	G203/19A1	Yes	Yes	Yes (no useful	Yes (3)	No	Yes	Same general	Likely sampling place deduced from photos

Region	Wetland Name and area	Wetland Code	Availability of historical resources					Same as historical project?		Comments
			Data Sheet?		Ortho-photo?	Photos?	Video?	Wetland	Sampling site	
			Office	Field						
	(lower)/floodplain				annotations)				area, but 300 m downstream?	and office datasheet. Because there was no running water at original site and because of security issues, we sampled approximately 300 m downstream in conservation area.
	Pinelands – The Crossing	G203/20	No	Yes (2)	Yes	Yes	No	This wetland has been drained and is now under housing and a recreational park. We are sure this is the correct area because of the annotated ortho-photo and photographs.		
West Coast	Burgerspan	G103/03	No	No	No	No	No	Yes	Unknown, but probably in same general area	Fairly easy to locate wetland because distinctive in the landscape. Assumed previous sampling near access point to wetland.
West Coast	Januariesvlei (Rondeberg)	G201/04	Yes (+ addn info)	Yes	Yes annotated	Yes	No	Yes	Yes – at site A	This is the only open water system in the area.
West Coast	Kiekoesvlei	G103/01A1	No	No	Yes	Yes	No	Yes	Unsure	Not sure where originally sampled, but this is a small wetland and seems to be fairly homogenous wrt vegetation.
West Coast	Koekiespan	G103/02A1	Yes	Yes	Yes annotated	Yes	No	Yes	Yes	Sampling site indicated on ortho-photo.
West Coast	Modder River	G201/06A1	Yes	Yes	Yes annotated	Yes	No	Yes	Yes	Sampling site indicated on ortho-photo.
West Coast	Rooipan	G201/01A1	Yes	Yes	Yes	Yes	No	Yes	Yes	Sampling site indicated on ortho-photo. But topography of wetland now different to when sampled previously.
West Coast	Witzand aquifer recharge	G201/07A1	Yes	Yes (short)	No	Yes	No	Yes	Unsure	Labelled as "Pond 7" on a historical diagram, which we re-sampled. From notes and photograph, fairly sure it was the same wetland. Exact sampling site = uncertain.
West Coast	Yzerfontein Salt Pan	G201/02B1	Yes	Yes	Yes	Yes	No	Yes	Not quite	Couldn't sample in middle of pan (old Site B) as indicated on ortho-photo because area being dredged. Sampled approx. 200 m to the south.
West Coast	Yzerfontein Salt Pan inflow	G201/08A1	Yes	Yes	Yes	Yes	No	This wetland seems to have disappeared. Likely due to alien vegetation and disruption to hydrology.		
Cederberg	Blomfontein	E201/03A1	Yes	Yes	No	No	No	Yes	Yes	Good description of location of wetland and sampling site in field notes.
Cederberg	Donker Kloof (tributary)	E201/01A1	No	Yes (short)	No	Yes	No	Could not sample due to snow		Not sampled. Probably similar to Blomfontein.

Area	Wetland Name and area	Wetland Code	Availability of historical resources: Data Sheet? Office	Data Sheet? Field	Ortho-photo?	Photos?	Video?	Same as historical project?: Wetland	Sampling site	Comments
	Driehoek	E201/06A1	Yes	Yes	No	Yes	No	Yes	No	Driehoek wetland is very large. Not sampled at same sites because we only found historical aerial photos with sampling site locations after our visit.
	Hoogvertoon	E201/05A1	No	Yes (short)	No	No?	No	Yes	Unsure	We located the general area from the coordinates and description (although no longer any "oaks and old ruins").
	Middelberg West	E100/01A1	No	Yes (short)	No	No	No	Yes	Unsure	Same wetland not exactly same site?
	Sederhoutkop	E201/02A1	Yes	Yes	No	Yes	No	Could not sample due to snow		Not sampled. Probably similar to Blomfontein
	Sneeuberg Hut stream	E201/04A1	Yes	Yes	No	No	No	Yes	In general vicinity	Good description of location of wetland and sampling site in field notes.
	Suurvlakte	E201/08A1	Yes	Yes	No	Yes	No	Yes	Near to "site B"	We sampled close to an inflow into the dam (not sure if same inflow as historic project) but in general area. Access difficult because of pine trees.
	Wagenbooms River	E201/09A1	No	Yes (short)	No	No	No	Yes	Yes	Fairly certain this is the same wetland from the description and from an old 1:50 000 map.
Tulbagh/Worcester	Die Vlakte	H101/06A1	Yes	Yes	No	Yes	No	Yes	Yes	Sampling site recorded in historic field sheet as "at culvert".
Tulbagh/Worcester	Kluitjieskraal (Verrekyker)	H101/05A1	Yes	Yes	Yes	Yes	No	Yes	Yes	Site A at "Skilpadsgat" re-sampled. Site B on farm "Verrekyker" no longer wetland.
Tulbagh/Worcester	Papenkuils (Bokkekraal)	H101/01A1	Yes	Yes	Yes	Yes	No	Yes	In general vicinity	Large braided valley bottom wetland. Part of the Breede River.
Tulbagh/Worcester	Platdrif	H101/03A1	Yes	Yes	No	No	No	The section of this wetland that was sampled by King & Silberbauer now a farm dam.		
Betty's Bay	Groot Rondevlei (Bettys Bay)	G401/02A1	No	Yes (short)	Yes (no annotations)	No	No	Yes	Close-by	Old 1:50 000 map of area also exists. Not sure for all 3 of these wetlands where the original sampling sites were, but small and isolated depressions. The site for Malkopsvlei is recorded as "near boat launching end" which we took to be the westerly (grassy) side.
Betty's Bay	Groot Witvlei	G401/03A1	Yes	Yes	Yes (no annotations)	No	No	Yes	Close-by	
Betty's Bay	Malkopsvlei (Bass Lake)	G401/01A1	Yes	Yes	Yes (no annotations)	No	No	Yes	Unsure	
Vermont	Belsvlei	G403/04A1	Yes	Yes	No	No	No	Yes	Yes in general vicinity	Office datasheet says on "Onrus R. at Nuwepos". Exact sampling site not recorded. Presumably at road crossing?
Vermont							The lower half of Belsvlei wetland has effectively been lost due to erosion.			

Wetland Name and area		Wetland Code	Availability of historical resources					Same as historical project?		Comments
			Data Sheet?		Ortho-photo?	Photos?	Video?	Wetland	Sampling site	
			Office	Field						
	De Diepte Gat	G403/05A1	Yes	Yes	Yes (partially)	No	No	Yes	No	This is a large mountain seep. Unsure where the WQ sample was taken from. Recorded as in firebreak, but not sure where that was.
	Elias Gat: Site A (Violskloof)	G403/03A1	Yes	Yes	Yes (annotated)	No	No	Yes	Yes	Clear record from ortho-photo of location of veg types and sampling sites. In historic and present project WQ taken only at site A (because no open water at site B).
	Elias Gat: Site B (Violskloof)	G403/03A1	Yes	Yes	Yes (annotated)	No	No	Yes	Yes	
	Hemel-en-Aarde	G403/02A1	Yes	Yes	Yes (annotated)	No	No	Yes	Yes	Clear description in field datasheet and ortho-photo of where sampled.
	Salmonsdam – Site A	G404/01A1	Yes	Yes	No	No	No	Yes	Unsure	Recorded as "Small stream in wetland (next to track)". We presume it is where the track crosses the seep wetland in the Nature Reserve.
	Salmonsdam – Site D	G404/01A2	Yes	Yes	No	No	No	Yes	Unsure	"Out-flow of wetland". We took this as being close to the entrance gate to the Nature Reserve.
	Salmonsdam – Site E	G404/01A3	Yes	Yes	Yes (annotated)	No	No	Yes	Unsure	At "Papjesvlei". Exact sampling site unknown
	Vermont Pan	G403/01B1	No	No	Yes	Yes	No	Yes	Unsure	Annotated ortho-photo indicates where vegetation sampled. Unsure where WQ sample taken – possibly of shore near to parking site?
Agulhas – other wetlands	Agulhas Salt Pan	G501/06A1	Yes	Yes	Yes (annotated)	Yes	No	Yes	Yes	Sampling site (A) shown on ortho-photo. Also some old 1:50 000 maps of Agulhas area.
	Die Pan (Vispan)	G501/17A1	No	Yes (short)	Yes (annotated)	No	No	Yes	Yes	Sampling site (A) shown on ortho-photo.
	Gans Bay	G403/09A1	Yes	Yes	Yes	Yes (colour + B&W)	No	Yes	Yes	This is a small depression wetland, directions unclear but from the photographs it would seem to be the same one.
	Melkbospan	G501/16A1	Yes	Yes	Yes (annotated	Yes	No	Yes	Yes	Small pan.
	Ratel River Estuary	G501/15A1	No	Yes (short)	No	No	No	Yes	Unsure	We sampled u/s of estuary at access point. Riverine in this section – not wetland.
	Rhenosterkop Pan	G501/07A1	No	No	No	Yes	No	Yes	Unsure	Presume historical sampling site at closest access point from road, corresponding with photo.

Wetland Name and area		Wetland Code	Availability of historical resources					Same as historical project?		Comments
			Data Sheet?		Ortho-photo?	Photos?	Video?	Wetland	Sampling site	
			Office	Field						
	White water dam	G501/03A1	Yes (incomplete)	Yes	Yes (annotated)	Yes?	No	Yes	Unsure	Sampled near dam wall. Unsure if photo from same wetland.
Agulhas – Nuwejaars River	Farm 182 (Peters bog)	G501/21A1	No	Yes (short)	No	Yes	No	Yes	Unsure	Large seep wetland. Unsure where historic sampling site was. Recorded as "Next to Agulhas Rd near 10 km road marker – east side". Photos show a ditch. Dry when visited 2013. Comment on historical datasheet "only filled-up 3 weeks ago".
	Soetendalsvlei	G501/08A1	Yes	Yes	Yes (annotated)	Yes	No	Yes	Yes – or close by	Two sites historically? We sampled at site "A". Not sure where site "B" was.
	Soetendalsvlei Ditch	G501/19B1	Yes	Yes	Yes (annotated)	Yes	No	Yes	Yes – or close by	Site located from ortho-photo and description in office datasheet. On LHS verge facing north. Dry – no samples taken
	Voelvlei	G501/05A1	No	No	Yes	Yes	No	Yes	No	No annotations on ortho-photo. Unsure where sampling site was and this is a fairly large wetland.
	Waskraalsvlei (Modder Valley)	G501/04A1	No	No	Yes	Yes	No	Yes	Unsure.	Possibly more or less same site from the photos?
	Wiesdrif	G501/18A1	No	No	Yes (annotated)	No	No	Yes	Yes	Site indicated on ortho-photo.
	Varkensvlei	G501/20A1	Yes	Yes	Yes (annotated)	Yes	No	Yes	In general vicinity	Not completely sure where sampling site for historic project was.
Agulhas – Groot Hagelkraal	Groot Hagekraal Upper	G501/09A1	Yes	Yes	Yes	Yes	No	Yes	No	Unsure of exact sampling site. Only one site on the river sampled by King and Silberbauer. Couldn't get to other side of river because of flooding and bridge washed away in Waterford portion of Agulhas National Park.
	Groot Hagelkraal Lower	G501/14A1								
	Pearly Beach site 1	G501/10A1	Yes	Yes	Yes (annotated)	Yes	No	Yes	No – opposite side	We could not get to sites A and B because of the thick alien vegetation. Site D was dry.
	Pearly Beach site 2	G501/10C2	Yes	Yes	Yes (annotated)	No	No	Yes	Just on the edge	Upstream of site D above. The other side of road. Flooded so we could not access it and sampled from the road.

Wetland Name and area		Wetland Code	Availability of historical resources					Same as historical project?		Comments
			Data Sheet?		Ortho-photo?	Photos?	Video?	Wetland	Sampling site	
			Office	Field						
Mossel Bay and Riversdale	Riversdale	H900/01A1	No	No	Yes	Yes	No	Yes	Unsure	This is one of the largest wetlands in the S Cape (on the Goukou R). We sampled vegetation in the same area. Not sure exactly where the historical WQ sample was taken. Possibly at the watering hole where there is open water?
	Gouriqua	H900/02A1	Yes	Yes	Yes	Yes	No	Yes	No	Three small wetlands (A, C and D) close to each other. Vegetation very overgrown, wetlands dry when sampled.
	Blinde Estuary	K101/01A1	No	No	No	No	Yes	Yes	Yes	This is a riverine system (the Blinde River) with no wetland characteristics. Therefore only WQ and diatom were sampled in the present project.
	Blinde River	K101/04A1	No	No	No	No	Yes	Yes	Unsure	

The original sampling was carried out over the period 1987-1989 and some wetlands were visited more than once. In the present project, although a few (located in Cape Town and the West Coast area) were sampled in the winter of 2012, the majority were sampled during the winter of 2013 and were visited only once. King and Silberbauer sometimes sampled at more than one site on a given wetland. Because of the constraints of the present project, if the wetland was small, *e.g.* Groot Rondevlei (Betty's Bay) we sampled only at one site. But if the wetland was large, particularly if the sites were in different HGM types we sampled more than one site (*e.g.* Salmonsdam).

2.4 GENERAL ASSESSMENT

The following questions were asked of the land-owner/manager (although sometimes this person was unavailable or unwilling to be interviewed):

1. How deep is the wetland? Are there inflows/outflows?
2. What is the extent of inundation at the moment – *i.e.* how full is it?
3. For how long does the wetland usually contain water?
4. How long have you owned/managed the wetland/surrounding area?
5. What is the current management regime and how does it differ from the historical management?
6. Any special fauna/flora, *e.g.* otters, fish, etc.?
7. Are you aware of any obvious water quality impacts, *e.g.* storm water?
8. Are you aware of any other studies that have been carried out on the wetland?
9. Are there any specific plans to modify the wetland in the future?

2.5 IMPORTANCE AND BENEFITS

The importance of each wetland and the ecosystem services or benefits that they supply was assessed using the approach of Rountree *et al*. (2012). This assessment method scores wetland attributes within three main categories namely; Ecological Importance and Sensitivity, Hydrological Importance, and thirdly; Direct Human Benefits. A scale of 0-4 is used, where 0 = not important and 4 = important at a national scale. It was found that insufficient guidance was given in the information accompanying the method for scoring some of the attributes. For example, in Table 2-2a for Ecological Importance and Sensitivity, the presence of Red Data species at a wetland increases the importance (and thus the score). But no guidelines are given as to what this score should be if there is more than one Red Data species. Also Red Data species themselves are classified under different categories (vulnerable, least endangered, critically endangered, *etc.*). Therefore in this project, additional rules were drawn-up to score the presence of Red Data species as shown in red in Table 2-2a. In the case of Direct Human Benefits, it was felt by the project team that the presence of a wetland increasing the value of surrounding property, or the harvesting of minerals are benefits that should also be included. After consultation with one of the authors of the assessment method (Dr Donovan Kotze, UKZN, p*ers. com.* Nov. 2012) these factors were included in the scoring scheme (Table 2-2c). Rather than reporting only the maximum value as recommended by Rountree *et al.* (2012), the score for each of the three aspects namely (Table 2-2a, b and c) was recorded in order to maximise the information for the landowner.

2.6 OVERVIEW OF THE WETLAND IMPORTANCE AND BENEFIT SCORES

A summary of the importance and the benefits each wetland provides is given in Table 2-3. For most of the wetlands the Ecological Importance and Sensitivity (EIS) was the highest contributor to the overall score. This is because many of the wetlands are situated in un-impacted areas in vegetation of high importance (*e.g.* Elim ferricrete). Kenilworth scored the highest possible score = 4 (range 0-4) because it is situated on Cape Flats Sand Fynbos vegetation, an extremely scarce vegetation type (only ± 70 ha remain globally and <1% of the original extent is conserved). There are 310 plant species growing there, of which 34 are on the Red Data list, as are several of the amphibians found in and around the wetland. Similarly the wetlands from the Agulhas Plain area all scored very highly for EIS. According to Belinda Day (Wetland Status Reports), the Agulhas Plain has been recognised as an area of high conservation significance and a biodiversity hotspot for fynbos vegetation (Willis *et al.* 1996; Myers *et al.* 2000; Kraaij *et al.* 2009) and amphibians – the Cape platanna, the microfrog and the Western leopard toad all either breed there, or are thought to have potential breeding sites. Furthermore, the total suite of wetlands on the Agulhas Plain has been recognised as a priority area for conservation during the CAPE project (Jones *et al* 2000). Due to the enormous complexity of the underlying geology and the diversity of wetland types in the region, many of which are rare, wetlands in the area differ in terms of water chemistry, degree of permanence, wetland vegetation, size, origin. etc.

When considering the hydrological benefits (Table 2-2b) wetlands differed in the benefits they supplied, depending on the HGM type and the opportunity for providing the service (Kotze *et al*. 2008). For example, Goukou Wetland (called Riversdale Wetland in the historical project) scored the highest for hydrological benefits because it is an extensive valley bottom wetland which is likely to be highly efficient in improving WQ (there is considerable agriculture in the catchment). Not only that, the wetland is critical in protecting the downstream town of Riversdale from flooding.

Direct Human Benefit scores were fairly low amongst the study wetlands, probably due to the low levels of subsistence use in the Western Cape and the fact that the wetlands were located almost exclusively in private or conservation areas (rather than in communal land). Any subsistence use is thus likely to be low-key, and due to the rapid scoping nature of the sampling, might have been missed. Livestock were being watered at the Khayelitsha Wetland when we visited, and harvesting of waterblommetjies by local people occurs in Papenkuils (Bokkekraal) Wetland (Kotze and Adey *in pub*. 2014). Nevertheless, many of the wetlands do contribute to DHB through provision of opportunities for tourism (especially avitourism) and through increasing the value of adjacent property (and thus increasing local municipal rates paid by the land-owner).

A discussion on various aspects of the wetlands (*e.g.* water chemistry, vegetation) is given in the relevant chapter. A brief overview is given here of the wetlands we visited, our success in re-locating them and those that are no longer in existence.

Table 2-2a: Assessment of wetland importance and benefits: Ecological Importance and Sensitivity. (Adapted from Rountree et al. 2012. Comments shown in red are amendments made for this project. RD = Red Data).

Ecological Importance and Sensitivity	**Score (0-4)**	**Confidence (1-5)**	**Motivation**	**Guideline**
A. Biodiversity support				
Presence of Red Data species				Presence of endangered or rare Red Data species. 1x RD species of "least concern" = 2. I or more RD species more vulnerable than "least concern" = 4. > 1 RD species = "least concern" = 4. Likelihood of RD species but unconfirmed =1.5.
Populations of unique species				Uncommonly large populations of wetland species
Migration/breeding/feeding sites				Importance of the unit for migration, breeding or feeding.
B. Landscape scale				
Protection status of the wetland				National (4), provincial (3), municipal (1 or 2) or public area (0-1)
Protection status of the vegetation type				SANBI guidance on the protection status of surrounding vegetation
Regional context of the ecological integrity				Assessment of the PES (habitat integrity), especially in light of regional utilisation
Site and rarity of the wetland type/s present				Identification and rarity assessment of the wetland types
Diversity of habitat types				Assessment of the variety of wetland types present within a site
C. Sensitivity of the wetland				
Sensitivity to changes in floods				Floodplains (4), valley bottoms (2 or 3), pans and seeps 0 or 1.
Sensitivity to changes in low flows/dry season				Un-channelled valley bottom wetlands probably most sensitive
Sensitivity to changes in water quality				Especially naturally low nutrient waters
ECOLOGICAL IMPORTANCE AND SENSITIVITY				**TOTAL SCORE**

Table 2-2b: Assessment of wetland importance and benefits: Hydro-functional importance. (Adapted from Rountree et al. 2012. Comments shown in red are amendments made for this project).

Hydro-functional importance			Score (0-4)	Confidence (1-5)	Motivation	Guideline
Regulating and supporting benefits	Flood attenuation					The spreading out and slowing down of floodwaters in the wetland, thereby reducing the severity of floods downstream.
	Streamflow regulation					Sustaining streamflow during low flow periods.
	Water quality enhancement	Sediment trapping				The trapping and retention in the wetland of sediment carried by runoff waters.
		Phosphate assimilation				Removal by the wetland of phosphates carried by runoff waters, thereby enhancing water quality
		Nitrate assimilation				Removal by the wetland of nitrates carried by runoff waters, thereby enhancing water quality
		Toxicant assimilation				Removal by the wetland of toxicants (*e.g.* metals, biocides and salts) carried by runoff waters, thereby enhancing water quality
		Erosion control				Controlling of erosion at the wetland site, principally through the protection provided by vegetation
	Carbon storage					The trapping of carbon by the wetland, principally as soil organic matter
HYDRO-FUNCTIONAL IMPORTANCE						**TOTAL SCORE**

Table 2-2c: Assessment of wetland importance and benefits: Direct Human Benefits. (Adapted from Rountree et al. 2012. Comments shown in red are amendments made for this project).

Direct Human Benefits		Score (0-4)	Confidence (1-5)	Motivation	Guideline
Subsistence benefits	**Water for human use/livestock**				
	Harvestable resources				
	Cultivated foods				
Cultural benefits	**Cultural heritage**				
	Tourism and recreation				*e.g.* increased revenue to hotel/restaurant/conference centre due to location next to wetland
	Education and research				
	Aesthetic value – residential				*e.g.* increased property value due to location next to wetland
Commercial use	**Water for irrigation/livestock**				
	Mining or other				*e.g.* salt, gypsum
DIRECT HUMAN BENEFITS					**TOTAL SCORE**

Table 2-3: A summary of the importance and benefits supplied by the project wetlands. (EIS = Ecological Importance and Sensitivity).

Wetland Name	**Wetland Importance and Benefits**				**Comments and motivation**
	Ecological importance	**Hydrological benefits**	**Direct Human Use**	**Overall EIS**	
Cape Corps	Unknown	Unknown	Unknown	**Unknown**	Couldn't locate wetland
Groot Rondevlei (Cape Point)	2.7	1.1	0.7	**4.5**	High EIS (plants, amphibians).
Kenilworth Race Course	4	1.3	1.5	**6.8**	Extremely rare vegetation type. 34 Red Data species (plants, amphibians).
Khayelitsha Pool	2	2.2	2.5	**6.7**	EIS = waterbirds. WQ amelioration, prevention of flooding. Recreation. Livestock.
Klaasjagers Estuary	3.4	1.4	1.7	**6.5**	EIS= high due to veg, waterbirds. Rare wetland type, *i.e.* free-flowing riverine wetland close to city.
Kleinplaas Dam/Kleinplaats West	2.4	1.6	1.3	**5.3**	EIS = high due to veg. Improves WQ of water flowing into dam.
Lake Michelle/Noordhoek Salt Pan	1.8	2.3	1	**5.1**	Red Data species (otters). Improves WQ for downstream wetlands.
Silvermine Dam inflow	3	1.4	1.5	**5.9**	EIS = high due to rare plant species and amphibians. Also rare wetland type, *i.e.* free-flowing river near city.
Silvermine River (lower)/floodplain	2.7	2.6	2	**7.3**	Red Data species (otters). Improves WQ for downstream estuary and prevention of flooding. Very important for recreation.
Pinelands – The Crossing	N/A	N/A	N/A	N/A	Wetland destroyed.
Burgerspan	2.2	1.4	0.7	**4.8**	EIS = high due to Red Data birds (flamingos) and otters.
Januariesvlei (Rondeberg)	3.2	1.5	0.8	**5.5**	EIS= very high due to rare plant species, birds (black harriers). Unusual wetland type.
Kiekoesvlei	2.7	1.1	1.1	**4.9**	EIS = high due to Red Data birds (flamingos). Also *Oxalis disticia*.
Koekiespan	1.3	1	0.5	**2.8**	This is a saline pan. Important for waterbirds.
Modder River	1.7	2.3	0.5	**4.5**	Supplies important hydrological services – WQ amelioration, and supply of water in the dry season.
Rooipan	2.3	1	1.3	**4.6**	EIS = high due to waterbirds. Increased value to houses/hotel in area.
Witzand aquifer recharge	3	1.4	0.8	**5.2**	EIS = high due to waterbirds (pelicans, marsh harriers, fish eagles). WQ amelioration.
Yzerfontein Salt Pan	3	1.4	1.7	**6.1**	EIS = high due to waterbirds. Extraction of gypsum provides employment.
Yzerfontein Salt Pan inflow	**N/A**	**N/A**	**N/A**	**N/A**	Wetland destroyed.

Blomfontein	2.7	2.3	1.8	**6.8**	EIS = high. Water source area.
Donker Kloof (tributary)	ND	ND	ND	**6.8**	Estimated. Same as Blomfontein.
Driehoek	2.7	2.8	1.8	**7.3**	EIS = high. Water source area.

Wetland Name	**Wetland Importance and Benefits**				**Comments and motivation**
	Ecological importance	**Hydrological benefits**	**Direct Human Use**	**Overall EIS**	
Hoogvertoon	2.7	2.3	1.8	**6.8**	EIS = high. Water source area.
Middelberg West	2.7	2.4	1.8	**6.9**	EIS = high. Water source area.
Sederhoutkop	ND	ND	ND	**6.8**	Estimated. Same as Blomfontein.
Sneeuberg Hut stream	2.7	2.3	1.8	**6.8**	EIS = high. Water source area.
Suurvlakte	??	1.6	1	**??**	EIS = unknown.
Wagenbooms River	1.7	3	1	**5.7**	Important for WQ amelioration ad provision of water for d/s river which is ecologically important.
Die Vlakte	**N/A**	**N/A**	**N/A**	**N/A**	U/s area of Die Vlakte destroyed.
Die Vlakte	1.7	3.2	1	**5.9**	Important for WQ amelioration ad provision of water for d/s river.
Kluitjieskraal (Verrekyker)	ND	ND	ND	**ND**	Upper: WQ amelioration, provision of water for d/s. Ecotourism (cycling)
	N/A	N/A	N/A	N/A	Lower: Wetland destroyed.
Papenkuils (Bokkekraal)	3	2.8	2.5	**8.3**	EIS = high (rare veg type). Scarce wetland type. WQ amelioration, prevention of d/s flooding.
Platdrif	N/A	N/A	N/A	N/A	Wetland destroyed.
Groot Rondevlei (Bettys Bay)	3.2	1.5	1.5	**6.2**	EIS = very important due to rare plant species and amphibians. Recreation.
Groot Witvlei	3.2	1.5	1.5	**6.2**	
Malkopsvlei (Bass Lake)	3	1.4	1.6	**6**	
Belsvlei	2	2.3	0.7	**5**	Upper: EIS = high – scarce wetland type. WQ amelioration, flooding.
	N/A	N/A	N/A	**N/A**	Lower: Very little wetland functioning remains
De Diepte Gat	2.3	2	1.1	**5.4**	Large seep wetland. Rare plant species. Water source area.
Elias Gat (Vioolskloof) Site A	1.5	1.6	1	**4.1**	WQ amelioration, provision of water for d/s.
Elias Gat (Vioolskloof) Site B	1.5	2.2	1	**4.7**	WQ amelioration, provision of water for d/s.
Hemel-en-Aarde	2	2.9	0.7	**5.6**	WQ amelioration, provision of water for d/s, prevention of flooding.
Salmonsdam – Site A	2.3	2.4	1.8	**6.5**	EIS = high. Water source area.
Vermont Pan	3	1	2.3	**5.3**	EIS = very high (water birds).
Agulhas Salt Pan	3.2	1.5	1.5	**6.2**	For all the Agulhas Plain wetlands, EIS is very high due to endemic vegetation, birds and amphibians. Tourism important.

Die Pan (Vispan)	3.2	1.3	1.0	**5.5**	For all the Agulhas Plain wetlands, EIS is very high due to endemic vegetation, birds and amphibians
Gans Bay	1.8	1	1	**3.8**	Distinct wetland because of milkwood (*Sideroxylon inerme*) trees.
Melkbospan	3.2	1.3	1.0	**5.5**	For all the Agulhas Plain wetlands, EIS is very high due to endemic veg, birds and amphibians
Wetland Name	**Wetland Importance and Benefits**				**Comments and motivation**
	Ecological importance	**Hydrological benefits**	**Direct Human Use**	**Overall EIS**	
Ratel River Estuary	N/A	N/A	N/A	**N/A**	Riverine system. Assessment method not applicable
Rhenosterkop Pan	3.0	1.5	1.6	**6.1**	For all the Agulhas Plain wetlands, EIS is very high due to endemic vegetation, birds and amphibians
White water dam	3.3	1.8	1.7	**6.8**	For all the Agulhas Plain wetlands, EIS is very high due to endemic vegetation, birds and amphibians
Farm 182 (Peters bog)	ND	ND	ND	**ND**	Couldn't locate wetland
Soetendalsvlei	3.7	3.4	2.0	**9.1**	Unique aquatic system. Important for flood prevention, WQ amelioration and tourism.
Soetendalsvlei Ditch	N/A	N/A	N/A	**N/A**	Assessment method N/A.
Voelvlei	2.8	2.2	1.2	**6.2**	EIS = high. Also rare wetland type with unusual hydrology.
Waskraalsvlei (Modder Valley)	2.8	2	1.2	**6**	EIS = high. Important or WQ amelioration and prevention of flooding.
Wiesdrif	1.9	2.2	1.2	**5.3**	WQ amelioration and supply of water for d/s Soetendalsvlei (which is an ecologically important wetland)
Varkensvlei	1.5	1.2	1.2		EIS = high (amphibians).
Groot Hagekraal Upper	3.3	2.3	1.7	**7.3**	EIS = high (vegetation).
Groot Hagelkraal Lower	3.3	2.3	1.7	**7.3**	EIS = high (vegetation).
Pearly Beach	3.3	2.3	1.7	**7.3**	EIS = high (vegetation).
Riversdale	2.3	3.3	1.5	**7.1**	Rare vegetation type. WQ amelioration. Prevention of d/s flooding.
Gouriqua	3	1	1	**5**	Possible new snail species (unconfirmed).
Blinde Estuary	N/A	N/A	N/A	N/A	Riverine system. Assessment method not applicable.
Blinde River	N/A	N/A	N/A	N/A	

2.7 GREATER CAPE TOWN AREA

The wetlands in this area range from those located in pristine fynbos vegetation (*e.g.* the upper part of Silvermine River, Groot Rondevlei, Kleinplaas Dam) to those in the residential areas of Noordhoek (Lake Michelle) and Khayelitsha (Khayelitsha Pool). The wetlands also varied in hydrogeomorphological (HGM) type from a mountain seep (Kleinplaas Dam) to riverine systems (*e.g.* the Silvermine River, both upper and lower wetlands), to isolated depressions (*e.g*. Kenilworth).

Of the original 10 wetlands in the Greater Cape Town area, we were able to re-visit 8 of them. We were unfortunately unable to locate “Cape Corps wetland” on the Cape flats. Although we know the general area in which the wetland was located, we don’t know if it has survived and exactly where it is. The limited historical information records this wetland as being a “coastal vlei” – but currently no obvious open-water areas are visible on Google Earth. The area in which the wetland was located falls within land owned by the military (as it did in the late1980s) and is or at least was, probably part of a mosaic of wetlands in the area. Only an ortho-photo survives from the historical project and the entire area is blacked-out due to information restriction during that time. Interestingly, ortho-photos of coastal areas only became available to the general public shortly before the 1980s project began (Dr Mike Silberbauer, DWS, *pers. com*. Nov. 2014). In contrast to outside of the Cape Corps military area where there has been intensive urbanisation (see the Wetland Status Report for “Khayelitsha Wetland”), the military area is less developed. The area has been somewhat diminished in extent, however, by construction of a Waste Water Treatment Works and powerlines. Whether the actual wetland has survived or not is unclear.

Another wetland we visited, but were unable to sample is “Pinelands – The Crossing” located in a formal residential area of the City of Cape Town. Photographs and an annotated ortho-photograph enabled the exact location to be found. Unfortunately this wetland has been drained, and is partly under housing, the rest of the area being changed to a play-park (Figure 2-2). Correspondence between a concerned resident of the area, the Municipality of Pinelands, and Pinelands Ratepayers/Residents Association has survived from 1987-1988. This is in connection with the then potential future development of the seasonally-inundated area and loss of the wetland birds that visited the wetland (sacred ibis, herons, waders, seagulls) and frogs. As Figure 2-2 shows, the concerns of this resident were justified and the wetland has been efficiently removed. One wonders if current legislation would be robust enough to prevent this happening today?

2.8 WEST COAST AREA

Nine of the wetlands are situated in the West Coast Area, north of Cape Town and all were successfully located. These wetlands include several isolated pans, a few of which are saline (*e.g.* Koekiespan) or fresh (*e.g.* Kiekoesvlei), one was riverine (Modder River). Yzerfontein Salt Pan is currently being mined for gypsum (used in agriculture and in the construction industry) and Rooipan has been rehabilitated after previously having been mined for this mineral. The freshwater depression at the Witzand Aquifer Recharge area on the other hand, is completely artificial – it receives treated stormwater runoff from the town of Atlantis which is purified by filtration through the dune system underlying the wetland.

We were intrigued by the “stripes” across the ortho-photo (dated 1974) for Kiekoesvlei, an isolated freshwater depression surrounded by agricultural land. These markings are not visible on either the historical aerial photograph (Wetland Status Report for Kiekoesvlei) or on the more recent images (aerial photographs and Google Earth). They were caused by disturbance to the vegetation – perhaps mowing or planting of crops. Unfortunately the current landowner did not know what historical agricultural practices had been carried out. There is currently no cultivation within the wetland itself, although there is heavy grazing around the edges.

King and Silberbauer recorded two wetlands at Yzerfontein Salt Pan, the main pan itself, and an inflow area (G201/08 – Table 2-1). Although we think we were successful in locating the inflow area itself there is little wetland left. The above researchers sampled at: Site A ("small inflowing brown stream"), Site B ("in pan" G201/02) and Site C ("small brown pan near inflow" G201/08). Despite the fact that we sampled during a fairly wet winter, after a period of high rainfall (Chapter 3) we could find no flowing stream, and no small brown pan near the inflow. Figure 2-3 shows photographs both from the historical sampling programme and from the present. We suspect that alteration to flow in the small stream has occurred (possibly with the upgrading of the West Coast Road – although this is unconfirmed) which has reduced the amount of water entering at this point. The proliferation of alien vegetation in the area and deepening of the main pan due to dredging activities during gypsum extraction may have also contributed to the loss of wetland area.

Figure 2-2: Pinelands – The Crossing. LHS photos (top and bottom) taken in August 1989 and RHS (top and bottom) in April 2013. The railway pylons visible in the top LHS photo can just be seen in the top RHS photo, behind the houses.

Figure 2-3: Yzerfontein Salt Pan and Yzerfontein Inflow. The two top photographs show the wetland named "Yzerfontein Inflow" in May 1988 and the bottom RHS the same view (as far as we can tell) in May 2012. Note the absence of wetland vegetation and the proliferation of alien invasive plants. The photograph bottom LHS is of the main salt pan showing infrastructure for the extraction of gypsum.

2.9 CEDERBERG AREA

There are seven project wetlands located in the Cederberg itself and two wetlands, namely "Suurvlakte Dam" and "Wagenbooms River" wetland located south of this area. The majority of the wetlands sampled in this locality are high-altitude mountain seeps set in undisturbed fynbos and include "Blomfontein", "Hoogvertoon" and "Sneeuberg Hut Stream". Two other wetlands in this area were visited by King and Silberbauer in May 1989, these being "Donkerkloof Tributary" and "Sederhoutkop" (unconfirmed locations 32° 22' 59"S 19° 08 59E and 32° 32' 59"S 19° 08' 59"E respectively), and are located further along the jeep track from "Blomfontein" wetland. Unfortunately, due to thick snow during the sampling trip we were unable to reach those two wetlands. From an examination of the Google Earth images, it would appear that they are also mountain seeps with little or no disturbance in the upstream catchment, the only impact being, as for Blomfontein, a single track across the wetland. Thus similar results (in terms of water chemistry, plant, diatom and invertebrate species) to those obtained for Blomfontein wetland would be expected. Another Cederberg wetland that we visited, "Middelberg West" is unusual in that it is a valley-bottom system, but is located at the top of the mountain plateau (1170 masl) and is formed where three channelled valley bottom systems converge forming a single channel which ultimately spills over the edge of the mountain escarpment as a waterfall (Wetland Status Report: Middelberg West).

All the original wetlands in the Cederberg area are still in existence (Table 2-1). For most of the wetlands we are fairly confident that we sampled in close proximity to the sites from the historic sampling programme. In the case of Suurvlakte Dam, however, although we sampled the eastern inflow area into the dam as was done in the historic project, this is a large seepage area, with several streams into the dam and the exact sampling place is uncertain. From a practical point of view in the field, there appears to be a lot more pine trees in the area than historically and these are both planted and self-seeded (see the new plantation on the northern edge of the dam – Wetland Status Report for Suurvlakte). The proliferation of alien trees obscured the view and made it difficult to compare the terrain with the historic photographs. It is important for the future NWMP that clear directions are given of where fixed-point, reference photographs are taken.

2.10 TULBAGH/WORCESTER AREA

There are four wetlands in this group. Die Vlakte and Kluitjieskraal (called "Verrekyker" in the previous project) are close to Ceres, whereas Papenkuils (formerly "Bokkekraal") and Platdrif are located just outside of the town of Worcester. All four wetlands are situated in agricultural regions and are part of lotic (flowing) systems, with Papenkuils being part of the Breede River floodplain itself and Platdrif forming a small drainage line to the Breede. All four wetlands (with the exception of Papenkuils where the main impacts have been upstream rather than in the wetland itself) have been severely modified. In the case of Kluitjieskraal, however, which is a "Working for Wetlands" site (W for W 2005) steps are being taken to remedy some of the damage (Wetland Status Reports – Kluitjieskraal/Verrekyker). At the time of the visit by King and Silberbauer in May 1988, the lower (Verrekyker) half of the wetland was being drained and now subsequently that area of wetland has completely disappeared.

Platdrif is a small channelled valley bottom wetland located in an agricultural area outside of Worcester. On the historical ortho-photos, two sites (Platdrif A and B) are shown at the two road crossings respectively, with the Platdrif wetland running from east to west (Figure 2-4). The fieldsheet, however, records sampling at Site A only, stating that this is *"? Borrow pit. W of road. 3 m offshore. Shallow*." The location of this sampling site agrees with the photograph from the wetland (see below, Figure 2-4). It would seem that the portion of the Platdrif wetland that used to lie to the west of the Goudiniweg has now been lost and converted to a farm dam. If it was a borrow pit formerly, however, it was certainly far from natural, although probably some ecological functioning occurred, and as can be seen from the photograph, some wetland vegetation was present. The wetland downstream, to the east, has also been heavily degraded, with encroachment of cultivated fields laterally, excavation at the two road crossings and only remnants of wetland survive. The N2 by-pass was under construction at the time of the historical project (Dr Mike Silberbauer, DWS, *pers. com*. Nov. 2014) which probably contributed to wetland loss.

2.11 BETTY'S BAY

The group of wetlands sampled in the coastal village of Betty's Bay consists of three isolated freshwater depressions (Groot Rondevlei, Groot Witvlei and Malkopsvlei, also known as Bass Lake). This is an area of exceptional biodiversity with regard to not only vegetation, but also to amphibians (Wetland Status Report). The three wetlands sampled in the original project are still in existence but increasingly under threat from urban development, including nutrient enrichment from leaking septic tanks. Problems with blooms of blue-green algae have been reported at Malkopsvlei (Ollis 2008).

Figure 2-4: Platdrif outside of Worcester. The Google Earth image at the top shows the linear form of the Platdrif wetland. King and Silberbauer sampled at Site A (pictured on the bottom LHS). The same view in 2013 shows that the former wetland has been converted into an irrigation dam.

2.12 VERMONT AREA

The wetlands in this group include an isolated, saline pan (Vermont Pan) and two large mountain seeps (Salmonsdam A and Die Diepte Gat). Belsvlei, Hemel-en-Aarde and Elias Gat wetlands are valley bottom wetlands: the first two on the Onrus River and the latter on the Hartbees River. There are three wetlands named “Salmonsdam” which are all on the Paardenberg River, but are all very different in HGM type. Salmonsdam A as noted above is a mountain seep leading into an extensive valley-bottom wetland and forms the source of the Paardenberg River. It is situated within the Salmonsdam Nature Reserve and is largely un-impacted. Salmonsdam D is the channelled outflow from the valley-bottom, located several kilometres downstream on the edge of the reserve. It is now a deeply eroded channel and probably was already in this state at the time of sampling by King and Silberbauer in May 1988 (Wetland Status Report – Salmonsdam). Where exactly the previous authors sampled along this channel is unknown since the ortho-photo has not survived. Salmonsdam site E appears to be a wetland area several kilometres downstream (it is shown as Paapjesvlei on the map) where a dam has been built. Serious erosion is evident at Paapjesvlei which, in contrast to the erosion in the channelled outflow, has happened very recently (Wetland Status Report).

Of the eight wetlands in this group, we were able to locate them all and are reasonably confident that we sampled in approximately the same area for most of them. One exception to this was the Diepte Gat which is a large mountain seep wetland for which we were unable to locate the original sampling site (only incomplete sampling records remain). The only surface water in this wetland was at the outflow located in the lowest part, which is where the water chemistry samples were taken. On the other hand, we were able to locate the valley bottom wetland, Belsvlei, which had in 1988 a road crossing through the middle of it. Now, the lower half of the wetland has effectively been lost due to erosion. The reasons for this are unclear, but may well have been caused by structural changes to the road crossing, which has modified the hydrology of the system. This is discussed in more detail in the relevant Wetland Status Report.

2.13 AGULHAS PLAIN

Eighteen of the wetlands from the project are located on the Agulhas Plain. These have been divided into those associated with the Nuwejaars River, those that form part of the Groot Hagelkraal River and the rest (largely isolated systems) and are discussed below.

The Nuwejaars River

The Nuwejaars River is an extensive system which drains a large part of the Agulhas Plain. It consists of the Nuwejaars River (and its tributaries) to the north which then flows into the large shallow, freshwater lake Soetendalsvlei and then flows to the sea as the Heuningnes River. There are 7 wetlands in this set – if Soetendals ditch (Figure 2-5) is included as a wetland. According to Dr Jackie King of Water Matters (*pers. com*. Nov. 2013) this ditch was one of the “wetlands” with the highest biodiversity in terms of invertebrates for the entire project. When we visited, despite the high antecedent rainfall, the ditch was dry. Photographs from the original visit in May 1989 show the road as being untarred. It is possible that when the road was upgraded sometime in the intervening years, the profile of the verge was altered and the ditch filled in.

Figure 2-5: Soetendalsvlei ditch on the Agulhas Plain. Not strictly a wetland in the conventional sense, nevertheless this was recorded as a site of extremely high aquatic invertebrate diversity in 1989, but little remains in 2013.

Peters Bog (Farm 182) also offered challenges in locating the sampling site. Notes from the original sampling programme record the wetland as being "Next to Agulhas Rd near 10 km road marker – east side" and "Just north of Afrikanderbosch and Karsrivier". It is probably part of the Kars River system, which flows into the Heuningnes River. The photograph that was taken in 1989 shows a ditch. At the time of our visit in October 2013, there was no open water in the wetland and it was not sampled in any detail.

The Groot Hagelkraal River

The Groot Hagelkraal River drains the highlands of the south-western Agulhas plain, flowing in a south-westerly direction and entering the sea just east of the coastal village of Pearly Beach. The historical geo-coordinates for the Groot Hagelkraal wetland are inexact and the description of the location is vague so we were unable to locate this wetland accurately. We sampled at one site in the upper catchment, one in the lower river, and far-downstream, around Pearly Beach Lake itself. Although the historic photographs of the general landscape for the Upper Hagelkraal wetland looks the same, the wetland itself is different, being composed of short tussocky vegetation. At the time of sampling the river had flooded and washed away the bridge and so access to other wetlands sites on the other side of the river was restricted.

Pearly Beach wetland consists of 4 sampling sites – the locations of which are indicated on an annotated ortho-photograph, although, historically, water chemistry, invertebrates and soils were only investigated at site A. Sites A and B are on the western side of the open water body and there are some historical photographs also from this site. We unfortunately could not access the western side of the wetland because of a high fence and the thick alien vegetation. We also could not get to the open water because of the dense band of *Phragmites*. Site D which we think is approximately 700 m further up the Groot Hagelkraal River was dry when we visited. Interestingly, the original sampling notes for this site say that site D is "*in spring feeding Bell's Dam*". We can find no indication of this spring or of a dam on the maps/ortho-photos and as noted above, the vegetation is now so dense in the area it is difficult to locate any features. Site C is still further up the river and appears to be located just on the other side of the coastal road. This area was completely flooded when we visited.

The coastal road that crosses the Groot Hagelkraal River has been upgraded in the intervening 25 years restricting downstream flow, probably promoting water retention upstream of the road, and resulting in desiccation in some areas downstream of the road crossing.

Other Agulhas wetlands

This set of wetlands is very diverse and includes isolated saline pans (Agulhas Salt Pan, Vispan, Melkbospan and Rhenosterkop Pan) and the Ratel River. White Water Dam is a spring that has at some point in its history (before the visit of King and Silberbauer in 1987) been impounded. The Gans Bay wetland is a small permanently inundated depression lying to the east of the town of Gans Bay and is currently surrounded by dense alien vegetation.

We were able to locate all of this set of wetlands and all are still in existence. In the case of the Ratel River we were unable to determine exactly where the historic sampling site had been. We sampled for the present project at a road crossing where the wetland has been channelled.

2.14 RIVERSDALE/MOSSEL BAY AREA

There are three wetlands, or more exactly, wetland systems in this group, spread out over a fairly large geographic area. Riversdale wetland, now more commonly known as the "Goukou wetland" after the river on which it is situated, is upstream of the town of Riversdale. It is an extensive valley-bottom wetland and although impacts have taken place in some areas, rehabilitation work by "Working for Wetlands" is taking place in the upper catchment (Heidi van Nieuwoudt, Working for Wetlands, *pers. com.* April 2013). We were able to locate the general area of historic sampling, although possibly not the exact point where water chemistry samples were taken.

The Blinde River is a short riverine system lying to the west of the town of Mossel Bay. It does not have wetland characteristics and thus was not sampled in detail. Of interest is the fact that since the visit by King and Silberbauer in March 1988, the Mossgas Refinery has been built on the upper source area for this river. Water quality impacts are discernible downstream in the river (Wetland Status Report for the Blinde River).

Finally, the "Gouriqua wetland" was re-visited, and is comprised of 3 freshwater seeps situated close to the seashore. The largest (WL1, Site A and B) is the most easterly, there is a small artificial seep in the middle (Site D) and another wetland WL2 (Site C). In the 1980s, the land belonged to the Atomic Energy Corporation and King and Silberbauer were requested to conduct a brief survey of the wetlands on the property and to recommend a management approach. Annotated ortho-photos, office and field datasheets, letters, the consultancy report and a few photos have survived from the historic project. At the time of the historic project, running water was present in WL1 and a potentially new snail species was found (Wetland Status Report – Gouriqua). In the present project especial effort was made to access Site A and in particular the upper seep area, but unfortunately at the time of our visit the wetlands were completely dry and consist predominantly of *Phragmites* (Figure 2-6). The surrounding terrestrial vegetation has proliferated in the intervening years (the land is now privately-owned) making access to and location of the wetlands difficult. We were unable to find any snails – possibly because they are no longer there or because they were aestivating when we visited due to the dry conditions.

Figure 2-6: Gouriqua wetland Site WL1 in 1988 LHS and 2013 RHS. The fencing alongside the wetland visible on the LHS has been removed, but there has been some development of infrastructure. Unfortunately when visited in 2013 the wetland was completely dry.

2.15 IN SUMMARY

On re-visiting the 65 wetlands sampled by King and Silberbauer in the late 1980s, the following wetlands are no longer in existence:

Pinelands crossing, Yzerfontein Inflow, and though not strictly a wetland, Soetendalsvlei ditch. Part of the following wetlands have been completely lost: Platdif (upper part), Kluitjieskraal (the lower, Verrekyker area), and the lower part of Belsvlei.

On the other hand, Lake Michelle and Rooipan are still in existence but have changed markedly in ecological character. Lake Michelle, which was a highly degraded saline pan in the late 1980s, is now a permanent freshwater system surrounded by residential development. Rooipan was a highly disturbed pan/flat from which gypsum was being extracted, and is now seasonally inundated pan that is important for waterbirds.

We were unable to accurately locate Cape Corps, Peters Bog, and Groot Hagelkraal wetland, although we are fairly sure that they are still in existence.

Finally, because of snow we were unable to access Sederhoutkop, Donkerkloof tributary in the Cederberg and Pearly Beach C on the Groot Hagelkraal due to flooding. From Google

Earth and from surviving information it would appear that both of the Cederberg wetlands are still there and in the same ecological condition. Pearly Beach C is also still there but may have increased in extent (due to restriction of outflow arising from road construction).

CHAPTER 3

CHANGES IN ANTECEDENT RAINFALL/INUNDATION LEVELS

3.1 INTRODUCTION AND METHOD

The inundation level (or degree of wetness) in a given wetland at the time of sampling is an important characteristic describing the system. Because of the difficulty of taking measurements, neither the extent of inundation, nor depth in lentic systems, nor discharge in the case of lotic systems were recorded either by King and Silberbauer or during the current project. In line with the descriptive nature of the project, it was deemed acceptable to record only a general indication of "how wet the wetland was" at the time of sampling compared to the historical sampling state. This was done by calculating the total amount of rainfall that had fallen that hydrological year up to the month of sampling. This was both for the historic and for the present project. The cumulative rainfall for the sampling year was also compared with the monthly average for the previous decade to give an indication of whether it was a particularly "wet" or "dry" year. Monthly rainfall data were supplied by the South African Weather Service (SAWS) and the weather station employed was the geographically closest one that had a sufficiently long and complete data-set. Occasionally, different stations had to be used to describe the present and the historical rainfall. Rarely, figures were missing for a month or two and in such cases they were patched from a nearby station, or if unavailable, average values were calculated and inserted into the dataset.

The results are given below for each geographical area in the form of a summary table listing the wetlands in a particular area, the name, code and geographical coordinates of the SAWS station used to describe the present and the historical sampling and the dates when those took place. A graph shows the monthly cumulative rainfall for each year of sampling and the average monthly cumulative rainfall for the previous decade.

3.2 CAPE TOWN AREA WETLANDS

Geographical area:	**Greater Cape Town**
Wetlands in area:	Noordhoek Salt Pan (Lake Michelle), Kenilworth Race Course, Silvermine Dam inflow, Silvermine River (lower), Kleinplaats West, Groot Rondevlei (Cape Point), Klaasjagers Estuary, Khayelitsha Pool.
Rainfall station: – present	Cape Town WO; code = 0021178A3; 33º 58' 12''S 18º 36' 0''E (at Cape Town International)
Rainfall station: – historic	Cape Town D.F. Malan; code = 00211790; 33º 58' 48''S 18º 36' 0''E And; Cape Town D.F. Malan; code = 00211789; 33º 58' 12''S 18º 36' 0''E
Date of sampling: – present project	Noordhoek Salt Pan – June 2012 Kenilworth Race Course – July 2012 Silvermine Dam inflow and Silvermine River – Sept 2012 Kleinplaats West – April 2013 Khayelitsha Pool – June 2013 Groot Rondevlei and Klaasjagers Estuary – Aug 2013
Date of sampling: – historic project	Noordhoek Salt Pan – June 1988 Kenilworth Race Course – July 1988 Silvermine Dam inflow and Silvermine River – Sept 1988 Kleinplaats West – December 1988 Khayelitsha Pool – May 1989, February 1988 Groot Rondevlei and Klaasjagers Estuary – January 1988

In the present project, wetlands in the Greater Cape Town area were sampled over a period of two years, namely in 2012 and 2013. In order to simplify the results, the cumulative monthly rainfall for the two years is plotted on different graphs (Figure 3-1 and 3-2) below. Although different rain stations were used to for the present and historic data they are all located at Cape Town International airport.

The hydrological year October 2011 to September 2012 was only slightly wetter than 1987/1988 so that the hydrological difference in the sampled wetlands as seen at the time of sampling was probably very small. Noordhoek Wetland (now called "Lake Michelle") has changed drastically in hydrogeomorphic type from 1988 to 2012 from an impacted seasonal saline pan to a freshwater lake in which water level is managed. Thus, even though antecedent rainfall in June 1988 and 2012 was similar, this is likely to be immaterial from the point of view of extent of inundation of the wetland.

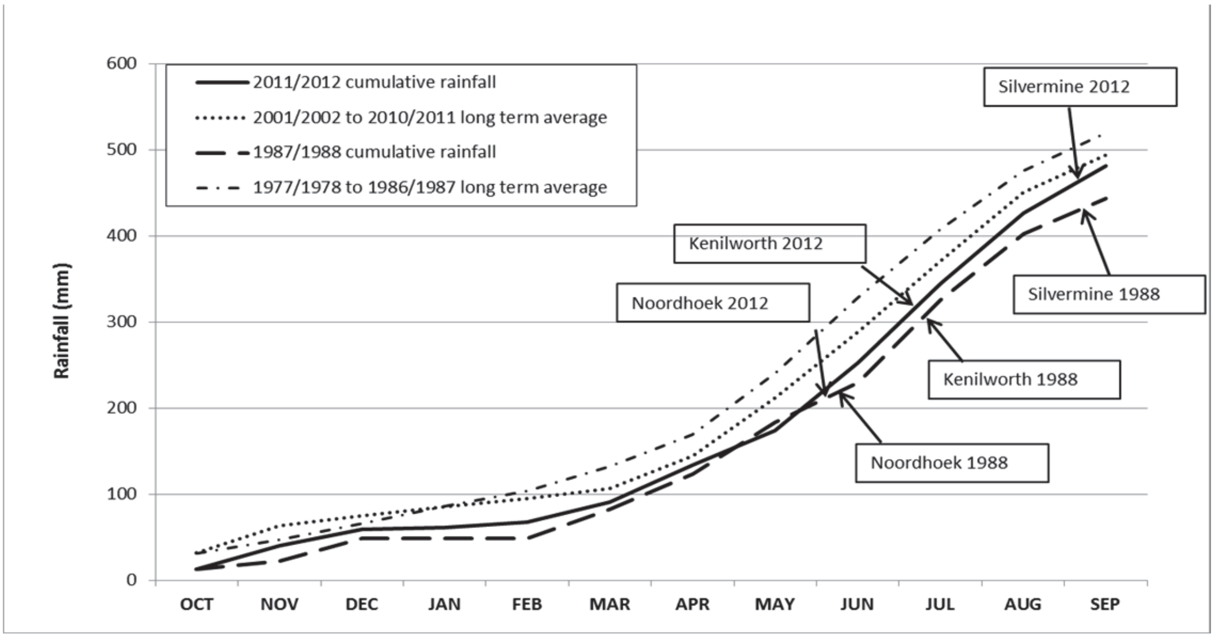

Figure 3-1: Cape Town: monthly cumulative rainfall for the present project (2012) and the historic project and the average for the preceding decade.

Lotic systems such as Silvermine wetland (both upper and lower) in contrast to isolated depressions are unlikely to vary markedly in extent with rainfall since the water drains fairly rapidly out of the system. Kenilworth wetland on the other hand, is a depressional system and is part of a mosaic of wetlands in the area. As far as can be discerned, it has not changed in hydrogeomorphic character since the historic project. When sampled in the present project, it is likely to have been as large as, or slightly more extensive than in 1988. The most recent decade appears to have been slightly drier than the decade prior to 1988 and both sampling years (2012 and 1988) were below average in rainfall.

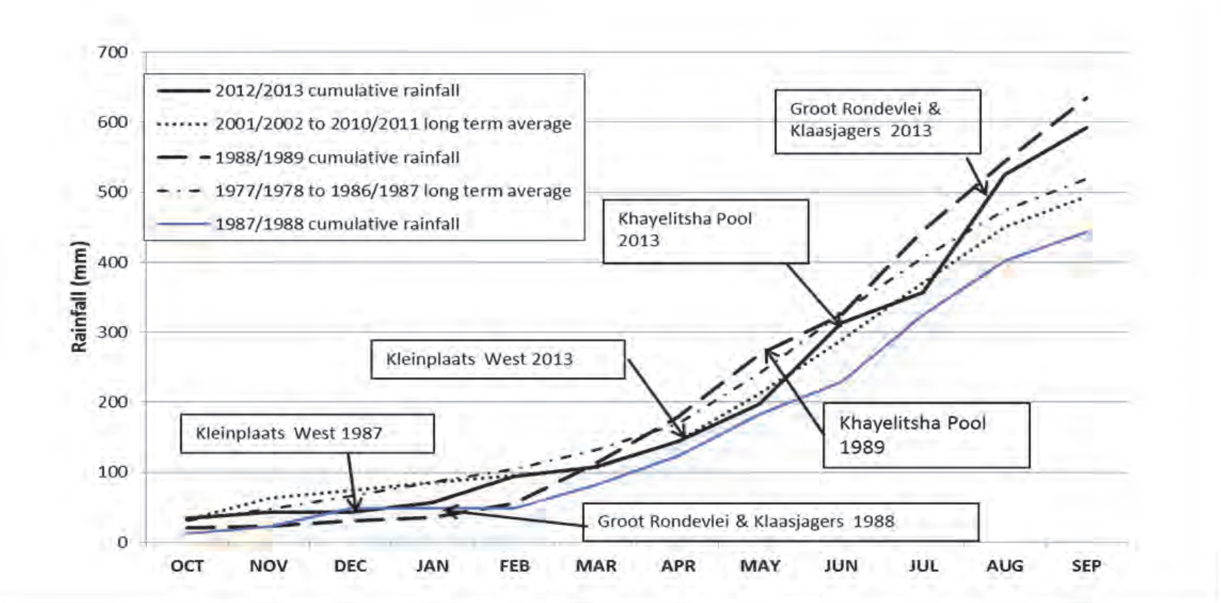

Figure 3-2: Cape Town: monthly cumulative rainfall for the present project (2013) and the historic project and the average for the preceding decade.

The annual cumulative rainfall for hydrological years 2012/2013 and 1988/1989 was higher than the preceding decadal average. King and Silberbauer visited Kleinplaats West (a mountain seep wetland), Groot Rondevlei (an isolated depression) and Klaasjagers Estuary during the dry summer period. In the present project, in order to ensure that there was water in the wetlands, sampling took place in winter. This makes comparing inundation levels difficult, except to say that Groot Rondevlei, Kleinplaats West and possibly Klaasjagers Estuary (a river which usually not open to the sea) are likely to have contained considerably more water when sampled in 2013 compared to 1987/1988. Antecedent rainfall in the case of the Khayelitsha Pool was higher for the present project sampling than in the case of the historic project. On the other hand, this is a floodplain wetland (i.e. exorheic) and there have been extensive modifications in the upper and surrounding catchment in the intervening years, probably making comparison between the two periods not particularly useful.

3.3 WEST COAST WETLANDS

Geographical area:	**Darling/Atlantis**
Wetlands in area:	Rooipan, Yzerfontein Salt Pan, Burgerspan, Koekiespan, Kiekoesvlei, Januariesvlei (Rondeberg), Modder River, (Witzand Aquifer*).
Rainfall station: – present	Darling; code = 00406828; 33° 22’ 12”S 18° 22’ 48”E
Rainfall station: – historic	Darling; code = 00406828; 33° 22’ 12”S 18° 22’ 48”E
Date of sampling: – present project	27-29 August 2012
Date of sampling: – historic project	1-5 August 1988

*Not directly filled by rainfall.

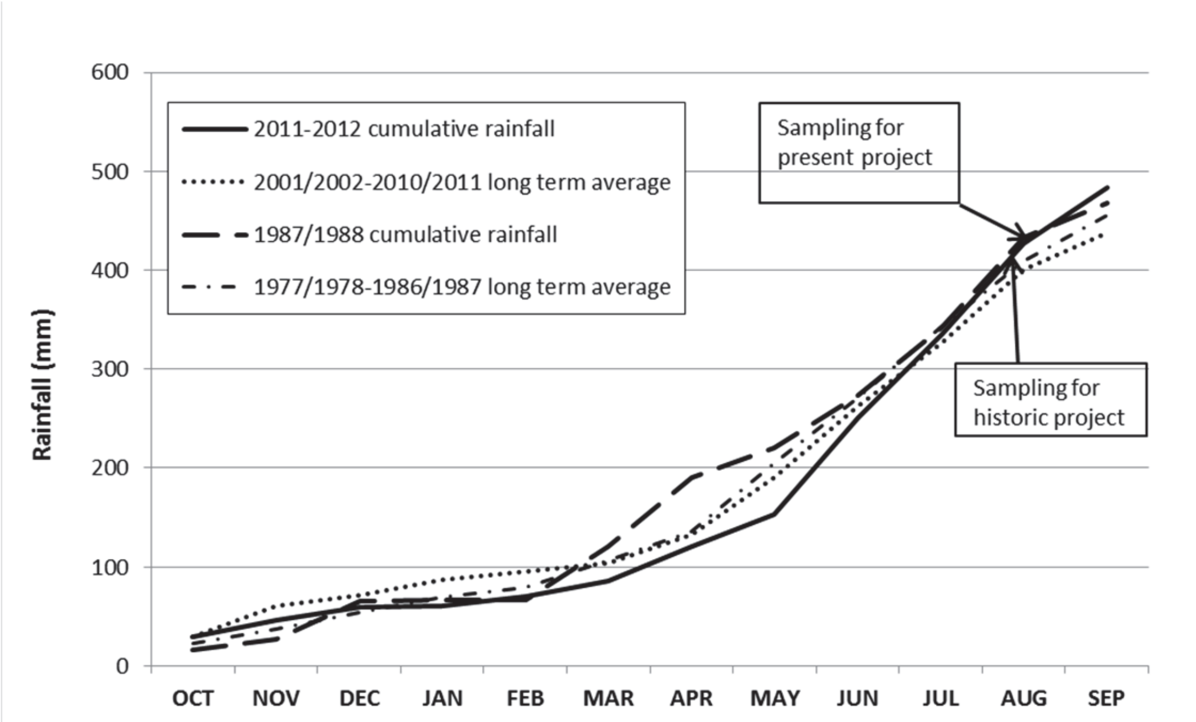

Figure 3-3: Darling: monthly cumulative rainfall for the years of sampling and for the preceding decade.

From consideration of the antecedent rainfall in the West Coast area for the present and the historic time periods, the wetlands were probably slightly “wetter” and more extensive when sampled in 2012 compared to when visited by King and Silberbauer in 1988 (Figure 3-3). The year 2012 was a little wetter than the previous decade. It is difficult, however, with this approach to gauge how a difference in the amount of rainfall for the area translates into the extent of land inundated. Witzand Aquifer Recharge wetland is pumped with storm water runoff/purified effluent and thus is only indirectly affected by rainfall. In the case of the endorheic depression wetlands situated in areas of low relief such as Rooipan, Yzerfontein Salt Pan, Kiekoesvlei, Koekiespan and Burgerspan, the impact of higher rainfall on the extent of the wetland would have been more marked than the case of exorheic systems such as Modder River. It appears that the inundation level of the endorheic wetlands was likely to be fairly comparable. These wetlands were sampled in 2012, which was not a particularly wet year. Of interest again is the lower present long term average compared to that of 25 years ago, although this reduction is not nearly as marked in the Darling area as in the Cederberg and Ceres regions (see below).

3.4 CEDERBERG WETLANDS

Geographical area:	**Cederberg**
Wetlands in area:	Blomfontein, Middelberg West, Sneeuberg Hut, Hoogvertoon, Driehoek, Suurvlakte, Wagenbooms River.
Rainfall station: – present	Algeria-Bos; code = 00851124; 32° 22' 12"S 19° 4' 12"E
Rainfall station: – historical	Algeria-Bos; code = 00851124; 32° 22' 12"S 19° 4' 12"E
Date of sampling: – present project	4-7 June 2013
Date of sampling: – historical project	23-29 May 1989

As can be seen from the graph (Figure 3-4), the wetlands are likely to have been "wetter" when sampled in June 2013 compared to when sampled by King and Silberbauer (May 1989), since roughly 100 mm more rain had fallen. At the time of sampling the wetlands for the present project it was during a period of intense rainfall, snow and accompanying cold weather. For the Cederberg area, 2012/2013 was a much wetter year than the average for the previous decade (especially the latter portion of the hydrological year). Of interest is the reduced average rainfall for 2002/2003-2011/2012 compared to 1978/1979-1987/1988.

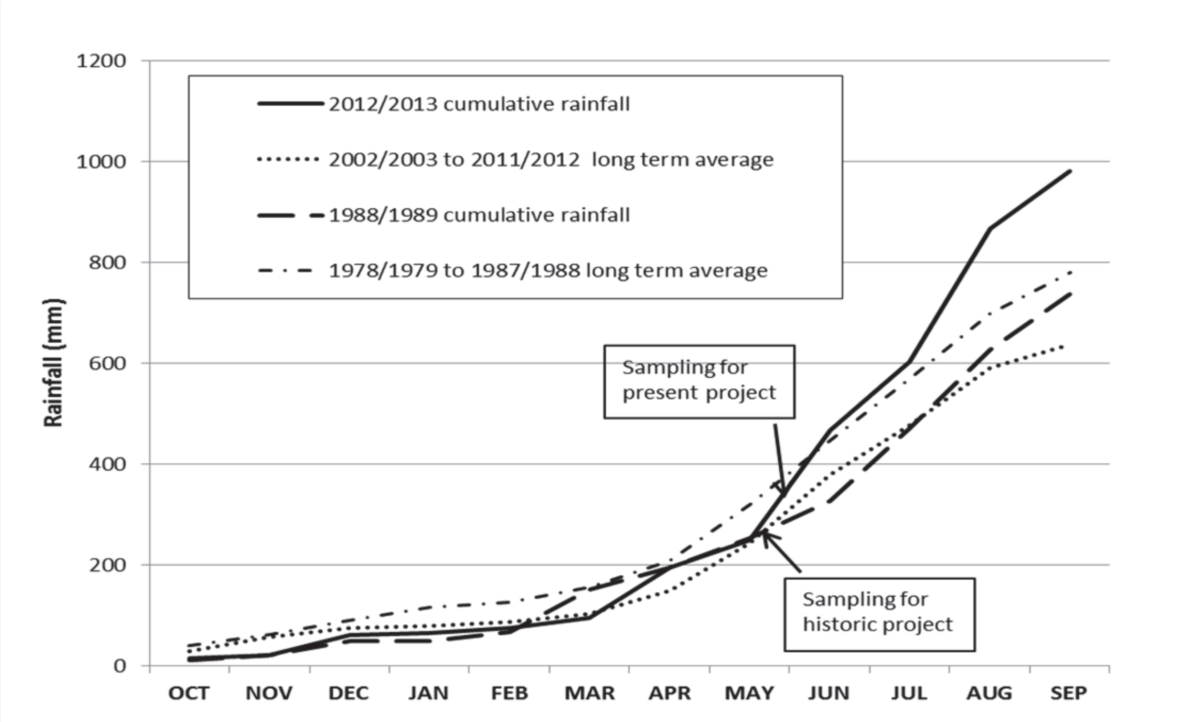

Figure 3-4: Algeria (Cederberg): monthly cumulative rainfall for the years of sampling and for the preceding decade.

3.5 CERES AREA WETLANDS

Geographical area:	**Ceres**
Wetlands in area:	Die Vlakte, Verrekyker (Kluitjieskraal).
Rainfall station: – present	Ceres; code = 0042532A0; 32° 22’ 12”S 19° 18’ 0”E
Rainfall station: – historical	Ceres; code = 0042532A0; 32° 22’ 12”S 19° 18’ 0”E
Date of sampling: – present project	7-8 June 2013
Date of sampling: – historical project	11 May 1988

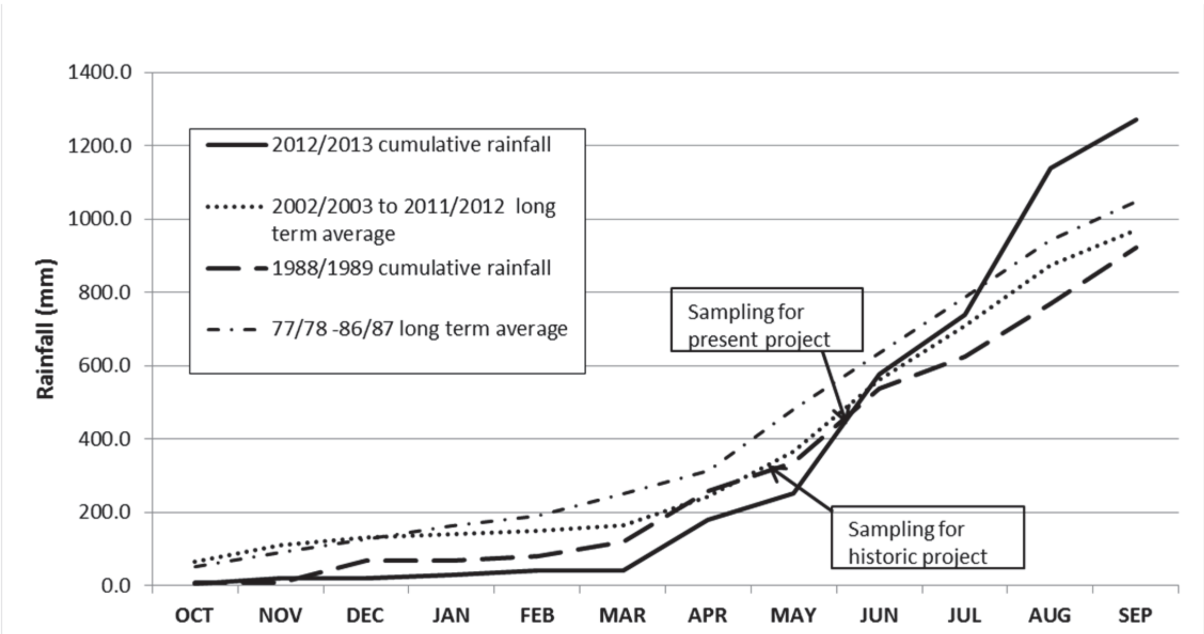

Figure 3-5: Ceres: monthly cumulative rainfall for the years of sampling and for the preceding decade.

As for the wetlands located further north in the Cederberg, Die Vlakte and Verrekyker, located in the Ceres area, were also likely to have been wetter at the time of sampling for the present project compared to the historic sampling (Figure 3-5). The antecedent rainfall differs by roughly 200 mm. As for the Cederberg, 2013 appears to have been an exceptionally wet year for the region around Ceres, above the average for the previous decade. During the sampling carried out by King and Silberbauer, the wetland would have been slightly drier than average. As for the Cederberg, the long term average (2002/2003-2011/2012) is lower than the historic long term average (1977/1978-1986/1987).

3.6 WORCESTER AREA WETLANDS

Geographical area:	**Worcester**
Wetlands in area:	Bokkekraal (Papkuils wetland)
Rainfall station: – present	Bellevue; code = 00228032; 33° 52’ 48”S 19° 27’ 0”E
Rainfall station: – historic	Bellevue; code = 00228032; 33° 52’ 48”S 19° 27’ 0”E
Date of sampling: – present project	20 June 2013.
Date of sampling: – historic project	9-10 May 1988

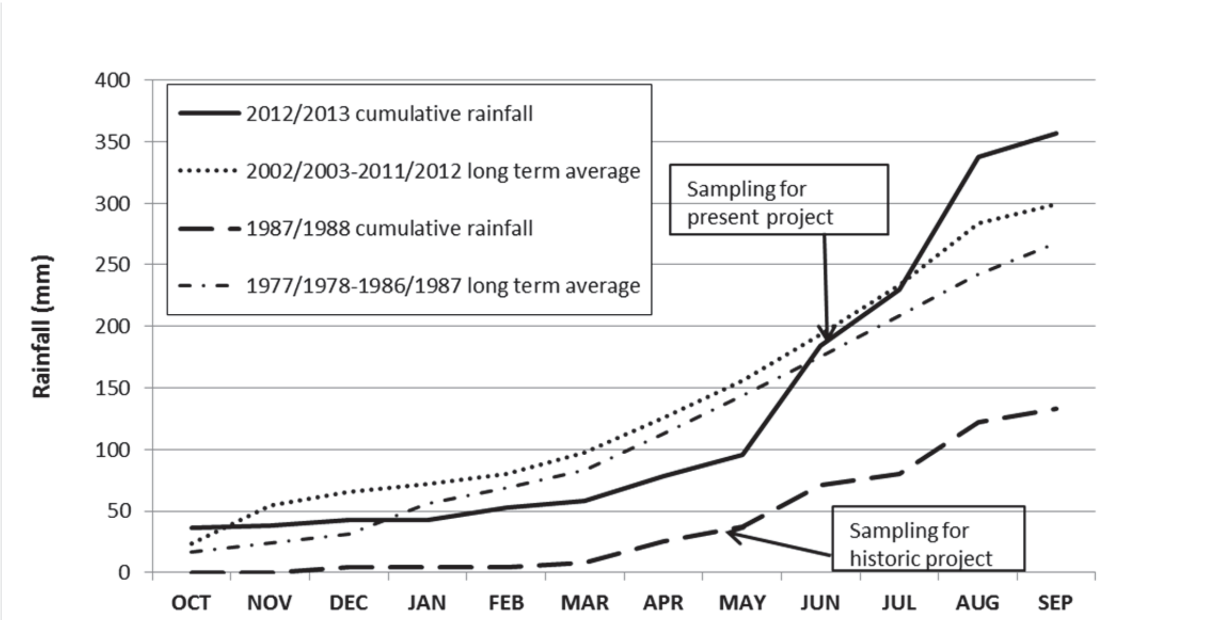

Figure 3-6: Worcester: monthly cumulative rainfall for the years of sampling and for the preceding decade.

From Figure 3-6 it can be seen that Bokkekraal when sampled in June 2013 is likely to have been a lot wetter than when sampled in May 1988. This wetland is a floodplain system, subjected to periods of flooding during the wet, winter season. When it was sampled in June 2013, this was just after flooding. On the other hand, 1988 appears to have been a particularly dry year in Worcester and the surrounding region. In this region of the Fynbos Biome, unlike the Cederberg, Ceres and West Coast regions, the long term cumulative rainfall for the two time periods is comparable, and the present average slightly higher (by roughly 30 mm) than the historic average.

3.7 BETTY’S BAY AND VERMONT AREA WETLANDS

Geographical area:	**Hermanus/Vermont/Betty’s Bay**
Wetlands in area:	Bettys Bay wetlands: Malkopsvlei (Bass Lake), Groot Rondevlei 2, Groot Witvlei. “The other wetlands”: Vermont Pan, Hemel-en-Aarde, Elias Gat (Vioolskloof), Belsvlei, De Diepte Gat, Salmonsdam.
Rainfall station: – present	Hermanus; code = 00064158; 34° 25’ 12”S 19° 13’ 48”E
Rainfall station: – historic	Hermanus; code = 00064158; 34° 25’ 12”S 19° 13’ 48”E
Date of sampling: – present project	11 April 2013 Bettys Bay 7-9 October 2013 The other wetlands
Date of sampling: – historic project	19 March 1989 Bettys Bay 23-26 May 1988 The other wetlands

Figure 3-7 shows that at the time of sampling the three wetlands in the Betty’s Bay area (Malkopsvlei/Bass Lake, Groot Rondevlei and Groot Witvlei) in April 2013, the wetlands are likely to have been wetter than in March 1989. The three wetlands are depressions (although Malkopsvlei does have an outlet to the sea), and have not changed in hydrogeomorphic character since 1989. Thus higher antecedent rainfall is likely to have resulted in a higher water table, and in the wetlands containing more water.

Unfortunately in the case of the other set of wetlands (located in the Hermanus/Vermont area) sampling months for the historic and present projects were in May and October respectively, making comparison difficult. Nevertheless, the wetlands are likely to have been drier in 2013 than when sampled in 1988. The present day average rainfall is slightly higher than the historic average. 2013 and 1989 were wetter than average, but 1988 was drier in this region.

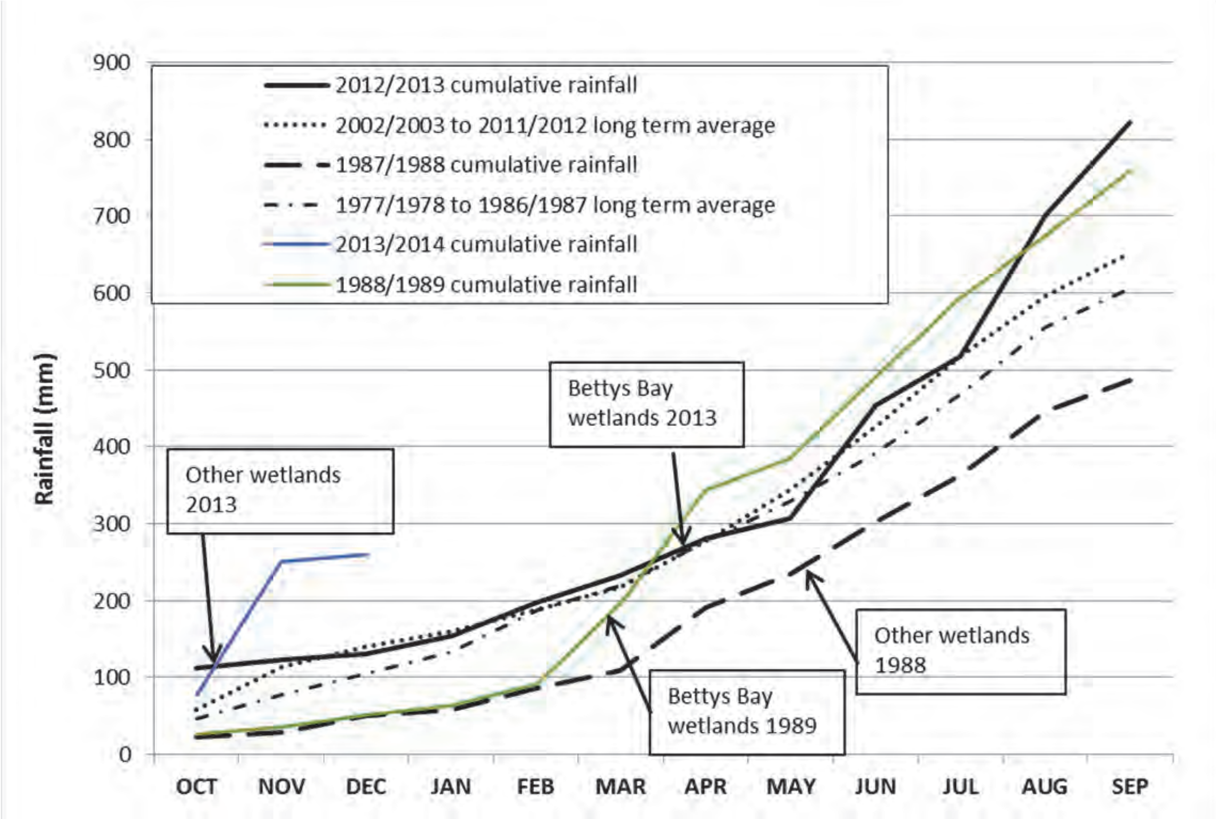

Figure 3-7: Hermanus: monthly cumulative rainfall for the years of sampling and for the preceding decade.

3.8 AGULHAS PLAIN WETLANDS

Geographical area:	**Agulhas Plain and Gans Bay**
Wetlands in area:	Various wetlands – see table below
Rainfall station: – present	Cape Agulhas; code = 00030204; 34º 49' 48"S 20º 1' 12"E
Rainfall station: – historic	Cape Agulhas; code = 00030204; 34º 49' 48"S 20º 1' 12"E
Date of sampling: – present project	July or August 2013
Date of sampling: – historic project	August 1987 and/or September 1988 and/or May 1989

In terms of cumulative rainfall (Figure 3-8) the hydrological year October 2012-September 2013 was similar to average and slightly wetter only for the latter part of the wet season (August and September). On the other hand 1988/1989 was a very wet year with the cumulative monthly rainfall for the entire period more than 200 mm in excess of average in the Point Agulhas region. 1986/1987 was slightly drier and 1987/1988 very much drier than the average calculated from the preceding decade. The average for the decade preceding the present sampling is slightly below that of the historical average.

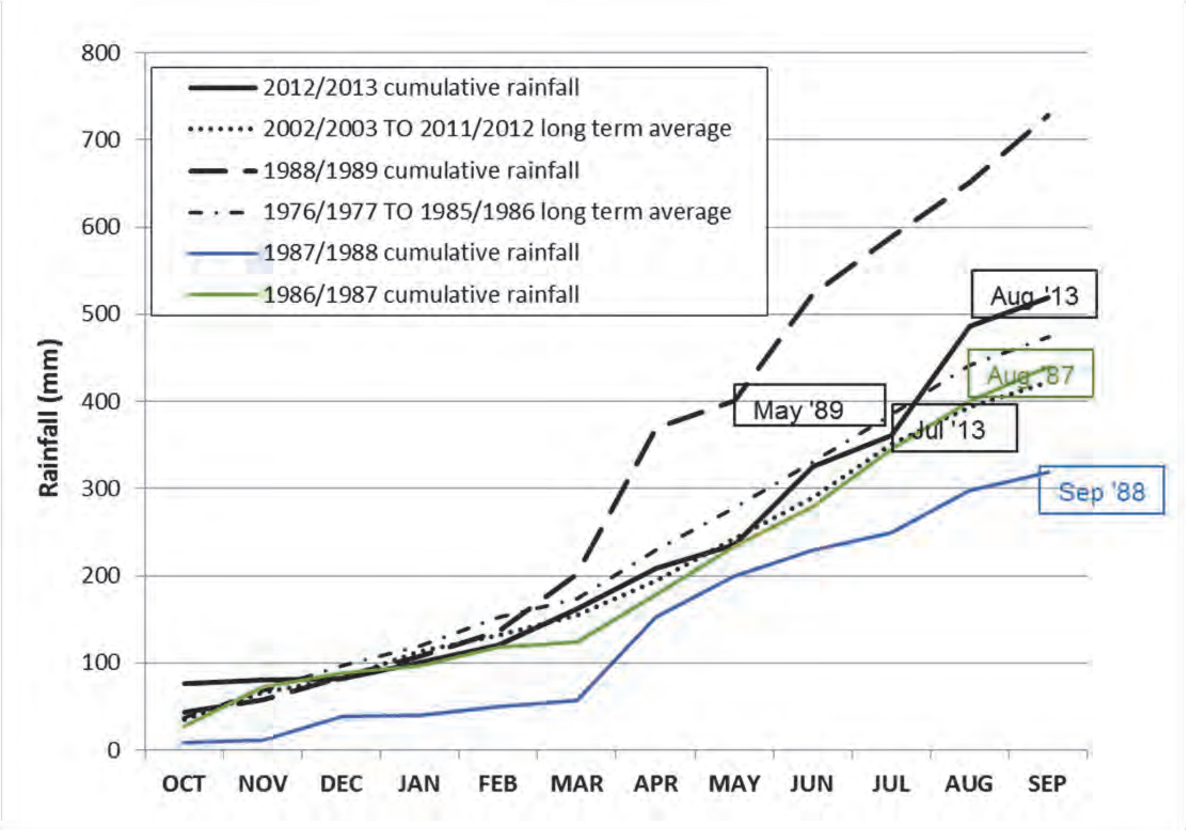

Figure 3-8: Agulhas: monthly cumulative rainfall for the years of sampling and for the preceding decade.

Because so many wetlands were sampled in the Agulhas Plain area, often over multiple sampling occasions for the historical project, each wetland is described individually below in Table 3-1 in terms of whether it is likely to have been wetter or drier when sampled in 2013 compared to the historical sampling.

3.9 MOSSEL BAY WETLANDS

Geographical area:	**Mossel Bay area**
Wetlands in area:	Blinde River, Gouriqua
Rainfall station: – present	Mossel Bay TNK; code = 0012220A8; 34º 10' 12"S 22º 7' 48"E (3 missing values)
Rainfall station: – historic	Cape St Blaize; code = 0012251 7; 34º 10' 48"S 22º 9' 0"E
Date of sampling: – present project	28-30 April 2013
Date of sampling: – historic project	Blinde River 2 March 1988 Gouriqua 22 October 1988

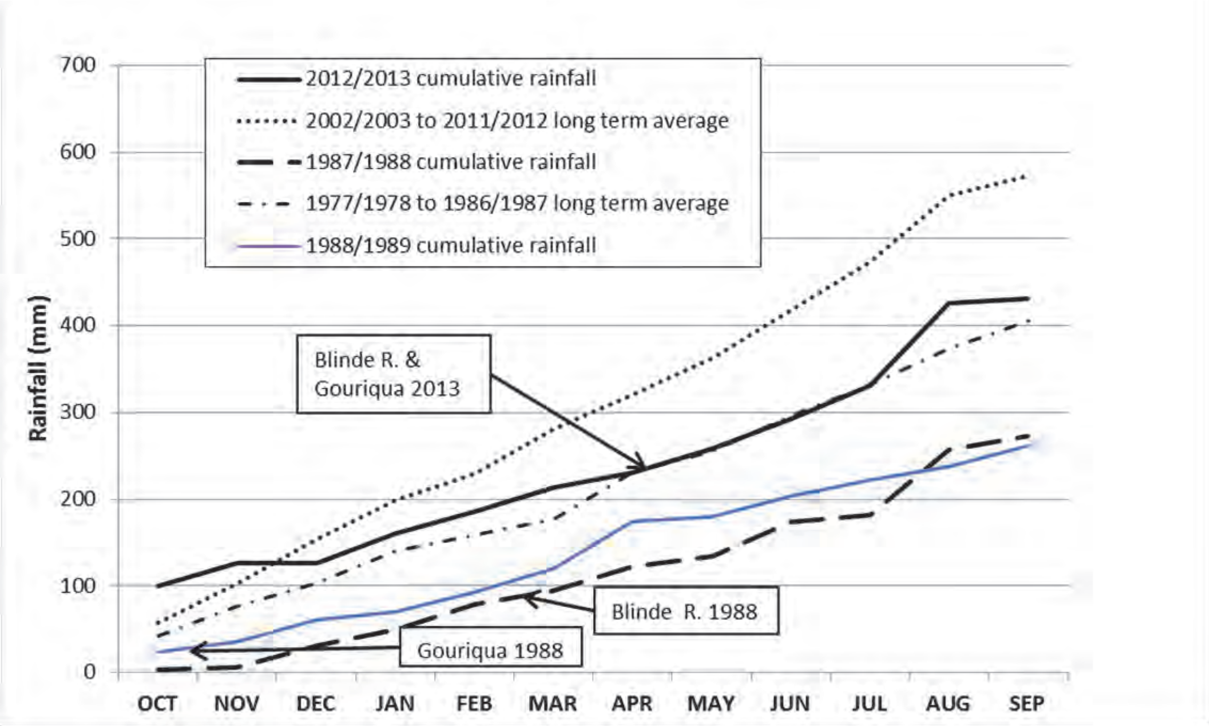

Figure 3-9: Mossel Bay: monthly cumulative rainfall for the years of sampling and for the preceding decade.

Table 3-1: List of the wetlands sampled in the Agulhas Plain area, the HGM type, date of sampling and "wetness" in 2013 compared to the historical sampling.

Wetland	Code	HGM type	Sampling date (month + year)		Likely hydrological status of wetland
			Historic	Present	
White water dam	G501/03A1	Dam	Aug '87; May '89	July '13	Artificial – not applicable
Agulhas Salt Pan	G501/06A1	Isolated depression	Aug '87; May '89	July '13	Fairly similar
Rhenosterkop Pan	G501/07A1	Isolated depression	Aug '87	July '13	Fairly similar
Soetendalsvlei	G501/08A1	Depression with outflows	Aug '87; May '89	July '13	Fairly similar
Ratel River Estuary	G501/15A1	River	Aug '87	July '13	Riverine – applicable?
Melkbospan	G501/16A1	Isolated depression	Aug '87	July '13	Fairly similar
Die Pan (Vispan)	G501/17A1	Isolated depression	Aug '87	July '13	Fairly similar
Waskraalsvlei (Modder Valley)	G501/04A1	Depression with outflows	Aug '87	Aug '13	Wetter
Voelvlei	G501/05A1	Depression with inflows + outflows	Aug '87	Aug '13	Wetter
Groot Hagekraal Upper	G501/09A1	Valley bottom/river	Aug '87; Sept '88	Aug '13	Wetter than Aug '87 and very much wetter than Sept '88. Riverine – applicable?
Pearly Beach	G501/10A1	Depression with inflows + outflows	Aug '87; Sept '88	Aug '13	Wetter than Aug '87 and very much wetter than Sept '88
Wiesdrif	G501/18A1	Valley bottom	May '89	Aug '13	Slightly wetter. Riverine – applicable?
Gans Bay	G403/09A1	Isolated depression	Sept '88	Aug '13	Wetter
Varkensvlei	G501/20A1	Depression with inflow channels	May '89	Oct '13	Slightly wetter

The graphs of the antecedent rainfall as shown above (Figure 3-9) show a wide range in cumulative values. The Blinde River as its name implies is a riverine system and thus as noted earlier the effect of increased rainfall is not as marked as for non-flowing systems. In addition, for this river between 1988 and the present there has been a massive change in the source area of the river with the building of Mossgas and associated water impoundment infrastructure in the upper catchment. This makes it difficult to compare the present and historic data. In the case of the Gouriqua wetlands which are coastal seep areas, water was present in these wetlands when they were visited in October 1988, but they were more or less dry in 2013, despite the higher antecedent rainfall in the present period. This may be a consequence of the encroachment of natural bush around the formerly cleared (grassed) areas and due to the suspected proliferation of *Phragmites* within the wetland, which has lowered the water table. It is, however, difficult to be certain in the absence of detailed multi-season sampling of the wetlands.

Figure 3-9 also shows that the average cumulative monthly rainfall for the last decade is higher than for the decade prior to the sampling by King and Silberbauer in 1988. 2013 was a “dry” year, but wetter than 1988.

CHAPTER 4

CHANGES IN WATER CHEMISTRY

4.1 INTRODUCTION

In the present project, each wetland was sampled for water chemistry only once and these measurements were then compared with results from the historic project which was usually also comprised once-off sampling. Water chemistry in water resources varies naturally both with time and space, hence, once-off measurements such as those obtained in this project, can give only an indication of the true water quality. Some of the wetlands that were visited are large systems and the measurements of chemical constituents and values of physical variables could be expected to vary in different parts of the wetland for example as a consequence of a tributary joining a riverine wetland, or the presence of a pollution source, *e.g.* agricultural field close-to, or within a wetland. Because of the rapid sampling protocol, both for the present and for the historic projects, only a "snap-shot" of the water chemistry of each wetland could be obtained, so deducing changes that have occurred in the intervening 25 years is difficult. It is only when there are gross differences in the concentrations of chemical constituents or the values of physical variables that a significant alteration in water chemistry can be reliably inferred. This is an acknowledged short-coming of the data from this project which needs to be kept in mind when interpreting the results.

Temperature, dissolved oxygen, turbidity, water colour, electrical conductivity (EC) and pH were measured in the field and water samples were taken for laboratory analysis. For most of the wetlands, two sets of analyses were undertaken – by the Dept. Oceanography, UCT (phosphate, nitrate, nitrite and ammonium) and by the DWS (see Table 4-1 for the list of parameters that were quantified by the DWS, only some of which were used in this study).

4.2 METHOD

The following protocol for measuring the concentration of chemical constituents and values of physical parameters was followed:

Table 4-1: The parameters analysed by the laboratory of the Department of Water and Sanitation for this project. Samples were preserved with mercuric chloride.

Data from DWA	Parameter
ASAR-Diss-Water	Sodium adsorption ratio adjusted for calcium precipitation
CORR-Diss-Water	An indicator of the corrosivity of water (for irrigation)
Ca-Diss-Water	Calcium
Cl-Diss-Water	Chloride
DMS-Tot-Water	Total Dissolved solids estimated as the sum of solutes
EC-Phys-Water	Electrical conductivity of the sample in the laboratory
F-Diss-Water	Fluoride
HARD-Mg-Calc-Water	Hardness due to Magnesium
HARD-Tot-Water	Total hardness (Calcium and magnesium)
K-Diss-Water	Potassium

Data from DWA	Parameter
KJEL N-Tot-Water	Kjeldahl nitrogen
LANGL-Index-Water	Langelier Saturation Index (a scaling index used in irrigation)
Mg-Diss-Water	Magnesium
N-Tot-Calc-Water	Total Nitrogen
NH3(25)-Union-Diss-W	Ammonia
NH4-N-Diss-Water	Ammonium
NO3+NO2-N-Diss-Water	Nitrate + nitrite
Na-Diss-Water	Sodium
P-Tot-Water	Total phosphorus
PO4-P-Diss-Water	Phosphate
RYZNAR-Index	An indicator of water hardness
SAR-Diss-Water	Sodium adsorption ratio
SO4-Diss-Water	Sulphate
Si-Diss-Water	Silica
TAL-Diss-Water	Total alkalinity
pH-Diss-Water	pH of the sample in the laboratory
pHs-Calc-Water	pH at saturation with respect to $CaCO_3$

1. Dissolved oxygen, turbidity and temperature were measured *in situ* at a depth of approximately 10 cm. Dissolved oxygen and temperature were measured using an Orbeco Series 150 multimeter and turbidity using either a Hach 2100P or an Orbeco TB200 turbidimeter.
2. pH and specific conductivity were measured in a beaker at the vehicle (rather than *in situ* or in the laboratory) using a Crison pH25 meter and a Crison CM35 conductivity meter respectively.
3. In order to avoid contamination, all samples for analysis by the Dept. of Oceanography, were collected in sample bottles that had been immersed overnight in 2.5% hydrochloric acid, rinsed in water, soaked for a further 6-24 hr in 2% phosphate-free detergent (Extran), followed by rinsing in de-ionised water for 6 hr. Sample bottles for the DWS were already washed according to their standard laboratory procedure (Dr Mike Silberbauer, DWA/DWS *pers. com*. May 2012).
4. One x 250 ml unfiltered sample was collected for nutrient analysis by DWS. Each sample was preserved by adding one ampule of mercuric chloride and keeping cool, in the dark.
5. A further 2 x 250 ml samples, one unfiltered and the other filtered (see below), were collected for the analysis of dissolved nutrients at the Dept. Oceanography, UCT. These samples were kept cold in the field with ice and frozen as soon as possible after sampling.
6. The colour of the water was measured using a Hach Model CO-1 colour test kit.
7. Approximately 400 ml of water (or more if the water was very clear) were filtered, in the field through a Whatman Glass microfibre filter and the exact volume filtered recorded. After filtering the first 150 ml of sample, the next 250 ml of filtrate was collected for the analysis of dissolved nutrients (filtered sample). The filter paper was place in a labelled petri dish, wrapped in tin foil to exclude the light, kept on ice and frozen as soon as possible. The residue on the filter paper was analysed for chlorophyll using the method of Biggs and Kilroy (2000) at the Dept. Zoology, UCT.
8. The unfiltered sample was frozen and kept as a back-up sample.

4.3 INTERPRETING THE RESULTS

For several parameters (EC, pH, nitrate, nitrite, phosphate and ammonium), for most of the wetlands, we had results from both the Dept. of Oceanography and from DWS laboratories. Whilst this was beneficial in that it offered confirmation of results when they concurred, sometimes the values were very different. Some discussion of discrepancies is given under the appropriate water chemistry parameter (*e.g.* pH). A general observation here is that no systematic difference could be found in the results and no correlation with other environmental parameters. Thus, it was not always the case that pH measured by DWA was higher than that measured in the field and, for example, differences were not apparent only in highly saline or acidic systems. Possible reasons for the differences between analytical laboratories include:

- The DWS samples were unfiltered (but filtered later at the laboratory), preserved using mercuric chloride and could spend months in storage before analysis.
- Samples analysed by Oceanography, UCT were filtered in the field and kept cold in the field and frozen in the evening. It is possible that some de-frosting occurred taking the samples to the laboratory after the field-trip.
- Different methods of analysis were used with different detection limits.
- Although care was taken to ensure all sample bottles and other equipment was cleaned appropriately, contamination may have occurred on occasion.
- In connection with inadvertent contamination, there was a possible systematic source in the samples destined for analysis by Dept. Oceanography. Samples were filtered in the field and that process could have caused "carry-over" from the previous sample – although care was taken to minimise this and a consistent effect was not evident in the results.

The following approach was used to deal with the two sources of results:

1. The values for each key WQ variable were compared with what was expected from land-use/historic data.

2. Any obviously anomalous values were ignored.

3. *In situ* measurements of pH and EC, if the readings seemed sensible, were used rather than laboratory-measured values.

4. In the case of values for nutrients, the average of the measurement recorded by DWS and that from Dept. Oceanography was used. For calculation purposes, any measurements recorded below the detection limit (DL) were replaced by half the DL.

4.4 ELECTRICAL CONDUCTIVITY

Electrical conductivity (EC) in the wetlands from the present project varied from roughly 2 mS/m for Silvermine Dam inflow (a mountain seep on Table Mountain) to 17170 mS/m for Koekiespan, an endorheic depression on the West Coast near the town of Darling. Freshwater wetlands included those from the Cederberg (Driehoek, Blomfontein, Sneeuberg Hut) and Suurvlakte in the mountains near the Cederberg. Saline wetlands, in addition to Koekiespan, included, Vispan (Die Pan), Rooipan, Agulhas Salt Pan, Yzerfontein Salt Pan and Burgerspan. The saline wetlands were all, as might be expected, inwardly draining depressions or "pans". The freshwater systems, on the other hand, tended to be seeps or valley bottom systems located in the mountains. The EC for 80% of the wetlands lay between 5 and 4250 mS/m with a median EC of 57 mS/m. Malan and Day (2010) investigating the effect of wetland HGM type on water chemistry, reported that seeps exhibited the lowest EC followed by valley bottom systems, with depressions the highest. The same authors also reported little correlation between EC and the PES of the wetland. Wetlands, particularly endorheic systems vary naturally in EC both temporally and geographically. The above findings with regard to the effect of HGM type on EC and lack of correlation with PES are supported by the results found here.

4.5 pH

pH was measured both in the field and in laboratory samples by DWS. Problems were encountered in the field in that it was difficult to obtain a stable reading in low-salinity samples. Difficulties in measuring pH in natural waters with conductivities less than 10 mS/m are well-recognised in the literature (Busenberg & Plummer 1987; Ritz & Collins 2008). Such systems are poorly-buffered resulting in continual change in pH as CO_2 dissolves into the sample from the atmosphere, resulting in drifting of the value recorded by the pH meter. Ritz and Collins (2008) recommend the use of special electrodes and buffers to circumvent this problem and specify that measurements should be taken as soon after sampling as possible. For this project, in the field, the pH electrode was placed in a clean container with the sample, and the pH value taken as soon as it stabilised or after 5 minutes (which ever happened first). The measurements by DWS on the other hand were made in the laboratory. Frequently, there was a difference of 1 pH unit (or even more) between the values measured in the field and those measured by DWA, with the latter usually, but not always, being a higher value. Because of problems in measuring pH accurately, a statistical analysis of the data was not carried out, but instead the wetlands were divided into three broad bands – "acidic" (pH< 6), circum-neutral (pH 6-8) and "alkaline" (pH >8). The majority of wetlands were in the circum-neutral group with roughly 25% of the wetlands being acidic. All of the acidic wetlands were located in largely natural, fynbos vegetation (apart from Salmonsdam E – a lowland impoundment which is fed by water from a fynbos-dominated wetland.). Surprisingly, the pH for Januariesvlei was fairly high (7.43 recorded in the field and 8.44 recorded by DWA). Being a small depression surrounded by undisturbed fynbos vegetation a more acidic pH would have been expected. It is likely that the local geology (King and Silberbauer report the presence of "an ironstone ridge") is resulting in elevated pH. Roughly 10% of the wetlands are alkaline, and these (excluding Witzand, which as explained earlier derives its water from effluent) are mostly saline pans – such as Vispan, Rooipan and Vermont. Blinde River was unexpectedly in the "alkaline" group, but this is likely to be natural because the pre-Mossgas value recorded King and Silberbauer was also alkaline (8.2).

Table 4-2: Grouping of the wetlands into broad pH bands and water colour (**measured in APHA Platinum Cobalt units). ND = not determined.**

pH	Wetland name	Colour
Acidic wetlands (< pH=6)	Die Diepte Gat	350
	Silvermine Dam inflow	375
	Klaasjagers Estuary	360
	Suurvlakte	25
	Groot Rondevlei (Cape Peninsula)	>500
	Sneeuberg Hut stream	<10
	Middelberg West	<5
	Salmonsdam A (mountain seep)	250
	Groot Hagelkraal Upper	500
	Salmonsdam D	500
	Kleinplaats West	400
	Hoogvertoon	1
	Salmonsdam E (lowland dam)	>500
Circum-neutral wetlands pH 6-8	Groot Rondevlei (Betty's Bay)	300
	Modder Valley	250
	Pearly Beach site A	400
	Wagenbooms River	32
	Die Vlakte	30
	White Water Dam	30
	Verrekyker	21
	Gans Bay	300
	Ratel River	35
	Malkopsvlei (Betty's Bay)	210
	Riversdale	100
	Voelvlei	300
	Wiesdrif	450
	Groot Hagelkraal Lower	>500
	Pearly Beach site C (road)	>500
	Elias Gat	300
	Bokkekraal	10
	Kenilworth Racecourse	ND
	Hemel-en-Aarde	>500
	Khayelitsha Pool	20
	Blomfontein	<10
	Soetendalsvlei	50
	Noordhoek Salt Pan	ND
	Kiekoesvlei	70
	Januariesvlei	60
	Varkvlei	60
	Driehoek	10
	Modder River	90
	Blinde Estuary	40
	Melkbospan	<10
	Silvermine lower	265
	Agulhas Salt Pan	10
	Koekiespan	30
	Burgerspan	10
	Belsvlei upper	300
	Yzerfontein Salt Pan site 2	20
	Rhenosterkop Pan	15
	Yzerfontein Salt Pan	25
	Groot Witvlei (Betty's Bay)	175
Alkaline wetlands pH>8	Vispan (Die Pan)	<10
	Witzand Aquifer Recharge	50
	Blinde River	ND
	Noordhoek Salt Pan (site 2)	ND
	Vermont Pan	200
	Rooipan	ND

4.6 WATER COLOUR

The colour of the water was measured using a Hach Model CO-1 colour test kit which gives an approximate indication of water colour and hence the concentration of dissolved organic substances such humic acids. The method is based on comparing the colour of the water with that on a calibrated test wheel and as such is somewhat subjective. The results are show in Table 4-2. The highest values tended to be linked with the most acidic wetlands. This was expected, since tannin-stained waters are usually acidic due to the presence of humic acids. The wetland systems that had the highest level of water colour were those associated with the Groot Hagelkraal River (including Pearly Beach), Salmonsdam (sites A and E) and Hemel-en-Aarde. The saline, alkaline pans such as Melkbospan, Vispan and Koekiespan often recorded low levels of water colour.

4.7 PHOSPHORUS

Phosphate was measured by both UCT Oceanography and by DWS, the DLs being 0.0003 and 0.01 mg P/L respectively. The large difference in DL made it difficult to compare the results statistically, however, in general the results for individual wetlands were in agreement, particularly at low concentrations of phosphate. Values for the more impacted wetlands sometimes varied but were generally in the same "ballpark". Differences that were apparent between the two measurement sets did not appear to be systematic.

Water column phosphate concentrations ranged from below detection to a maximum value of 3.05 mg P/L (Kiekoesvlei – a depression wetland on the West Coast impacted by agriculture). The median phosphate concentration was 0.01 mg P/L and 25% of wetlands had phosphate concentrations below 0.005 mg P/L, indicating that the DL and the protocol used by DWS to monitor phosphate in wetlands may need to be re-examined. There was a trend of increasing phosphate concentration with elevated levels of impact, but this was not clear-cut. The exorheic seeps and valley-bottom wetlands located in the mountains tended to record low phosphate levels. At the other end of the scale the most impacted systems, which were often endorheic, such as Witzand Aquifer Recharge (storm-water), Koekiespan (agricultural impacts), Vermont Pan (residential), Khayelitsha Pool (urban development) did, as expected, have the highest levels of phosphate. There were some aberrations, for example, Januariesvlei (called Rondeberg wetland by King and Silberbauer) is located in a least-impacted area, was classified as an "A" category in terms of PES, and yet had a very high phosphate level (0.585 and 0.580 mg P/L measured by Oceanography and DWS respectively). Nitrogen levels in this wetland were also unexpectedly high, and yet it had very high levels of invertebrate biodiversity (see appropriate Wetland Status Report). This is an intriguing wetland (note the earlier comment also regarding the unexpectedly high pH value) and it would be interesting to study the limnology of this system in more detail.

Belsvlei (lower) wetland on the other hand had very low phosphate levels (below detection) despite having a PES category assigned of "E". This is probably because the WQ sample was taken just downstream of the road bridge which separates the upstream intact wetland from Belsvlei lower. In other words the phosphate levels rather reflect the upstream wetland which is in a relatively good condition ("B"). Elias Gat (PES category = "D") also exhibited fairly low phosphate concentrations (median value = 0.003 mg P/L), probably because the sampling visit occurred at the end of the winter after a period of high rainfall (which had flushed out pollutants and sediments). This shows that whilst predictions of WQ based on ecological condition can be useful, there are often site-specific factors which can profoundly affect WQ and which may be difficult to take into account without a deeper understanding of a given system.

For roughly half of the wetlands Total Phosphorus (TP) was measured by DWS (this WQ was not measured by the other laboratory). It is interesting to note that many of the endorheic, saline wetlands (*e.g.* Yzerfontein Salt Pan, Rooipan, Vermont Pan, Agulhas Salt Pan) have the highest TP concentrations, the highest being Rhenosterkop in the Agulhas National Park, a largely un-impacted wetland (PES = “B”). Januariesvlei also exhibited very high levels of TP.

4.8 NITROGEN

Various forms of nitrogen were measured namely: nitrate, nitrite, ammonia, ammonium, kjeldahl nitrogen and for some wetlands, Total Nitrogen. The value of Total Inorganic Nitrogen (TIN) was calculated because it was available for all the wetlands, could be calculated from both laboratories and could be compared with the values from the Wetland WQ database and guideline values presented in Malan and Day (2010).

Again the difference in DL between the two analytical laboratories made comparison difficult. The DL for nitrate and nitrite is 0.0017 and 0.05 mg N/L from the Dept. Oceanography and DWS respectively. The DL for ammonium is 0.0053 and 0.05 mg N/L respectively. The median TIN value obtained in the present project was 0.083 mg N/L. In the case of the ammonium values returned by DWS, 74% were less than the DL (*i.e.* recorded as 0.025 mg N/L). For nitrate, 61% were below the detection limit. This indicates that the analysis methods used by DWA to measure different forms of nitrogen in wetlands needs to be re-examined.

Total Inorganic Nitrogen varied from less than 0.01 mg N/L (Driehoek, Kenilworth Racecourse, Silvermine Dam inflow), to more than 1.0 mg N/L (Koekiespan, Khayelitsha Pool, Witzand Aquifer Recharge, Platdrif and Die Vlakte). In general, high TIN levels could be explained by land-use in the area or by other impacts. The wetlands that had low TIN values could also sometimes be predicted, *e.g.* mountain seep/valley bottom systems such as Driehoek, Silvermine Dam inflow, and possibly Kenilworth wetland (a non-impacted humic acid-stained wetland). But there are also some unexpected wetlands in the < 0.01 mg N/L group including a dam in the middle reaches of a river (Salmonsdam E).

4.9 CHANGES IN WATER CHEMISTRY OVER THE INTERVENING 25 YEARS

In the “Wetland Status Report” for each wetland (Volume 2 of this report) the measured values of chemical concentrations and physical variables both for the historical and the present are given along with a brief description of water quality and any changes that might have occurred over the last 25 years. In this report, general trends in water chemistry are discussed. Table 4-3 shows for each of the project wetlands, what changes in water quality over the past 25 years have taken place and the factors likely to have caused any impacts. For each wetland, the HGM type, the present-day land-use and the major impacts to the wetland are also listed since these can all affect water chemistry. The likely change in water chemistry in the wetland since the historical project is recorded as; “Same” (*i.e.* water quality unlikely to have changed from the historic condition), “Slight deterioration” (one WQ variable has increased in the present condition relative to the historic), “Deteriorated” (indicated by significant increases in one or more variables), and “Improved” (present measurements of WQ variables considerably lower than those recorded by King and Silberbauer). The variables used to assess WQ were EC, phosphate, TIN (or individual species of nitrogen, *e.g*. ammonium, nitrate, nitrite, as determined by the availability of data). Historical ammonium values were not taken into account because they are possibly inaccurate (Silberbauer and King *unpub*.). Changes in pH were also not assessed because of the problems mentioned earlier in this chapter in recording pH accurately for low-salinity wetlands, and the differences between field measurements and the DWS data. Water quality and thus an estimate of the extent to which water chemistry has been impacted, was assessed using the guidelines given in Malan and Day (2010).

Of the 65 wetlands listed in Table 4-3, because of a lack of historical data (usually for nutrients) the change in water chemistry of 14 of them is unknown. The present water chemistry for a further 11 wetlands was not determined ("ND"), either because the wetland no longer exists, because we couldn't access it to take samples (*e.g.* because of dense vegetation, flooding, snow) or because the wetland was dry at the time of visiting. For some of the wetlands, for example the mountain seeps in the Cederberg, we were unable to access all of them, or otherwise historical nutrient data were lacking. Despite this we were confident that WQ has not changed because land-use has not changed (or it has improved) and other similar wetlands in the area have remained unchanged in terms of water chemistry. Wetlands in this situation were assigned to the "likely to be the same" category.

For the rest of the wetlands the following results were obtained:

3% of the wetlands have **improved** in terms of water quality
17% of the wetlands are the **same** in terms of water quality
9% of the wetlands **likely to be the same** in terms of water quality, but data are lacking
9% of the wetlands have **deteriorated** (significantly) in water quality
17% of the wetlands show a **slight deterioration** in water quality
6% of the wetlands have **possibly deteriorated** but data are too limited/cryptic to be conclusive

The change in WQ for the remaining 39% could not be determined (lack of historical data or unable to sample in the present project for various reasons).

As noted in the introduction to this chapter, water chemistry is naturally variable in aquatic resources, both spatially and temporally, and thus the above results from once-off sampling need to be taken with caution. Also, analysis techniques and associated detection limits have improved over the past 25 years, making comparison of the historical and contemporary data potentially inaccurate. On investigating the phosphate concentrations recorded in the wetlands by King and Silberbauer, almost all the values are recorded as "< 0.01 mg P/L" which makes it difficult to compare with the current phosphate levels. Nevertheless, the analysis of the results from Table 4-3 indicates that only a disappointing 3% of the wetlands show an improvement in WQ. One of the wetlands where WQ appears to have improved is Lake Michelle, where the reported levels of nutrients have dropped considerably compared to in the historical project. Note though that the ecological character of this wetland has changed from an (impacted) saline pan, to a managed freshwater lake (see relevant "Wetland Status Report"). Surprisingly, given the development of agriculture upstream, the nutrient levels in Soetendalsvlei on the Agulhas Plain also seem to have improved, even though the levels of TIN are still relatively high. For 26% of the wetlands, WQ is (or likely to be) similar to that of 25 years ago.

Nine percent of the wetlands show a significant decrease in WQ. For a few wetlands, salinity has increased significantly. This is the most marked in the Blinde River where the level of EC in the river (upstream just below the road bridge – not at the estuary) has increased 100 fold, with the likely cause of this being discharge from the upstream Mossgas refinery (see relevant "Wetland Status Report"). Although not nearly so marked, salinity also seems to have increased in the Modder River, Papenkuils (Bokkekraal) and Kluitjieskraal (Verrekyker) wetlands. In the first two wetlands, this is most likely a result of increased agricultural development upstream and for Kluitjieskraal, due to discharge from the town of Wolseley. In evaluating the change in EC, note was taken of the HGM type of the wetland. It is well-known that particularly in endorheic systems (*e.g.* “pans”) salinity as indicated by EC, is likely to fluctuate naturally quite widely with season and over different years depending on the climate and weather (Malan and Day 2010). Increased salinity in flowing systems, however, (as for the four wetlands mentioned above) is likely to be more serious since it reflects more widespread catchment impacts and is likely to be a long-term effect.

Deterioration of WQ in the wetlands frequently took the form of increased levels of either (or both) nitrogen or phosphorus. For example, in Koekiespan, the most saline of all the wetlands (both historically and present-day) there has been a significant increase in the levels of nutrients. A similar increase in both nitrogen and phosphorus is noted at Die Vlakte and Kluitjieskraal (Verrekyker). In some wetlands only phosphorus levels have increased (*e.g*. Rooipan, Yzerfontein Salt pan, Gans Bay, Wiesdrif) and in others only nitrogen (*e.g.* Silvermine Lower, Belsvlei, Varkensvlei). General nutrient enrichment could usually be predicted from the change in land-use – *i.e.* increased development of agriculture, urban development, but the form that enrichment would take (*i.e.* elevated phosphorus, or nitrogen, or both) could not.

Of especial interest are the wetlands where there was a discrepancy in land-use change and the observed change in water chemistry. For example, in the case of Klaasjagers Estuary, the difference in EC between historical and present sampling occasions is probably due to natural fluctuations. But it was difficult to decide if the increase in phosphate from <0.01 to 0.13 mg P/L is due to changes in the upstream catchment (which have been minor in terms of those visible from aerial photographs/maps) or is a natural change. The unexpectedly high phosphate results for Januariesvlei have already been mentioned. The cause of present-day elevated nutrient levels in the Agulhas Salt Pan, Melkbospan and White Water Dam are difficult to explain based on land-use change, which remains unchanged/improved (Table 4-3), but may be a result of natural cyclical changes.

Table 4-3: Changes in water quality over the past 25 years and the factors bringing this about. (*Values given, unless otherwise stated are from the present project. TIN = total inorganic nitrogen, WWTW = waste water treatment works).

Wetland Name and area		Present "Ecological Health"				Comment*
		HGM type	Land-use	Major impacts	Change in water quality	
Greater Cape Town	Cape Corps	Unknown (depresssion?)	Appears natural veg	Unknown. WWTW, powerlines.	Unknown	Couldn't locate wetland
	Groot Rondevlei (Cape Point)	Depression	Natural veg	Jeep track (infrequently used). Hiking trail	Little change (currently very good)	Typical fynbos system – acidic (pH = 4.6), low nutrients (P04 = 0.013 mg P/L; TIN = 0.006 mg N/L). EC = roughly 200 mS/m). Difference in EC explained by season of sampling.
	Kenilworth Race Course	Depression	Natural veg	Steeplechase course removed. Veg now managed scientifically.	Little change. Currently very good	Typical fynbos system – low nutrients (PO4 = 0.02 mg P/L; TIN = roughly 0.006 mg N/L). EC = 31 mS/m). pH higher than expected (6.7).
	Khayelitsha Pool	Floodplain depression	Roads/low-cost housing/commercial. But good buffer area of vegetation.	Road culverts, WQ impacts, land clearance for housing. Densification of infrastructure around and upstream of wetland.	Unknown (no historical values). Currently poor.	High nutrients; PO4 = 0.6 mg P/L and TIN = roughly 0.9 mg/L – due to intensive development of catchment and WWTW upstream.
	Klaasjagers Estuary	Channelled valley bottom	Natural veg	Some limited development in upstream catchment. None in immediate environs.	Deteriorated? Currently good.	Big difference in pH and EC (but probably due to difference in season of sampling). PO4 unexpectedly high (= 0.13 mg P/L).
	Kleinplaas Dam/Kleinplaats West	Mountain seep	Natural veg	None (but dam in lower part of wetland).	Same (currently very good)	Typical fynbos system – acidic (5.5); low PO4 = 0.01 mg P/L. EC = 53 mS/m), TIN higher than expected (TIN = 0.1 mg N/L) – due to recent fire in area?
	Lake Michelle/Noordhoek Salt Pan	Perennial depression	Residential development	Infrastructure development, altered hydrology.	Improved? Currently good.	Reduction in levels of phosphate and nitrogen. System now less saline than previously due to change in ecological character.
	Silvermine Dam inflow	Channelled valley bottom	Natural veg	Trees on edge of catchment removed.	Same (currently very good)	Typical fynbos system, low EC = 2 mS/m); acidic (pH = 4.0); low nutrients (PO4 = 0.02 mg P/L; TIN = roughly 0.02 mg N/L).
	Silvermine River (lower)/floodplain	Floodplain	Rehabilitated natural veg.	Stormwater inflow, abstraction of water upstream.	Slight deterioration	Although EC is very low and PO4 = low (0.03 mg P/L), the levels of nitrogen in the system are high (TIN = 0.84 mg N/L)

	Pinelands – The Crossing	This wetland is no longer in existence				
Wetland Name and area		**Present "Ecological Health"**				**Comment***
		HGM type	**Land-use**	**Major impacts**	**Change in water quality**	
West Coast	Burgerspan	Depression	Natural veg and cultivated fields	Cultivated fields. Farm buildings.	Unknown (no historical data). Currently nutrients elevated	A highly saline (EC = 13 260 mS/m), circum-neutral pan. High levels of nutrients (PO4 = 0.11 mg P/L; TIN > 1.3 mg N/L).
	Januariesvlei (Rondeberg)	Depression	Natural veg	Infrastructure development but far away from wetland.	Elevated nutrients? Cause unknown.	Phosphate (PO4 = 0.6 mg P/L) and ammonium (NH4 = 0.16 mg N/L) unexpectedly high, but not nitrate and nitrites (0.01 mg N/L).
	Kiekoesvlei	Depression	Agricultural lands (pasture)	Pasture lands. Farm buildings.	No historic data (currently poor).	Freshwater system. Very high levels of PO4 (= 3.1 mg P/L) and NH4 (= 1.2 mg N/L).
	Koekiespan	Depression	Agricultural lands.	Agriculture, farm buildings. No longer mining salt, but pans still remain. Berm.	Nutrients elevated historically, but now even higher.	The most saline of all the wetlands sampled (EC = 18 300 mS/m), PO4 is elevated (PO4 = 0.2 mg P/L) and N is very high in the system (TIN = 1.6 mg N/L).
	Modder River	Channelled valley bottom + unchannelled tributary	Agricultural lands (slight increase in extent)	Roads, agricultural impacts, upstream abstraction. No active erosion visible. Alien and terrestrial veg encroachment.	Large increase in salinity	Nutrients more or less the same, but EC has increased from 65 to 466 mS/m. This is unlikely to be natural variation because it is a flowing system.
	Rooipan	Three saline depressions (seasonal open water)	Residential and vacant land	Residential development encroachment. Dirt track.	Similar? Phosphates elevated?	Phosphates elevated (PO4 = 0.16 mg P/L compared to <0.01 mg P/L).
	Witzand aquifer recharge	Depression (artificial)	Conservation/recharge area	Dirt tracks	No historic data. Nutrient levels currently high (but artificial system, ameliorating stormwater).	High nutrient levels (PO4 = 0.7 mg P/L: TIN = 1.06 mg N/L).
	Yzerfontein Salt Pan	Saline depression	Natural/disturbed veg. Mining infrastructure (limited).	Dirt tracks, pipes, spoil-heaps, buildings. Residential (not close).	Similar water quality – phosphates elevated.	Saline system (EC = roughly 11 000 mS/m). Phosphates = 0.14 mg P/L.

	Yzerfontein Salt Pan inflow	Wetland no longer exists.				
Cederberg	Blomfontein	Mountain seep	Natural veg	Jeep track (private/infrequently used).	Similar (very good)	Low EC = 5 mS/m; low nutrients (PO4 < 0.005 mg P/L; TIN = roughly 0.05 mg N/L).
Cederberg	Donker Kloof (tributary)	Mountain seep	Natural veg	Jeep track (private/infrequently used).	Expected to be similar (very good).	No data (not sampled), but WQ predicted from land-use to be very good

Wetland Name and area		Present "Ecological Health"				Comment*
		HGM type	**Land-use**	**Major impacts**	**Change in water quality**	
Cederberg	Driehoek	Channelled valley bottom	Natural veg (some agriculture in lower half bordering on wetland)	Road crossings. Agriculture along edge.	Similar (very good)	Very low EC (= 2 mS/m). PO4 below detection, TIN = 0.04 mg N/L.
Cederberg	Hoogvertoon	Mountain seep	Natural veg	Jeep track (private/infrequently used).	Similar (very good)	Low EC = 3 mS/m; fairly low nutrients (PO4 < 0.01 mg P/L; TIN = roughly 0.08 mg N/L).
Cederberg	Middelberg West	High altitude, channelled valley bottom	Natural veg	Hiking trail, 2 huts, 4 alien trees. No active erosion or bracken.	No historical data for nutrients but likely to be similar (very good WQ)	Low EC, low nutrients.
Cederberg	Sederhoutkop	Mountain seep	Natural veg	Jeep track (private/infrequently used).	Expected to be similar	No data (not sampled)
Cederberg	Sneeuberg Hut stream	Mountain seep	Natural veg	Jeep track (private/infrequently used). No sign of erosion.	Similar (very good)	Low EC = 4 mS/m; fairly low nutrients (PO4 < 0.007 mg P/L; TIN = roughly 0.04 mg N/L).
Cederberg	Suurvlakte (u/s of dam)	Channelled valley bottom	Natural and alien (pines)vegetation	Pine trees and dam	Similar (good). Slightly elevated N?	EC low (= 5 mS/m). Low PO4 = 0.005 mg P/L. Possibly nitrogen elevated (TIN = 0.1 mg N/L).
Cederberg	Wagenbooms River	Unchannelled valley bottom	Agricultural lands	Cultivation, abstraction upstream, encroachment of agriculture into wetland	Salinity increased. No historical data for nutrients.	EC = 18 mS/m (increased from 2 mS/m). Nitrogen levels fairly high (TIN = 0.74 mg N/L).
Tulbagh/Wo	Die Vlakte	Upstream wetland gone. Downstream wetland still persists.				
Tulbagh/Wo		Channelled valley bottom	Agricultural lands – not sure if any conserved.	Encroachment by cultivation. Road crossing. Poor water quality. Fires?	Slight increase in salinity. Phosphate and nitrogen levels increased significantly.	EC has increased from 10 to 36 mS/m. PO4 = 0.05 mg P/L and TIN = 0.9 mg N/L.

	Kluitjieskraal (upper wetland). Verrekyker (downstream wetland)	Mosaic of seeps, channels and depressions	Rehabilitated land. Alien veg currently being removed	Ongoing threat alien veg, aquatic weed, lack of indigenous veg.	Salinity , phosphate and nitrogen levels increased.	EC has increased from 17 to 32 mS/m. PO4 increased from <0.01 to > 0.1 mg P/L. TIN increased from <0.02 to > 0.8 mg N/L.
		Downstream wetland gone. Upstream wetland persists.				
	Papenkuils (Bokkekraal)	Floodplain	Agriculture, dam, urban.	Upstream abstraction, pollution. Alien vegetation. Road crossing.	Salinity and nitrogen levels increased	Probably due to upstream increase in agricultural activity.
	Platdrif	Upstream wetland gone. Downstream wetland still persists.				

Wetland Name and area		Present "Ecological Health"				Comment*
		HGM type	Land-use	Major impacts	Change in water quality	
Betty's Bay	Groot Rondevlei (Bettys Bay)	Depression	Residential	Obstruction of flow by roads, drainage ditches, septic tanks. Clearing of natural veg (Malkopsvlei)	Probably similar (no historical nutrient data). WQ currently good.	Acidic, low nutrient system.
Betty's Bay	Groot Witvlei	Depression (with outlet to sea)	Residential		Probably similar (no historical nutrient data). WQ currently good.	Alkaline, low nutrient system.
Betty's Bay	Malkopsvlei (Bass Lake)	Depression with outflow to sea	Residential		Similar water chemistry but possible nutrient elevation in summer	WQ currently good, but algal blooms have been reported in summer (not reflected in the sampling data – because carried out in winter).
Vermont	Belsvlei	Channelled valley bottom	Agriculture	Road crossing, encroachment d/s of orchards and cultivated lands, lawns and other alien veg.	WQ currently good (but an increase in nitrates)	EC = fairly low (19 mS/m); phosphate very low, but nitrogen elevated (TIN = 0.16 mg N/L).
Vermont		Downstream wetland severely eroded. Upstream wetland persists.				
Vermont	Die Diepte Gat	Large mountain seep	Agriculture	Fire-break along edge and pines. Erosion at bottom of wetland.	WQ similar. Currently good	Large wetland, with erosion towards bottom of wetland but doesn't appear to be impacting on WQ. EC = 13 mS/m; PO4 = 0.007 mg P/L; TIN = 0.03 mg N/L

	Elias Gat (Violskloof) Site A	Channelled valley bottom	Agriculture	Alien veg. Infilling. Road crossing	Similar WQ, but N higher?	EC and PO4 similar (30 mS/m and 0.003 mg P/L) to historical. But TIN > 0.3 mg N/L – probably due to upstream agricultural impacts.
	Hemel-en-Aarde	Channelled valley bottom	Agricultural land	Encroachment of cultivation, infilling from road. Power lines. Alien vegetation (also some recently planted!)	Similar (very good)	WQ is surprisingly good. EC low and PO4 and nitrates and nitrites below detection level. Upstream wetland areas probably absorbing excess nutrients.
	Salmonsdam – Site A	Unchannelled valley bottom	Nature reserve	Few remnants of farming activities. Limited recreational infrastructure. Road crossing.	Similar (very good)	The low salinity, low pH (acidic) and low nutrient values are typical of streams draining un-impacted fynbos catchments.
	Vermont Pan	Depression (endorheic)	Residential	Densification of housing. Building of seep to n-east of pan.	Similar WQ.	EC very different between the two periods (but probably natural). Nutrient levels remain high.

Wetland Name and area		Present "Ecological Health"				Comment*
		HGM type	**Land-use**	**Major impacts**	**Change in water quality**	
Agulhas – other wetlands	Agulhas Salt Pan	Depression (endorheic)	Conservation	Road, earth berms, infrastructure (minimal impact).	Nutrients higher than previously.	Nutrients currently high, but high salinity probably prevents algal blooms. Not sure if increase in nutrients is a real effect.
	Die Pan (Vispan)	Depression	Conservation	Minimal disturbance	No historical nutrient data.	Saline system (EC = roughly 4 250 mS/m). Phosphates = very low, but TIN = 0.06 mg N/L and thus currently quite high.
	Gans Bay	Depression (endorheic)	Vacant land, quarries. Some natural veg (*e.g.* milkwood forest). Landfill site nearby.	Quarries, alien veg. 4 X4 route close-by.	Phosphates higher than historically.	Nitrogen levels very low (0.013 mg N/L) but PO4 = 0.06 mg P/L. EC = 134 mS/m.
	Melkbospan	Saline depression	Conservation	Minimal disturbance	Saline system. Nitrates higher than historically?	Land-use in area is natural vegetation. Difficult to understand what might have caused increase in nitrates from <0.01 to 0.09 mg N/L.
	Ratel River Estuary	River	Conservation	Road crossing	No historical nutrient data.	Phosphates currently low, but nitrogen high.

	Rhenosterkop Pan	Saline depression	Conservation – other half conservancy.	Conservation, low intensity agriculture	No historical nutrient data.	Saline system (EC = 3 174 mS/m). Phosphates low (0.02 mg P/L) but nitrogen fairly high (TIN > 0.1 mg N/L).
	White water dam	Depression	Conservation	Road, low level abstraction of water.	Possibly salinity and nitrates have increased?	Difficult to know if increases are real effect or not. No obvious cause. Extensive alien veg in area recently felled, but not yet cleared.
Agulhas – Nuwejaars	Farm 182 (Peters bog)	Wetland flat/ditch?	Agriculture	Grazing ++++?	Not determined	
Agulhas – Nuwejaars	Soetendalsvlei	Large freshwater depression	Agriculture/conservation	Conservation, agriculture	WQ similar or possibly improved in terms of nitrogen levels.	EC naturally ranges from fresh to saline. PO4 = 0.003 mg N/L (very low); TIN levels high = 0.08 mg N/L.
Agulhas – Nuwejaars	Soetendalsvlei Ditch	Not a wetland. No longer in existence.				
Agulhas – Nuwejaars	Voelvlei	Freshwater lake depression	Agricultural lands	Grazing, agricultural activities.	No historical nutrient data.	Phosphates currently high (PO4 = 0.46 mg P/L). Because of the unique drainage system of this wetland it is vulnerable to pollution.
Agulhas – Nuwejaars	Waskraalsvlei (Modder Valley)	Freshwater lake depression	Agricultural lands/conservation	Grazing, agricultural activities.	No historical nutrient data. WQ currently good	Phosphates = low (0.005 mg P/L), TIN slightly high (0.06 mg N/L).

Wetland Name and area		Present "Ecological Health"				Comment*
		HGM type	Land-use	Major impacts	Change in water quality	
	Wiesdrif	Channelled valley bottom	Agricultural lands	Grazing, churning by tractor along edge. Upstream abstraction, pollution?	WQ currently good. Possibly increase in salinity and phosphates.	EC higher than previously (145 vs 109 mS/m). Extensive agriculture upstream, probably ameliorated by wetland.
	Varkensvlei	Depression	Agricultural lands	Grazing, tractor tracks along edge.	Possibly increase in nitrates	TIN = 0.22 mg N/L. Endorheic system vulnerable to pollution.
Agulhas – Groot Hagelkraal	Groot Hagekraal Upper	Floodplain depression	Conservation	Alien veg being removed. Track crossing upstream	WQ currently very good	Neither of these wetlands was sampled in the historical project, thus WQ cannot be compared.
Agulhas – Groot Hagelkraal	Groot Hagelkraal Lower	Unchannelled valley bottom	Conservation/Eskom	Alien veg being removed. Track crossing upstream. Farm infrastructure (historic homestead). Flower harvesting.	WQ currently very good	

	Pearly Beach	Depression (with river inflow and outflow to sea)	Vacant land/natural vegetation.	Limited infrastructure (house and road). Massive alien infestation. Decrease in extent of open water (Phragmites).	Not determined (lack of data).	
Mossel Bay and Riversdale	Riversdale (excluding the Kruis River)	Unchannelled valley bottom	Agriculture/conserved	Drainage, excavation, grazing, burning. Alien veg, erosion channels from Kruis R. Erosion channel upstream.	No historical nutrient data. Probably similar. WQ currently good.	EC similar.
	Gouriqua	3 X freshwater seeps	Conservation/low level development	Infrastructure development (conference centre, few holiday houses) – not currently much used.	ND (dry)	
	Blinde Estuary	Estuary	Natural and very low density residential	Septic tanks. Upstream WQ impacts	No historical nutrient data.	
	Blinde River	River	Natural/low level agricultural	Upstream pollution impacts.	Marked increase in salinity. No historical nutrient data.	Salinity appears to have increased 100-fold to 721 mS/m. Salinity results supported by DWA data for individual ions. Phosphate levels reasonably low (0.02 mg P/L). TIN slightly high (0.32 mg N/L).

CHAPTER 5

CHANGES IN PLANT COMMUNITY STRUCTURE

5.1 WETLANDS AS HABITATS FOR PLANTS

Wetland plants are morphologically and physiologically adapted to growing in wetlands, either in or on the water, or where soils are saturated long enough for anaerobic conditions to exist in the root zone (Cowardin *et al*. 1979; Sorrell *et al*. 2000; Cronk & Fennessy 2001). Plants that are physiologically dependent on water and where at least part of the generative cycle requires part or all of their structure to be submerged in, or floating on, water are known as “hydrophytes” (Cook 2004). Hydrophytes can be either floating or rooted in the substrate, and have their shoots floating on the surface of the water or submerged. Plants not physiologically dependent on water but able to tolerate long periods of submergence are known as “helophytes” (Cook 2004). Wetland plant communities usually include both hydrophytes and helophytes.

Wetlands support plants adapted to inundation for variable periods, so the hydrological regime of a wetland influences the composition, distribution and diversity of wetland plant species (Mitsch & Gosselink 2000; Mucina and Rutherford 2006; Keddy 2004). Wetland types and associated habitats can therefore be grouped into habitat units in which characteristic patterns of plant assemblage can be expected (SANBI 2009).

Within wetlands, hydrological zones (Figure 5-1) range from permanently to seasonally or temporarily wet and provide different conditions that suit different plant species. The exact conditions pertaining in these zones are not easy to define as water levels tend to fluctuate seasonally and from year to year with rainfall, infiltration and evapo-transpiration.

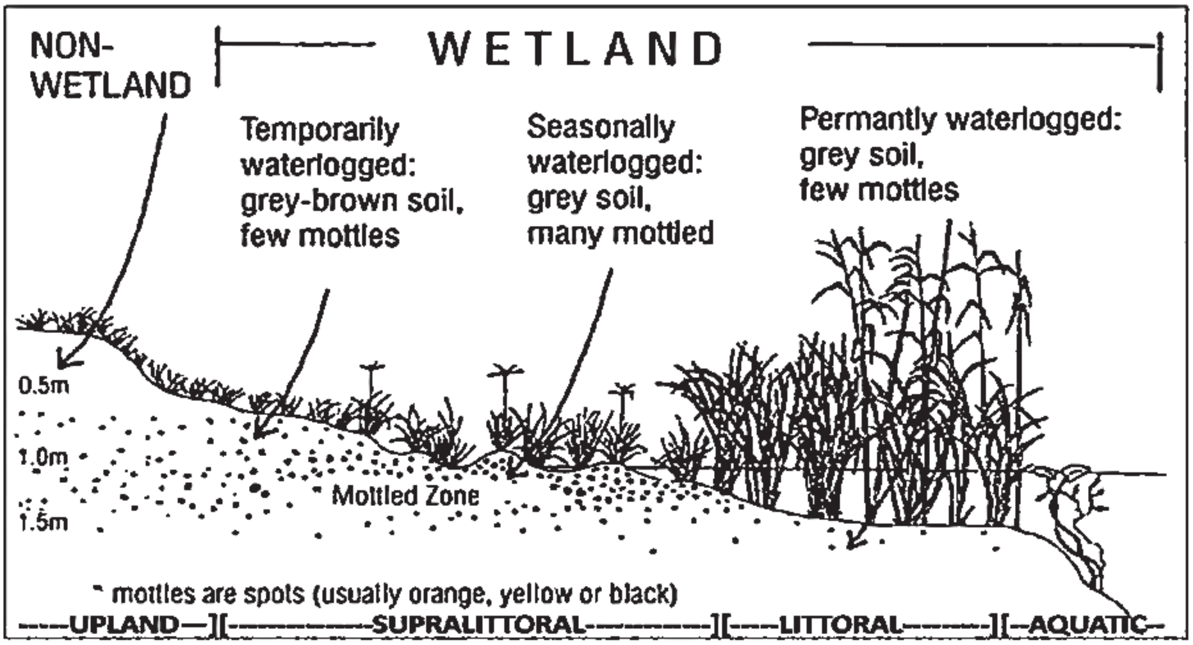

Figure 5-1: Cross-section through a hypothetical wetland, indicating how vegetation changes along a soil wetness gradient (Corry 2012 adapted from Kotze and Marneweck 1999).

Three hydrological habitats or zones are generally recognized (US EPA 2002), distinguished by the residence time of water inundating or saturating the substrate of wetlands. The generally accepted wetland zones are:

- The *supra-littoral zone*, which is temporarily to seasonally saturated and dominated by vegetation that does not usually occur in standing water, although the roots can at times cope with anoxic conditions;
- The *littoral zone*, which is seasonally to permanently saturated or inundated and dominated by emergent vegetation;
- The *aquatic zone*, which is permanently inundated and sometimes supports floating or submerged vegetation.

Any of the three zones may or may not be present within a wetland depending on availability of water and the type of substratum.

5.2 WETLAND PLANT COMMUNITIES

A plant community can be defined as “a characteristic group of plants that naturally grow together in a particular and homogenous environment” (Maarel and Franklin 2013). The species composition of that plant community is determined by the interactions of factors such as climate, soil type, and position in the landscape (Cronk & Fennessy 2001; Mitsch & Gosselink 2000). Differences in the wetness gradient within the zones of a wetland result in differences in the plant communities in open water, the wetland edge and dry land. Valuable information can be obtained for defining wetland boundaries and understanding the environmental conditions of a wetland by analysing patterns of species composition (US EPA 2002; van Ginkel *et al*. 2011).

Wetland plant communities as indicators of change

Plant community composition thus changes along environmental gradients (Whittaker 1967). Analyses have shown that the distribution of species forms a pattern within the landscape as a result of interactions with the surrounding physical and biological environment (Whittaker 1962 & 1967; van der Valk & Davies 1976). Plant species can survive within a range of environmental conditions but outside of this range the species composition of the plant community will change (Whittaker 1967). The species assemblage present at any time thus characterizes, or represents, a particular set of environmental conditions present at a given location. (Mitsch & Gosselink 2000; Keddy 2004) and so plants are useful for monitoring and assessing impacts (Adamus *et al.* 2001).

Wetland plants are useful biological indicators as they are the most visible and common biotic component of wetland ecosystems. The unique association between climatic and hydrological factors that shapes wetlands within the landscape also makes plant communities some of the best indicators of change (Bedford 1996). Both current and historical environmental conditions are often reflected in plant species composition, however, since some plants when once established are able to survive changing conditions (Cronk & Fennessy 2001).

5.3 ANTHROPOGENIC IMPACTS ON WETLAND PLANT COMMUNITIES

Globally, humans have modified plant communities extensively and many studies have searched for patterns in the responses of plant communities to biotic and abiotic, natural and anthropogenic, alterations to the environment (Adamus *et al*. 2001). Natural or anthropogenic disturbances can remove a species or prevent its growth, or can open areas where new species can become established (Cronk & Fennessy 2001). Human disturbances may alter the physical or chemical environment of a wetland resulting in change in the biota; these disturbances may be localised or catchment-wide (Cronk & Fennessy 2001). The forces that threaten wetland ecosystems are the same forces that threaten wetland plants. Five major classes of impacts are described in Table 5-1.

Table 5-1: Human-induced threats to wetlands and wetland plants.

Threat	**Description**
Hydrologic alterations	Human activities (*e.g.* agriculture, flood control and urbanization) result in hydrological changes (ter Braak & Wiertz 1994; Cronk & Fennessy 2001), which in turn lead to either a decrease or increase in wetland area or a change in hydrological regime.
Alien and invasive species	The impacts of invasive and alien species can be severe, resulting in an alteration of the nutrient cycle, development of monoculture stands of vegetation and the extirpation of indigenous species. Alien invasive species may use more water than the species they replace so a loss in indigenous biodiversity threatens not only wetlands but many other types of ecosystem, especially in arid and semi-arid regions, such as South Africa (Richardson & van Wilgen 2004).
Impacts of global change	Human activities often have a negative effect on land-use patterns, atmospheric chemistry, and climate (Vitousek 1997). The increase in mean annual temperature and changes in hydrological cycle will drive many changes in wetland plant communities.
Physical alteration of wetland habitat	Alteration to wetland habitats can have very significant effects on wetland ecosystems and can result in wetland loss. Many have recognized and concluded that alteration and/or loss in wetland habitat area, is a complex interaction of factors, acting at different spatial and temporal scales (*e.g.* Turner & Cahoon 1987; Kesel 1988; Boesch *et al*. 1994; Day *et al*. 1995; 1997 Day *et al*. 2000).
Pollution	Pollutants can be particularly damaging to wetlands, which by their nature are depositing systems where materials can collect.

5.4 TECHNIQUES FOR IDENTIFYING WETLAND PLANT COMMUNITIES

Wetland plant communities are identified on the basis of species assemblages, usually employing multivariate analytical techniques (Little 2013). Several techniques are available.

- *Hierarchical analysis,* commonly used in vegetation studies, is based on a (dis)similarity matrix such as that of Sorenson or Bray-Curtis (Sharma 1996). This information is displayed visually using cluster dendrograms. The different wetland community groups can be identified/defined *post hoc* either subjectively or using objective methods such as ANOSIM, PERMANOVA and PERMDISP, which assess the homogeneity or heterogeneity within the wetland community groups (Sharma 1996; Little 2013).

- *Ordination* is used to discover patterns and underlying structures in the multivariate data (*e.g.* non-metric multidimensional scaling or MDS) (Kenkel 2006; Little 2013). Ordination has been used to assess the effects of management practices on wetland plant communities (e.g. Hall *et al.* 2008); in restoration studies (*e.g.* Rooney & Bayley 2011); in studies on the effects of alien invasive species (*e.g.* Mills *et al*. 2009); and in understanding how environmental degradation affects wetland systems (*e.g.* Carr *et al*. 2010). Several ordination techniques reduce variability, expressing the main patterns in the data using correlations between multiple variables (Little 2013). When examining changes with time it is sensible to focus the ordination plot on change over time by eliminating trends in space (*i.e.* differences among plots), allowing assessment of the statistical significance of the change with time (ter Braak and Wiertz 1994).
- *Indicator species analysis* identifies certain species as indicators for different groups of sites or plant communities (*e.g.* SIMPER analysis) (Little 2013). This type of analysis determines how exclusive or not a particular species is within a group or plant community. Such species can then be used to describe plant communities (Rooney & Bayley 2011), differentiate wetlands, and associate plant species with different wetland conditions (Johnson *et al*. 2007).

5.5 RELATIONSHIPS BETWEEN WETLAND PLANTS AND WETLAND TYPE: DO WETLAND PLANTS REFLECT WETLAND TYPE?

Vegetation is the most noticeable feature of a wetland and has been used extensively as an indicator of wetland presence and extent (US EPA 2002). American and European ecosystem managers have traditionally used vegetation to describe different types of wetlands. In addition wetland plants can be used as indicators of wetland (water) quality and integrity (Cronk & Fennessy 2001).

Many wetland plants, largely monocots, are widely distributed, although some species are endemic to small areas or to specific wetland types (Cronk & Fennessy 2001). It may therefore be possible to identify wetland types by the plant communities present although very little, if any, literature is available on the subject for Africa. Plant communities have been used to characterize wetlands in the United States (Cowardin *et al*. 1979) where dominant plant species are used to describe subclasses within the classification scheme. Other literature has shown that certain species depend on a unique wetland type (Griggs & Jain 1983; Keeley 1988; Baskin 1994; Messmore & Knox 1997). In California many endemic species, such as the mint *Pogogyne abramsii,* and grasses belonging to the genera *Neostapfia, Tuctoria,* and *Orcuttia,* are now rare and endangered due to the destruction of vernal pools in the state (Griggs & Jain 1983; Keeley 1988; Baskin 1994). *Helenium virginicum,* a species of Asteraceae is a narrow endemic restricted to 25 sinkholes in West Virginia and listed as endangered or threatened (Messmore & Knox 1997). With the rapid rate of urbanization and industrialization, the list of threatened species dependent on a single wetland type is probably growing, not only in the United States but worldwide.

5.6 WETLAND MAPPING TECHNIQUES

Lyon and McCarthy (1995) provide useful insights as to how wetlands can be mapped in the environment and the different tools and platforms that can be used to do so. The use of aerial and satellite remote sensing allows the recording and assessing of the conditions of wetland features in the environment. These methods are periodic, however, change being documented through a series of observations over time. The two main objectives involving remote sensing data and wetlands are: 1) resources mapping, which involves obtaining baseline information on the type, extent and condition of wetland plant communities, and 2) detection of change in those communities. These types of data are of interest to those involved in management and conservation of wetlands and the resources that wetlands provide.

Detecting change with aerial photography

Remotely-sensed data and technology are useful to inventory wetlands and track changes in the extent and plant communities over time. Furthermore, these techniques are important for the conservation of wetland ecosystems and for preventing future losses, not just for wetland biodiversity but also for ecosystem goods and services (MacDonald 1999; Ozesmi & Bauer 2002). Over the years, aerial photography and satellite images, together with Geographical Information Systems (GIS), have been used to produce vegetation, hydrological and land-use maps. These maps can be overlain to compare previous and current conditions, identifying areas of change (MacDonald 1999; Ozesmi & Bauer 2002). Detection of change in wetlands requires that ecological data be collected under optimum conditions so that effective comparisons can be made between several points in time. Change detection projects involve the use of one or more historical aerial photographs to document natural or anthropogenic changes (Lyon & McCarthy 1995). Examining the rate of environmental change over time, using these long-term data, provides the opportunity to interpret biological responses, the extent of wetland boundaries and increases or decreases in the fragmentation of wetland communities, and to offer future predictions of change (Lyon & McCarthy 1995; MacDonald 1999 Gosz *et al*. 2010).

5.7 HISTORICAL COMPARISON OF WETLANDS

In recent years, qualitative and quantitative changes in wetland patterns, and the reasons for those changes, have become a hotspot in wetland studies (Xie *et al*. 2010). Williams and Lyon (1995) studied historical changes in wetland area between 1939 and 1985 in the wetlands of the St. Marys River, Michigan, USA. A digital database together with GIS software was constructed for photo interpretation, mapping and digitizing of aerial photographs. Past, present and potential changes in the wetlands were considered in the historical inventory to determine their changes over time. They concluded that: there were no significant changes in the total area of wetland; that changes in the emergent wetland plants appeared to be related to changes in water level; and, that long-term successional trends were indicated.

Lee and Lunetta (1996) reviewed methods for producing an inventory of, and detecting change in, wetlands and investigated the ability of aerial photography and satellite imagery to detect wetlands and to monitor change, and the cost associated with maintaining a database of wetland inventories. They examined historical studies from across the United States that utilized aerial and satellite imaging for various wetland, riverine and land-cover/use projects at local and regional levels. The interpretation of the aerial photography studies (at a scale of 1:24 000) provided insights as to the best remote sensed imaging (film type) and what time of year and day imagery should be acquired for various wetland types and their respective vegetation types. Data sources on different wetland features and change detection analysis such as wetland boundary delineation, vegetation growth, natural vegetation removal, etc. have become available from these different projects. The cost involved in detailed interpretation of aerial photography was found to be high. The projects involving satellite imaging are more technical in interpretation in wetland identification, resource analysis and land-cover/current use of wetlands. These projects covered larger areas of the project sites and at a lower cost but aerial photography and other sources of image data were usually needed to refine the satellite image data.

Rebelo *et al*. (2009) reviewed two case studies conducted at different spatial scales. The first study investigated wetland change on the Muthurajawela Marsh and the adjoining Negombo Lagoon, in Sri Lanka. In summary, it was shown that increased urbanization and industrialization within the wetland complex had contributed to wetland loss and degradation. In the second study, at a much broader scale, remote sensing techniques were to assess land-cover changes within and around the Lake Chilwa wetland complex in Malawi. The multiple land-use practices of these wetlands were examined in order to assess the sustainability of agricultural practices for management purposes.

5.8 WETLAND HGM TYPES IN THE GREATER CAPE FLORISTIC REGION

Wetland distribution and character are the reflection of their physical backgrounds. Seven inland wetland HGM types are recognized by Ollis *et al.* (2013) in their system for classifying (typing) wetlands in South Africa.

- *Rivers* are linear landforms with distinctive bed and banks carrying concentrated flow of water permanently or periodically. Both the active channel and the riparian zone are included in the unit.
- *Channelled valley-bottom wetlands* are located along a valley floor with a distinctive river channel running through.
- *Unchannelled valley-bottom wetlands* are located along a valley floor but without a distinctive channel.
- *Floodplain wetlands* associated with depositional processes of a river system are located on flat or gently sloping areas, adjacent to a alluvial river channel periodically inundated by over-topping,
- *Depressions* are wetlands with closed or partly closed elevation contours that increase in depth towards the centre. Flat-bottomed depressions are typically referred to as pans. Depressions may have inlets, outlets, a combination, or neither.
- *Seep*s are located on gently to steeply sloping valley slopes, with gravity-driven unidirectional movement of water and sediment down-slope.
- *Wetland flats* are situated on a plain or a bench and are associated with weak multidirectional movement of water, due to the lack of change in gradient.

Further subdivision of inland systems is based on descriptors, which include structural, chemical and biological indicators. “Structural” descriptors refer to the origin of the wetland system, *i.e.* whether the system is natural or artificial. “Chemical” descriptors refer to salinity, pH, etc. Biological descriptors refer largely to vegetation. Use of vegetation for further classifying wetlands can be important for conservation planning, rehabilitation and wetland health assessments even if the vegetation is invasive, alien, cropland or plantations. The Ollis *et al.* (2013) classification system distinguishes between unvegetated areas, which consist either of bare substratum or of open water, and vegetated areas. These in turn are divided into vegetation form (*i.e.* aquatic, herbaceous, shrub/thicket or forest) and vegetation status (*i.e.* indigenous or alien).

Classifying wetlands based on their vegetation can be useful, as vegetation links hydrological, edaphic and biogeochemical indicators (US EPA 2002). Wetland vegetation also responds rapidly to anthropogenic and natural disturbances, however, which can be a disadvantage as rapid changes can be missed or not detected at all in long-term datasets (Little 2013).

5.9 WETLAND VEGETATION IN THE GREATER CAPE FLORISTIC REGION

Because of fragmented literature and localized focus the composition of wetland vegetation in South Africa is poorly known, with most botanical research involving terrestrial vegetation (Mucina *et al*. 2006; Sieben 2011). Furthermore, only a few wetland ecologists are trained in sampling and identifying wetland plants which, together with lack of data, makes comparison from one site to another difficult (Sieben 2011).

"*The Vegetation of South Africa, Lesotho and Swaziland"* edited by Mucina and Rutherford (2006) included the classification of wetland vegetation types for the first time in the history of South African vegetation mapping. The classification is based on a broad-scale meta-analysis of the available information and recognized the need for a more rigorous and data-intense wetland vegetation classification. While wetland vegetation is largely distinct from the surrounding terrestrial vegetation, many freshwater wetlands within the Greater Cape Floristic Region are currently included within terrestrial vegetation units due to their small extent, lack of data and the extensive degree of endemism of the plants (Mucina *et al*. 2006). They are considered to be azonal, meaning that the species composition of the vegetation is determined by features other than local climate and vegetation – *i.e.* by the presence of water. This classification ignores any vegetation patterns based on species composition.

When mapping the spatial distribution of larger wetland vegetation units, however, Mucina *et al*. (2006) classified wetland vegetation based on azonality, hydrological regime and salinity as follows.

Freshwater wetlands are typically wetlands with stagnant or slow-flowing water where the dominant species are reeds such as *Phragmites australis.*

Alluvial vegetation is found on the fringes of watercourses such as rivers suited to supporting wetlands characterized by flooding and associated disturbance (floodplain wetlands). Vegetation associated with alluvia is primarily structured by environmental gradients reflecting the habitat differences vertically and longitudinally along river courses. Alluvial habitats arise from three basic zones, which in turn describe and give rise to different plant species in those zones. Lower banks (aquatic/wet bank) are populated by temporary (annual) herbs. Reeds dominate banks of slow-flowing rivers. Grasslands are usually found on the lower and middle banks and riparian thicket on the higher dry bank.

Inland saline vegetation is diverse in character and originates from salt-bearing substrates or mineral-rich ground water. Typically, vegetation patterns form at the edge of the pan floor and on the banks of the pans with salt tolerant vegetation, where the centre of the pan is devoid of vegetation.

Within the three main wetland vegetation types mentioned above, the following vegetation units are recognized by Mucina *et al.* (2006) and are found in wetland habitats in the Core Cape Region:

Freshwater wetlands

- *Cape lowland freshwater wetlands* are freshwater inland vleis (depressions) in the Western Cape, such as Verloerenvlei (West coast), De Hoop Vlei, vleis on the Cape Flats, Papenkuils wetland, vleis on the Agulhas Plain and the Wilderness Lake system found between George and Knysna. Found at altitude ranging from sea level to about 400 m, these wetlands are located in renosterveld and alluvia fynbos.
- *Cape vernal pools* are seasonal habitats that occur from the Cape Peninsula to the Cape Flats and up the West Coast and far as Niewoudtville and Vanrhynsdorp in the Northern Cape at altitudes from 50 to 850 m.

Alluvial vegetation (river ecologists refer to this as riparian vegetation)

- *Fynbos riparian vegetation* predominantly located within the Western Cape partially found in the Eastern Cape in narrow bands of vegetation along the upper reaches of rivers flowing through mountain fynbos, mainly in alluvial thickets and *Prionium serratum* (palmiet)-dominated vegetation bands at altitudes from near sea level to 1 300 m.
- *Cape lowland alluvial vegetation* is found on the broad alluvia of the middle and lower reaches of rivers such as the Olifants, Breede, Berg and Gouritz at altitudes ranging from 20 to 300 m above sea level.

Inland saline vegetation

- *Cape inland salt pans* are largely confined to the Western Cape, although some are found in the Eastern Cape. Most pans occur between sea level and 150 m, but a few are found at 500 m. Saline habitats, such as saline alluvia, saline floodplain flats and slope saline scars include Yzerfontein Salt Pan, Noordhoek, and the salt pans/vleis of the Agulhas Plain and Kars River.

Recent work by Sieben (2011) provides a central database for the inventory of existing wetland vegetation data from all types of data sources, a standardized sampling protocol and a provincial classification of wetland vegetation types. Currently completed for only KwaZulu-Natal, Free State and Mpumalanga, this study includes data from other comparable studies across the country as well.

The Red Data List of South African plants by Raimondo *et al*. (2009) provides information on species status, distribution and habitat of threatened wetland plants. Examining this list revealed that *Isolepis bulbifera,* a species endemic to wetlands on the Cape Flats, is considered extinct due to urbanisation and the presence of alien invasive plants in its known habitat. *Ficinia distans*, found in fynbos seeps, is vulnerable as all known localities are threatened by coastal development and alien invasive species. On the Agulhas Plain, the known localities of *Ficinia latifolia* are in danger as the result of crop cultivation, invasive alien plants and urbanization. *Aponogeton angustifolius*, encountered during field sampling at Bokkekraal (= Papenkuils) wetland near Worcester, is vulnerable with a narrow distribution range, being found mostly in isolated populations at the edges of vleis and slow-flowing rivers. The habitat of this species is continuing to degrade as a result of altered hydrological regimes associated with urbanization and upstream agriculture. *Cotula filifolia* is another critically endangered species encountered during fieldwork in marshy and damp places. The range of this species, with its small area of occurrence (10 km^2), has become fragmented and continues to become more so due to agricultural and urban development. These are just a few illustrations of wetland species that are vulnerable, threatened or extinct. Distinguishing plants as wetland rather than "azonal" species can be helpful in the management of wetland habitats and their species diversity by conserving those endemic to certain wetland types and regions.

5.10 THIS STUDY

The goal of the present project was to investigate the extent to which wetland vegetation and associated environmental variables in the CFR have changed over the past 25 years. Current plant community assemblages are compared with those identified by King and Silberbauer for the same wetlands in an attempt to identify the trajectories and drivers of change in the wetland vegetation.

Research Aim and objectives

The aim of this part of the overall project was to assess plant community composition and identify the environmental factors that affect community assemblage distribution past and present, as a basis of inferring change over time.

To fulfil the aim of the study the following objectives were set:

- to characterize and assess wetland plant communities and wetland types of the CFR in the late 1980s and currently
- to identify major environmental factors influencing plant species distribution in the wetlands in the late 1980s and currently
- to assess changes in plant community composition over time and in relation to changes in surrounding land-use.

5.11 MATERIALS AND METHODS

5.11.1 Study area

The localities of the subset of Silberbauer and King sites included in the current vegetation study are indicated in Figure 5-2 and some environmental features of each are listed in Table 5-2. Geographical coordinates and the sampling dates are given in Appendix B.

The Core Cape Region (CCR) (Figure 5-3), previously called the Cape Floristic Region (CFR) and now included in the Greater Cape Floristic Region (GCFR) (Manning & Goldblatt 2012), covers an area of 90 760 km^2. It is dominated by the Fynbos Biome and characterized by small-leaved, sclerophyllous shrubs and geophytes. The GCFR is characterized by a Mediterranean climate with winter rainfall and summer drought (de Moor and Day 2013). Rainfall varies dramatically across the landscape varying from 2000 mm per year in the mountains to less than 200 mm on the interior slopes and to the north. In the west and south-west rainfall is experienced mainly in the winter months with hot and dry summers, where the east receives more all year round rainfall (Manning & Goldblatt 2012).

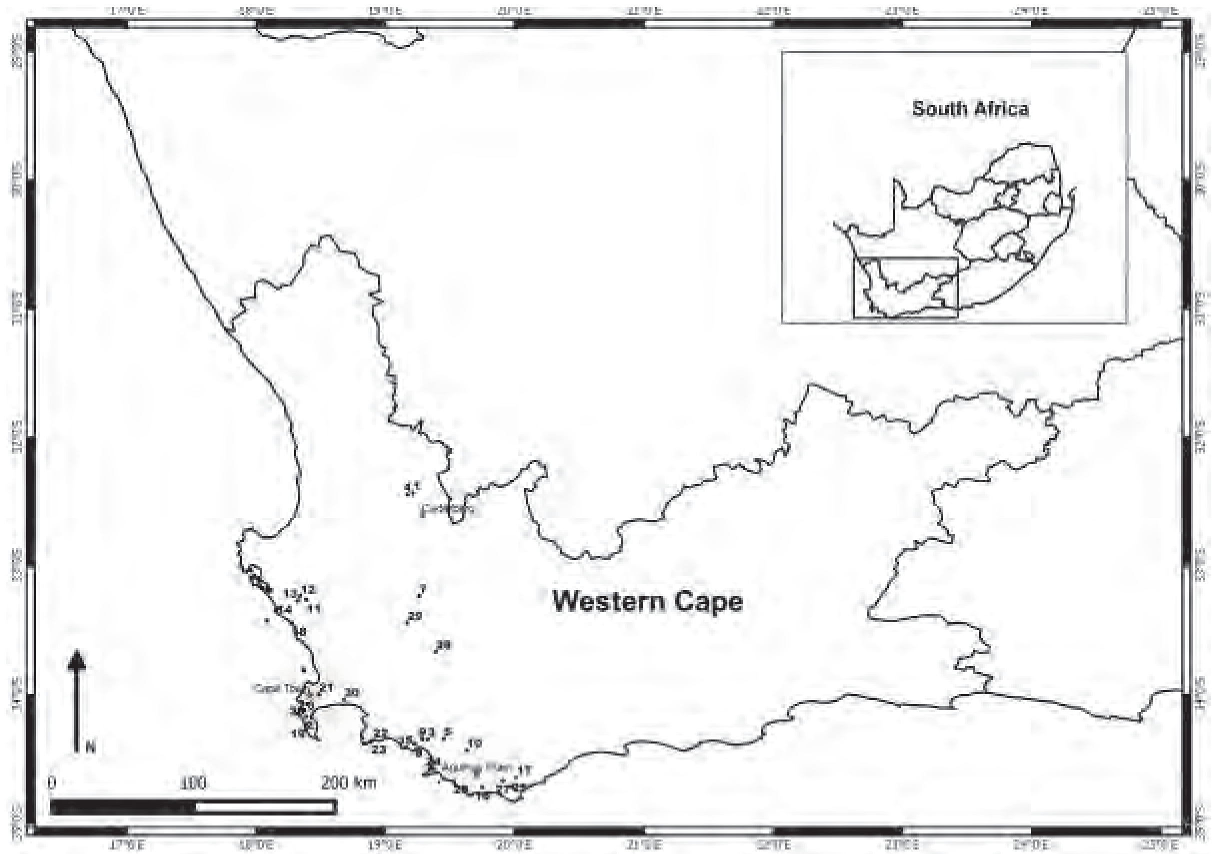

Figure 5-2: The study area with the different wetland sites used for the analysis of vegetation in the Western Cape. (SANBI 2006; generated from vegm2006.shp from Mucina et al. 2006).

Most soils in the GCFR are derived from the sedimentary Table Mountain, Witteberg and the Bokkeveld Groups of the Cape Supergroup. Soils resulting from this lithology are mostly acidic, coarse-grained sandy soils, poor in nutrients in the mountains, fine-grained clay soils richer in nutrients on the lower slopes, and limestone on some of the coastal lowlands between the Agulhas Plain and Mossel Bay (Lambrechts 1979; Cowling *et al*. 2003; Manning & Goldblatt 2012).

5.11.2 Historical field data collection

Procedures for sampling plants in the historical study are not systematically documented. The plant collection books, field notes, maps and annotations on maps, and drawings from the previous project, together with conversations with Drs King and Silberbauer, were therefore used in an attempt to ascertain the sampling strategy. We concluded that sampling was conducted qualitatively to collect the dominant wetland plants associated with each wetland. Plants were systematically collected and pressed, however, and are now housed in the Bolus Herbarium at the University of Cape Town.

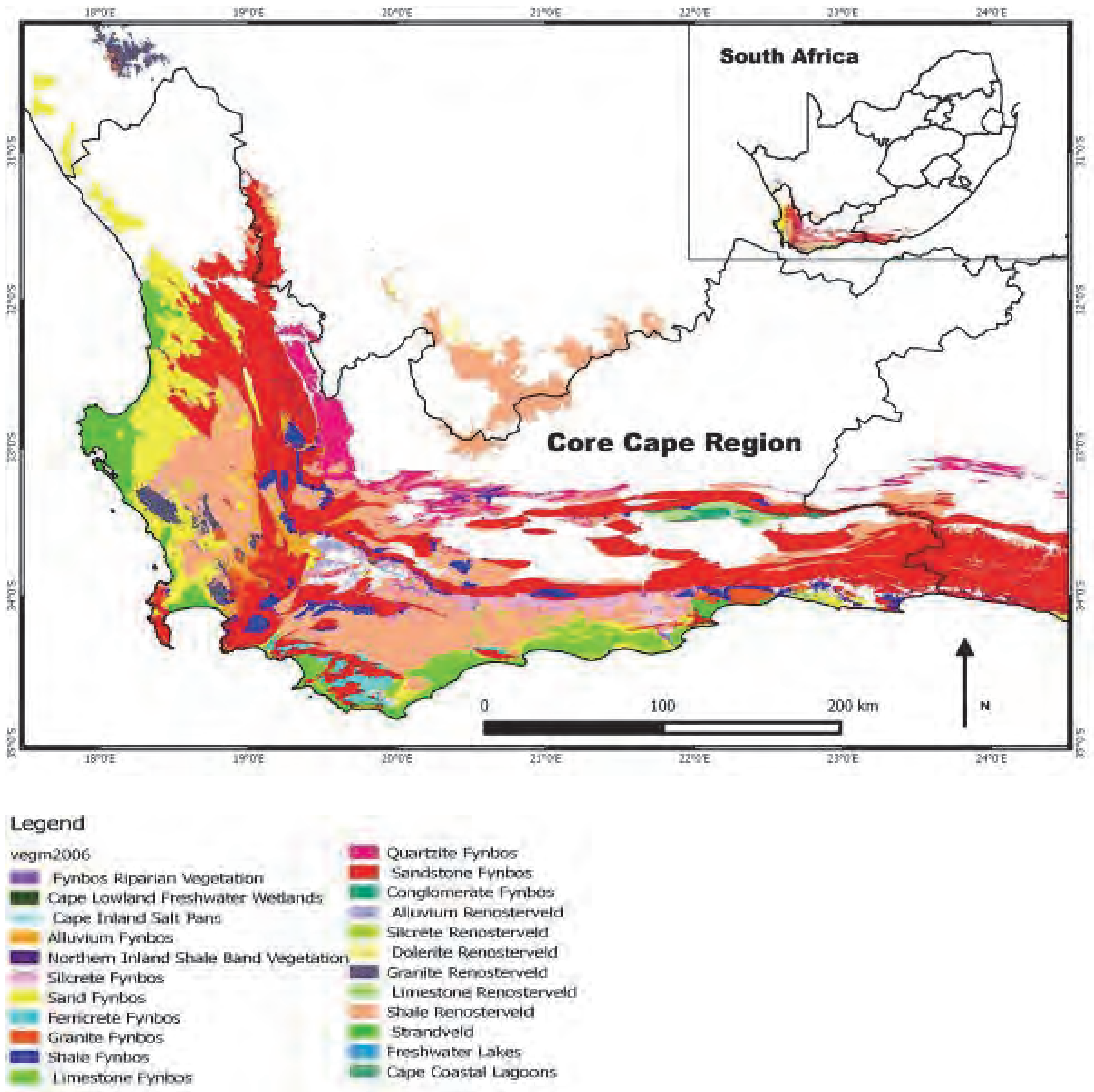

Figure 5-3: The study area with the different vegetation units found in the Greater Cape Floristic Region (South African National Biodiversity Institute (SANBI) 2006; generated from vegm2006.shp from Mucina et al. 2006).

Table 5-2: Study sites and their names, wetland codes, wetland (HGM) type, phytogeographic centre, altitude, and vegetation type. (Phytogeographic subcentres of the Cape Region: NW =Northwest Centre, SW =Southwest Centre, AP =Agulhas Plain. Adapted from Goldblatt and Manning, 1999)

Wetland name	**Wetland code**	**Wetland type** (Ollis *et al*. 2013)	**Phytogeographic centres /Area**	**Surrounding land-use**	**Alt (m)**	**Vegetation type** (Mucina & Rutherford 2006)	**Surrounding terrestrial vegetation type (when azonal)** (Mucina *et al*. 2006)
Blomfontein	E201/03	Seep	NW / Cederberg	Nature reserve	1360	Northern Inland Shale Band Vegetation	
Kleinplaats Dam West	G203/01	Seep	SW / Simonstown	Natural land, Dam	270	Peninsula Sandstone Fynbos	
De Diepte Gat	G403/05	Seep	SW/ Hermanus	Agriculture	270	Elim Ferricrete Fynbos	
Driehoek	E201/06	Channelled valley-bottom	NW / Cederberg	Nature reserve	890	Cederberg Sandstone Fynbos	
Elias Gat	G403/03	Channelled valley-bottom	SW / Stanford	Agriculture	133	Cape Lowlands Freshwater Wetland	Western Rûens Shale Renosterveld
Silvermine Dam Inflow	G203/18	Channelled valley-bottom	SW / Silvermine	Nature reserve	455	Peninsula Sandstone Fynbos	
De Vlakte	H101/06	Channelled valley-bottom	NW / Wolseley	Agriculture	881	Kouebokkeveld Shale Fynbos	
Hemel-en-Aarde	G403/02	Unchannelled valley-bottom	SW/ Hermanus	Agriculture	72	Elim Ferricrete Fynbos	
Belsvlei	G403/04	Unchannelled valley-bottom	SW / Hermanus	Agriculture	260	Elim Ferricrete Fynbos	
Salmonsdam	G404/01	Unchannelled valley-bottom	SW / Stanford	Nature reserve	160	Cape Lowlands Freshwater Wetland	Elim Ferricrete Fynbos
Kiekoesvlei	G103/01	Saltpan (Depression)	SW / Darling	Agriculture	55	Cape Inland Salt Pan-Inland Saline Vegetation	Swartland Shale Renosterveld
Koekiespan	G103/02	Saltpan (Depression)	SW / Darling	Agriculture	57	Swartland Shale Renosterveld	

Burgerspan	G103/03	Saltpan (Depression)	SW / Darling	Agriculture	70	Cape Inland Salt Pan-Inland Saline Vegetation	Swartland Granite Renosterveld
Wetland name	**Wetland code**	**Wetland type** (Ollis *et al*. 2013)	**Phytogeographic centres /Area**	**Surrounding land-use**	**Alt (m)**	**Vegetation type** (Mucina & Rutherford 2006)	**Surrounding terrestrial vegetation type (when azonal)** (Mucina *et al*. 2006)
Rooipan	G201/01	Saltpan (Depression)	SW / Darling	Private land	2	Cape Inland Salt Pan-Inland Saline Vegetation	(E) Saldanha Flats Strandveld (W) Langebaan Dune Strandveld
Vermont Pan	G403/01	Saltpan (Depression)	SW / Hermanus	Residential	18	Cape Lowland Freshwater Wetland	Hangklip Sand Fynbos
Melkbospan	G501/16	Saltpan (Depression)	AP / Agulhas	Nature reserve	30	Cape Lowland Freshwater Wetland	Agulhas Sand Fynbos
Varkensvlei	G501/20	Saltpan (Depression)	AP / Agulhas	Agriculture	4	Agulhas Limestone Fynbos	
Rondeberg	G201/04	Depression	SW / Darling	Private Conserved land	15	Langebaan Dune Strandveld	
Groot Rondevlei	G203/04	Depression	SW / Cape Point	Nature reserve	3	Cape Flats Dune Strandveld	
Noordhoek Salt Pan	G203/12	Depression	SW/ Noordhoek	Residential	3	Cape Lowland Freshwater Wetland	Hangklip Sand Fynbos
Kenilworth Racecourse	G203/13	Depression	SW / Kenilworth	Race course, conservation area	25	Cape Flats Sand Fynbos	
Malkkopsvlei / Bass Lake	G401/01	Depression	SW / Betty's bay	Residential	10	Hangklip Sand Fynbos	

Groot Witvlei	G401/03	Depression	SW/ Betty's bay	Residential	8	Cape Lowland Freshwater Wetland	Hangklip Sand Fynbos
Gans Bay	G403/09	Depression	SW / Gans Bay	Open land	37	Overberg Dune Strandveld	
Wetland name	**Wetland code**	**Wetland type** (Ollis *et al*. 2013)	**Phytogeographic centres /Area**	**Surrounding land-use**	**Alt (m)**	**Vegetation type** (Mucina & Rutherford 2006)	**Surrounding terrestrial vegetation type (when azonal)** (Mucina *et al*. 2006)
Soetendalsvlei	G501/08	Depression	AP / Agulhas	Agriculture, nature reserve	2	Cape Inland Saltpan-Inland Salt Vegetation	(E) Agulhas Sand Fynbos (W) Central Rûens Shale Renosterveld
Pearly Beach	G501/10	Depression	AP / Pearly Beach	Private open land	2	Cape Lowland Freshwater Wetland	(S) Overberg Dune Strandveld (N) Agulhas Sand Fynbos
Wiesdrif	G501/18	Depression	AP / Agulhas	Agriculture	4	Cape Inland Saltpan-Inland Salt vegetation	Central Rûens Shale Renosterveld
Bokkekraal	H101/01	Depression* (Floodplain)	NW/ Worcester	Agriculture	198	Breede Alluvium Fynbos	
Verrekyker	H101/05	Depression	NW / Wolseley	Conservation, agriculture	252	Breede Alluvium Fynbos	
Khayelitsha Pool	G204/02	Depression* (Floodplain)	SW/ Khayelitsha	Residential-Rural, Urban	18	Cape Lowland Freshwater Wetland	Cape Flats Dune Strandveld

*Depressions (Floodplain) are floodplain wetlands that are cut off from the main river channel.

5.11.3 ***Present-day field data collection***

A total of 37 wetland sites were sampled from June 2012 to November 2013. To reduce the effect of seasonality in the comparison between current and historical data, sampling of each wetland occurred in the same calendar month as the equivalent sample collected in the historic study.

Other environmental variables considered were rainfall (Chapter 3) and altitude. Altitude was obtained from topographical maps of the Western Cape from the National Geo-Spatial Information (Mapping and Survey) Department in Mowbray, Cape Town. Details of methods employed in collecting and analysing physico-chemical variables taken from the water column are given in Chapter 4.

5.11.4 Plant collection and identification

The sampling procedure used in this study was the same as the one followed by King and Silberbauer for comparative purposes and because time and budget constraints did not allow a more intensive sampling programme. The most common species of plants were collected in and around the wetland. Where necessary, specimens of each species were collected. Easily visible plants were identified in the field where possible. Species that could not be identified in the field were collected and pressed for later identification. Photographs were taken of each plant species and the habitat in which it was found. Records or collections were made of emergent, submerged and floating plants.

Specimens were identified with the aid of field guides, material housed in the University of Cape Town's Bolus Herbarium with the assistance of the Curator, Dr Terry Trinder-Smith, and specialists in the Department of Biological Sciences, UCT. Most specimens could be identified to species, but some could only be identified to genus or family, as many plants were not flowering when sampled.

5.11.5 Analysis of aerial photographs

Digitized aerial photographs were obtained from the National Geo-Spatial Planning Department, Cape Town. Historical images for different parts of the study area were available for different times ranging from 1986 to 1991. These images were compared with ortho-rectified 2010 aerial photographs (*e.g*. Figure 5-4).

With the use of Quantum Geographic Information System v 2.2.1 (QGIS) the historical aerial photographs were geo-rectified and digitized to allow change in land-use in and around the wetland sites to be visually assessed. The catchment boundaries of certain wetlands were difficult to establish, and thus a 1 km standardized buffer zone around all the wetlands was delineated. The rationale was that the types of land-use closest to a wetland would have more direct and easily detectable impacts that those in the wider catchment. In the case of river systems, a 1 km wide X 1 km long buffer was drawn parallel to the river from the sampling point. Land-use change was assessed within these buffer zones for comparative purposes (Figure 5-4C). The resultant images were then used to identify land-cover classes:

Development:
- formal residential or
- informal residential or
- industrial

Natural or undeveloped land
Agriculture (crop farming).

Control points such as railways, main roads or intersections were used for geo-referencing. Area of change was estimated by comparing the size (m^2) of the different classes for each year.

5.11.6 Statistical analysis

Multivariate statistics were used to analyse both plant and environmental variables. The statistical analysis package Plymouth Routines in Multivariate Ecological Research (PRIMER-E: Clarke & Gorley 2006) and its add-on Permutational Multivariate Analysis of Variance (PERMANOVA+: Anderson *et al*. 2008) were used for analyses of both historical and present data sets. All tests for significance were made at $\alpha = 0.05$ and/or 5%.

Both historic and present-day data were available for 37 wetlands. Seven wetlands were removed from the data set, two being outliers (estuaries with only one plant species listed) that skewed the data in multivariate space and five with no historical vegetation data. Therefore, a total of 30 wetland sites (Table 5-2) with both historical and present-day data were used in the comparative analyses of the vegetation data.

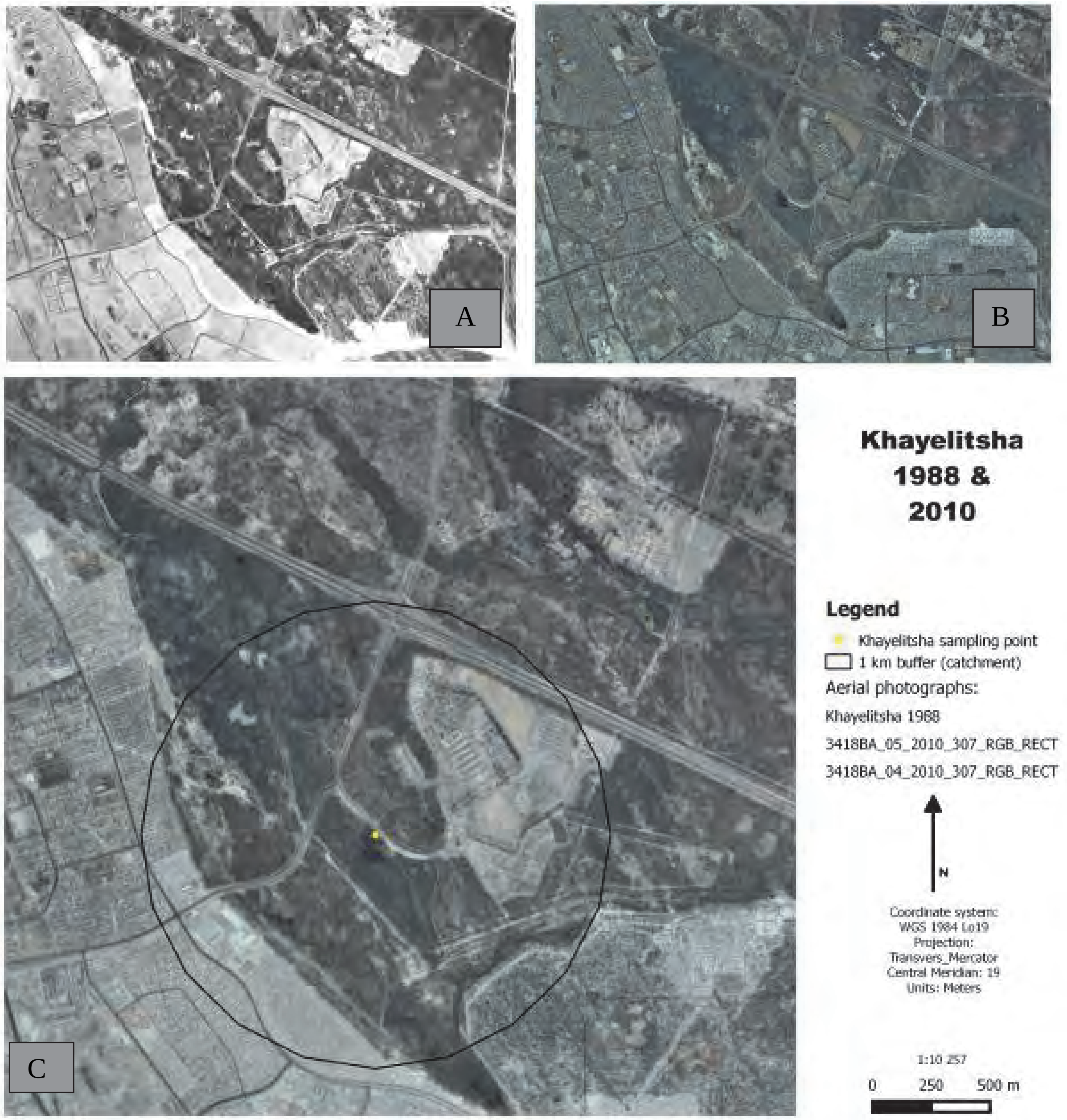

Figure 5-4: Aerial photographs of the wetland site Khayelitsha Pool and surrounding area. A was taken in 1988 and B in 2012. C shows the outline of the 1 km buffer area which was digitized for the different land-cover classes and the sampling point in the wetland.

Of the 30 wetland sites environmental data was available for 17 in the historical period. Thus analysis of environmental variables related to the historical plant species communities was performed on a subset of the wetlands (n=17). Four variables were examined: pH, conductivity, altitude, and annual rainfall. Nutrient analyses, which included phosphate ($P0_4^{3-}$-P), nitrite ($N0_2^-$-N) + nitrate ($N0_3^-$-N) and ammonium (NH_4^+-N) for the historic data were patchy and were therefore not included as this would have resulted in further reduction of sample size. Environmental data for 30 wetland sites in the present-day study were examined separately to investigate relationships with the plant communities. Seven variables were included in those analyses: pH, conductivity, altitude, rainfall, $P0_4^{3-}$-P, $N0_2^-$-N + $N0_3^-$-N and NH_4^+-N.

Five of the seven wetland HGM types recognized by Ollis *et al*. (2013) are found in this study: depressions, channelled valley-bottoms, unchannelled valley-bottoms, floodplain wetlands and wetland seeps. Wetland types that were represented by only one or two sites were analysed together with other similar wetland groups, *e.g*. channelled and unchannelled valley-bottoms. Floodplain wetlands cut off from the river channel functioned as depressions and were added to the depression group, while salt pans were separated from depressions based on their water chemistry. The following wetland groups were therefore used for analysis of wetland types: depressions, salt pans, valley bottoms and seeps.

The following techniques were used in the analysis of the vegetation and environmental data. Dendrograms determine how similar one sample is to another, grouping like samples, while searching for outliers in the data set. In PRIMER, a group-average linkage classification technique was applied to cluster assemblages of similar species composition between sites. The cluster analysis combined with the SIMPROF 'similarity profile' was applied to the resemblance matrix of the samples/sites. SIMPROF is a permutation test, which looks for statistically significant evidence of clusters in the samples/sites. The SIMPROF test is done at every node of a completed dendrogram, a group being sub-divided suggesting that samples (sites) in that group illustrate evidence of multivariate pattern, *i.e.* 'significant' internal structure (Clarke & Gorley 2006). Therefore, in the figures, the black lines identify the main groups and the branches coloured red indicate samples (sites) that are significantly similar. Hierarchal cluster analysis was used to determine the different plant communities in the 1988/89 and 2012/13 vegetation data.

Ordination by non-metric Multi-dimensional Scaling (MDS) in PRIMER was deemed an appropriate technique for displaying similarity amongst sites based on plant species composition. Two-dimensional MDS with a stress value of less than 0.2 indicates a good representation of the patterns in the data. The visual interpretation of the MDS is such that the distances between sample points is a measure of their degree of similarity and points that are close together will represent samples/sites which are similar in plant species composition.

The Analysis of Similarity (ANOSIM) in PRIMER is a non-parametric permutational procedure, applied to the rank data of a resemblance matrix that allows testing of the null hypothesis of no difference between groups of sample (Clarke & Gorley 2006). ANOSIM allows one to test the null hypothesis by comparing within-group rank dissimilarity with among-group rank dissimilarity. In the case of the plant species composition data, ANOSIM was used to assess the among-plant-community-types differences, the among-wetland-type differences, and the between-survey-year differences in plant composition above background variability. Two-way crossed layouts with replicates ANOSIM also allowed, for example testing the null hypothesis that there are no differences in plant communities or between time periods in terms of species assemblages. The two-way layout only identifies the main effect between the two factors, however, and does not allow one to test for interactions between them (Clarke & Gorley 2006).

Since ANOSIM cannot test for interactions, two-way PERMANOVAs were used to test for differences over the time periods between plant communities. This allowed testing not only of the difference in main effect between survey-years and among plant communities but also for the interaction effect of compositional difference among plant communities that can differ between years.

The next natural step was identifying species that differentiate between the different plant community groups identified by the cluster analysis by performing a SIMPER analysis. Examining the pairwise comparisons from an ANOSIM with a SIMPER analysis will indicate where those differences lie between plant community groups and which wetland species are shared amongst them The SIMPER analysis identified species that are characteristic of, or distinguish between, groups of vegetation species data.

A *post hoc* test of one-way permutational multivariate analysis of variance (PERMANOVA), in PERMANOVA+, at 9999 permutations under a reduced model, was conducted to confirm the plant groupings identified in the cluster analysis, plant groups between the two survey years, environmental variables, and environmental variables between the two survey years.

A two factor PERMANOVA, in PERMANOVA+, at 9999 permutations under a reduced model, was conducted to test for the interaction effect between the effects of plant communities and year on differences in the plant species composition between the two time periods.

In the simplest form (*i.e.* one-way) PERMANOVA was used to compare differences due to the group effect of plant communities and survey year to total within-group differences (residual sum of squares) to test for the null hypothesis of no differences between groups (Anderson *et al.* 2008).

PERMANOVA and ANOSIM are both sensitive to differences in dispersion among groups, therefore homogeneity of multivariate dispersions is implicit in the partitioning between groups (Anderson *et al*. 2008). The PERMDISP routine in PERMANOVA+ was used to test for the homogeneity of multivariate dispersion among samples to assess the validity of significant difference determined by PERMANOVA.

Distance-based Linear Modelling (DISTLM) in PERMANOVA+ was used to determine the relative importance of individual environmental variables in explaining differences in the plant species composition between sites. An approach by DISTLM called distance-based Redundancy Analysis (dbRDA) (Lengendre & Anderson 1999; McArdle & Anderson 2001) a non-parametric multivariate multiple regression ordination procedure based on any given dissimilarity measure, was implemented as it fits values from the linear model with an overlay of those variables. *P*-values were tested by 9999 permutations of residuals under the reduced model. ‘Best’, a procedure, which examines for all possible combinations of predictor variables, was chosen as the selection procedure. The regression procedure incorporated an adjusted R^^{2}. Adjusted R^^{2} is used to compensate for the addition of environmental variables to the model (Anderson *et al.* 2008).

5.12 RESULTS

Fifty percent (15) of the wetlands studied in this part of the overall project were depression wetlands, 23% (7) were valley-bottom wetlands (both channelled and unchannelled), 17% (5) were salt pans, and the remaining 10% (3) were seeps.

A hundred and forty-two plant species were recorded in the present-day samples and 173 in the historical samples, in the 30 wetland study sites (Electronic appendices D and E). Of the 142 species in the present-day study, 114 were identified to species and 28 to genus. Of the 173 species in the King and Silberbauer study, 115 were identified to species and 58 to genus.

5.12.1 Characterization of plant communities and wetland types in 1988/89 and in 2012/13

Separate multivariate analyses were carried out on historical and present-day wetland plant species data in order to characterize wetland plant communities. The first step was to order the presence-absence data in a resemblance matrix. Both data sets were analysed using the Bray-Curtis measure of similarity, and no transformation of the data was needed.

Multivariate analysis of 1988/89 vegetation data

Hierarchical clustering (Figure 5-5) of the vegetation in the 30 wetlands identifies four plant communities at a similarity of 12% (SIMPROF, $p < 0.05$). The main groups in the dendrogram are identified by the black lines and the branches coloured red indicate that these samples (sites) are significantly similar. The corresponding MDS (Figure 5-6) low stress value of 0.12 indicates that the two-dimensional MDS plot is a good representation of the patterns in the data.

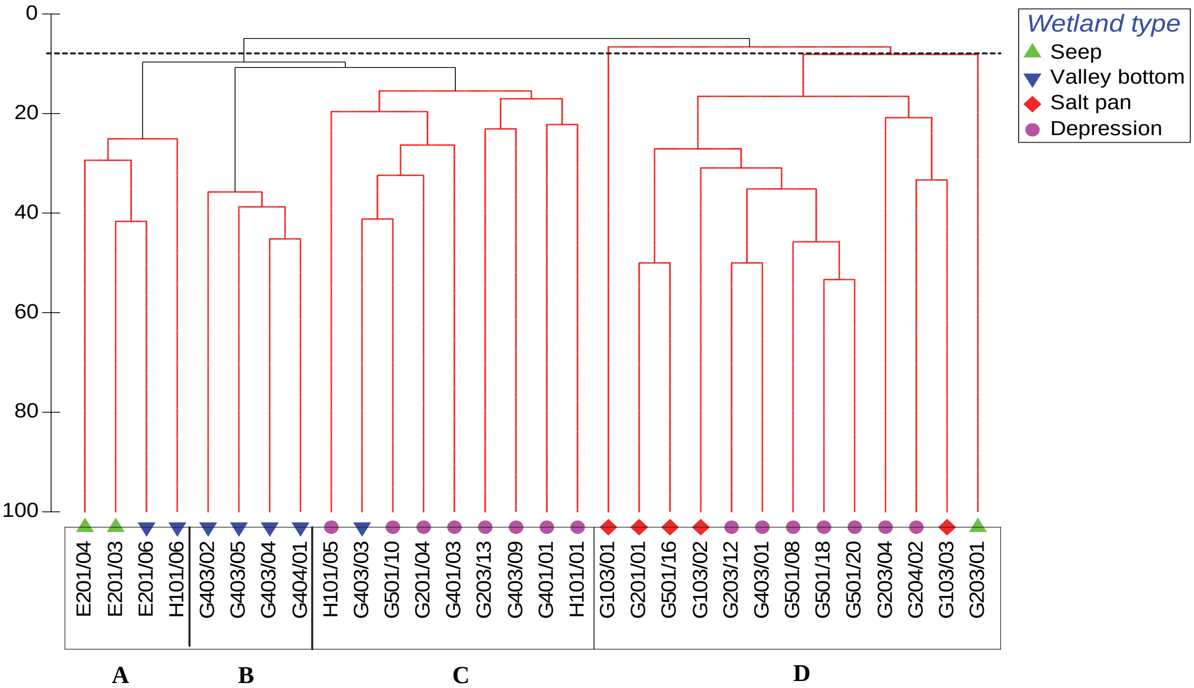

Figure 5-5: Hierarchical cluster analysis of plant assemblages in different wetland types for 1988/89. The main groups are identified by the black lines and the branches coloured red indicate that these samples (sites) are significantly similar. Wetlands may be identified by their wetland site codes (Table 5-2).

There is a gradient across the different plant groups from the upper left (Group A and Group B) to the lower right (Group D). Groups D and A have a very modest species composition effect (*i.e.* spread), while Group B has a much spread across the MDS. In general the MDS plot illustrates the differences between plant communities and the variation within the plant communities. The differences and/or similarities between the plant communities groups can be found in Table 5-3 (pair-wise comparison).

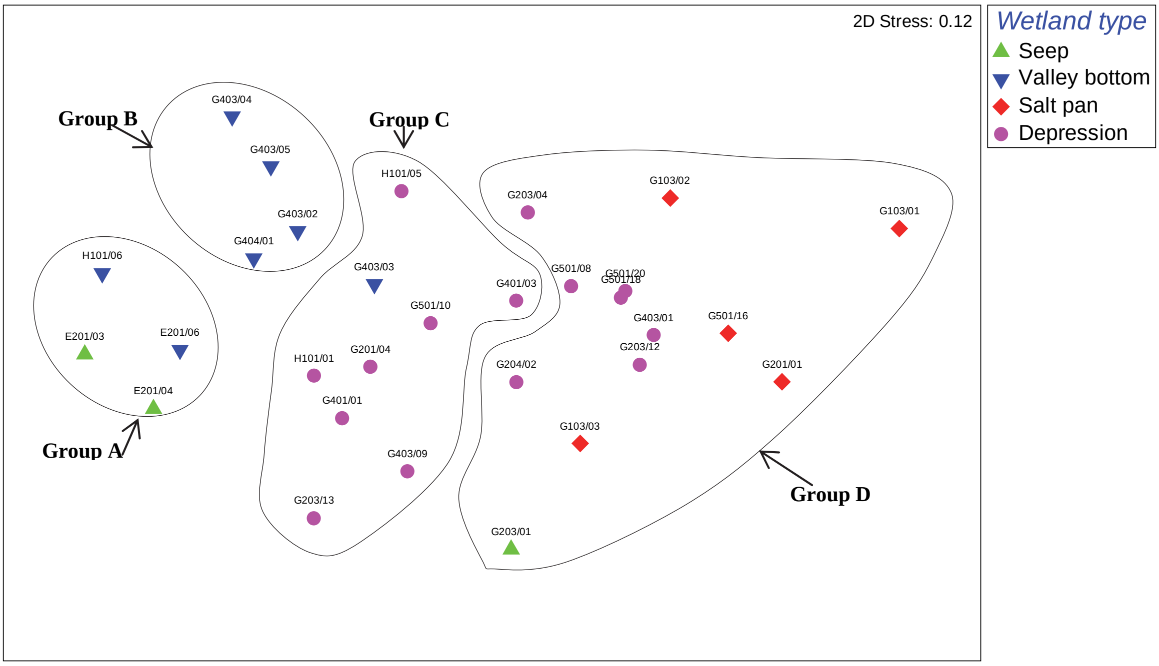

Figure 5-6: MDS plot of the wetland plant communities for wetland type (stress 0.12) as identified by the cluster analysis (n=30) for 1988/89. Wetlands may be identified by their wetland site codes.

The same vegetation data (of 1988/89) was used in the cluster analysis and MDS plots produced for wetland types, based on the HGM approach, to ascertain whether wetland plant communities reflect wetland type, *i.e.* using the same plots twice but illustrating different aspects. In general the plant community groups identified by the hierarchical cluster analysis (Figure 5-5) do not consistently group wetlands of the same type. Moreover, the gradient across the different plant groups in the MDS (Figure 5-6) is evident. The role of altitude in shaping community composition was clearly revealed by the clustering of high altitude (Table 5-2, altitude range from 883 to 1369 m) seeps and valley-bottoms (plant community group A) separately from the lower-altitude (Table 5-2, altitude range from 72 to 245 m) depressions and salt pans (plant community Group D).

ANOSIM was performed to test the null hypothesis that there are no significant differences in species composition between plant communities for 1988/89. Although the plant communities are highly significantly different (ANOSIM global $R = 0.62$, $p = 0.001$), the 'R' values are close to zero (Table 5-3). This suggests that some species occur in more than one group.

The pairwise comparisons (Table 5-3) reveals that the most dissimilar groups are A and B (R = 0.92), and groups A and D (R = 0.76). Additionally, groups A and D and groups D and B are more significantly different (p = 0.04) from each other than are groups A and B, (p > 0.05), while most significant similarity is observed groups D and C (R = 0.51, p = 0.01).

Table 5-3: Analysis of similarity of the Bray-Curtis resemblance of species composition identified by the cluster analysis for 1988/89. Groups significantly different from each other are marked with *.

Pairwise Tests			
Groups	**R Statistic**	**P-value**	**Possible Permutations**
A, B	0.92	2.9	35
A, D	0.76	0.04*	2380
D, B	0.70	0.04*	2380
A, C	0.63	0.1	715
C, B	0.57	0.1	715
D, C	0.51	0.01*	497420

SIMPER analysis of species composition was used to ascertain which species were characteristic of, and distinguished between, the different plant groups. As indicated by the low ‘R’ values in the ANOSIM (Table 5-3), the SIMPER analysis shows the species shared between plant groups. SIMPER analysis here reveals the percentage contribution of each species per group identified in the cluster analysis (Figure 5-6) for the historical vegetation data. The two species that contributed the most to each group are used to describe it.

The SIMPER results (Table 5-4) showed that the sites clustering in group A have an average similarity between pairs of sites of 29.3%, made up mainly of contributions from the species *Isolepis prolifera* (35.7%) and *Pennisetum macrourum* (35.7%). The sites in group B have an average similarity of 38.3% and are made up mainly of contributions from the three species *Calopsis paniculata* (18.4%), *Carpha glomerata* (18.4%) and *Cliffortia strobelifera* (18.4%). Sites in group C have an average similarity of 19.1% and are mainly characterized by *Typha capensis* (29.3%), *Juncus kraussii* (14.8%) and *Laurembergia repens* (10.3%). Finally, sites clustering as group D have an average similarity of 20.2% and are largely made up of *Juncus kraussii,* (36.6%) and *Sarcocornia natalensis* (32.4%). The species mentioned above can be considered to be ‘typical’ of each group. Several species describing communities are shared between more than one plant community group: *Isolepis prolifera* and *Pennisetum macrourum* are shared between groups A and C, *Prionium serratum* is shared between groups B and C, and *Juncus kraussii* and *Elegia tectorum* are common to plant communities C and D.

Table 5-4: Plant species characteristic of the four 1988/89 communities identified in the cluster analysis. Biotic and environmental differences between the communities are noted. (Phytogeographical centres: NW = Northwest, SW = Southwest, AP =Agulhas Plain).

<table>
<tr><th colspan="2">Plant community groups</th><th rowspan="2">Description</th></tr>
<tr><th>Species</th><th>Contribution %</th></tr>
<tr><td>Group A</td><td></td><td rowspan="9">Isolepis prolifera – Pennisetum macrourum community

Characterized by high altitude (883-1369 m) and fresh water species.
Wetland types include seeps and a channelled valley-bottom
Phytogeographical spread of wetlands: NW: E201/03, E201/04, E201/06, H101/06</td></tr>
<tr><td>Average similarity:</td><td>29.27</td></tr>
<tr><td>Isolepis prolifera</td><td>35.66</td></tr>
<tr><td>Pennisetum macrourum</td><td>35.66</td></tr>
<tr><td>Juncus lomatophyllus</td><td>4.95</td></tr>
<tr><td>Laurembergia repens</td><td>4.95</td></tr>
<tr><td>Cyperus thunbergii</td><td>4.74</td></tr>
<tr><td>Elegia capensis</td><td>4.74</td></tr>
<tr><td>Cumulative contribution</td><td>90.70</td></tr>
<tr><td>Group B</td><td></td><td rowspan="12">Calopsis paniculata – Carpha glomerata – Cliffortia strobilifera community

Characterized by fresh water species, systems mostly lotic, moderate altitudes (72-245 m).
Wetlands are all channelled valley-bottoms
Phytogeographical spread of wetlands: SW: G404/01, G403/02, G403/04, G403/05</td></tr>
<tr><td>Average similarity:</td><td>38.31</td></tr>
<tr><td>Calopsis paniculata</td><td>18.41</td></tr>
<tr><td>Carpha glomerata</td><td>18.41</td></tr>
<tr><td>Cliffortia strobilifera</td><td>18.41</td></tr>
<tr><td>Psoralea aphylla</td><td>8.27</td></tr>
<tr><td>Pteridium aquilinum</td><td>8.27</td></tr>
<tr><td>Platycaulos major</td><td>7.68</td></tr>
<tr><td>Prionium serratum</td><td>7.68</td></tr>
<tr><td>Erica curviflora</td><td>2.81</td></tr>
<tr><td>Wachendorfia thyrsiflora</td><td>2.81</td></tr>
<tr><td>Cumulative contribution</td><td>92.61</td></tr>
<tr><td>Group C</td><td></td><td rowspan="17">Typha capensis – Juncus kraussii community

Characterized by brackish to fresh water species, high nutrients, low to moderate altitudes (4-263 m).
Wetland types include depressions and a channelled valley-bottom
Phytogeographical spread of wetlands:
NW: H101/01
SW: G203/13, G401/03 and G403/03
AP: G501/10.</td></tr>
<tr><td>Average similarity:</td><td>19.06</td></tr>
<tr><td>Typha capensis</td><td>29.34</td></tr>
<tr><td>Juncus krausii</td><td>14.81</td></tr>
<tr><td>Laurembergia repens</td><td>10.29</td></tr>
<tr><td>Phragmites australis</td><td>6.48</td></tr>
<tr><td>Centella asiatica</td><td>5.63</td></tr>
<tr><td>Prionium serratum</td><td>3.65</td></tr>
<tr><td>Elegia fistulosa</td><td>3.39</td></tr>
<tr><td>Psoralea pinnata</td><td>3.09</td></tr>
<tr><td>Isolepis prolifera</td><td>2.51</td></tr>
<tr><td>Juncus lomatophyllus</td><td>2.45</td></tr>
<tr><td>Senecio halimifolius</td><td>2.31</td></tr>
<tr><td>Aponogeton distachyos</td><td>1.27</td></tr>
<tr><td>Polygonum sp.</td><td>1.21</td></tr>
<tr><td>Persicaria decipiens</td><td>1.17</td></tr>
<tr><td>Conyza scabrida</td><td>1.12</td></tr>
</table>

Elegia tectorum	1.08	
Pennisetum macrourum	1.08	
Cumulative contribution	**92.76**	
Group D		*Juncus kraussii – Sarcocornia natalensis* community
Average similarity:	**20.21**	Characterized by mostly brackish to saline species, low to moderate altitudes (2-272 m) Wetland types found in this group include salt pans, depressions and seeps. Phytogeographical spread of wetlands: NW: G103/01, G103/02 and G103/03. SW: G203/04, G204/02, G203/12, G203/01 and G403/01 AP: G501/08, G501/16, G501/18 and G501/20.
Juncus krausii	36.55	
Sarcocornia natalensis	32.38	
Elegia tectorum	11.13	
Bolboschoenus maritimus	7.90	
Sporobolus virginicus	4.64	
Cumulative contribution	**90.89**	

The *post hoc* test of the one-way PERMANOVA was conducted to confirm the plant grouping identified in the cluster analysis and revealed that these groupings are significantly different ($p = 0.001$). PERMDISP, performed to test the homogeneity of dispersions, suggests, however, that the differences between plant groups are not significant ($p = 0.633$). A non-significant PERMDISP with a significant PERMANOVA means that there is no difference in the dispersion between the plant groups but significant differences in the position of the group centroids.

In summary, for the historical data, four plant communities and their main indicator species were identified. The differences between the plant community groups were found to be significantly different, but differences should be recognized within the plant groups rather among them. The cluster analysis (Figure 5-5) and MDS plot (Figure 5-6) indicate that the identified plant communities group wetlands of the same type, but not consistently. The next step was to follow the same analysis procedure for the 2012/13 vegetation data and then to see whether the plant communities have changed from those identified for 1988/89.

Multivariate analysis of vegetation data collected for 2012/13

The hierarchical clustering (Figure 5-7) of the vegetation in the 30 “present-day” wetlands identifies five plant communities distinct at a similarity of 8% (SIMPROF, $p < 0.05$). The main groups in the dendrogram are identified by the black lines and the branches coloured red indicate that these samples (sites) are significantly similar. The low stress value of 0.1 indicates that the two-dimensional MDS plot (Figure 5-8) is a good representation of the patterns in the data.

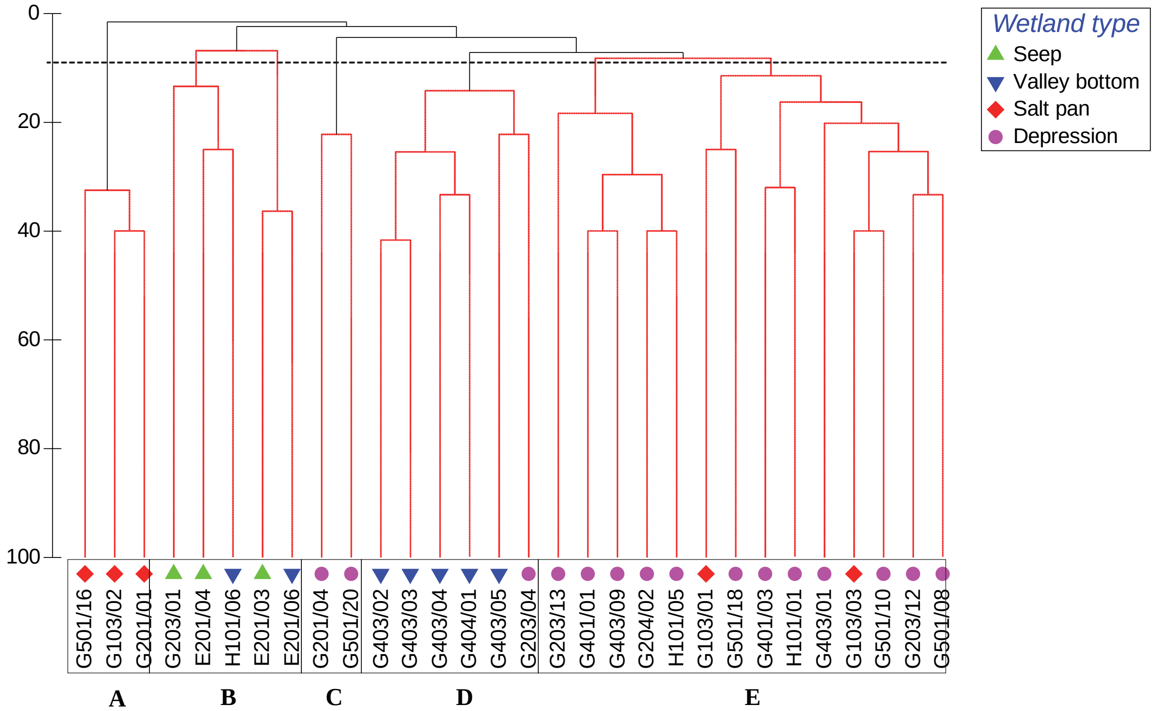

Figure 5-7: Hierarchical cluster analysis illustrating the main plant communities for wetland types for 2012/13. The main groups are identified by the black lines and the branches coloured red indicate that these samples (sites) are significantly similar. Wetlands may be identified by their wetland site codes (Table 5-20.

The gradient across the different plant communities is not as clear in this data set as in the previous MDS plot of 1988/89 (Figure 5-6). Furthermore, there is a trend from the left (Group Band D) to the lower right (Group A). More specifically, Groups C and A have a very modest species composition effect (*i.e.* spread), while Group E has a much larger effect, with a wider spread up the MDS plot. In general the MDS plot illustrates the differences between plant communities and the variation within them (ANOSIM, pair-wise comparison, Table 5-5 (ANOSIM, pair-wise comparison).

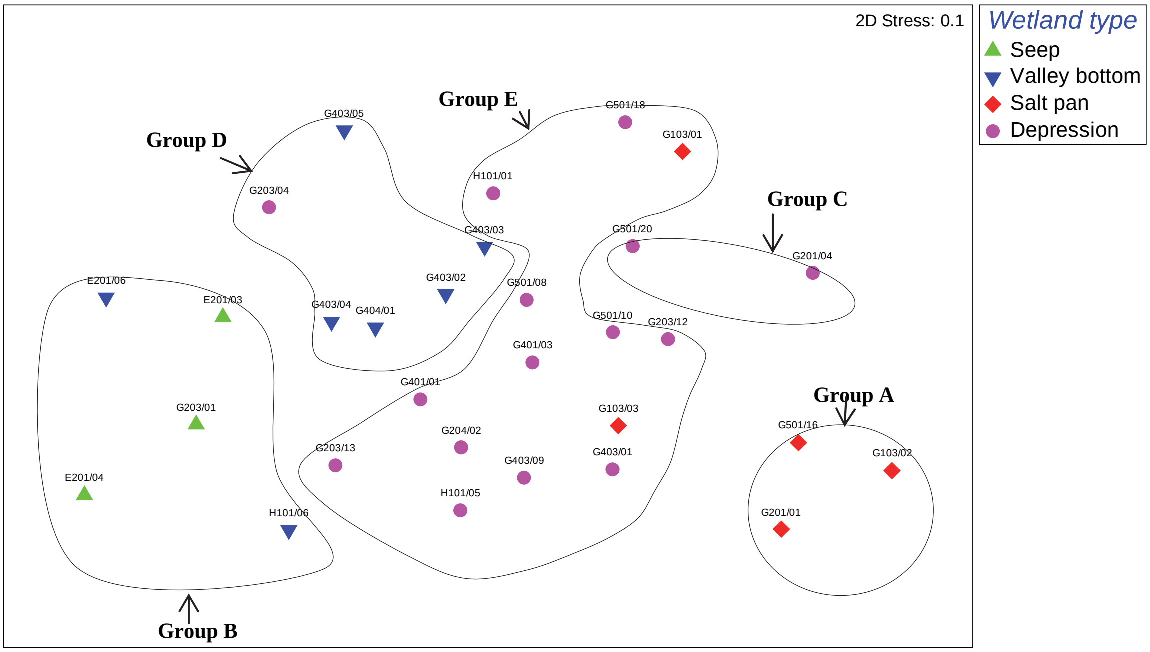

Figure 5-8: MDS plot of the wetland plant communities for wetland type (stress 0.1) as identified by the cluster analysis (n=30) for 2012/13. Wetlands sites may be identified by their wetland site codes.

The same vegetation data was used in the cluster analysis and MDS plots produced for wetland types, to ascertain whether wetland plant communities reflect wetland type, *i.e.* using the same plots twice but illustrating different aspects. In general the plant community groups identified by the hierarchical cluster analysis (Figure 5-7) do not consistently group wetlands of the same type. Moreover, the gradient across the different plant groups in the MDS plot (Figure 5-8) illustrated the role of altitude and wetland water chemistry in shaping community composition. High-altitude (Table 5-2, altitude range from 272 to 1369 m) freshwater wetlands seeps and valley-bottoms (plant community group B) separated from the lower-altitude (Table 5-2, altitude range from 2 to 57 m) saline (plant community group A) wetlands.

ANOSIM revealed significant differences in species composition of different plant community groups for 2012/13 (global R = 0.55, p = 0.001). The null hypothesis, that there is no difference in observed communities, is supported when the ‘R’ values are equal or close to zero. Examining the pairwise comparisons (Table 5-5) from the ANOSIM with a SIMPER analysis indicates where those differences lie and which species are shared amongst the groups. In the pairwise test (Table 5-5) many of the groups differ, but not significantly, except for groups D and E (R=0.57, p = 0.01). The most dissimilar are groups A and C (R=1), groups A and D, and groups C and D but the relationships between the groups is not significant (p > 0.05). The ‘R’ values close to zero (*e.g.* groups E and D) signifies an overlapping of species between the groups.

Table 5-5: Analysis of similarity of the Bray-Curtis resemblance of species composition of plant communities for 2012/13. Significant groups different are marked with *.

Pairwise tests			
Groups	**R Statistic**	**Significance level %**	**Possible permutations**
A, C	1	10	10
A, D	0.944	1.2	84
C, D	0.807	3.6	28
B, A	0.769	1.8	56
B, C	0.727	4.8	21
B, D	0.7	0.2	462
B, E	0.573	0.01*	11628
E, A	0.532	0.1	680
E, C	0.417	0.8	120
E, D	0.378	0.06	38760

The SIMPER analysis reveals the percentage contribution of each species per plant group identified in the cluster analysis. The two species that contribute most to each group are used to describe that group.

The SIMPER analysis (Table 5-6) showed that the sites clustering in Group A have an average similarity between pairs of sites of 35.0%, made up mainly of contributions from *Sarcocornia natalensis* (100%) a salt tolerant species. The sites in group B have an average similarity of 12.9% and are chiefly made up of *Pennisetum macrourum* (71.8%) with equal contributions from *Elegia capensis* and *Psoralea oligophyla* (14.1% each). The sites in group C have an average similarity of 22.2% and are characterized by *Ficinia nodosa* (100%). The species contributing most to group D are *Calopsis paniculata* (13.5%) and *Cliffortia strobilifera* (13.5%) and have an average similarity between pairs of sites of 20.8%. Lastly, sites clustering as group E have an average similarity of 14.0%, and are characterised by *Phragmites australis* (33.4%) and *Juncus kraussii* (23.2%). The species mentioned above can be considered to be ‘typical’ of each group. Several species are shared between more than one plant community groups, namely *Phragmites australis* and *Pennisetum cladestinum* are both shared in group D and E.

Table 5-6: Plant species characteristic for 2012/13 communities identified in the cluster analysis. Biotic and environmental differences between the communities are noted. (Phytogeographical centres: NW = Northwest, SW = Southwest, AP = Agulhas Plain).

Plant community groups		**Description**
Species	**Contribution %**	
Group A		*Sarcocornia natalensis community* Similar to historic group D Characterized by species tolerant of saline conditions found at altitudes ranging from 2-57 m. Wetland types found in this group are salt pans Phytogeographical spread of wetlands: NW: G103/02 and G201/01 AP: G501/16
Average similarity:	**35.00**	
Sarcocornia natalensis	100	
Cumulative contribution	100	
Group B		*Pennisetum macrourum – Elegia capensis community* Similar to group A of 1988/89 Characterized by high altitude wetlands (1369-272 m) with fresh water species Wetland types found in this group include seeps and valley-bottoms Phytogeographical spread of wetlands: NW: E201/06 and E201/03 and H101/06 SW: G204/01
Average similarity:	**12.91**	
Pennisetum macrourum	71.83	
Elegia capensis	14.08	
Psoralea oligophylla	14.08	
Cumulative contribution	**100**	
Group C		*Ficinia nodosa community* Arose from historic group C Characterized by brackish species at low altitude of 7-11 m. Wetland type found in this group are depressions Phytogeographical spread of wetlands: NW: G201/04 AP: G501/20
Average similarity:	**22.22**	
Ficinia nodosa	100	
Cumulative contribution	**100**	
Group D		*Calopsis paniculata – Cliffortia strobelifera community* Similar to group B of 1988/89 Characterized by freshwater species at low to moderately high altitudes (8-228 m)
Average similarity:	**20.84**	
Calopsis paniculata	13.52	
Cliffortia strobilifera	13.52	
Berzelia lanuginosa	11.45	

Prionium serratum	10.79	Wetland types found in this group are valley-bottoms Phytogeographical spread of wetland sites: SW: G404/01, G403/02, G403/04 and G403/03
Pteridium aquilinum	8.25	
Psoralea aphylla	7.91	
Carpha glomerata	7.40	
Isolepis prolifera	6.13	
Phragmites australis	6.13	
Laurembergia repens	3.37	
Pennisetum clandestinum	2.56	
Cumulative contribution	**91.03**	
Group E		*Phragmites australis – Juncus kraussii community* Similar to historic group C & D Characterized by brackish to freshwater species, some of which establish in high nutrient wetlands ranging from low to moderately high altitudes (4-263 m). Wetland types found in this group are depressions Phytogeographical spread of wetlands: NW: G103/01 and G103/03, H101/01 and H101/05 SW:G203/12, G203/13 and G204/02
Average similarity:	**14.04**	
Phragmites australis	33.37	
Juncus kraussii	23.21	
Typha capensis	8.88	
Persicaria decipiens	7.78	
Pennisetum clandestinum	5.77	
Mentha aquatica	5.19	
Schoenoplectus scirpoides	2.61	
Searsia lucida	2.45	
Centella asiatica	2.29	
Cumulative contribution	**91.54**	

The *post hoc* test of the one-way PERMANOVA, conducted to confirm the plant groupings identified in the cluster analysis (Figure 5-8), revealed that these groupings are significantly different (p = 0.001). The PERMDISP, performed to test the homogeneity of dispersions, suggests that the differences between plant groups is not significant (p = 0.675), however. A non-significant PERMDISP and a significant PERMANOVA result means that there is no difference in the dispersion between the plant community groups but significant differences in the position of the plant community group centroids.

In summary, for the present-day vegetation data, five significantly distinct plant communities and their main indicator species were identified. The differences between the plant groups were found to be significant, but differences should be recognized within the plant groups rather among them. The SIMPER analysis revealed species such as *Sarcocornia natalensis* and *Ficinia nodosa* as 'typical' single dominant species describing groups A and C, respectively. Many of the plant communities in the present-day data are similar to those found in the historical data set but vary in terms of percentage species contribution. For example historical group A, characterized as an *Isolepis prolifera* (35.7%) – *Pennisetum macrourum* (35.7) community type, is described in the present-day group B as a *Pennisetum macrourum* (71.8%) – *Elegia capensis* (14.1%) community type, indicating a shift in the diagnostic plant species over time, as suggested and supported by the PERMDISP. Furthermore, *Ficinia nodosa* characterizes a plant community group in the present-day vegetation data that was not evident in the historical data. The cluster analysis, supported by the SIMPER analyses, indicated that the plant groups do not consistently group wetlands of the same type.

The next step was to analyse the correlations between the environmental variables and the plant species assemblages of 1988/89 and 2012/13.

5.12.2 Environmental variables influencing plant species distribution in the wetlands

Table 5-8 lists the values for the variables; altitude, electrical conductivity (EC), pH, phosphate, nitrite + nitrate, ammonium and rainfall for both periods. EC historically ranged from 70 to 9770 mS/m and the present-day values from 1.5 to over 17 000 mS/m. While pH values range historically from 6.4 to 9.8, with the majority between 6 and 7, a few acidic wetlands increase the present-day range from 3.8 to 9.4. Many of the wetlands in the historic study had phosphate values of <0.01 mg/L, which is the detection limit, but phosphate values range from 0.003 to 3.051 mg/L in the present-day data set. Nitrite + nitrate ranged from 0.01 to 1.31 mg/L in the historical data set whereas present-day values are lower, ranging from 0.003 to 0.803 mg/L. Historically, ammonium values range from < 0.01 (detection limit) to 3.6 mg/L and present-day values from <0.01 to 1.51 mg/ L. Rainfall ranged from 263 to 1250 mm per annum in the historical data set whereas in the present-day study the range was 398 to 1374 mm per annum.

Table 5-7: Environmental variables for the 1988/89 and 2012/13 study wetlands[4].

Wetland name	Wetland code	Alt (m)	EC (mS/m)		pH		Phosphate (mg P/L)		Nitrites + Nitrates (mg N/L)		Ammonium (mg N/L)		Rainfall (mm/a)	
			1988/89	**2012/13**	**1988/89**	**2012/13**	**1988/89**	**2012/13**	**1988/89**	**201/13**	**1988/89**	**2012/13**	**1988/89**	**2012/13**
Blomfontein	E201/03	1310		4.63		7.2	<0.01	0.003	0.01	0.043	0.03	0.034	499	1374
Driehoek	E201/06	890		1.88		7.55	<0.01	0.005	0.32	0.056	0.04	0.062	430	1374
Kiekoesvlei	G103/01	55		49.5		7.4		0.216		0.803		1.508	396	1374
Koekiespan	G103/02	57	70	18300	9.8	7.76	<0.01	0.125	0.28	0.236	3.60	1.412	354	443
Burgerspan	G103/03	70	9730	13260	7.8	7.77		0.155		0.008		0.547	354	443
Rooipan	G201/01	2	9770	4440	7.3	9.45	<0.01	0.582	0.02	0.01	0.80	0.441	354	443
Rondeberg	G201/04	15	4250	322	8.2	7.43	<0.01	0.014		0.003	0.08	0.045	418	443
Kleinplaats West	G203/01	270	552	180	8.9	4.6	<0.01	0.007		0.063	<0.01	0.065	417	443
Groot Rondevlei	G203/04	3		60		4.04	<0.01	0.014		0.003	<0.01	0.0313		699
Noordhoek Salt Pan	G203/12	3	1561	31.2	7.8	6.7	0.17	0.077		0.006	0.78	0.002	335	699
Kenilworth Race Course	G203/13	25	417	1.58	8.1	4.04	<0.01	0.013		0.008	1.02	0.026	750	596
Silvermine Dam Inflow	G203/18	455	23	3.96	4.2	7.67	<0.01	0.022	0.02	0.011	0.11	0.007	765	466
Khayelitsha Pool	G204/02	18	1042	78.7	7.9	7.97		0.728		0.637		0.287	426	655
Malkopsvlei	G401/01	10	72	1447	6.8	8.75	<0.01	0.003	0.03	0.049	0.06	0.06	426	655
Groot Witvlei	G401/03	8		30.9		6.5		0.005		0.063		0.053	1146	919
Vermont Pan	G403/01	18	123.5	19.4	8.3	7.79	0.60	0.231	0.14	0.128	<0.01	0.3159	1146	919

[4] Based on the results obtained from the Dept. of Oceanography, UCT.

Wetland name	Wetland code	Alt (m)	EC (mS/m)		pH		Phosphate (mg P/L)		Nitrites + Nitrates (mg N/L)		Ammonium (mg N/L)		Rainfall (mm/a)	
			1988/89	2012/13	1988/89	2012/13	1988/89	2012/13	1988/89	201/13	1988/89	2012/13	1988/89	2012/13
Hemel-en-Aarde	G403/02	72	500	11.8	8.2	3.8	<0.01	0.003	0.05	0.003	0.17	0.0272	636	919
Elias Gat	G403/03	133		138		6.24	<0.01	0.003	0.05	0.255	0.28	0.0737	591	919
Belsvlei	G403/04	260		26.2		5.48	<0.01	0.003	0.04	0.142	0.04	0.0372	624	919
De Diepte Gat	G403/05	270		68.5		6.22	<0.01	0.007		0.016	0.80	0.0397	779	919
Gans Bay	G403/09	37		147		6.05	<0.01	0.06		0.003	0.03	0.034	767	919
Salmonsdam	G404/01	160	163	166.5	8.5	6.32	<0.01	0.005	0.01	0.003	0.80	0.0078	465	919
Soetendalsvlei	G501/08	2		20.8		5.4	<0.01	0.003	0.12	0.045	0.21	0.055	603	554
Pearly Beach	G501/10	2	445	1800	6.4	7.6	<0.01	0.009	0.01	0.003	0.03	0.0587	457	554
Groot Hagel kraal	G501/14	77	164	4250	7.9	8.05	<0.01	0.014		0.003	0.16	0.0264	601	554
Melkbospan	G501/16	30		189		7.5	0.01	0.01		0.091	0.14	0.239	584	554
Wiesdrif	G501/18	4	1561		7.8		<0.01	0.107		0.003	0.04	0.0317	519	554
Varkensvlei	G501/20	4	109	32	7.3	6.24	<0.01	0.013		0.152	0.39	0.0959	456	554
Bokkekraal	H101/01	198	566	36	6.9	6.2	<0.01	0.003		0.463	0.02	0.037	402	554
Verrekyker	H101/05	252					<0.01	0.127		0.103	0.03	0.049	427	456
De Vlakte	H101/06	881				7.6	<0.01	0.03		0.746	0.04	0.127	511	1374

Multivariate analysis of environmental variables

Complete environmental data were available for 17 wetland sites in the historical period so analysis of environmental variables was performed on this subset of the wetlands for both periods (n=17). Four variables were examined: pH, conductivity, altitude, and annual rainfall. Nutrient analyses for the historic data are patchy and were therefore not included as this would have resulted in further reduction of sample size. Environmental and water chemistry data of seven variables for 30 wetland sites in the present-day study were examined separately to investigate relationships with the plant communities. Together with the four variables used in the historical data, nutrient measurements for phosphate, nitrite + nitrate, and ammonium were included. The environmental data were normalised and analysed using Euclidean distance.

Distance-based Linear Modelling (DistLM) was used to determine which environmental variables were most responsible for differences in the species assemblages of the different plant communities. “Best”, which examines all possible combinations of predictor variables was chosen as the selection procedure. The regression procedure incorporated an adjusted R^2. A dbRDA constrained ordination was used to fit the values from the linear model with an overlay of those variables. Separate DistLM analyses were carried out on the historical and present data.

Historical relationship between plant assemblages and environmental variables

The DistLM results for the historic data (data not shown) revealed that none of the environmental variables are statistically significant ($p > 0.05$) in explaining the relationship between the plant species communities and the environmental variables for 1988/89.

Present-day relationship between plant assemblages and environmental variables

The seven present-day variables considered in the DistLM analysis are pH, conductivity, altitude, rainfall, phosphate, nitrite + nitrate and ammonium. The DistLM (Table 5-8) reveals that the environmental variable best explaining the relationship between the plant species communities is altitude ($p = 0.0005$), which explains 7.6% of the total variation observed. Another variable yielding statistically significant results is pH ($p = 0.0035$, 6.2% of the variation). Conductivity (EC) explains 5.0 % of the variation in the model but it is only marginally significant ($p = 0.0413$). Results for ammonium, rainfall, phosphate and nitrite + nitrate are non-significant ($p > 0.05$) and explain < 5.0% of the variation in the model. Figure 5-9 shows the DistLM results by means of a dbRDA plot, where wetlands E201/06 and E201/03 are highly influenced by the altitude axis, G103/02, G103/03 and G201/01 are influenced by the EC and pH axis, H101/01 and G204/02 are influenced by the nitrite + nitrate axis, and H101/06 and G403/05 by the ammonium axis.

Table 5-8: Test statistics of the DistLM, based on "Best" procedure and adjusted R^2 selection criterion of transformed environmental variables for wetland species composition for 2012/13 data. Significant results are marked with an *.

DistLM ANOVA table of results					
Variables	**SS**	**Pseudo-F**	***P*-value**	**Prop (%)**	**Res *df***
Alt (m)	9206	2.2055	0.0005*	7.55	27
pH	7595.5	1.794	0.0035*	6.23	27
EC (mS/m)	6105.7	1.4236	0.0413*	5.01	27
Ammonium (mg N/L)	5293.5	1.2256	0.1695	4.34	27
Rainfall (mm/a)	5182	1.1987	0.2129	4.25	27
Phosphate (mg P/L)	4535.3	1.0433	0.4312	3.72	27
Nitrate + Nitrite (mg N/L)	4286.1	0.98389	0.495	3.52	27

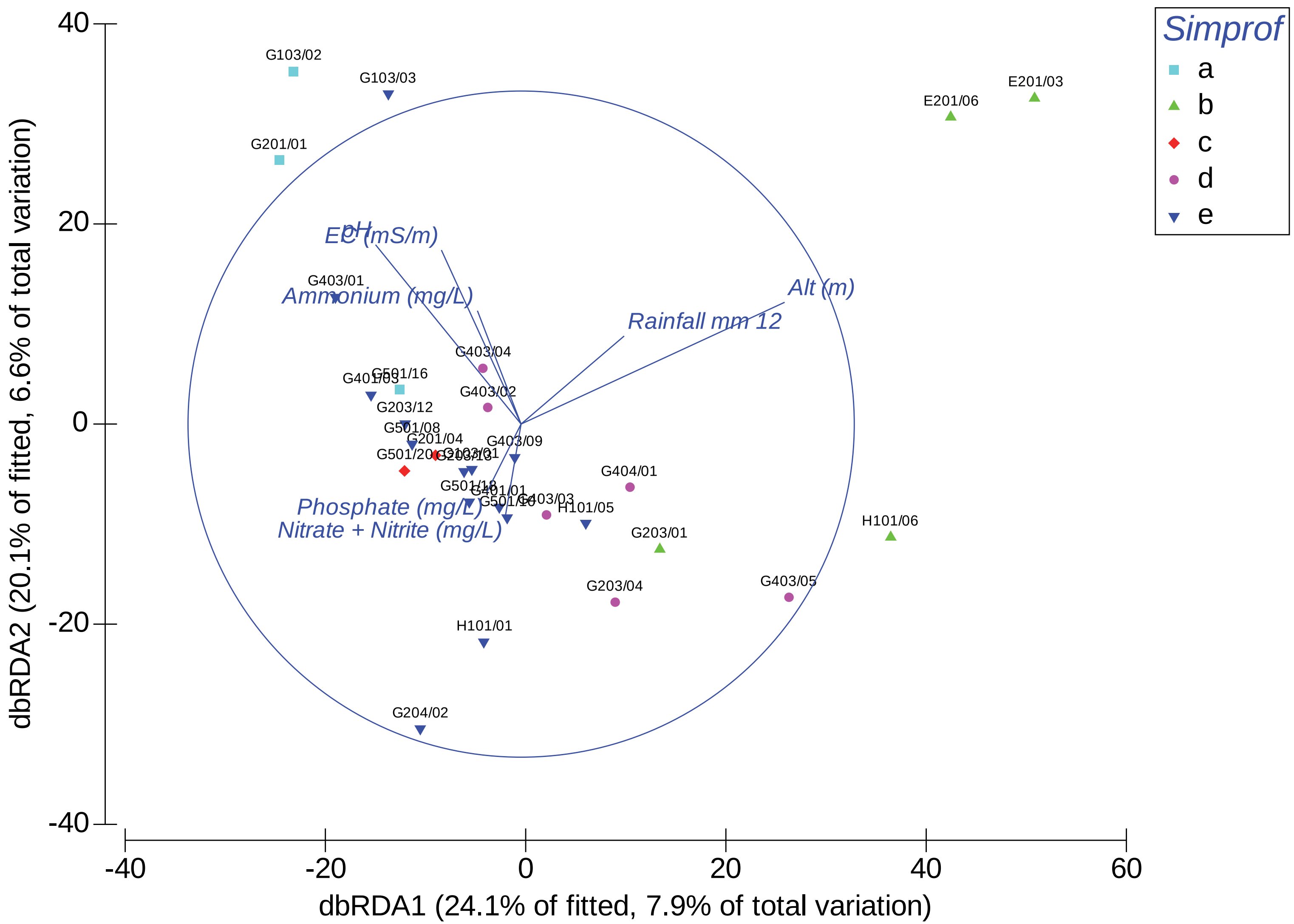

Figure 5-9: dbRDA ordination plot showing the relationship between present-day plant assemblages and the environmental variables in a DistLM model for 2012/13 (n=30). Wetlands may be identified by their wetland site codes. The different symbols (a-e) indicate the plant communities identified in Figure 5-8.

In summary, none of the environmental variables was shown to be significant ($p > 0.05$) in explaining the relationship between the plant species communities in the historic data set. Altitude was the major variable correlating to the plant species communities in present-day data set. EC and pH significantly ($p < 0.05$) related to plant species communities in the historic data set but rainfall and phosphate were not.

5.12.3 *Have the wetland plant communities changed over time and has surrounding land-use influenced these changes?*

Multivariate analysis of plant assemblages

Historic and present plant data were combined to examine the effect of survey year (*i.e.* change over time) on species composition of the different plant assemblages and environmental variables (n = 30 wetlands x 2 survey years).

The hierarchical clustering (Figure 5-10) of the vegetation in the 60 wetland samples identifies nine distinct plant communities at a similarity of 10% (SIMPROF, $p < 0.05$). The main groups, in the dendrogram, are identified by the black lines and the branches coloured red indicate that these samples (sites) are significantly similar. The low stress value of 0.13 indicates that the two-dimensional MDS plot (Figure 5-11) is a good representation of the patterns in the data. Changes in plant community type over time, indicated with colour arrows, are observed for eight wetland sites.

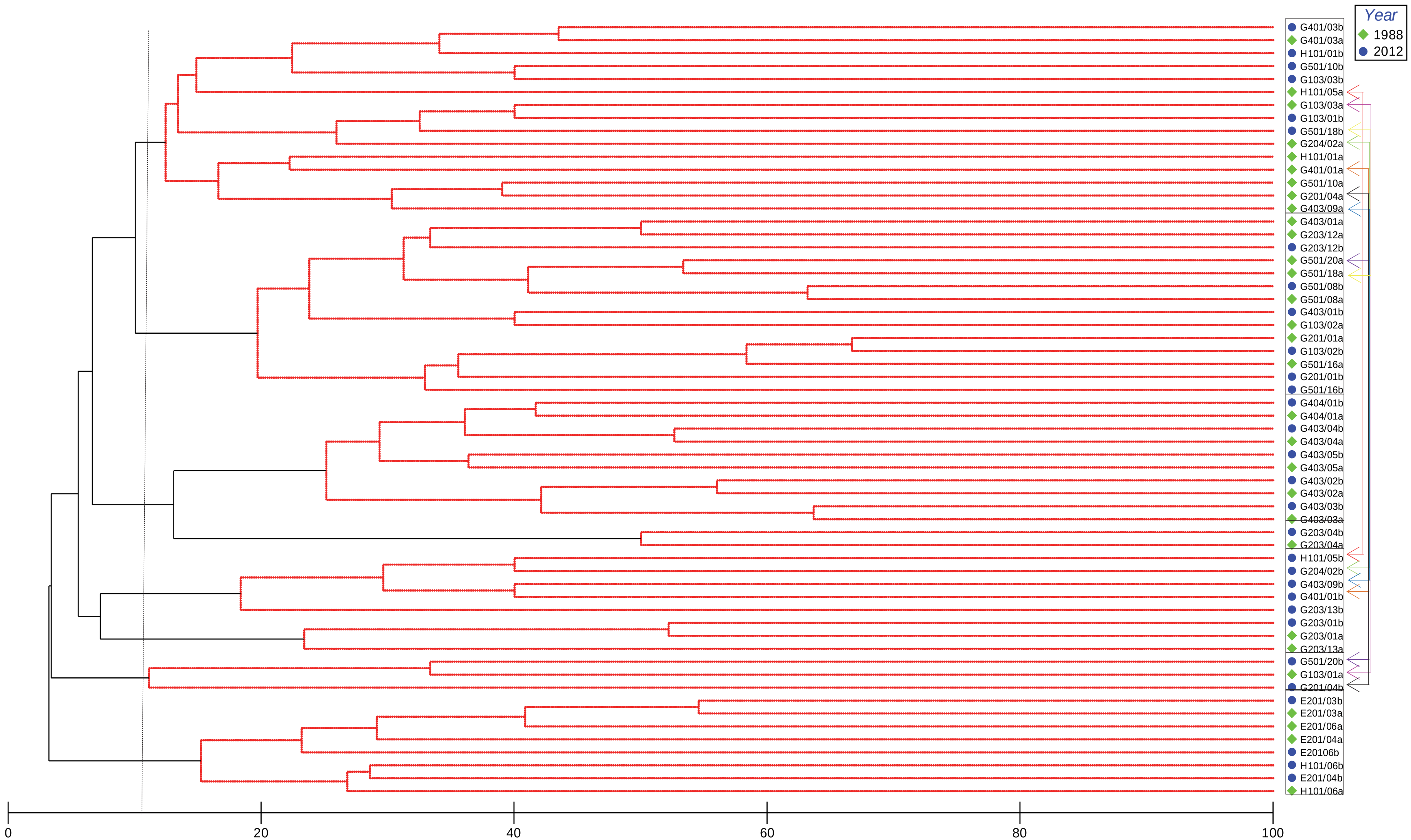

Figure 5-10: Hierarchical cluster dendrogram of the nine plant communities identified for 1988/89 (green triangle) and 2012/13 (blue triangle) (n=60). The colour arrows indicate change in plant communities of wetland sites. Wetlands may be identified by their wetland site codes (Table 5-2).

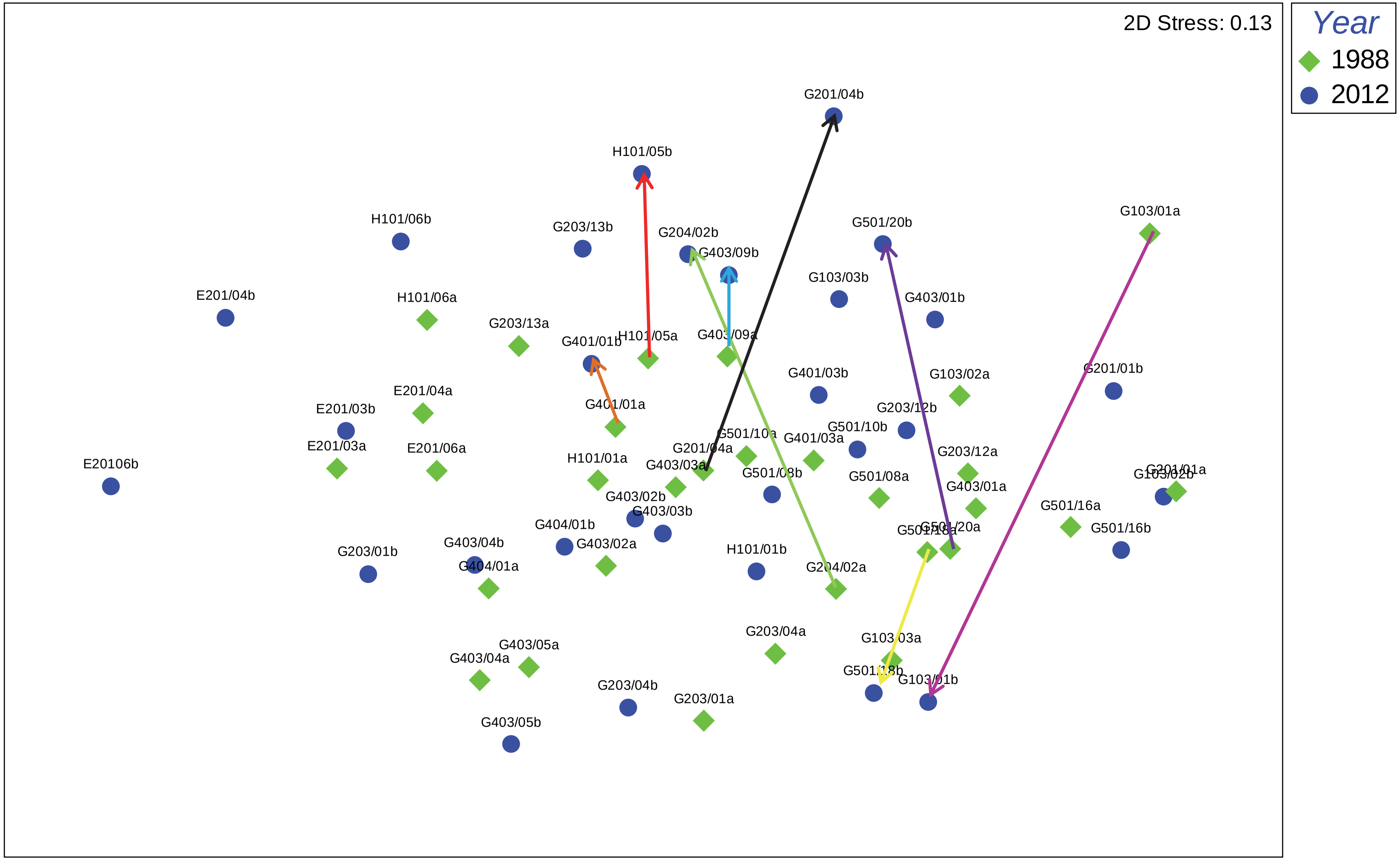

Figure 5-11: MDS plot of the species composition data of 1988/89 and 2012/13 (n=60). The colour arrows indicate change in plant communities of wetland sites, as identified in the cluster analysis (Figure 5-10). Wetlands sites may be identified by their wetland site codes (Table 5-2).

The MDS plot of the vegetation species assemblage data (Figure 5-11) illustrates the wetland sites whose plant communities shifted most over time, as revealed and indicated by the cluster analysis. These wetlands with the respective colour arrows indicate the magnitude of the shifts include: G103/01 (pink arrow: Koekiesvlei, a coastal depression located on the West Coast, SW phytogeographic centre); G201/04 (black arrow: Rondeberg, a coastal depression located on the West Coast, SW phytogeographic centre); G204/02 (green arrow: Khayelitsha pool, a floodplain wetland that functions as a depression found in Khayelitsha on the Cape Peninsula, SW phytogeographic centre); G401/01 (orange arrow: Malkopsvlei, a coastal depression in Betty's Bay, SW phytogeographic centre); G403/09 (blue arrow: Gans Bay, a depressional wetland in Gans Bay, SW phytogeographic centre); G501/18 (yellow arrow: Wiesdrif, a depressional wetland on the Agulhas plain); G501/20 (purple arrow: Varkensvlei, a depressional wetland surrounded by agriculture on the Agulhas Plain); and H101/05 (red arrow: Verrekyker, a depressional wetland in Wolseley, NW phytogeographic centre). The proximity of the sample points on the MDS plot (Figure 5-11) illustrates and reveals the magnitude of change in multivariate space. If plant communities had not changed one would expect sample sites from different years to be similar, so dissimilarities would suggest shifts in vegetation. Table 5-9 provides a summary description of the historical and present-day plant communities at the eight wetland sites that have changed over the sampling period of 1988/89 to 2012/13.

The one-way PERMANOVA confirmed the plant groupings identified in the cluster analysis, and revealed that these groupings are significantly different ($p = 0.001$). Two-way crossed ANOSIM revealed a significant difference (global $R=0.74$, $p=0.001$) between the plant community groups across the survey years. The two-factor PERMANOVA to test change over time of the plant species composition and environmental variables across the years revealed the effects of survey years to be significant ($p < 0.05$) for plant species composition, supporting the ANOSIM, and insignificant ($p > 0.05$) for the environmental variables. In general, time had no effect on environmental variables although differences in the species composition between the plant communities are significant. Furthermore, it must be noted that there may be changes in the measured environmental variables that do not affect species presence/absence but may affect the dominance of certain species.

Table 5-9: Historical and present-day plant communities of the eight wetland sites that have changed over the sampling period of 1988/89 to 2012/13. (h – historical, p – present-day plant community groups).

Wetland code and name	**Plant communities**	
	1988/89	**2012/13**
G103/01 (pink) Koekiesvlei	*Juncus kraussii – Sarcocornia natalensis* (h – group D)	*Phragmites australis – Juncus kraussii* (p – group E)
G201/04 (black) Rondeberg	*Typha capensis – Juncus kraussii* (h – group C)	*Ficinia nodosa* (p – group C)

Wetland code and name	Plant communities	
	1988/89	**2012/13**
G204/02 (green) Khayelitsha pool	*Juncus kraussii – Sarcocornia natalensis* (h – group D)	*Phragmites australis – Juncus kraussii* (p – group E)
G401/01 (orange) Malkopsvlei	*Typha capensis – Juncus kraussii* (h – group C)	*Phragmites australis – Juncus kraussii* (p – group E)
G403/09 (blue) Gans Bay	*Typha capensis – Juncus kraussii* (h – group C)	*Phragmites australis – Juncus kraussii* (p – group E)
G501/18 (yellow) Wiesdrif	*Juncus kraussii – Sarcocornia natalensis* (h – group D)	*Phragmites australis – Juncus kraussii* (p – group E)
G501/20 (purple) Varkensvlei	*Juncus kraussii – Sarcocornia natalensis* (h – group D)	*Ficinia nodosa* (p – group C)
H101/05 (red) Verrekyker	*Typha capensis – Juncus kraussii* (h – group C)	*Phragmites australis – Juncus kraussii* (p – group E)

Analysis of land-use changes

GIS mapping of aerial images of the land-use practices in and around the wetlands was used to explore potential reasons for changes in plant assemblages over time. (See Electronic appendix F for aerial photographs). Table 5-10 shows estimated changes in area over the study period with the historic and present-day plant species community groups previously identified in the cluster and described by SIMPER analysis, environmental results and plant species data. It provides a summary of the results found in the statistical analysis of plant species assemblages, environmental variables and land-use and how they correlate for 23 wetland sites.

The analyses indicate that 48% (11 wetlands) of the wetland sites experienced a change in land-use. Four percent (1 wetland) experienced an increase in surrounding agriculture; land-use around 13% (3) depressions and salt pans changed from agricultural to conserved land, many of these wetlands have shifted in terms of the dominant species which describe them. Another 30% (7 wetlands) of the sites, all depressional wetlands, experienced an increase in urban/informal residential development. Of these, three support species such as *Typha capensis* and *Phragmites australis* that are indicative of nutrient enrichment or more continuous inundation. Twelve wetlands, especially depressions, have experienced an introduction of, or increase in cover of, alien and/or invasive species since the previous survey. Twelve known alien and/or invasive plants were recorded in the historic data, while 23 are recorded in the present study.

Table 5-10: Historical and present day land-use surrounding the wetland sites as determined using aerial photographs (Electronic appendix F). Identified historical and present-day plant communities are provided for each site. Environmental data are provided for those wetlands which strongly correlated with certain variables in the DistLM in Table 5-8.

Wetland name	Wetland code	Plant community groups		Land-use		Description of the area within the 1 km buffer, % change, and general comments
		1988/89	2012/13	1988/89	2012/13	
Blomfontein	E201/03	*Isolepis prolifera – Pennisetum macrourum* (group A)	*Pennisetum macrourum – Elegia capensis* (group B)	Conserved	Conserved	A Seep high in the Cederberg mountains has not experienced any land-use changes over the past 25 years. The present plant community is explained by the high altitude (1369 m above sea level) of the wetland, which correlates with the findings of the environmental variables analysis. 1986: 100% conserved land 2010: 100% conserved land
Kleinplaats Dam West	G203/01	*Juncus kraussii – Sarcocornia natalensis* (group D)	*Pennisetum macrourum – Elegia capensis* (group B)	Open land, dam	Open land, dam	There are no indications of land-use change in this area over the past 25 years 1988: 100% natural open land 2010: 100% natural open land
De Diepte Gat	G403/05	*Calopsis paniculata – Carpha glomerata – Cliffortia strobilifera* (group B)	*Calopsis paniculata – Cliffortia strobelifera* (group D)	Agriculture	Agriculture	The land-use around the wetland has not changed over the past 25 years but there has been an increase in agricultural lands. This area has become overgrown and is dominated by *Berzelia lanuginosa* which is a common native of wetlands in the region. 1989: 51% natural land, 49% agricultural land 2010: 44% natural land, 56% agricultural land
Varkensvlei	G501/20	*Juncus kraussii – Sarcocornia natalensis* (group D)	*Ficinia nodosa* (group C)	Agriculture	Agriculture	From the aerial photographs it is evident that the surrounding land-use has not changed over the years. There is evidence of grazing within the wetland. This wetland has completely shifted its plant community type from 1988/89 to 2012/13. 1989: 100% agricultural land 2010: 100% agricultural land
Melkbospan	G501/16	*Juncus kraussii – Sarcocornia natalensis* (group D)	*Sarcocornia natalensis* (group A)	Agriculture	Conserved	Once completely surrounded by agricultural land now falls within SANParks land. Rehabilitated and protected. 1989: 12% natural (wetland), 88% agriculture 2010: 100% SANParks(conserved)land
Kiekoesvlei	G103/01	*Juncus kraussii – Sarcocornia natalensis* (group D)	*Phragmites australis – Juncus kraussii* (group E)	Agriculture	Agriculture	Agricultural land-use around the wetland has not changed over the past 25 years. There are indications of mowing to the water's edge. This wetland is known to hold the rare emergent species *Oxalis distichia* but agricultural weeds, such as *Cotula turbinata* and *Erodium moschantum* are common within the wetland. 1988: 100% agricultural land 2010: 100% agricultural land

Burgerspan		*Juncus kraussii -Sarcocornia natalensis* (group D)	*Phragmites australis – Juncus kraussii* (group E)	Agriculture	Agriculture	Agricultural land-use around the salt pan has not changed but there are signs that the inlet has been channelized. Many agricultural weeds, such as *Cotula turbinata* are now present. EC seems strongly too influence the plant community of the present-day. The second highest EC reading of 13260 mS/m is recorded for this site. 1988: 100% agricultural land 2010: 100% agricultural land
Wetland name	**Wetland code**	**Plant community groups**		**Land-use**		**Description of the area within the 1 km buffer, % change, and general comments**
		1988/89	**2012/13**	**1988/89**	**2012/13**	
Koekiespan	G103/02	*Juncus kraussii -Sarcocornia natalensis* (group D)	*Sarcocornia natalensis* (group A)	Agriculture	Agriculture	Agricultural land-use around this salt pan has not changed over the past 25 years. Agricultural weeds *Cotula turbinata* and *Erodium moschantum* is commonly found surrounding the wetland. The analysis of the environmental variables suggests EC strongly influence the change in plant community over time. From the DistLM analysis of the plant community assemblages EC and pH strongly influence the variation of the plant community of the present day study. This clearly correlates with the EC measured for this site which is the highest reading of 18 300 mS/m. This wetland also has high concentration of phosphate, nitrite + nitrate and ammonium. These high concentrations are likely to be due to runoff from the surrounding cultivated lands. 1988: 100% agricultural land 2010: 100% agricultural land
Rooipan	G201/01	*Juncus kraussii – Sarcocornia natalensis* (group D)	*Sarcocornia natalensis* (group A)	Private land, housing	Private land, housing	This area was mined for gypsum many years ago, potentially removing wetland species and deepening the system so that currently it functions as a salt pan. The number of houses south of the pan has increased. EC strongly influence the plant community of this wetland in the present day study. This is clear from the EC reading of 4440 mS/m was measured for this Salt pan. 1988: 98% natural land, 2% developed 2010: 96% natural land 4% developed
Vermont Pan	G403/01	*Juncus kraussii – Sarcocornia natalensis* (group D)	*Phragmites australis – Juncus kraussii* (group E)	Residential	Residential	Land-use has changed in the west from natural land (wetland seep) to residential housing. Proliferation of macro-algae *Ulva cf flexulosa* in the pan has been noted. This species which tolerates a wide range of salinity, temperature and water quality is a useful, classical organism which indicates eutrophication within a wetland. The water chemistry measurements (Table 5-7) reveal that this wetland has generally high concentration of nutrients all of which contribute to eutrophication. 1989: 64% natural land, 36% developed 2010: 51% natural land, 49% developed
Driehoek	E201/06	*Isolepis prolifera – Pennisetum*	*Pennisetum macrourum – Elegia capensis*	Conserved	Conserved	This channelled valley bottom wetland in the Cederberg wilderness area indicate no change in land-use over the past 25 years although there are signs in the present day aerial photographs of possible agriculture activities in the wetland downstream outside of

		macrourum (group A)	(group B)			the 1 km buffer . Declared a nature reserve in the 1960s. The present plant community is explained by the high altitude (903 m above sea level), which correlates with the findings of the environmental variables analysis. 1986: 100% conserved land 2010: 100% conserved land
Hemel-en-Aarde	G403/02	*Calopsis paniculata* – *Carpha glomerata* – *Cliffortia strobilifera* (group B)	*Calopsis paniculata* – *Cliffortia strobelifera* (group D)	Agriculture	Agriculture	Land-use has not changed around the wetland area. Impacts however, are not just from around the wetland but also from further upstream, as a distinctive channel is starting to form within parts of the wetland. 1989: 42% natural land, 58% agricultural land 2010: 42% natural land, 58% agricultural land
Wetland name	**Wetland code**	**Plant community groups**		**Land-use**		**Description of the area within the 1 km buffer, % change, and general comments**
		1988/89	**2012/13**	**1988/89**	**2012/13**	
Belsvlei	G403/04	*Typha capensis* – *Juncus kraussii* (group C)	*Calopsis paniculata* – *Cliffortia strobelifera* (group D)	Agriculture	Agriculture	The surrounding land-use has not significantly changed from agricultural lands over the years; housing has been recently built with lawns extending into the wetland. The surrounding agriculture has led to the introduction of many alien invasive plants such as, *Pinus sp* and *Acacia sp* within the wetland. Different species are dominant in the wetland in the present-day study, thus indicated by the change in plant community. 1989: 22% natural land, 78% agricultural land 2010: 22% natural land, 78% agricultural land
Salmonsdam	G404/01	*Calopsis paniculata* – *Carpha glomerata* – *Cliffortia strobilifera* (group B)	*Calopsis paniculata* – *Cliffortia strobelifera* (group D)	Conserved	Conserved	Largely un-impacted with no land-use change. Erosion gullies were evident within the wetland. 1989: 100% conserved land 2010: 100% conserved land
De Vlakte	H101/06	*Isolepis prolifera* – *Pennisetum macrourum* (group A)	*Pennisetum macrourum* – *Elegia capensis* (group B)	Agriculture	Agriculture	The surrounding agricultural land-use within and around the 1 km buffer has not changed over the past 25 years. There are signs of cutting, ploughing and cultivation to the water's edge of the wetland site, thus the removal of majority of the wetland plants, which has allowed for the introduction of many alien invasive species such as, *Pennisetum clandestinum*, *Rumex sp* and *Rubus sp*. The plant community is strongly influenced by nitrite + nitrate concentration 0.746 mg/L (Table 5-7). Nitrate may enter systems via fertilizers and agricultural runoff. This high concentration reading is surely effects of runoff from the surround agriculture lands, as there is no vegetation buffer between the system

						and the surrounding crop agriculture. 1987: 100% agricultural land 2010: 100% agricultural land
Noordhoek Salt Pan	G203/12	*Juncus kraussii -Sarcocornia natalensis* (group D)	*Phragmites australis – Juncus kraussii* (group E)	Excavated (marina)	Residential marina	Excavated in the 1970s for a marina. Housing development started in 2000 and is still increasing presently in and around the wetland. Many of the plants and trees have been planted in the wetland system to give it a natural feel however there are remnants of natural/indigenous wetland species such as *Schoenoplectus scirpoides* and *Ficinia nodosa* that can be seen in some parts of the wetland system, especially at the water's edge. 1988: 99% natural land, 1% developed 2010: 67% natural land, 33% developed
Kenilworth Racecourse	G203/13	*Typha capensis – Juncus kraussii* (group C)	*Phragmites australis – Juncus kraussii* (group E)	Horse race course	Horse race course/conser vation area	Surrounded by a horse racing track the Kenilworth race course conservation area was declared in 2005, in an area already highly developed in the 1980s there has been a slight increase in the proportion of developed land surrounding the wetlands. The immediate area surrounding the wetland is conserved and managed well. 1988: 69% conserved land, 31% developed 2010: 60% conserved land, 40% developed
Wetland name	**Wetland code**	**Plant community groups**		**Land-use**		**Description of the area within the 1 km buffer, % change, and general comments**
		1988/89	**2012/13**	**1988/89**	**2012/13**	
Khayelitsha Pool	G204/02	*Juncus kraussii -Sarcocornia natalensis* (group D)	*Phragmites australis – Juncus kraussii* (group E)	Rural development	Residential-Rural /Urban, wetland park	Over the years there have been land-uses changes around the wetland with in the buffer zone, where land which once was agricultural land has now become developed with housing (formal and informal housing). More alien invasive and cosmopolitan species, such as *Pennisetum clandestinum*, *Foeniculum vulgare*, *Berula erecta* and *Centella asiatica* can be found within the wetland. The dominant species in this system is *Typha capensis* which is an indicator of high nutrients. 1988: 69% natural land, 18% developed, 13% agricultural land 2010: 71%, natural land, 29% developed
Malkopsvlei	G401/01	*Typha capensis – Juncus kraussii* (group C)	*Phragmites australis – Juncus kraussii* (group E)	Residential	Residential	There has been an increase in the extent of residential houses around the wetland, many of which are known to have septic tanks. Many of the species are indigenous species such as, *Cyperus rotundus*, *Psoralea pinnata* and *Cliffortia ferruginea*. 1988: 99% natural land, 1% developed 2010: 82% natural land, 18% developed
Groot Witvlei	G401/03	*Typha capensis – Juncus kraussii* (group C)	*Phragmites australis – Juncus kraussii* (group E)	Residential	Residential	There has been a sizable increase in the extent of residential houses around the wetland, many of which are known to have septic tanks. *Typha capensis* and *Phragmites australis* are dominant with in the wetland. The 1 km buffer includes an adjacent wetland found in the area.

						1988: 99% natural land, 1% developed 2010: 65% natural land, 35% developed
Gans Bay	G403/09	*Typha capensis* – *Juncus kraussii* (group C)	*Phragmites australis* – *Juncus kraussii* (group E)	Open natural land	Open natural land	Change in land-use is not evident on the aerial photographs. Open water can be seen on the historical aerial photographs, but not now. The site was overgrown with *Phragmites australis, Typha capensis* and *Acacia saligna. Typha capensis* and *Phragmites australis* are indicators of increased nutrients and stabilized water levels. 1989: 100% natural land 2010: 100% natural land
Rondeberg	G201/04	*Typha capensis* – *Juncus kraussii* (group C)	*Ficinia nodosa* (group C)	Grazing	Private Conserved land	King and Silberbauer made reference to grazing around the wetland, which is not very evident on the aerial photographs. Presently the land around the wetland is conserved on private land. 1988: grazed?, natural? (unsure about past land-use) 2010: 100% conserved land
Bokkekraal	H101/01	*Typha capensis* – *Juncus kraussii* (group C)	*Phragmites australis* – *Juncus kraussii* (group E)	Agriculture/ dam	Agriculture/ dam	Land-use has not changed over the years although there has been an slight increase in agriculture overall in this area; impacts to the wetland may arise from upstream effects as well as known direct impacts which cannot be seen on the aerial photographs, *e.g.* too frequent fires, loss of water to the wetland. *Aponogeton angustifolius* a vulnerable and threatened species is found in this wetland system. *Lotus subiflora* an invasive species has become prominent within the wetland as well. 1987: 65% natural land (35% partially a dam and river) 2010: 65% natural land (35% partially a dam and river)
Wetland name	**Wetland code**	**Plant community groups**		**Land-use**		**Description of the area within the 1 km buffer, % change, and general comments**
		1988/89	**2012/13**	**1988/89**	**2012/13**	
Verrekyker	H101/05	*Typha capensis* – *Juncus kraussii* (group C)	*Phragmites australis* – *Juncus kraussii* (group E)	Agriculture/ plantations	Rehab wetland	Land-use has changed from agriculture and plantations to a rehabilitated land. Rehabilitation has largely removed alien vegetation. The high concentration of nutrients (Table 5-7) especially that of phosphorus and nitrites + nitrates indicate the system to be eutrophic. The presence and infestation of *Typha capensis*, *Lemna gibba* and *Eichornia crassipes* are indicators which supports this. 1987: 100% agricultural land 2010: 100% conserved land

In summary, many of the wetlands that have changed in terms of surrounding land-use support species that are indicators of nutrient enrichment and stabilizing water levels. These species include *Typha capensis* and *Phragmites australis,* which describe many of the plant community groups as well. Inspection of the environmental data, especially of nutrient concentrations, revealed that wetlands like G201/01 and H101/01 are affected by runoff from surrounding agriculture while G403/01 and G204/02 have been affected by residential development (urban and/or informal).

Overall in this chapter we have shown that four plant community groups could be distinguished on the basis of the historic data and five on present-day data. Indicator species describing the plant community groups in the different years were identified. Single dominant species strongly described wetland plant groups for the present-day vegetation, while no single dominant species described the historical vegetation data. The relationship between environmental variables and species composition revealed that the historical plant species composition was not significantly correlated with any of the environmental variables whereas present-day species composition was significant correlated with altitude, pH and conductivity. The effect of survey year was insignificant for the environmental variables but the plant groups were significantly different across years. Differences in community composition are apparent between the historical and present vegetation data. It is clear that one of the historic plant communities has split, and *Ficinia nodosa* characterizes a present-day plant community group that was not evident in the historical data, perhaps because it was overlooked during sampling. From this study a biological change in plant species communities can be distinguished, more so in depressional wetlands than any other wetland type, over the past 25 years. The biological change was not supported by the environmental variables that were examined but was linked to surrounding land-use.

5.13 DISCUSSION

This chapter discussed the wetland plant communities identified in 1988/89 and 2012/13; the relationship between the distribution of these communities and the underlying environmental variables; how plant community composition has changed over time; and the relationship between plant community composition and surrounding land-use.

Sampling the wetlands

Different approaches can be used to examine and detect changes over time in wetland vegetation. Numerous studies have examined and recorded changes in plant communities, plant community distribution, characterization of wetland plant communities, species cover and distribution, and many other factors, utilizing satellite images and aerial photography which involves visually assessing images of wetlands and wetland vegetation (*e.g.* Williams & Lyon 1995; Lee & Lunetta 1996; Rebelo *et al*. 2009). The use of permanent quadrat sampling plots is another repeated sampling method that records wetland species composition, visually or by the relevé method (listing of species), through field data collection across a number of years (Odland & del Moral 2002; Childer *et al*. 2003; Pyšek *et al*. 2004; Rolon & Maltchik 2006; Johnston & Brown 2013). Using aerial photography and field observations through ground-truthing, Russell (2003) produced distribution maps and evaluated changes in the distribution of emergent aquatic plants in the Wilderness Lakes, a brackish South African estuarine-lake system, between 1975 and 1997.

Assessing change over time in this project was constrained by the previous sampling procedure. Replicating the sampling protocol of King and Silberbauer was a difficult task, as they did not provide a detailed description of their procedures for collecting the floral data. The present-day sampling procedure – the how, when and where, was kept as close as possible to King and Silberbauer's methods. Vegetation sampling was therefore conducted with the help of the previous plant collection book, field notes and map drawings and visual observation of the presence/absence of dominant wetland plants. Potential source of error in the environmental data collection could possibly be found due to 1) the sampling technique, 2) the precision of the sampling equipment used in the historical and present-day data collection (technology improvement over the years) and 3) operator use. Although previous studies (*e.g.* Griffith & Weisberg 2011) have demonstrated that the underlying technology or challenges with technology transfer are not the biggest problems when implementing new technology in water quality analysis. A few wetlands were difficult to assess, in terms of vegetation sampling and were therefore not included in the study. Most of the wetlands in the previous study were visited during the winter rainfall months of 1988/89, so for accuracy and comparative purposes they were sampled in the same months during the current study. This made identification of many of the plants difficult as many of them do not flower or fruit during the winter months. The limitations of the previous study cannot be ignored because they have probably resulted in some inaccuracy in sampling and therefore in analysis of the results. Intensive sampling within homogenous and 'representative' stands of wetland vegetation during spring and/or early summer months would have been a more appropriate procedure of sampling. Within each relevé the vegetation might have been recorded using the Braun Blanquette method (Westhoff & van der Maarel 1978). The results of such a sampling regime would provide a more accurate picture of the plant communities. Depending on the purpose and the objectives of vegetation research the most appropriate and applicable sampling procedure should be adapted.

Characterization of plant communities and wetland types

Cluster analysis and MDS plots of the plant species data identified four main plant community groups historically, and five in the present-day study (Figures 5-5 to 5-8). PERMANOVA confirmed the plant community groups identified by the cluster analysis to be significantly different from each other ($p < 0.05$). Multivariate techniques can be used to summarise the basic attributes of wetland vegetation in terms of plant communities (Little 2013). The MDS plots (Figures 5-6 and 5-8) indicate the importance of an altitude gradient across the plots which, together with water chemistry, appears to be shaping the plant communities, especially in the present-day study. Historic plant community groups A and B and present-day groups B and D are characterized by freshwater, high altitude seeps and valley-bottom wetlands. Historic plant groups C and D and present-day plant groups E, C and A are located in low to moderate altitudes and vary from fresh to saline habitats. A split of historic plant community group D can be seen between the two sampling periods, where two wetlands create a new separate group, C. The reason for this separation is unclear because even though significant differences are observed between the groups there is an overlap and sharing of species between groups (Tables 5-3 and 5-5). In other words, some of the groups share the same diagnostic species.

Where a species is exclusive to a group, it can be used as a diagnostic or indicator species to describe plant communities (Rooney & Bayley 2011), to differentiate wetlands, and to associate plant species with different wetland conditions (Johnson *et al*. 2007; Little 2013).

The SIMPER analysis identified characteristic species and the two contributing the most to the identity of each group were then used to describe the plant community in each group (Tables 5-4 and 5-6). Nine plant communities (four from the first sampling period and five from the second) were identified and shown to be characterized by various obligate wetland plants, mostly dominated by indigenous, and sometimes CFR endemic, species. In two cases single species, such as *Sarcocornia natalensis* and *Ficinia nodosa,* are strongly dominant and describe plant community groups observed in the present-day vegetation data. A general pattern is that saline to brackish depressional wetland communities are characterized by *Sarcocornia natalensis* – *Juncus kraussii,* or *Sarcocornia natalensis* and *Ficinia nodosa*. *Sarcocornia natalensis* also characterizes the hypersaline wetlands of Sieben (2011). *Juncus kraussii,* a salt pan macrophyte, is widely distributed in southern Africa. This species is commonly found in brackish to saline environments such as salt pans or marshes bordering lagoons and near the sea (Naidoo and Kift 2005, Sieben 2011). The *Ficinia nodosa* community was exclusively associated with two wetland sites, G501/20 and G 201/04 while the *Sarcocornia natalensis* community exclusively characterized three sites, G103/02, G201/01 and G501/16, in the present-day study. *Calopsis paniculata* – *Carpha glomerata* – *Cliffortia strobilifera* and *Calopsis paniculata* – *Cliffortia strobilifera* communities characterize permanent freshwater, high altitude valley-bottom wetlands. *Calopsis paniculata*, *Carpha glomerata* and *Cliffortia strobilifera* are obligate wetland species that inhabit and characterize lotic wetlands, such as channelled valley-bottoms. These species are common dominant species in riparian vegetation communities (Clever *et al*. 2004; Hugo *et al*. 2012; Meek *et al*. 2013). *Typha capensis* – *Juncus kraussii* and *Phragmites australis* – *Juncus kraussii* communities characterize low-lying semi-permanent to permanent, freshwater to brackish depressional wetlands, high in nutrients, with stabilized water levels, indicating that over time these wetlands have become more permanent, with less fluctuating water levels. *Typha capensis* is a common wetland emergent, mainly distributed within shallow standing or slow-flowing habitats of the Western Cape, but is also common in the rest of South Africa (van Wyk *et al*. 1997). *Phragmites,* an emergent species found in aquatic habitats, is one of the most widely distributed plants in the world (Marks *et al*. 1999). Kotze and O'Connor (2000) found *Phragmites australis* and *Typha capensis* to be dominant in semi-permanently-wet wetlands below 800 m. *Isolepis prolifera* – *Pennisetum macrourum* and *Pennisetum macrourum* – *Elegia capensis communities* characterize high-altitude freshwater wetlands, most of which are seeps. *Pennisetum macrourum* was not found in wetlands below 800 m (Kotze & O'Connor 2000).

Underlying environmental characteristics such as geomorphology and hydrology affect biotic and chemical processes in wetlands. These characteristics shape and define the functions of wetlands and their water-holding capacity within the environment (Brinson 1993; Maltby *et al*. 1994). Wetlands of different types can therefore be expected to provide different habitats for plants. Ollis *et al*. (2013) proposed that dominant vegetation forms (*e.g.* aquatic, herbaceous, shrub/thicket and forested) and vegetation status (*i.e.* indigenous or alien) of wetlands should describe wetland type within their classification system of wetlands and other aquatic ecosystems in South Africa. Considering these factors in the current study, wetland sites from both study periods were classified using the HGM (hydrogeomorphic) approach Ollis *et al*. (2013) in order to ascertain whether similar HGM units (*i.e.* similar wetland types) hold similar plant communities. The cluster analyses (Figures 5-5 and 5-7) and MDS plots (Figures 5-6 and 5-8) show that plant community groups do not consistently group wetlands of the same wetland HGM type, which suggests that the plant species data alone cannot be reliably used to identify different types of wetlands. Wetland vegetation can, however be used to improve classification systems. Furthermore, aquatic forms are good indicators of wetland condition (Goslee *et al*. 1997; US EPA 2002) while *Sarcocornia* is indicative of saline conditions and emergent plants, such as *Typha capensis* and *Phragmites australis*, can be used to identify permanently inundated wetlands. For many wetland types a few species tend to dominate in terms of the number of individuals and in the percentage of aerial cover. The existence of these species indicates that the wetland meets the habitat requirements for these plants. It is best therefore to use plant species composition to describe wetland type rather than to define it (Cowardin *et al*. 1979; Jones 2002; Ollis *et al*. 2013).

The relationship between plant communities and environmental variables

Several studies have analysed environmental variables affecting species diversity and richness in riparian wetland vegetation (*e.g.* Ssegwa *et al*. 2004; Rolon & Maltchik 2006; Johnston & Brown 2013). Analysis of environmental variables can be explored by direct gradient analysis, *i.e.* the position of samples along axes determined by environmental variables (Kenkel 2006). Data on water chemistry rather than sediment chemistry were available for the current study, a situation that is not uncommon especially in aquatic botany field studies. Sediment chemistry data would have been preferable because emergent vegetation takes up nutrients from the substrate, and water chemistry data may not mirror those found in the soil (Johnston *et al*. 2001).

Distance-based Liner Modelling (DistLM) was used to characterize the plant communities in terms of the biotic and environmental variables with which they are associated. The DistLM for the historical data found none of the four variables examined (pH, altitude, rainfall and EC) to be statistically significant in explaining the relationship between the plant communities and the measured environmental variables, although 8.9 % of the variation within the model can be best explained by pH. Examining the relationship between the plant communities and the environmental variables for the 2012/13 study period using DistLM, altitude, pH and EC were shown to be significant variables in explaining the relationship between the plant community groups and the environmental variables. Altitude, furthermore, is the main predictor of plant communities, explaining 8.0% of the variation in species composition in the 30 wetlands. Seeps and valley-bottom wetlands, ranging in altitude from 903 to 1369 m, strongly correlate with the attitude axis in the dbRDA plot (Figure 5-9). Similarly, altitude was identified as one of the important predictors of macrophyte richness in southern Brazil (Rolon and Maltchik 2006) and as strongly influencing wetland plant species composition and diversity in 66 wetlands in KwaZulu-Natal, South Africa (Kotze and O' Connor 2000). Furthermore, Johnston and Brown (2013) report that certain water chemistry variables such as pH and electrical conductivity (EC) should be considered when setting standards to support wetland vegetation. They also suggest that interactions in wetlands should not be oversimplified, as multiple interactions such as present and historical land-use, water fluctuations and many other factors are influential as well.

pH represents the negative log of the concentration of hydrogen ions in water. Vestergaard and Sand-Jensen (2000) demonstrated that plant species composition of Danish lakes strongly correlated with alkalinity and pH, while a case study (Bird *et al.* 2013a) within the current study area investigated the effects of invasion by alien vegetation on temporary wetlands in the Kenilworth Racecourse Conservation Area (G203/13). They found pH, to be the strongest response variable and that pH increased linearly as indigenous fynbos vegetation around the wetlands was replaced by alien species, thus indicating that low pH values are natural for the fynbos wetlands in the study area. In the present-day study, the lack of correlation between environmental variables and plant communities for the historical data could possibly be attributed to the small number of samples sites or the environmental variables considered in the analysis.

Plant assemblages of saline wetlands G103/03, G201/01 and G103/02 were strongly correlated with high EC (Figure 5-9 and Table 5-8). Electrical conductivity has shown to distinguish wetland plant community types in comparative studies in North and South America and Europe (Vitt & Chee 1990; Rey Benayas & Scheiner 1993; Thomax *et al*. 2003; Rolon & Maltchik 2006; Sass *et al*. 2010). The significantly high conductivity values in wetlands G103/03, G201/01 and G103/02 maybe due to the underlying geological substrate, as other wetlands in the vicinity (Darling, West Coast) are mined for gypsum, as G201/01 had been previously.

Nutrient concentrations in the present-day study were not significantly correlated with the plant assemblages in the 2012/13 DistLM (Table 5-8), but a few wetlands, such as H101/01, G204/02, G403/01, and H101/06 showed a strong correlation between nutrient (phosphorus, nitrite + nitrate and ammonium) axes and plant communities (dbRDA, Figure 5-9). The lack of the relationship between the nutrients and plant communities was unexpected, based on the significant relationship findings reported some previous studies (Craft *et al*. 2007; Croft and Chow-Fraser 2007). Many other wetland studies (*e.g.* Jones *et al*. 2003, Rolon & Maltchik 2006; Johnston & Brown 2013) have, however, reported non-significant relationships between water nutrient concentrations and aquatic plant diversity.

Change over time in wetland plant communities and the influence of land-use on species composition

Many studies have searched for patterns in plant communities in response to alterations to the environment (Adamus *et al*. 2001). Studying changes in vegetation requires monitoring the same location a number of times over a period of years (Kent 2012). The most frequently asked question in monitoring is, “how variable are plant communities among sites and over time?” Little (2013) recognizes that considerable change in wetland vegetation can be tracked using random sampling of the same sites at different times and that statistical power and assurance that change has occurred comes with sampling exactly the same place at different times. Depending on the study objectives, permanent sample plots could be placed randomly or representative of particular communities. In this study changes in plant communities between 1988/89 and 2012/13 were examined.

After comparing the plant communities identified by cluster analyses, a change or addition of a plant community group is apparent from the historic to the present-day plant communities. A split in one of the historic plant communities appears to have occurred. Plant community group D (*Juncus kraussii – Sarcocornia natalensis*) of the historic data has split and is shared in two groups of plant community group A (*Sarcocornia natalensis*) and plant community group E (*Phragmites australis – Juncus kraussii*) in the present-day data. A dominant diagnostic species, *Ficinia nodosa*, now characterizes wetlands G201/04-Rondeberg and G501/20-Varkensvlei in the present-day vegetation data. Furthermore, the cluster analysis reveals that the *Ficinia nodosa* community type is new and is believed to have arisen from the *Typha capensis – Juncus kraussii* community (historical group C). Dominant species of the plant communities of wetland sites G103/01, G204/02, G403/09, G401/01, H101/05 and G501/18 have also shifted (Table 5-9). The majority of these wetland sites experienced a shift in species composition from *Typha capensis – Juncus kraussii* to *Phragmites australis – Juncus kraussii*. *Phragmites* is more common in permanent wetlands with stable water levels, whereas *Typha* more commonly occupies wetlands with fluctuating water levels. *Phragmites* spreads and establishes stands easily through rhizome spread and clonal growth of open disturbed wetland habitat. Furthermore, the transformation to brackish habitats kills many freshwater species creating opportunity for *Phragmites* to exploit this open space rapidly (Chambers *et al*. 1999). The current study thus indicates that wetlands in this study have become more permanent, with water levels stabilizing over time. A study in Long Point, Ontario, Canada, found that *Phragmites australis* was common in, and invaded, aquatic habitats that had experienced disturbances such as altered hydrologic regimes, dredging or increased nutrient availability (Wilcox *et al*. 1999). Other plant communities have remained the same and are still present from 1988/89 to 2012/13 except for changes in the diagnostic species which describe them: *Calopsis paniculata – Carpha glomerata – Cliffortia strobilifera* to *Calopsis paniculata – Cliffortia strobilifera* and *Isolepis prolifera – Pennisetum macrourum* to *Pennisetum macrourum – Elegia capensis*.

A change in species composition over time can indicate environmental change (Cronk & Fennessy 2001). Mitsch and Gosselink (2000) noted that some shifts in plant community composition can be attributed to an increase in nutrients levels in the soils. Sediment nutrients were not examined in this study, but others (*e.g.* Vitt & Chee 1990; Craft *et al*. 2007 and Croft & Chow-Fraser 2007) have shown relationships between wetland vegetation and surface-water nutrients. The ANOSIM reveals differences within plant communities to be significant across years, suggesting change over time in species composition of the plant communities. The PERMANOVA indicated no significant change in environmental variables and supported the suggestion of the significant effect of survey year on plant community composition. This indicates that there are no apparent significant differences in environmental variables selected between sampling periods and that the main source of variation is therefore in plant species composition. The majority of wetlands whose plant communities have changed are depressions (Figure 5-11), perhaps because depressions are often located in areas vulnerable to human disturbance. Furthermore, their depressional nature means that they retain water and nutrients draining from their surroundings.

The results are supported by similar studies by ter Braak and Wiertz (1994) and Childers *et al*. (2003). Ter Braak and Wiertz (1994) found changes over time in wetland vegetation from 1977 to 1988 due to changes in pH and water depth in the Netherlands and Childers *et al*. (2003) found dramatic changes in species composition in Everglade wetlands from 1989 to 1999. De Steven and Toner (2004) recognize that even without changes in measured environmental variables, biological changes may arise due to additional factors such as hydrological regime, soil type, wetland size and disturbance history, all of which may directly influence the vegetation of depression wetlands.

Analysis of land-use changes

Since the changes in species composition were not correlated with change in the environmental variables measured in this study, the land-use dynamics were investigated, since disturbance is known to influence vegetation of wetlands (De Steven & Toner 2004).

Walters *et al*. (2006) found that land-cover and use have had noticeable effects on wetland plant composition, diversity and structure, and wetland functioning.

GIS together with field studies and historical aerial photography provide an opportunity to investigate temporal changes in land-use (Johnston & Naiman 1990). Aerial photographs from 1987 to 2010 were used in this study to assess the changes in land-use to infer changes in wetland plant species composition. Table 5-10 shows that 48% of the wetlands experienced a change in land-use, either as an increase in human use of the land or as a change from one type of land-cover to another. Four percent of wetland sites have experienced an increase in surrounding agriculture; 13% of wetland sites, all of which are depression and salt pans, such as H101/05, G501/16 and G201/04, reverted from agricultural to conserved land. Phosphorus, nitrate, nitrite and ammonium, which enter surface water *via* runoff, are major nutrients that contribute to nutrient enrichment in standing waters and water quality has been shown to be significantly correlated with land-use activities (Berka *et al*. 2001; Alam *et al*. 2011). The presence of alien and/or invasive species such as *Typha capensis*, *Lemna gibba* and *Eichhornia crassipes* in H101/05 are indicators of nutrient enrichment. Species like *Typha* can also be used to infer high nutrient loads in a wetland system because *Typha* is efficient at the taking up nutrients during periods of abundance (Quick 1987). Thirty percent of the wetlands, all of which are depressions, have experienced an increase in the surrounding urban/informal residential development. Furthermore, the surrounding agriculture of G403/01, H101/06 and H101/05 correlates with the high nutrient concentration readings (Table 5-7). Without the historical nutrient data (which is lacking), exploring whether there has been a change over time is impossible, however.

5.14 CONCLUSIONS

- This research provides baseline data on the plant communities of various wetlands of the Core Cape Region.
- Differences in sampling intensity and procedure (and thus sampling area) between the 1988/89 and 2012/13 surveys may have resulted in some inconsistency in sampling and may therefore have complicated and affected the interpretation of the results. It can be concluded for the study wetlands, however, that although HMG types cannot be identified by plant communities, plant communities do seem to reflect HGM units. Several HMG units are recognized, each with characteristic plant communities and indicator species.
- Differences in species composition over time were reflected in differences in plant communities at depressional wetland sites.
- Differences in species composition over time seem to be tied to changes in land-use despite few changes over time in the measured environmental variables. As such, the trajectories of change are not readily predictable. Shifts in species dominance may alter the aspect and ecology of these wetlands.

CHAPTER 6

THE DIATOMS OF THE WESTERN CAPE AND THEIR USE IN MONITORING WETLAND WATER QUALITY

6.1 DIATOMS AS TOOLS FOR INFERRING WETLAND WATER QUALITY

Diatoms are microscopic organisms living in water and moist soils, and are distributed world-wide. They belong to the algal class Bacillariophyceae, and occur as single cells or in colonies. A golden-brown mucilaginous film on the surface of a substratum indicates the presence of benthic diatoms while planktonic diatoms occur in the water columns of rivers, lakes and dams. More than 100 000 species of diatoms are thought to exist (Mann & Droop 1996) and they often form the main component of phytoplanktonic and phytobenthic communities in shallow waters.

The most obvious morphological characteristic of diatoms is the siliceous cell wall or frustule, which consists of two almost identical shells or valves. The taxonomy of diatoms is based on the ornamented structure of the valves, which are identified and enumerated in ecological studies of diatom communities (Barber & Hayworth 1981). Diatoms can be placed loosely into two morphological groups, centric and pennate. Centric diatoms are non-motile and radially symmetrical while pennate diatoms are often motile and are commonly bilaterally symmetrical. Centric diatoms usually form part of the phytoplankton, and species of genera such as *Cyclotella* species may have chitinous extrusions from the mantle that aid in flotation (Barber & Hayworth 1981; Saros & Fritz 2000). Pennate diatoms are predominantly attached to hard substrata and often produce mucilaginous stalks or pads that keep the cells in contact with the substratum in flowing waters (Anderson & Cabana 2007).

6.2 THE USE OF DIATOMS IN BIOMONITORING

While water quality monitoring originally focused on physical and chemical measurements, other indicators can greatly enhance the assessment and management of aquatic ecosystems (Cairns & Pratt 1993). In this regard diatom assemblages have been recognised as being useful for assessing the condition of aquatic ecosystems, particularly water quality, since the 1960s (*e.g.* Giffen 1966; Cholnoky 1968; Archibald 1972; Schoeman 1979).

Diatoms are used as biological indicators for a number of reasons:

- Attached diatoms are not easily washed away so the effects of antecedent pollution may be assessed (Round *et al.* 1990).
- As primary producers they are affected by nutrients and other components of water quality (Round *et al.* 1990).
- They are easy to sample (King *et al*. 2000).
- They respond sensitively to differences in pH, conductivity, sediments, pesticides and many other contaminants (Adamus *et al*. 2001), and individual species have specific requirements with regard to water chemistry and habitat (Tilman 1977; Sabater & Sabater 1988; Salomoni *et al*. 2006).
- Diatom assemblages are species rich so provide redundancy of data (Dixit *et al.* 1992).

- Diatoms have short generation times (about two weeks) and may thus reflect short-term changes in water quality (Rott1998).
- The taxonomy of the diatoms is well documented (Krammer & Lange-Bertalot 2000-2008; Lavoie *et al*. 2008).
- Due to the siliceous nature of their cell walls, diatoms are usually well preserved in sediments and can therefore be used to infer past environmental conditions (Deny 2004; Taylor *et al*. 2007).
- Diatoms can be found on different substrata even when dry, so they can often be sampled throughout the year (Cremer *et al.* 2004).
- Diatoms are found in almost all aquatic habitats (Gell *et al.* 2005).
- The combined costs of sampling and sample assay are relatively low when compared to some other biomonitoring techniques (Yallop *et al*. 2006).
- Samples can easily be archived for future analysis and long-term records (Round 1993; Johnson *et al*. 2006).
- Software (Omnidia) has been developed for the calculation of diatom indices (Lecointe *et al.* 1993; Smol & Stoermer 2010).

In summary, the biological characteristics of diatoms make them useful indicators of water quality, but despite their ecological importance, the knowledge of lentic communities is less comprehensive than the knowledge of lotic communities and diatom identification requires taxonomic expertise and training.

Understanding the degree of endemism of species of diatom is important when indices developed in one part of the world are used in another. The assumption that individuals of similar morphology are in fact the same species throughout the world, and therefore have the same tolerance ranges, has to be tested for each region, despite the argument that diatoms are sub-cosmopolitan. The designation "sub-cosmopolitan" infers that the specific environmental variables at a site, and not the genetic makeup of individual diatoms, determine their distribution patterns (Kelly *et al*. 1998).

6.3 DIATOM INDICES

A series of thirteen diatom-based indices have been developed (Omnidia ver. 3.1, Lecointe *et al*. 1993) for estimating various aspects of water quality. The current study uses four indices (Table 6-1), which are discussed in more detail in Section 6.6.4.

Table 6-1: The diatom indices available in Omnidia that are used in this study.

Abbreviation	Full name
SPI	Specific Pollution Sensitivity Index
GDI	Generic Diatom Index
BDI	Biological Diatom Index
%PTV	Pollution Tolerant Valves

Most indices are based on a weighted average equation (Zelinka & Marvan 1961). In general, each species used in the calculation of the index is assigned two values. The first value (*s*) reflects the tolerance or affinity of the particular diatom species for certain aspects of water quality while the second value (*v*) indicates how strong or weak the relationship is (Taylor 2004). These values are then weighted by the abundance of the particular diatom species in the sample (Taylor 2004; Lavoie *et al*. 2006; Besse 2007). The main difference between indices is in the number of indicators and the list of taxa used in calculations (Eloranta & Soininen 2002).

These indices form the foundation for computer software used to estimate “water quality” (although it is usually aspects of water chemistry that are actually assessed). Omnidia (Lecointe *et al*. 1993), one such software package, has been approved for use by the European Union, where it is used with increasing frequency. It is also used in the current study. The program hinges on a taxonomic and ecological database of 7500 diatom species, and contains indicator values and degrees of sensitivity for given species, using data generated from European diatoms in European streams. It permits the user to perform rapid calculations of indices of general pollution, saprobity, trophic state and species diversity (Szczepocka 2007).

Diatom-based water quality indices have been evaluated and implemented in South Africa (Taylor 2004; RHP 2005) for riverine ecosystems. De la Rey *et al*. (2004) and Taylor (2004) showed that diatom-based pollution indices may be good bio-indicators of water quality in rivers in South Africa by demonstrating significant relationships between variables such as pH, electrical conductivity, phosphorus and nitrogen concentrations, and the structure of diatom communities as reflected by diatom index scores. These authors concluded that the European Indices are suitable for monitoring South African rivers.

The %PTV, BDI, GDI and SPI indices have been successfully applied in South African rivers by Taylor (2004) and also in a preliminary study on wetlands in the Western Cape by Matlala *et al*. (2011). Matlala’s study indicated that diatoms can be used for inferring aspects of the water quality of wetlands, since physico-chemical results correlated with the diatom index scores generated. Based on the results of Taylor (2004) and Matlala *et al.* (2011) and Koekemoer (*in prep*.), the %PTV, BDI, GDI and SPI indices are also used in the current study. A South African Diatom Index (SADI) is being developed and is currently based on the analysis of 768 individual samples, together with their water quality information. The SADI is based on the same principles as most of the European indices but is yet to be completed, further data being required, especially for the Western Cape region (Harding and Taylor 2011). Recent studies have shown macro-invertebrate assemblages to be an unreliable tool for inferring water quality of wetlands (Bowd *et al*. 2010; Bird *et al.* 2013b) and alternative tools for biomonitoring of wetlands need to be developed.

6.4 DIFFERENCES BETWEEN RIVERS AND WETLANDS THAT MAY INFLUENCE DIATOM COMMUNITIES

Diatoms as indicators of environmental conditions in wetland ecosystems have not been definitively formulated for South Africa. There are reasons to indicate that indices suitable for rivers may not provide accurate results for wetlands because of the very different physical and chemical conditions in standing and running waters. The amount of rainfall, evaporation rates and groundwater level are the most important features influencing the water regime and inundation period of isolated wetlands. Salinity can also change markedly during the year, especially in temporary wetlands such as pan depending on inundation period and wetland size; turbidity depends on pan depth, vegetation cover and wind action; and pH varies with conductivity and rate of photosynthesis (Meintjies *et al.* 1987 *in* Allan *et al*. 1995). Since water level, hydrological variability, habitat availability and spatial heterogeneity affect the distribution of diatoms (Gaiser *et al*. 1998; Weilhoefer & Pan 2007) diatom indices are likely to provide different results in standing and running waters. In addition, in rivers diatoms prefer rocky substrata whereas wetland systems may have a variety of substrata and rocks may be absent. It is necessary, therefore, also to investigate the most suitable substrata to sample in wetlands.

6.5 AIMS AND OBJECTIVES OF THE STUDY

The present study aimed to contribute information on the distribution and environmental preferences of diatoms in wetlands in the Western Cape, by achieving the following objectives.

- Work towards documenting the diatom flora of the Western Cape, by composing species lists for the wetlands studied.
- Ascertain the relationship between aspects of water quality and diatom community composition in the wetlands studied.
- Calculate index scores for each wetland in relation to the substrata sampled.
- Assess the correlation between water quality variables and results for diatom indices calculated during the study.

6.6 MATERIAL AND METHODS

6.6.1 The study area

This study focuses on a subset (Table 6-2) of the sites sampled during the wetland trajectories project. Details of the full set of study wetlands are provided in Appendix B (sampling dates and location), Table 2-3 (Importance and benefits), Table 4-3 (Changes in WQ and factors causing this change) and Table 7-2 (Present Ecological Health scores). Note that diatom samples were not collected in the historical project.

6.6.2 Field procedures

Sampling methods followed Taylor *et al.* (2005; 2007). Samples were taken from substrata by scrubbing with a small brush and rinsing both the brush and the substrate with distilled water. After collection, diatoms were preserved with ethanol to a final concentration of 20% by volume. Diatoms were then processed using the hot hydrochloric acid and potassium permanganate method (Taylor *et al*. 2007) and slides prepared.

Table 6-2: Wetlands and substrates sampled during the course of the study.

Wetland name	Substrata sampled	Wetland name	Substrata sampled
Noordhoek Salt Pan	Emergent vegetation	Verrekyker	Emergent vegetation Floating vegetation
Kenilworth Racecourse	Emergent vegetation Sediment	Khayelitsha Pool	Emergent vegetation
Rooipan	Sediment	Agulhas Salt Pan	Sediment
Yzerfontein Salt Pan	Sediment	Soetendalsvlei	Emergent vegetation Submerged vegetation
Burgerspan	Emergent vegetation	Melkbospan	Sediment
Kiekoesvlei	Emergent vegetation	Vispan (Die Pan)	Sediment
Koekiespan	Emergent vegetation	Ratel River	*Juncus* *Isolepis*
Januariesvlei	Emergent vegetation	White Water Dam	Emergent vegetation (*Nymphaea*) Floating vegetation (*Typha*)
Modder River	Emergent vegetation	Groot Rondevlei (Cape Peninsula)	Submerged stems (Cyperaceae) Plastic detritus
Witzand Aquifer Recharge	Emergent vegetation	Klaasjagers Estuary	*Isolepis*
Wetland name	Emergent vegetation	Pearly Beach site A	Emergent vegetation
Silvermine Dam inflow	Emergent vegetation	Pearly Beach site C (road)	Emergent vegetation
Silvermine lower	Emergent vegetation	Modder Valley	Emergent vegetation
Malkopsvlei	Emergent vegetation	Voelvlei	Emergent vegetation
Groot Rondevlei	Emergent vegetation	Wiesdrif	Emergent vegetation
Groot Witvlei	Emergent vegetation	Groot Hagelkraal Upper	Emergent vegetation
Kleinplaats West	Emergent vegetation	Groot Hagelkraal Lower	Emergent vegetation
Pinelands – the crossing	Emergent vegetation	Gans Bay	Emergent vegetation
Blinde River	Emergent vegetation	Vermont Pan	*Juncus* Floating algae
Riversdale	Sediment	Hemel-en-Aarde	Dead *Eucalyptus* *Juncus lomatophilous*
Blomfontein	Sediment	Belsvlei upper	Submerged *Wachendorfia* leaves.
Driehoek	Sediment	Belsvlei lower	No diatom sample
Sneeuberg Hut stream	Sediment	Elias Gat	Emergent vegetation
Hoogvertoon	Sediment	Die Diepte Gat	Submerged roots
Middelberg West	Sediment	Salmonsdam A	*Isolepis*
Suurvlakte	Sediment	Salmonsdam D	Fern
Wagenbooms River	Emergent vegetation	Salmonsdam E	*Phragmites*
Die Vlakte	Emergent vegetation	Varkvlei	Floating *Potamogeton*

6.6.3 Analyses

Three to four hundred diatom valves were counted per slide (Prygiel *et al*. 2002), using a high-resolution Nikon 80i microscope equipped with DIC optics, a 100×1.4 N.A. oil immersion objective and a Digital Sight DS-U2 5MB camera. Diatoms were counted along a horizontal traverse and each whole (*i.e.* not broken or damaged) diatom observed in the field of view was counted and identified.

Sources such as Krammer & Lange-Bertalot (1976-2002), Schoeman & Archibald (1976-1980), Round *et al*. (1990), Hartley (1996), Prygiel & Coste (2000), Kellog & Kellog (2002), Krammer (2002) and Taylor *et al*. (2007) were used to identify the diatoms to the lowest taxonomic level possible (usually species) and to review the nomenclature.

After enumeration of all the diatom slides, the species and environmental data were entered into an Excel spreadsheet to determine the relative abundance of each diatom species encountered according to Equation 6-1.

Equation 6-1: Formula used to calculate the relative abundance of diatom species encountered.

$$\text{Relative abundance} = \frac{\text{Number of individuals of species x}}{\text{Total number of individuals in the sample}} \times 100\%$$

6.6.4 Diatom indices and calculations

Based on the relative abundance, Omnidia version 5.3 was then used to calculate the different diatom indices, which are based on Equation 6-2 (developed by Zelinka & Marvan 1961).

Equation 6-2: Used to derive various diatom indices (based on Zelinka and Marvan 1961).

$$\text{Index} = \frac{\sum_{j=1}^{n} a_j s_j v_j}{\sum_{j=1}^{n} a_j v_j}$$

Where:

a_j = abundance (proportion) of species j in sample

s_j = pollution sensitivity of species

v_j = indicator value.

Each index was expressed as the mean of the pollution sensitivity of the taxa in the sample, weighted by the abundance of each taxon. The indicator value acts to further increase the influence of certain species (de la Rey *et al*. 2004; Harding *et al*. 2004). The indices listed in Table 6-1 and used in this study are described below.

%PTV = Pollution tolerant valves % (Kelly et al. 1995)

%PTV is calculated as the sum of valves belonging to taxa generally regarded as particularly tolerant to organic pollution and can be interpreted with the aid of Table 6-3.

Table 6-3: Interpretation of percentage Pollution Tolerant Valve (%PTV) results.

% Diatom valves belonging to tolerant taxa	Inferred degree of organic pollution
< 20	Site free of significant organic pollution
21-40	Some evidence of organic pollution at the site
41-60	Organic pollution likely to contribute significantly to eutrophication of the site
> 61	Site is heavily contaminated with organic pollution

GDI = Generic Diatom Index (Coste & Ayphassoro 1991)

This index offers the advantage that diatoms need only be identified to generic level. It uses every freshwater genus in the database. This index uses five (s) classes, varying from 5 (very sensitive) to 1 (very tolerant) and indicator values (v) varying from 1 to 3 ((s) and (v) values referring to equation 6-2).

SPI = Specific Pollution sensitivity Index (Coste in CEMAGREF 1982)

The SPI is correlated with parameters related to organic pollution, ionic strength, and eutrophication and gives a complex estimation of water quality. It utilizes all the diatoms identified to species level. It is one of the most precise indices and is commonly used for calibration and estimation of other indices. The scale runs from 1 (worst) to 5 (best) water quality. It is based on the same principle as the GDI but works at the level of species rather than of genus.

BDI = Biological diatom Index (Lenoir & Coste 1996).

The BDI is used for the biological assessment of water quality. This index is based on a list of 209 key species showing different pollution sensitivities. The pollution sensitivity, or “ecological profile”, is determined through the species presence.

The Omnidia version 5.3 (Lecointe *et al*. 1993) database indicates the sensitivity of each variable within the different indices where a maximum value of 5 (converted to 20 by Omnidia) indicates pristine waters. Table 6-4 shows the interpretation of the scores for the various indices against ecological category (the condition or degree of integrity of the site) in terms of water quality.

Table 6-4: Interpretation of BDI, SPI and GDI index scores (from Harding & Taylor 2011).

Interpretation of index scores		
Ecological Category	**WQ Class**	**Index Score**
A	High quality	18-20
A/B		17-18
B	Good quality	15-17
B/C		14-15
C	Moderate quality	12-14

Interpretation of index scores		
C/D		10-12
D	Poor quality	8-10
D/E		6-8
E	Very poor quality	5-6
E/F		4-5
F		<4

6.6.5 Multivariate analysis

Canonical Correspondence analysis (CCA) is a multivariate gradient analysis technique used extensively in the environmental sciences. The technique perceives the patterns of variation in diatom community composition and attempts to explain it according to the environmental variables provided (Ter Braak & Verdonschot 1995). In order to determine the relationship between the environmental variables and diatom assemblages, CCA biplots were drawn using CANOCO version 4.5 (Ter Braak & Smilauer 1998). Only diatom taxa occurring in at least one sample with a relative abundance of >10%, were included in drawing up the biplot. The relationships between the water quality variables and the calculated index scores were determined with Pearson's correlation coefficient, carried out in Statistica 11 (Statsoft 2011). The Pearson coefficient determined how closely different variables were related to one another. The chemical measurements, except for pH (already in logarithmic form) were Log_{10}-transformed to normalise the data.

Note that Table 6-2 lists all the diatom samples analysed during the course of the project, but because of time constraints, data for only a sub-set of wetlands (Table 6-5) were used for the CCA and Pearson correlation analyses.

Table 6-5: Wetlands included in the analyses for the Canonical Correspondence Analysis and Pearson Correlation.

Wetland name	Alternative name
Noordhoek Salt Pan	Lake Michelle
Kenilworth Racecourse	
Rooipan	
Yzerfontein Salt Pan	
Yzerfontein Salt Pan inflow	
Burgerspan	
Kiekoesvlei	
Koekiespan	
Januariesvlei	Rondeberg
Modder River	Pampoenvlei
Witzand Aquifer Recharge	
Hoogvertoon	
Middelberg West	
Suurvlakte	Zuurvlakte

Wetland name	Alternative name
Silvermine lower	
Malkopsvlei	Bass Lake
Groot Rondevlei	
Groot Witvlei	
Kleinplaats West	Kleinplaas Dam
Blinde River	
Riversdale	Goukou River
Blomfontein	
Driehoek	
Sneeuberg Hut stream	
Verrekyker	Kluitjieskraal
Wagenbooms River	Leeu River
Die Vlakte	Slagboom
Silvermine Dam inflow	

6.7 RESULTS

6.7.1 Dominant taxa

The list of dominant species (abundance ≥10%) found at each site is given in Table 6-6 together with the *s* and *v* values accorded by Omnidia version 5.3 (Lecointe *et al*. 1993). Sensitivity (*s*) values range from 1 (very tolerant species) to 5 (very sensitive species). Indicator (*v*) values range from 1 (for species which are not very specific for their class of tolerance) to 3 (for species which are very good indicators).

All of the species observed during the course of the study, the wetlands at which they occurred and their abbreviations are listed in Electronic appendix G).

During the course of the study 324 species belonging to 60 genera were found, distributed amongst the families Achnanthidiaceae, Achnanthaceae, Bacillariaceae, Eunotiaceae, Cymbellaceae, Gomphonemataceae, Fragilariaceae, Melosiraceae, Naviculaceae, Rhoicospheniaceae, Rhopalodiaceae and Surirellaceae. Three endemic species were observed, all at abundance values of <5%. They are *Cocconeis engelbrechtii* Cholnoky, *Navicula dutoitana* Cholnoky and *Achnanthidium standerii* (Cholnoky) J.C. Taylor, Morales & Ector. The rest are cosmopolitan species well documented in the literature. Some members of the genus *Eunotia* were not identified to species due to the complexity of the genus.

The most common and abundant species were *Achnanthidium*, *Cyclotella meneghiniana*, *Eunotia bilunaris*, *Gomphonema parvulum, Eunotia incisa*, *Staurosira elliptica*, *Fragilaria bicapitata*, *Cocconeis pediculus*, *Pinnularia intermedia*, *Brachysira brebissonii*, *Eunotia* C.G. Ehrenberg, *Gomphonema*, *Amphora coffeaeformis*, *Amphora veneta*, *Planothidium engelbrechtii*, *Aulacoseira ambigua*, *Eunotia genuflexa*, *Nitzschia frustulum*, *Melosira nummuloides* and *Nitzschia palea,* species that are also commonly found in rivers. *Eunotia spp.* are sensitive towards pollution and operate as good indicator species, occurring in acidic flowing or standing water with low electrolyte content. *Nitzschia littoralis*, *Brachysira* *brebissonii*, *Melosira nummuloides* and *Planothidium engelbrechtii* are all indicators of salinity. Species indicative of organic pollution include *Amphora veneta* and *Nitzschia palea*.

Table 6-6: The dominant species found during the course of the study, the pollution sensitivity value and indicator value of each species.

Wetland and area		**Substratum**	**Dominant species found at each site**	**Sensitivity value (*s*)**	**Indicator value (*v*)**
CAPE TOWN	Kenilworth	Emergent vegetation	*Eunotia bilunaris* Ehrenberg Mills	5	2
			Eunotia formica Ehrenberg	5	1
			Gomphonema gracile Ehrenberg	4	1
	Khayelitsha Pool	Emergent vegetation	*Gomphonema parvulum* (Kützing) Kützing	2	1
			Nitzschia amphibia Grunow	2	2
			Nitzschia desertorum Hustedt	1	2
	Klaasjagers Estuary	Emergent vegetation	*Eunotia incisa* Gregory	5	1
			Staurosira construens Ehrenberg	4	1
			Nitzschia hantzschiana Rabenhorst	5	2
	Kleinplaas Dam	Emergent vegetation	*Cyclotella meneghiniana* Kützing	2	1
			Navicula disjuncta Hustedt	4	3
			Eunotia sp. C.G. Ehrenberg	5	2
	Lake Michelle (Noordhoek Salt Pan)	Emergent vegetation	*Staurosira elliptica* Ehrenberg	3	1
			Epithemia adnata (Kutzing) Brebisson	4	3
			Nitzschia microcephala Grunow in Cleve & Moller	1	3
	Silvermine River Upper	Emergent vegetation	*Planothidium engelbrechtii* (Cholnoky) Round & Bukhtiyarova	3	2
			Gomphonema parvulum (Kützing) Kützing	2	1
			Nitzschia sp. 11 A.H. Hassall	1	2
	Silvermine River lower	Emergent vegetation	*Fragilaria bicapitata* A. Mayer	5	2
			Hippodonta capitata Ehrenberg Lange-Bertalot	4	1
			Gomphonema parvulum (Kützing) Kützing	2	1
WEST COAST	Burgerspan	Sediment	*Nitzschia littoralis* Grunow in Cl. & Grunow	2	2
			Eunotia sp C.G. Ehrenberg	5	2
			Amphora coffeaeformis (Agardh) Kützing	2	3
	Januariesvlei	Emergent vegetation	*Planothidium engelbrechtii* Cholnoky Round &Bukhtiyarova	2	3
			Gomphonema pumilum (Grunow) Reichardt & Lange-Bertalot	5	1
			Nitzschia microcephala – Grunow in Cleve & Moller	1	3
	Kiekoesvlei	Emergent vegetation	*Nitzschia palea* (Kützing) W. Smith	1	3
			Nitzschia sp.2 A.H. Hassall	1	2
			Navicula sp.3 J.B.M. Bory de St. Vincent	3	2
	Koekiespan	Emergent vegetation	*Amphora coffeaeformis* var. *aponina* (Kützing) Archibald & Schoeman	2	3
			Nitzschia communis Rabenhorst	1	3
			Navicula sp. J.B.M. Bory de St. Vincent	3	2
	Modder River	Emergent vegetation	*Planothidium engelbrechtii* Cholnoky, Round & Bukhtiyarova	3	3
			Navicula modica Hustedt	4	2
			Tabularia fasciculata (Agardh) Williams et Round	2	3
	Rooipan	Sediment	*Amphora coffeaeformis* (Agardh) Kützing	2	3
			Navicula pusilla W. Smith	5	3

			Achnanthes sp. 3 J.B.M. Bory de St. Vincent	5	2
Wetland and area		**Substratum**	**Dominant species found at each site**	**Sensitivity value (*s*)**	**Indicator value (*v*)**
WEST COAST	Witzand Aquifer Recharge Area	Emergent vegetation	*Cocconeis pediculus* Ehrenberg	4	2
			Lemnicola hungarica (Grunow) Round & Basson	2	3
			Fragilaria capucina var.*capucina* Desmazieres	5	1
	Yzerfontein Salt Pan	Sediment	*Nitzschia littoralis* Grunow in Cl. & Grunown.	2	2
			Nitzschia sp *A*.H. Hassall	1	2
			Eunotia sp. C.G. Ehrenberg	5	2
CEDERBERG	Blomfontei n	Sediment	*Nitzschia palea* (Kützing) W. Smith	1	3
			Amphora sp. C.G. Ehrenberg ex Kützing	3	2
			Frustulia rostrata Hustedt	5	2
	Hoogverto on	Sediment	*Pinnularia intermedia* (Lagerstedt) Cleve	5	2
			Pinnularia borealis Ehrenberg	5	3
			Pinnularia divergens W.M. Smith	5	2
	Sneeuberg Hut	Sediment	*Eunotia* sp. C.G. Ehrenberg	5	2
			Psammothidium sp. Bukhtiyarova & Round	5	2
			Eunotia sp 5 C.G. Ehrenberg	5	2
	Driehoek	Sediment	*Craticula molestiformis* (Hustedt) Lange-Bertalot	4	3
			Eunotia sp.5 C.G. Ehrenberg	5	2
			Eunotia sp. 1 C.G. Ehrenberg	5	2
	Middelberg West	Sediment	*Eunotia* sp. C.G. Ehrenberg	5	2
			Eunotia sp. C.G. Ehrenberg	5	2
			Eunotia sp. C.G. Ehrenberg	5	2
	Suurvlakte	Sediment	*Eunotia flexuosa* (Brébisson) Kützing	5	2
			Eunotia incisa Gregory	5	1
			Frustulia rostrata Hustedt	5	2
	Wagenboo ms River	Emergent vegetation	*Achnanthes* sp. J.B.M. Bory de St. Vincent	5	2
			Tabellaria flocculosa (Roth) Kützing	5	1
			Rhoicosphenia abbreviata (Agardh) Lange-Bertalot	4	1
TULBAGH/WORCESTER	Die Vlakte	Emergent vegetation	*Achnanthidium saprophilum* (Kobayasi & Mayama) Round & Bukhtiyarova	1	3
			Gomphonema lagenula Kützing	2	3
			Eunotia sp. 1 C.G. Ehrenberg	5	2
	Kluitjieskra al (Verrekyke r)	Emergent vegetation	*Fragilaria ulna* var. *biceps* (Kützing) Lange-Bertalot	3	1
			Cocconeis placentula Ehrenberg	4	1
			Navicula recens (Lange-Bertalot) Lange-Bertalot	3	2
	Papenkuils (Bokkekraa l)	Emergent vegetation	*Fragilaria bicapitata* A.Mayer	5	2
			Planothidium engelbrechtii (Cholnoky) Round & Bukhtiyarova	3	2
			Gomphonema gracile Ehrenberg	4	1
BETTY'S BAY	Groot Rondevlei	Emergent vegetation	*Navicula* sp. J.B.M. Bory de St. Vincent	3	1
			Tabellaria flocculosa (Roth) Kützing	5	1
			Eunotia porcellus Cholnoky	5	2
	Groot Witvlei	Emergent vegetation	*Staurosira elliptica* (Schumann) Williams & Round	3	1
			Cocconeis placentula Ehrenberg	4	1
			Fragilaria construens f. venter Ehrenberg Hustedt	4	1

Wetland and area		Substratum	Dominant species found at each site	Sensitivity value (*s*)	Indicator value (*v*)
	Malkopsvlei	Emergent vegetation	*Aulacoseira ambigua* (Grunow) Simonsen	3	1
			Tabellaria flocculosa (Roth) Kützing	5	1
			Rhopalodia gibberula (Ehrenberg) O. Muller	5	3
VERMONT	Belsvlei upper	Emergent vegetation	*Tabellaria flocculosa* (Roth) Kützing	5	1
			Eunotia exigua (Brebisson ex Kützing) Rabenhorst	5	2
			Eunotia sp. C.G. Ehrenberg	5	2
	Die Diepte Gat	Emergent vegetation	*Eunotia incisa* Gregory	5	1
			Staurosira construens (Ehrenberg) Hamilton	4	1
			Nitzschia hantzschiana Rabenhorst	5	2
	Elias Gat	Emergent vegetation	*Gomphonema parvulum* Kützing	2	1
			Eunotia incisa Gregory	5	1
			Fragilaria capucina Desmazieres	5	1
	Hemel-en-Aarde	Emergent vegetation	*Eunotia bilunaris* (Ehr.) Mills	5	2
			Eunotia incisa Gregory	5	1
			Fragilaria capucina Desmazieres	5	1
	Salmonsdam	Emergent vegetation	*Cyclotella meneghiniana* Kützing	2	1
			Eunotia sp. C.G. Ehrenberg	5	2
			Fragilaria tenera (W.Smith) Lange-Bertalot	4	2
	Vermont Pan	Emergent vegetation	*Nitzschia frustulum* (Kützing)Grunow	3	2
			Planothidium engelbrechtii (Cholnoky) Round & Bukhtiyarova	3	2
			Achnanthes sp. J.B.M. Bory de St. Vincent	5	2
AGULHAS PLAIN	Modder Valley (Waskraalsvlei)	Emergent vegetation	*Achnanthes* sp. J.B.M. Bory de St. Vincent	5	2
			Fragilaria capucina Desmazieres var. *capucina*	5	1
			Achnanthidium minutissima Kützing	5	1
	Voelvlei	Emergent vegetation	*Nitzschia palea* (Kützing) W.Smith	1	3
			Nitzschia gracilis Hantzsch	4	2
			Cyclotella meneghiniana Kützing	2	1
	Wiesdrift	Emergent vegetation	*Planothidium engelbrechtii* (Cholnoky) Round & Bukhtiyarova	3	2
			Nitzschia palea (Kützing) W.Smith	1	3
			Fragilaria tenera (W.Smith) Lange-Bertalot	4	2
	Groot Hagelkraal upper	Emergent vegetation	*Eunotia genuflexa* Norpel-Schempp	5	2
			Eunotia flexuosa (Brebisson) Kützing	5	2
			Planothidium engelbrechtii (Cholnoky) Round & Bukhtiyarova	3	2
	Groot Hagelkraal lower	Emergent vegetation	*Eunotia genuflexa* Norpel-Schempp	5	2
			Eunotia flexuosa (Brebisson) Kützing	5	2
			Eunotia minor (Kützing) Grunow in Van Heurck	5	1
	Pearly Beach	Emergent vegetation	*Cocconeis placentula* Ehrenberg	4	1
			Lemnicola hungarica (Grunow) Round & Basson	2	3
			Navicula libonensis Schoeman	3	2
	Agulhas Salt Pan	Sediment	*Navicula* sp. J.B.M. Bory de St. Vincent	3	2
			Amphora coffeaeformis (Kützing) Archibald	2	3

			Nitzschia erosa Giffen	1	2
	Die Pan (Vispan)	Sediment	*Navicula scintillosa* Manguin	3	2
			Amphora sp. C.G. Ehrenberg ex F.T. Kützing	3	2
			Navicula reichardtiana Lange-Bertalot	5	3
Wetland and area		**Substratum**	**Dominant species found at each site**	**Sensitivity value (*s*)**	**Indicator value (*v*)**
AGULHAS PLAIN	Gans Bay	Emergent vegetation	*Planothidium engelbrechtii* (Cholnoky) Round & Bukhtiyarova	3	2
			Nitzschia hantzschiana Rabenhorst	5	2
			Gomphonema gracile Ehrenberg	4	1
	Melkbospan	Sediment	*Amphora* sp. C.G. Ehrenberg ex F.T. Kützing	3	2
			Navicula sp. J.B.M. Bory de St. Vincent	4	2
			Pinnularia sp. C.G. Ehrenberg	5	2
	Ratel River Estuary	Emergent vegetation	*Cyclotella meneghiniana* Kützing	2	1
			Eunotia sp. C.G. Ehrenberg	5	2
			Fragilaria tenera (W.Smith) Lange-Bertalot	4	2
	Soetendals vlei	Emergent vegetation	*Achnanthes* sp. J.B.M. Bory de St. Vincent	5	2
			Achnanthidium crassum Potapova & Ponader	5	2
			Achnanthidium saprophilum Round & Bukhtiyar	3	2
	Varkensvlei	Emergent vegetation	*Amphora veneta* Kützing	1	2
			Tabularia fasciculata (Agardh)Williams et Round	2	3
			Gomphonema parvulum (Kützing	2	1
	White Water Dam	Emergent vegetation	*Brachysira brebissonii* Ross	5	2
			Encyonopsis subminuta Krammer & Reichardt	5	1
			Eunotia sp. C.G. Ehrenberg	5	2
RIVERSDALE/ MOSSEL BAY	Blinde River	Emergent vegetation	*Melosira nummuloides* (Dillwyn) Agardh	2	3
			Achnanthes duthii Sreenivasa	5	2
			Gomphosphenia oahuensis (Hustedt) Lange-Bertalot	3	2
	Goukou /Riversdale	Emergent vegetation	*Eunotia* sp.5. C.G. Ehrenberg	5	2
			Nitzschia linearis (Agardh) W.M. Smith	3	2
			Eunotia bilunaris (Ehrenberg) Mills	5	2

6.7.2 Diatom community composition in relation to measured environmental variables

In this section the relationship between diatom communities and some environmental variables is explored using Canonical Correspondence analyses (CCA).

Table 6-7: Summary of the CCA analysis on diatom community composition and measured environmental variables; n=28.

Axes	1	2	3	4	Total inertia
Eigenvalues	0.67	0.552	0.542	0.501	14.803
Species-environment correlations	0.966	0.949	0.952	0.947	
Cumulative percentage variance					
of species data	4.5	8.3	11.9	15.3	
of species-environment relation:	19.9	36.2	52.3	67.2	
Sum of all eigenvalues					14.803
Sum of all canonical eigenvalues					3.374

The Eigen values given in Table 6-7 are a measure of the extent of variance represented by each axis. The total inertia is the sum of the eigenvalues of all axes. The first three axes account for 52.3% of the relationship between environmental variables and species composition (Figure 6-1).

In CCA biplots (Figure 6-1), distances between the environmental variables indicate the degree of similarity in species composition of the samples. Distances between positions of species along the plot indicate how similar/different they are in their distribution along gradients. Species close together are likely to respond similarly to the environmental variables measured. Long arrows indicate a large and important effect of that environmental variable on the distribution of species in the plot and the angle between an arrow and an axis indicates the correlation of that variable to that axis – if the angle is small then the variable is strongly correlated with that axis. Species positions can also be projected at 90 degrees onto environmental variables. If they project towards the middle (origin) of the arrow then they occur at average conditions for that variable but if they project towards the head of the arrow they are most abundant at above-average values for the variable and if they project towards the tail they are most abundant at below-average values.

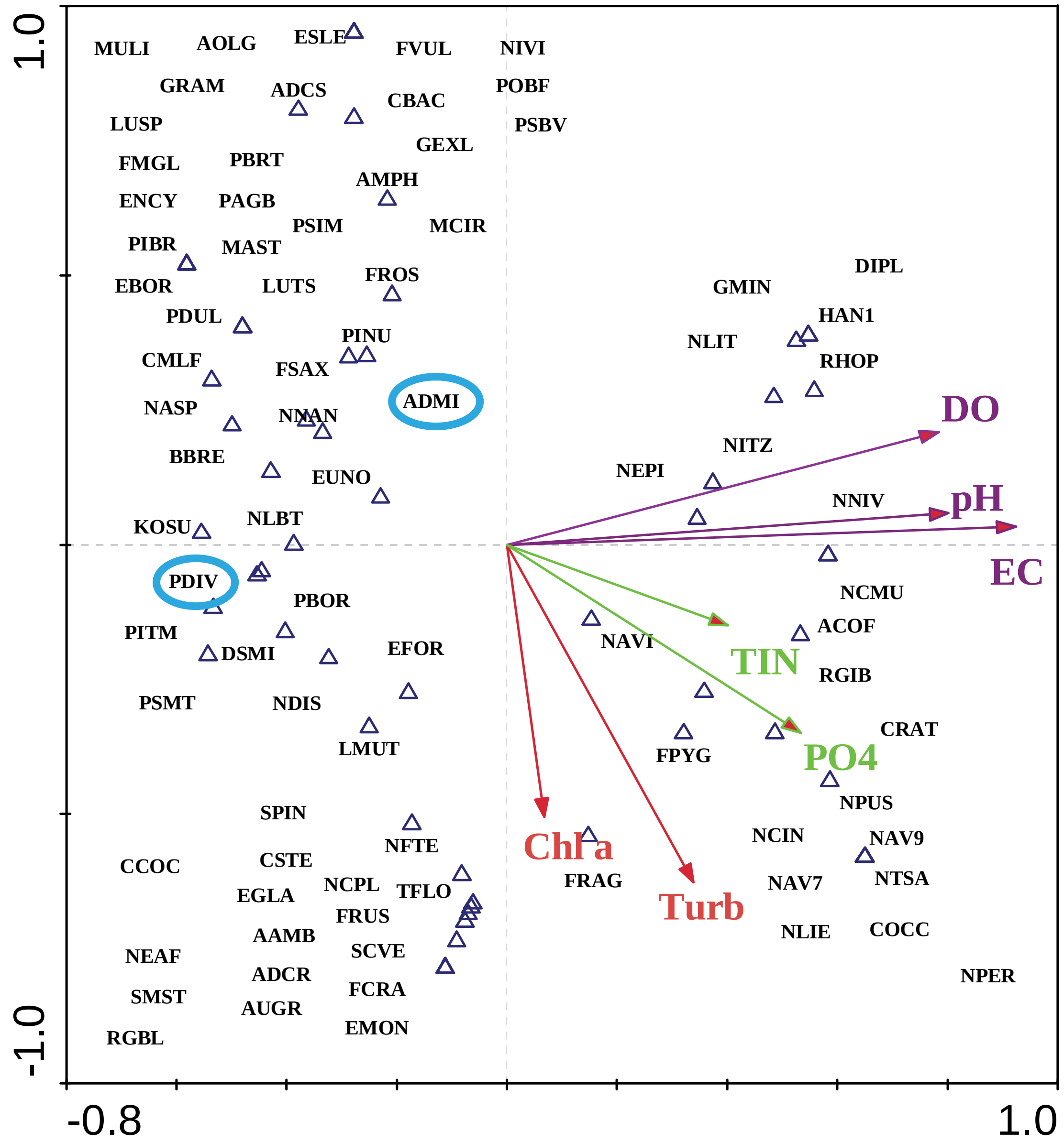

Figure 6-1: Canonical Correspondence Analysis (CCA) biplot for the wetlands showing the relationship between dominant diatom species (>10% relative abundance) and environmental variables. Sample number n=28. The abbreviations found in this figure are explained in Electronic appendix G. Blue circles represent examples discussed in the text.

In this ordination EC, DO and pH are most strongly correlated with the distribution of the taxa in multidimensional space, total inorganic nitrogen and chlorophyll *a* to a lesser extent. Species that seem to cluster at the lowest EC, pH and DO values (towards the projected tails of their arrows) are PDIV (*Pinnularia divergens*), KOSU (*Kobayasiella subtilissima*), PITM (*Pinnularia intermedia*) and DSMI (*Diploneis smithii*). Species clustering at higher EC, pH and DO values (towards the direction of the arrow) are NNIV (*Navicula nivalis*), NCMU (*Nitzschia commutatoides*), RGIB (*Rhopalodia gibba*), GMIN (*Gomphonema minutum*) and NLIT (*Nitzschia littoralis*), which appear to favour less acidic water.

Species close to the lowest values for total inorganic nitrogen and phosphate are EUNO (*Eunotia* spp.), BBRE (*Brachysira brebissonii*) and NNAN (*Nitzschia nana*). The species present in large numbers at the highest TIN and phosphate values are NAVI (*Navicula* species), FPYG (*Fallacia pygmeae*) and NPUS (*Navicula pusilla*).

Species clustering closest to high and moderate chlorophyll *a* and turbidity are FRAG (*Fragilaria* spp.), FPYG (*Fragilaria pygmeae*), AAMB (*Aulacoseira ambigua*) and AUGR (*Aulacoseira granulata*) and species closest to lower chlorophyll *a* and turbidity values are MUELI (*Muelleria linearis*), FMGL (*Frustulia magaliesmontana*) and GRAM (*Grammatophora* spp.).

With one exception, species included in the CCA ordinated as would be expected for samples from local rivers and from the international literature (*e.g.* Krammer & Lange-Bertalot 1986-2001). The exception is the species CMLF (*Craticula molestiformis*), which is reported to occur in relatively saline, often heavily polluted water, including sewage effluent. In the biplot (Figure 6-1), however, this species in this study seems to prefer electrolyte-poor waters with low nutrients. The rest of the species ordinate as expected. Two examples of these relationships will suffice (blue circles in Figure 6-1). *Achnanthidium minutissimum* (ADMI) occurs in waters relatively poor in nutrients and with moderate electrical conductivity. *Pinnularia divergens* (PDIV), a montane species, occurs in acidic, oligotrophic, electrolyte-poor water (50-100 µS cm^{-1}), optimally at pH 5.8-6.1 (Cholnoky 1968; Taylor *et al*. 2007). The Canonical Correspondence Analysis shows that in general diatom species react to change in water quality in the expected manner showing that for the wetlands in question the indices can be used outside of their continent of derivation.

6.7.3 Correlations between chemical variables and diatom index scores

Pearson's correlation was used to ascertain the relationship between the diatom index scores and the environmental variables measured during this study (Table 6-8). The diatom indices used for the correlation measurements were %PTV, GDI, SPI and BDI and the physical and chemical variables were pH, temperature, dissolved oxygen (% saturation), electrical conductivity and turbidity, and the concentrations of phosphate, nitrite, nitrate and ammonium.

Table 6-8: Pearson correlation coefficients between environmental variables and diatom index scores. Significant correlations at p< 0.05; n= 28. Non-significant correlations indicated by -----------

Environmental variable	**Diatom index**			
	SPI		**BDI**	
***EC (mS m^{-1})**	-0.4308	p=0.022	-0.6363	p=0.000
pH	-0.4173	p=0.02	-0.4884	p=0.008
Temperature (°C)	-0.4106	p=0.030	-0.4665	p=0.012
Dissolved oxygen (%)	-0.5511	p=0.002	-0.5651	p=0.002
Ammonium (mg N/L)	------	------	------	------
Nitrite (mg N/L)	------	------	------	------
Nitrate (mg N/L)	------	------	------	------
Phosphate (mg P/L)	-0.5419	p=0.003	-0.4226	p=0.025
Turbidity (NTU)	-0.4951	p=0.007	------	------

*****Note: EC = electrical conductivity

The SPI and the BDI correlated significantly with electrical conductivity, pH, temperature, dissolved oxygen and phosphate (Table 6-8). The %PTV and GDI showed no correlation with any of the environmental variables (data not shown). The SPI in addition, also correlated significantly with turbidity.

The correlations were negative for most environmental variables, which mean that as the concentrations of the variable in question rises, the SPI or BDI score decreases. The higher the value, the higher the quality of the water reflected by the score.

6.7.4 Diatom-based indices of water quality

From Table 6-8, it can be seen that the SPI index correlated best with the measured environmental variables. Thus this index was used in an attempt to describe the water quality class of each wetland.

Tables 6-9 and 6-10 show the SPI scores and the corresponding Ecological Category and Water Quality class for each wetland according to the criteria listed in Table 6-4. Scores were derived either from single samples (shown in Table 6-9) or from samples taken from more than one substratum type (Table 6-10).

Table 6-9: Diatom-derived index scores for water quality class and ecological category of each wetland where only one substratum was sampled.

Wetland name	Ecological Category	Class	SPI score	Substratum
Die Vlakte	C	Moderate quality	13	Vegetation
Wagenbooms River	B	Good quality	15.6	Vegetation
Sneeuberg Hut Stream	B	Good quality	16.9	Sediment
Driehoek	A/B	High quality	17.2	Sediment
Suurvlakte	A	High quality	18.7	Sediment
Blomfontein	C/D	Moderate quality	11.8	Sediment
Malkopsvlei	B/C	Good quality	14.6	Vegetation
Riversdale	B	Good quality	16,5	Sediment
Groot witvlei	C/D	Moderate quality	11,3	vegetation
Silver dam inflow	A	High quality	19.9	*Phragmite*s Sp.
Kiekoesvlei	F	Very poor quality	2.4	Sediment
Koekiespan	E	Very poor quality	6	Vegetation
Rooipan	C/D	Moderate quality	11.3	Sediment

The SPI index identified four wetlands in an “A category” (Hoogvertoon, Suurvlakte, Kenilworth Racecourse and Silvermine inflow), and two in the “very poor” F category (Koekiespan and Kiekoesvlei). The scores from different substrata sampled at single wetlands (Table 6-10) differed, but seldom by more than one class.

The dominant diatom taxa from wetlands in which more than one type of substratum was sampled are listed in Table 6-11. Of the twelve wetlands examined in this way, the dominant taxa differed in six.

Table 6-10: Diatom-derived index scores for water quality class and ecological category of each wetland where different substrata were sampled.

Wetland name	Ecological Category	Class	SPI score	Substratum
Hoogvertoon	A/B	High quality	17.8	Sediment
Hoogvertoon	A	High quality	18.8	Vegetation
Verrekyker	C/D	Moderate quality	10.9	Vegetation
Verrekyker	D/E	Poor quality	6.3	Floating vegetation
Verrekyker	D/E	Poor quality	7.4	Vegetation (grass)
Verrekyker	D	Poor quality	8.4	Floating vegetation
Kleinplaats	C	Moderate quality	12,3	Vegetation
Kleinplaats	C/D	Moderate quality	11,1	Sediment
Groot Rondevlei	B/C	Good quality	14,3	Sediment
Groot Rondevlei	B	Good quality	15,1	Vegetation
Kenilworth Racecourse	A	High quality	19.7	Sediment
Kenilworth Racecourse	A/B	High quality	17.5	Vegetation
Silver dam lower	C/D	Moderate quality	11.2	Reeds
Silver dam lower	D	Poor quality	10	Palriet
Lake Michelle	C	Moderate quality	10.4	Vegetation
Lake Michelle	C	Moderate quality	13.5	Reeds
Januariesvlei	C/D	Moderate quality	10.1	Emergent vegetation
Januariesvlei	B	Good quality	15.5	Submerged vegetation
Modder River	D	Poor quality	9.7	Vegetation
Modder River	D	Poor quality	9	Stones
Yzerfontein Soutpan A	D/E	Poor quality	6.6	Plastic pipe
Yzerfontein Soutpan B	D/E	Poor quality	7.5	Submerged vegetation
Yzerfontein Soutpan B	D	Poor quality	9.3	Plastic pipe
Yzerfontein Soutpan A	D/E	Poor quality	7.4	Sediment
Burgerspan	C/D	Moderate quality	10.4	Wooden crate
Burgerspan	C/D	Moderate quality	10.9	Juncus Sp.
Burgerspan	C/D	Moderate quality	11	Sediment

Table 6-11: Dominant diatom taxa from wetlands in which more than one type of substratum was sampled. Dominant taxa that differ on different substrata in a single wetland are indicated by bold face.

Wetland name	Dominant taxon	Substrate
Kenilworth Racecourse	*Eunotia bilunaris*	sediment
Kenilworth Racecourse	*Eunotia bilunaris*	vegetation
Silver dam lower	***Fragilaria ulna***	**reeds**
Silver dam lower	***Planothidium engelbrechtii***	**palmiet**
Witzand aquifer recharge	*Cocconeis placentula*	emergent vegetation
Witzand aquifer recharge	*Cocconeis placentula*	submerged vegetation
Hoogvertoon	***Pinnularia intermedia***	**sediment**
Hoogvertoon	***Pinnularia borealis***	**vegetation**
Verrekyker	***Nitzschia palea***	**submerged vegetation**
Verrekyker	***Cyclotella meneghiniana***	**floating vegetation**
Verrekyker	***Fragilaria ulna***	**emergent vegetation**
Verrekyker	***Nitzschia palea***	**macrophytes**
Kleinplaats	*Cyclotella meneghiniana*	vegetation
Kleinplaats	*Cyclotella meneghiniana*	sediment
Groot Rondevlei	***Staurosira construens***	**sediment**
Groot Rondevlei	***Tabellaria flocculosa***	**vegetation**
Januariesvlei	***Planothidium engelbrechtii***	**emergent vegetation**
Januariesvlei	***Gomphonema gracile***	**submerged vegetation**
Modder River	*Planothidium engelbrechtii*	vegetation
Modder River	*Planothidium engelbrechtii*	stones
Lake Michelle	***Sellaphora pupula***	**vegetation**
Lake Michelle	***Planothidium engelbrechtii***	**reeds**
Yzerfontein Salt Pan	*Nitzschia littoralis*	plastic pipe
Yzerfontein Salt Pan	*Nitzschia littoralis*	vegetation
Yzerfontein Salt Pan	*Nitzschia littoralis*	sediment
Yzerfontein Salt Pan	*Nitzschia littoralis*	Sediment
Burgerspan	*Nitzschia littoralis*	wooden crate
Burgerspan	*Nitzschia littoralis*	*Juncus* sp
Burgerspan	*Nitzschia littoralis*	sediment

6.7.5 Comparison of categories defined by SPI and WET-Health

Table 6-12 provides a comparison of the categories obtained for the 26 wetlands for which both SPI and WET-Health assessments were made. Ten of the wetlands were placed in the same or adjacent categories; two were placed one or two categories higher by the SPI; twelve were placed one or two categories higher by WET-Health. Two artificial systems were not categorized by WET-Health.

Table 6-12: Comparison of categories assessed by the SPI diatom index and WET-Health.

Wetland name	SPI category	WETHealth category	Diatom (D) or WETHealth (W) category higher?
Die Vlakte	C	C/D	
Wagenbooms River	B	C	D
Hoogvertoon	A-A/B	A	
Sneeuberg Hut Stream	B	A	W
Driehoek	A/B	B	
Suurvlakte	A	C	D
Verrekyker	C/D to D/E	C	W
Blomfontein	C/D	A	W
Malkopsvlei	B/C	B	
Riversdale	B	B/C	
Kleinplaats	C-C/D	A	W
Groot Rondevlei	B-B/C	B	
Groot Witvlei	C/D	B	W
Kenilworth Racecourse	A-A/B	A	
Silvermine dam inflow	A	A	
Silvermine dam lower	C/D-D	C	
Witzand Aquifer	C-D	ARTIFICIAL	
Kiekoesvlei	F	D	W
Lake Michelle	C	TRANSFORMED	
Januariesvlei	B-C/D	A	W
Modder River	D	C	W
Yzerfontein Salt Pan A	D/E	B	W
Yzerfontein Salt Pan B	D-D/E	B	W
Koekiespan	E	D	W
Rooipan	C/D	C	
Burgerspan	C/D	B/C	W

6.8 DISCUSSION

Despite the once-off sampling regime and our almost complete lack of knowledge of the diatom fauna of the south-western Cape wetlands, a number of useful results emerged from the analyses. The species *Eunotia genuflexa*, *Eunotia flexuosa*, *Eunotia* sp. C.G. Ehrenberg, *Rhopalodia gibberula*, *Navicula reichardtiana*, *Achnanthidium crassum*, *Brachysira brebissonii* and *Tabellaria flocculosa* are confirmed as being sensitive species, meaning that these species would be the first to die-off if a wetland became degraded. Note that species are useful indicators of the upper limits of pollution that they can tolerate and not the lower limit. Thus species such as *Gomphonema parvulum*, *Nitzschia palea, Lemnicola hungarica* and *Navicula recens,* which tolerate pollution, may also occur in fairly clean water.

The relationship between diatom communities and some environmental variables using CCA (Figure 6-1) showed that in general, local diatom communities respond in a similar manner to their European counterparts to key environmental variables. Interestingly, the biplot shows that in this analysis *Craticula molestiformis* is most likely to be found in electrolyte-poor waters with low nutrients, whereas in previous studies (Taylor *et al.* 2007) it was found in electrolyte-rich and often heavily polluted water, including sewage effluents. The most likely explanation for this discrepancy is that this is an example of sibling species, with apparently identical morphology but different levels of tolerance to pollutants, one preferring wetlands and the other preferring rivers, or one being a CFR endemic with different tolerance limits. This phenomenon is important for index derivation and needs further investigation.

Water quality in rivers is usually related to longitudinal position in the river, and to levels of pollution, both “natural” and of human origin. Natural water quality in wetlands is far more variable than in rivers, both from site to site and over time. For example, Yzerfontein Salt Pan and Rooipan, which are naturally saline systems, were assigned low SPI scores of 6.6 and 11.3, indicating poor to moderate water quality although according to the PTV% scores there was no indication of organic pollution. Blomfontein, located in the Cederberg Mountains, is virtually pristine and yet the SPI score for this wetland indicated only moderately good water quality, placing it in the C/D class, although it should be in an “A” class because of its natural, almost untouched, condition. Furthermore, low pH values are normal in many south-western Cape wetlands, while intermediate pH values are the norm in most systems elsewhere. Other systems are naturally extremely turbid (and still pristine) and many wetlands are naturally virtually anoxic or highly saline. These features are seldom encountered in rivers and can lead to misinterpretation of results of indices such as the SPI. Naturally saline or acidic systems are therefore special cases that cannot be adequately assessed using the unmodified SPI. In cases like these, where indices can be misinterpreted, it is important to compare results with other sources such as chemical analysis, diversity of diatoms and land-use. Caution needs to be exercised in the deciding what “good” water quality means: for whom is it “good”? Ultimately if diatoms are to be used routinely in bioassessment of water quality in wetlands, it will probably be necessary to develop new indices based on an understanding of what is naturally “good” water quality in systems whose water chemistry is different from that of rivers. It is likely that in several cases the differences in categories derived from the SPI and WET-Health can be explained by differences in natural water quality.

In a similar vein, the lack of correlation between any of the indices and nutrients, especially nitrite, nitrate and ammonium (Table 6-8), needs to be investigated. This project (Chapter 4) has shown that levels of nitrate in south-western Cape wetlands can be very low and fairly variable. A lack of correlation between nutrients and indicators is not necessarily problematic but the phenomenon does need explanation.

In general, diatom communities from different substrata in the same wetland reflected more or less the same water quality status (Table 6-9). Of the twelve sites for which more than one substratum was sampled (Table 6-10), though, the dominant species of diatom was the same in only six. Generally, rocks are the best substratum for sampling (Round 1991), but they are not always available in wetlands. It seems that vegetation and sediment samples are the best substrates to reflect the water quality status of a wetland since they were the dominant substrates present at most sampling sites, and yielded good results. Studies by Porter *et al*. (1993), Lowe & Pan (1996), Kelly *et al*. (1998) and Soinine and Eloranta (2004) have shown that consensus has yet to be reached concerning assessment of benthic diatom community structure based on epiphytic and epilithic communities. To obtain consistent results it will be necessary to investigate the issue of substratum further. It may be that the diatom assemblages in the CFR are sufficiently species rich that substratum is not important but in other cases it may even be necessary to consider the use of artificial substrata.

6.9 CONCLUSIONS

The following conclusions can be made from this part of the overall project:

- Despite the once-off sampling regime and the almost complete lack of knowledge of the diatom flora of the south-western Cape wetlands, the wetlands could be separated into “condition” or water quality classes based on an analysis of their diatom floras. Bioassessment using diatoms is therefore a potential tool for assessing the condition of wetlands of the south-western Cape of South Africa.
- Whilst diatom samples from different substrata gave similar results, further investigations are needed into the effect of substratum on the “condition” or water quality class identified by diatom analysis
- It seems that the species identified in this study as equivalent to European species do respond in the same way to water quality variables, suggesting that they are cosmopolitan species.
- Strong correlations exist between certain, but not all, water quality variables and the indices calculated during this study.
- The SPI (Sensitivity Pollution Index) showed potential for describing water quality in freshwater wetlands but caution should be used in interpreting results for naturally occurring saline systems.

CHAPTER 7

CHANGES IN ECOLOGICAL HEALTH AND THE FACTORS DRIVING THAT CHANGE

One of the primary objectives of this project was to identify how the wetlands have changed in terms of "ecological health" or "environmental condition" over the intervening 25 years. In this chapter we first discuss the approach that was used to assess the ecological health and the challenges that accompanied this. The results are then presented with regard to the change in ecological health of each wetland (whether it has deteriorated, improved or remained the same) and discuss the factors driving such changes.

7.1 PRESENT ECOLOGICAL STATE

In 2012, at the start of the present sampling programme, there was some confusion amongst the wetland community around which (South African) wetland assessment method to use to determine the ecological health (expressed as the "Present Ecological State") for different wetland (HGM) types. Water Research Commission project K5/2192 titled "Consolidation and optimization of wetland health assessment methods through development of a decision support tree (DST) that will provide guidelines" was an initiative to resolve some of this confusion and also started in 2012. There was collaboration between the two WRC projects and a sub-set of the project wetlands listed in Appendix B was assessed for the PES using multiple methods and assessors. The results from these trials (and from subsequent trials on other wetlands sampled in 2013) are reported in Ollis (2014) together with a gap analysis of existing South African assessment methods and recommendations for further research in Ollis and Malan (2014).

The wetland assessment methods that were investigated were the three main published methods, namely:

- The approach originally documented in the Resource Directed Methods manual for wetlands by Duthie (1999)
- The Wetland Index of Habitat Integrity (DWAF 2007)
- Wet-Health Level 1 (Macfarlane *et al*. 2009)

Other less well-developed methods such as the approach of calculating Human Development Scores (HDS) used in Bird (2010) and a draft method developed by Eskom were also investigated but found to be unsuitable.

No single method was found to be better than another and all had good points but also had problematic aspects. An emerging recommendation from WRC project K5/2192 (as of December 2012) was that a new method be developed by merging the best aspects of the existing methods. Only the method of Duthie (1999) was found to be applicable to *all wetland types*. The WIHI method is applicable only to flood plain and channelled valley bottom wetlands, and WET-Health is not really suitable for depressions. With regard to the present project, as noted in Chapter 2, the project wetlands represent a wide range of wetland types. In the light of the above findings, it was decided to use method of Duthie (1999) since it is reasonably rapid (a large number of wetlands were sampled and thus the time spent on each was limited), simple, flexible and fairly transparent. The scoring sheet used to assess ecological health is shown in Appendix C. The results were recorded as a

Present Ecological Health score ranging from A to E, where A= natural and E = extremely disturbed/ no or virtually no functional wetland remaining.

Further recommendations arising during the course of WRC project K5/2192 that were incorporated into the current study were the importance of including a description of the reference condition of a given wetland (because any impacts/changes are measured against this). Also that it is critical that the importance, in addition to the benefits (ecosystem services), that each wetland provides be determined. For each wetland surveyed, a description is given of the likely reference condition, an assessment made of the Ecological Importance and Sensitivity, in addition to an evaluation of additional benefits supplied by the wetland (Volume 2: Wetland Status Reports).

7.2 CHALLENGES ENCOUNTERED IN ESTABLISHING THE HISTORICAL AND PRESENT ECOLOGICAL STATE

Wetland science in South Africa was in its infancy when King and Silberbauer undertook the first survey of wetlands in the late 1980s. Thus assessment of wetland ecological health had not been formalised and no established method such as WET-Health or that of Duthie (1999) was used. Nevertheless, the field datasheet from the original project made provision for the following:

- A place to record “Subjective ecological judgement of the condition of this wetland” with a choice from the following ratings (per sampling site): Pristine, Mildly disturbed, In sustainable use, Over-utilised, Completely disrupted.
- There is a place on the datasheet in which to “Comment on any special value of this wetland (rare spp like µfrogs present, the most polluted water body in area, etc.)”.
- There is an entire page in the field datasheet dedicated to recording “Disturbances”. These are divided into those relating to the catchment, *e.g.* “Conserved”, “Forestry”, “Urban” and those relating to the wetland itself and include “Water abstraction (pumping)’, “Effluent discharge” and “Obstruction (dam/road/bridge)”. Each disturbance can be scored in terms of the extent/ magnitude of impact as; √, +, ++ or +++.
- Sometimes additional comments were recorded, for example information from discussion with the land-owner.

Unfortunately many of the original field datasheets are missing (Section 2.1), some are incomplete and even when available it is difficult to establish what the likely PES category (ranging from A = natural to E = highly disturbed) for each wetlands was. In the present project, all available information was used to estimate the historical ecological state including photographs, information on land-use change, clues from the biota (vegetation), water chemistry, and available reports. The resulting historical “ecological health score” (Table 9-1) however, is at best likely to be an educated guess.

7.3 ASSESSING THE HISTORICAL ECOLOGICAL HEALTH OF THE WETLANDS

To evaluate how each wetland has changed in terms of ecological health, the reference condition was first described, followed by any changes or impacts in the historical condition (when King and Silberbauer sampled) and an estimate of the ecological health in the historic condition was assigned. Finally, using the method of Duthie (1999) the present ecological health was determined. Whether ecological health has improved or deteriorated since the original survey was noted and what factors this can most likely be ascribed to. A distinction was made between the trajectory of change in ecological condition and any change in conservation status. Using this approach has yielded a semi-quantitative picture of trends in in wetland environmental condition for the Fynbos Biome over the past 25 years.

Table 7-1 shows a summary of results for the historical survey. For each wetland, the area it is located in and the HGM type are recorded. Also recorded are factors likely to have influenced the ecological health, such as the major land-use surrounding the wetland at that time, recorded impacts and the conservation status. Finally, the likely historical ecological health score is recorded and where available, any relevant comments from the field sheet (*e.g.* “in sustainable use”) on the overall ecological health. Those for which it was particularly difficult to assign a score are recorded with a question mark.

Table 7-1: Summary of historical Ecological Health Scores and the factors driving ecological condition. Comments in inverted commas from original fieldsheet. (WWTW = waste water treatment works, u/s = upstream, d/s = downstream).

Wetland name and area		**Historical "Ecological Health"**				
		HGM type	**Land-use**	**Conservation status**	**Major impacts***	**Ecological Health Score (subjective)**
Greater Cape Town	Cape Corps	Unknown (depresssion?)	Natural vegetation?	Military	WWTW present in 1988. Other impacts unknown.	Unknown (no records)
	Groot Rondevlei (Cape Point)	Depression	Natural veg.	Nature Reserve	Jeep track (infrequently used). Hiking trail	A
	Kenilworth Race Course	Depression	Natural veg.	Private land	Ringed by horse racing track. Steeplechase course through wetland? Limited horse grazing. Some drainage ditches in area.	B
	Khayelitsha Pool	Floodplain depression	Wetland area natural veg. But land nearby cleared for housing.	Private/municipal land	Road culverts, WQ impacts, land clearance for housing.	B/C
	Klaasjagers Estuary	Channelled valley bottom	Natural veg.	Nature Reserve	Some limited infrastructure upstream catchment. None in immediate environs.	A
	Kleinplaas Dam/Kleinplaats West	Mountain seep	Natural veg.	Nature Reserve	None (but dam in lower part of wetland).	A (above dam)
	Lake Michelle/ Noordhoek Salt Pan	Saline flat	Undeveloped, natural/disturbed veg.	Private land	Partial dredging, alien vegetation, grazing by cattle, horses.	C/D
	Silvermine Dam inflow	Channelled valley bottom	Natural veg.	Nature Reserve?	Jeep track (infrequently used). Hiking trails.	A
	Silvermine River (lower)/floodplain	Floodplain	Natural/disturbed veg and residential	Municipal	Residential development. Upstream farming. Alien veg. Straightened channel.	D
	Pinelands – The Crossing	Depression	Exotic grasses, residential, train lines	Private land	Infrastructure. Clearing of natural veg. Debris in water.	D

Wetland name and area		Historical "Ecological Health"				
		HGM type	Land-use	Conservation status	Major impacts*	Ecological Health Score (subjective)
West Coast	Burgerspan	Depression	Natural veg and cultivated fields	Private land	Agricultural impacts.	B/C
	Januariesvlei (Rondeberg)	Depression	Natural veg and pasture lands	Private land	Livestock, some drainage of seep area, flower picking.	B
	Kiekoesvlei	Depression	Agricultural lands	Private land	Agricultural impacts.	D
	Koekiespan	Depression	Agricultural lands	Private land	Agricultural impacts, mining of salt at some stage, berm.	D
	Modder River	Channelled valley bottom + unchannelled tributary	Agricultural lands	Private land	Roads, agricultural impacts, upstream abstraction. Alien veg. "Disruption of wetlands seems to be cause of erosion of river bank".	C
	Rooipan	Saline flat (no open water)	Residential and vacant land	Private land	Residential development. "Sorely churned up and mined for gypsum". Forestry? Alien veg (Acacias).	D/E
	Witzand aquifer recharge	Depression (artificial)	Natural/disturbed veg	Municipal land? Private land?	Tracks. Alien veg (Acacia).	N/A
	Yzerfontein Salt Pan	Saline depression	Natural/disturbed veg	Private land	Not recorded	B
	Yzerfontein Salt Pan inflow	Valley bottom	Natural/disturbed veg	Private land	Not recorded	C?
Cederberg	Blomfontein	Mountain seep	Natural veg	Conservation area	Jeep track across wetland. Sheep kraals? Erosion?	B
	Donker Kloof (tributary)	Mountain seep	Natural veg	Conservation area	Jeep track across wetland	A

Wetland name and area		Historical "Ecological Health"				
		HGM type	**Land-use**	**Conservation status**	**Major impacts***	**Ecological Health Score (subjective)**
	Driehoek	Channelled valley bottom	Natural veg (some agriculture in lower half)	Private land	Road crossings. Encroachment of agriculture, grazing in lower half. Abstraction, old drainage ditches. Erosion. Oaks, Poplars.	B
Cederberg	Hoogvertoon	Mountain seep	Natural veg	Conservation area	Jeep track/bridge across wetland. "Oaks plus old ruins".	B
Cederberg	Middelberg West	High altitude, channelled valley bottom	Natural veg	Conservation area	Hiking trail, hut, few alien trees, erosion in stream. Bracken.	B
Cederberg	Sederhoutkop	Mountain seep	Natural veg	Conservation area	Jeep track/bridge across wetland	A
Cederberg	Sneeuberg Hut stream	Mountain seep	Natural veg	Conservation area	Jeep track across wetland. Eroding. Litter. Classified as "over-utilised".	B
Cederberg	Suurvlakte (u/s of dam)	Channelled valley bottom	Natural veg.	Private land	Dam at lower end of wetland	B
Cederberg	Wagenbooms River	Unchannelled valley bottom	Agricultural lands	Private land	Pivot sprays, cultivated areas. Abstraction upstream.	B
Tulbagh/Worcester	Die Vlakte	Channelled valley bottom	Agricultural lands (although some "conserved")	Private land	Orchards upstream (north). D/s and immediately u/s "looks fairly stunted but natural". Road crossing.	B/C (u/s part) B (d/s part)
Tulbagh/Worcester	Kluitjieskraal (upper wetland).	Mosaic of seeps, channels	Forestry plantations	State forest	Plantations and other alien veg (*Sesbania, Eichhornia*). Sheep? Cultivation. Drainage ditches.	C/D (upper part)

Wetland name and area		Historical "Ecological Health"				
		HGM type	Land-use	Conservation status	Major impacts*	Ecological Health Score (subjective)
	Verrekyker (downstream wetland)	and depressions	Agriculture	Private	Burning and removal of palmiet. Some removal of wetland already completed	D (d/s part)
Tulbagh/Worcester	Papenkuils (Bokkekraal)	Floodplain	Agriculture, dam, urban.	Municipal and private land	Upstream agriculture, abstraction, encroachment of cultivation. Grazing. Alien veg (Sesbania, Acacia). Road crossing. Sand pumping.	C
	Platdrif	Channelled/unchannelled valley bottom	Agriculture	Private	Drainage, excavation, grazing. Eutrophication.	C?
Betty's Bay	Groot Rondevlei (Bettys Bay)	Depression	Low density residential	Municipal	Obstruction of flow by roads, drainage ditches, septic tanks. Clearing of natural veg (Malkopsvlei)	A/B
	Groot Witvlei	Depression (with outlet to sea)	Low density residential	Municipal		A/B
	Malkopsvlei (Bass Lake)	Depression with outflow to sea	Low density residential	Municipal		A/B
Vermont	Belsvlei (u/s and d/s)	Channelled valley bottom	Agriculture	Private	Road crossing, agricultural impacts (burning, ploughing).	B ("in sustainable use") both u/s and d/s parts.
	Die Diepte Gat	Large mountain seep	Agriculture	Private	Alien veg (pines, acacia), erosion, some grazing, cultivation	B
	Elias Gat (Vioolskloof) Site A	Channelled? Valley bottom	Agriculture	Private	Road crossing, alien vegetation.	C/D ("completely disrupted")
	Elias Gat (Vioolskloof) Site B	Unchannelled valley bottom	Agriculture	Private	Alien vegetation.	B ("in sustainable use")
	Hemel-en-Aarde	Channelled valley bottom	Agricultural land	Private land	Encroachment of cultivation, infilling from road. Alien veg (planted pines). Gums, acacia.	B/C ("in sustainable use")

Wetland name and area		Historical "Ecological Health"				
		HGM type	**Land-use**	**Conservation status**	**Major impacts***	**Ecological Health Score (subjective)**
	Salmonsdam – Site A	Unchannelled valley bottom	Nature reserve	Provincial	Few remnants of farming activities. Limited recreational infrastructure. Road crossing.	A
	Vermont Pan	Depression (endorheic)	Low density residential	Municipal	Roads, limited infrastructure	A/B
Agulhas – other wetlands	Agulhas Salt Pan	Saline depression	Vacant land	Conservancy	Agriculture. Infrastructure from salt mining	B "in sustainable use"
	Die Pan (Vispan)	Depression	Natural vegetation	Private land	Minimal disturbance	A
	Gans Bay	Depression	Vacant land, quarries. Some natural veg (*e.g.* milkwood forest).	Private land	Quarries in general area, grazing, alien veg. Landfill site nearby.	B "very good condition" apart from alien veg.
	Melkbospan	Saline depression	Natural land	Private land	Minimal	A
	Ratel River Estuary	River	Agricultural lands	Private land	River straightened, drained. Agriculture, alien veg? Road crossing?	D
	Rhenosterkop Pan	Saline depression	Agriculture/vacant land	Private land	Grazing, cultivation, houses.	B
	White water dam	Depression	Agriculture	Private	Agriculture, abstraction? Alien veg.	C
Agulhas – Nuwejaars	Farm 182 (Peters bog)	Wetland flat/ditch?	Agriculture	Private	Grazing ++++?	Unknown
	Soetendalsvlei	Large freshwater depression	Agriculture	Private	Cattle grazing, silt, sheep. Eutrophication.	B
	Soetendalsvlei Ditch	Not a wetland				

Wetland name and area		Historical "Ecological Health"				
		HGM type	Land-use	Conservation status	Major impacts*	Ecological Health Score (subjective)
	Voelvlei	Freshwater lake depression	Agricultural lands	Private land	Grazing, agricultural activities.	B
	Waskraalsvlei (Modder Valley)	Freshwater lake depression	Agricultural lands	Private land	Grazing, agricultural activities.	B
	Wiesdrif	Channelled valley bottom	Agricultural lands	Private land	Grazing, agricultural activities.	B
	Varkensvlei	Depression	Agricultural lands	Private land	Grazing, agricultural activities.	B
Agulhas – Groot Hagelkraal	Groot Hagekraal Upper	?	Agricultural lands	Private land	Unknown. None?	?
	Groot Hagelkraal Lower	Unchannelled valley bottom	Agricultural lands	Private land	Cultivation in some areas. Farm infrastructure (historic homestead). Road crossing?	?
	Pearly Beach	Depression (with river inflow and outflow to sea)	Vacant land/natural vegetation	Private land	Alien vegetation. Altered inflow	B?
Mossel Bay & Riversdale	Riversdale (excluding the Kruis River)	Unchannelled valley bottom	Agricultural lands	Private	Drainage, excavation, grazing, burning. Erosion channels from Kruis R. Erosion channel upstream.	B
Mossel Bay & Riversdale	Gouriqua	3 X freshwater seeps	Conservation (previously agricultural)	Kernkor (State)	Road crossing, abstraction, canal, draining. Limited infrastructure. Fencing enclosure	B
	Blinde Estuary	Estuary	Natural	Private land	Natural (?)	A?
	Blinde River	River	Natural/agriculture	Private land	Fairly natural	A?

It can be seen from Table 7-1 that in addition to a wide range of wetland HGM types, the wetlands chosen by King and Silberbauer varied in terms of the surrounding land-use (including agricultural areas, natural/undisturbed, residential), the type of impacts that they were subjected to (alien vegetation, draining, etc.) and consequently the ecological health. The majority of the wetlands (roughly two thirds) were in a natural/slightly impacted condition (*i.e.* A or B category). Some wetlands were already significantly impacted, however, and probably in a "C" or "D" category in terms of ecological heath. The most impacted of all the wetlands was probably Rooipan ("D/E" score) which was being mined for gypsum in the 1980s (Wetland Status Report – Rooipan).

7.4 ASSESSING THE CURRENT ECOLOGICAL HEALTH

Table 7-2 summarises information pertaining to the ecological health of the wetlands in the present day – namely land-use, conservation status, current impacts, including how water chemistry has changed from the historical project. The present ecological health score recorded from the assessment using Duthie (1999) is recorded and in the final column the trajectory of change since the historical survey 25 years ago is given. In the case of wetlands where a portion of the wetland was severely impacted or lost (*e.g.* Kluitjieskraal, or Die Vlakte), but the other portion is still in a relatively good condition, the two parts are evaluated separately.

Analysis of the results in Table 7-2 reveals that 25% of the wetlands visited in the present survey are in a natural ("A" category); 24% are in a "B" or slightly impacted category. A further 24% are fairly seriously modified (categories B/C, C and C/D) and 6% are in a "D" category or lower. Almost all of the wetlands in a natural condition included, unsurprisingly wetlands in the conservation areas such as the Cederberg, Table Mountain National Park, or the Agulhas National Park. Exceptions to this are Januariesvlei (West Coast) and Waskraalsvlei (Nuwejaars River, Agulhas Plain) which are both on private land.

The wetlands in the worst condition were Khayelitsha Pool (C/D) which is on the Kuils River and drains a highly developed urban catchment. Kiekoesvlei (D) and Koekiespan (D) which are both endorheic isolated depressions, are surrounded by agricultural lands. The lower portion of Belsvlei wetland which has eroded in the last few years (Wetland Status Report – Belsvlei) was assigned a D/E as there is very little functional wetland area remaining in the lower section of Belsvlei.

Table 7-2: Summary of Present-day Ecological Health Scores, the factors influencing this and the trajectory of change from the historical condition. (WfW = Working for Wetlands, CoCT =City of Cape Town).

Wetland name and area		Present "Ecological Health"						Trajectory of Ecological Health	Major cause of change
		HGM type	Land-use	Conservation status	Major impacts	Change in water quality	Ecological Health score		
Greater Cape Town	Cape Corps	Unknown (depresssion?)	Appears natural veg.	Military	Unknown. WWTW, powerlines.	Unknown	**Unknown**	**Unknown (likely to have deteriorated)**	Building of infrastructure
	Groot Rondevlei (Cape Point)	Depression	Natural veg	National Park	Jeep track (infrequently used). Hiking trail	Similar (currently very good)	**A**	**Same**	None
	Kenilworth Race Course	Depression	Natural veg	CoCT conservation area	Steeplechase course removed. Veg now managed scientifically.	Similar. Currently good	**A**	**Improved**	Scientific management of veg.
	Khayelitsha Pool	Floodplain depression	Roads/low-cost housing/commercial. But some buffer area of vegetation	CoCT conservation area	Road culverts, WQ impacts, land clearance for housing. Densification of infrastructure around and upstream of wetland.	Unknown (currently poor)	**C/D**	**Deteriorated**	Upstream development leading to increased treated effluent.
	Klaasjagers Estuary	Channelled valley bottom	Natural veg	National Park	Some in upstream catchment. None in immediate environs.	Deteriorated? Currently good	**A**	**Same/slight deterioration**	Possible threat from upstream development?
	Kleinplaas Dam/Kleinplaats West	Mountain seep	Natural veg	National Park	None (but dam in lower part of wetland).	Same (currently very good)	**A (above dam)**	**Same**	None
	Lake Michelle/Noord-hoek Salt Pan	Perennial depression	Residential development	Private land	Infrastructure development, altered hydrology.	Improved	**??**	**Complete change in ecological character**	Dense residential development.
	Silvermine Dam inflow	Channelled valley bottom	Natural veg	National Park	Trees on edge of catchment removed.	Same (currently very good)	**A**	**Same/slight improvement**	Scientific management of veg
	Silvermine River (lower)/floodplain	Floodplain	Rehabilitated natural veg.	CoCT conservation area	Stormwater inflow, abstraction of water upstream.	Slight deterioration?	**C**	**Improved**	Better management of veg, but WQ a threat.

Wetland name and area		Present "Ecological Health"						Trajectory of Ecological Health	Major cause of change
		HGM type	Land-use	Conservation status	Major impacts	Change in water quality	Ecological Health score		
	Pinelands – The Crossing							**Disappeared**	Drained, under housing and a playpark.
West Coast	Burgerspan	Depression	Natural veg and cultivated fields	Private land	Cultivate fields. Farm buildings.	No data	**B/C**	**Same**	Possible encroachment of cultivation.
	Januariesvlei (Rondeberg)	Depression	Natural veg	Private land	Infrastructure development but far away from wetland.	Elevated nutrients? Cause unknown.	**A**	**Improved**	Pasture lands reverted to natural veg.
	Kiekoesvlei	Depression	Agricultural lands (pasture)	Private land	Pasture lands. Farm buildings.	No data (currently poor)	**D**	**Same**	Same
	Koekiespan	Depression	Agricultural lands.	Private land	Agriculture, farm buildings. No longer mining salt, but pans still remain. Berm.	Elevated nutrients?	**D**	**Same**	Same
	Modder River	Channelled valley bottom + unchannelled tributary	Agricultural lands (slight increase in extent)	Private land	Roads, agricultural impacts, upstream abstraction. No active erosion visible. Alien and terrestrial veg encroachment.	Salinity increased	**C**	**Same**	Erosion decreased, but u/s agriculture increased.
	Rooipan	Three saline depressions (seasonal open water)	Residential and vacant land	Private land	Residential development encroachment. Dirt track.	Similar? Phosphates elevated?	**C**	**NA**	Gypsum mining ceased.
	Witzand aquifer recharge	Depression (artificial)	Conservation/recharge area	CoCT conservation area	Dirt tracks	No data	**N/A**	**Improved**	Alien veg removed. Indigenous veg established.
	Yzerfontein Salt Pan	Saline depression	Natural/disturbed veg. Mining infrastructure (limited).	Private land	Dirt tracks, pipes, spoil-heaps, buildings. Residential (not close).	Similar, but elevated phosphates	**B**	**Deteriorated***	Gypsum mining
	Yzerfontein Salt Pan inflow	Wetland no longer exists.						**Disappeared**	Reduced inflow of water

Wetland name and area		Present "Ecological Health"						Trajectory of Ecological Health	Major cause of change
		HGM type	Land-use	Conservation status	Major impacts	Change in water quality	Ecological Health score		
Cederberg	Blomfontein	Mountain seep	Natural veg	Conservation area	Jeep track (private/infrequently used).	Similar (very good)	**A**	**Improved**	Better management.
Cederberg	Donker Kloof (tributary)	Mountain seep	Natural veg	Conservation area	Jeep track (private/infrequently used).	Expected to be similar	**A**	**Improved/Same**	Better management.
Cederberg	Driehoek	Channelled valley bottom	Natural veg (some agriculture in lower half bordering on wetland)	Greater Cederberg Conservancy	Road crossings. Agriculture along edge.	Similar (very good)	**B**	**Improved**	Better management. Containment of agricultural activities.
Cederberg	Hoogvertoon	Mountain seep	Natural veg	Conservation area	Jeep track (private/infrequently used).	Similar (very good)	**A**	**Improved**	Better management (*e.g.* oaks and ruins removed)
Cederberg	Middelberg West	High altitude, channelled valley bottom	Natural veg	Conservation area	Hiking trail, 2 huts, 4 alien trees. No active erosion or bracken.	Similar (very good)	**A**	**Improved**	No erosion, bracken removed.
Cederberg	Sederhoutkop	Mountain seep	Natural veg	Conservation area	Jeep track (private/infrequently used).	Expected to be similar	**A**	**Improved/Same**	Better management.
Cederberg	Sneeuberg Hut stream	Mountain seep	Natural veg	Conservation area	Jeep track (private/infrequently used). No sign of erosion.	Similar (very good)	**A**	**Improved**	Better management. No erosion or litter.
Cederberg	Suurvlakte (u/s of dam)	Channelled valley bottom	Natural and alien (pines)vegetation	Private land	Pine trees and dam	Similar (good)	**C**	**Deteriorated**	Invasion of pine trees
Cederberg	Wagenbooms River	Unchannelled valley bottom	Agricultural lands	Private land	Cultivation, abstraction upstream, encroachment of agriculture into wetland	Salinity increased. No historical data for nutrients.	**C**	**Deteriorated**	Encroachment of agriculture
/Worces	Die Vlakte	Upstream wetland gone. Downstream wetland still persists.						**Disappeared**	Cultivation and removal of wetland vegetation.

Wetland name and area		Present "Ecological Health"						Trajectory of Ecological Health	Major cause of change
		HGM type	Land-use	Conservation status	Major impacts	Change in water quality	Ecological Health score		
		Channelled valley bottom	Agricultural lands – not sure if any conserved.	Private land	Encroachment by cultivation. Road crossing. Poor water quality. Fires?	Salinity, phosphate and nitrogen levels increased significantly.	**C/D**	**Deteriorated**	Encroachment by cultivation. Poor water quality. Alien vegetation.
Tulbagh/Worcester	Kluitjieskraal (upper wetland). Verrekyker (downstream wetland)	Mosaic of seeps, channels and depressions	Rehabilitated land. Alien veg currently being removed	Private land?	Ongoing threat alien veg, aquatic weed, lack of indigenous veg.	Slight increase in salinity. Phosphate and nitrogen levels increased.	**C**	**Improved**	Removal of alien veg. raising of water table.
		Downstream wetland gone. Upstream wetland persists.						**Disappeared**	Drained, wetland veg removed.
	Papenkuils (Bokkekraal)	Floodplain	Agriculture, dam, urban.	Conservancy: CapeNature/Municipality/private owners/BOCMA	Upstream abstraction, pollution. Alien vegetation. Road crossing.	Salinity and nitrogen levels increased	**B**	**Improved**	Limited grazing, no encroachment of cultivation
	Platdrif	Upstream wetland gone. Downstream wetland still persists.						**Disappeared**	Excavation, draining.
Betty's Bay	Groot Rondevlei (Bettys Bay)	Depression	Residential	Municipality – Public Open Space	Obstruction of flow by roads, drainage ditches, septic tanks. Clearing of natural veg (Malkopsvlei)	Probably similar. WQ currently good.	**B**	**Slight deterioration**	Increased housing. Phragmites now established
	Groot Witvlei	Depression (with outlet to sea)	Residential	Municipality – Public Open Space			**B**	**Slight deterioration**	Increased housing

Wetland name and area		Present "Ecological Health"						Trajectory of Ecological Health	Major cause of change
		HGM type	Land-use	Conservation status	Major impacts	Change in water quality	Ecological Health score		
	Malkopsvlei (Bass Lake)	Depression with outflow to sea	Residential	Municipality – Public Open Space		WQ currently good (but problems in summer)	**B**	**Slight deterioration**	Increased housing
Vermont	Belsvlei	Channelled valley bottom	Agriculture	Private	Road crossing, encroachment d/s of orchards and cultivated lands, lawns and other alien veg.	WQ currently good (possibly increase in nitrates)	**B**	**Same**	Same
Vermont		Downstream wetland severely eroded. Upstream wetland persists.					**D/E**	**Deteriorated to disappeared**	Road crossing, erosion.
	Die Diepte Gat	Large mountain seep	Agriculture	Private land	Fire-break along edge and pines. Erosion at bottom of wetland.	WQ similar. Currently very good	**B**	**Same**	Erosion hasn't progressed further up wetland
	Elias Gat (Vioolskloof) Site A	Channelled valley bottom	Agriculture	Private land	Alien veg. Infilling. Road crossing	Similar WQ, but N higher?	**C/D**	**Same**	Alien veg.
	Elias Gat (Vioolskloof) Site B	Unchannelled valley bottom	Agriculture	Private land	Alien veg.	WQ data not collected	**B**	**Same**	Alien veg
	Hemel-en-Aarde	Channelled valley bottom	Agricultural land	Private land	Encroachment of cultivation, infilling from road. Power lines. Alien vegetation (also some recently planted!)	Similar (very good)	**B/C**	**Same**	Same
	Salmonsdam – Site A	Unchannelled valley bottom	Nature reserve	Conservation area	Few remnants of farming activities. Limited recreational infrastructure. Road crossing.	Similar (very good)	**A**	**Improved**	Alien veg eradicated.

Wetland name and area		Present "Ecological Health"						Trajectory of Ecological Health	Major cause of change
		HGM type	Land-use	Conservation status	Major impacts	Change in water quality	Ecological Health score		
	Vermont Pan	Depression (endorheic)	Residential	Conservation area	Densification of housing. Building of seep to n-east of pan.	Similar WQ.	**B/C**	**Deterioration**	Densification of residential development.
Agulhas – other wetlands	Agulhas Salt Pan	Depression (endorheic)	Conservation	Agulhas National Park	Road, earth berms, infrastructure (minimal impact).	Nutrients higher than previously.	**A**	**Improved**	WfWs have rehabilitated u/s feeder wetlands. Alien clearance.
Agulhas – other wetlands	Die Pan (Vispan)	Depression	Conservation	Agulhas National Park	Minimal disturbance	No historical nutrient data.	**A**	**Same**	Good management
Agulhas – other wetlands	Gans Bay	Depression (endorheic)	Vacant land, quarries. Some natural veg (*e.g.* milkwood forest). Landfill site nearby.	Private land	Quarries, alien veg. 4 X4 route close-by.	Phosphates higher than historically.	**D**	**Deteriorated**	Alien veg (acacias). Phragmites encroachment?
Agulhas – other wetlands	Melkbospan	Saline depression	Conservation	Agulhas National Park	Minimal disturbance	Saline system. Nitrates higher than historically?	**A**	**Same**	Good management
Agulhas – other wetlands	Ratel River Estuary	River	Conservation	Agulhas National Park	Road crossing	No historical nutrient data.	**B**	**Improved**	WfW has rehabilitated u/s. Alien clearance.
Agulhas – other wetlands	Rhenosterkop Pan	Saline depression	Conservation other half conservancy.	Agulhas National Park/Private land	Conservation, low intensity agriculture	No historical nutrient data.	**B**	**Same**	Some impacts still from agriculture.
Agulhas – other wetlands	White water dam	Depression	Conservation	Agulhas National Park	Road, low level abstraction of water.	Possibly salinity and nitrates have increased?	**B**	**Improved**	Alien removal
Agulhas –	Farm 182 (Peters bog)	Wetland flat/ditch?	Agriculture	Private	Grazing ++++?	WQ not determined.	**B**	**Unknown**	
Agulhas –	Soetendalsvlei	Large freshwater depression	Agriculture/conserv ation	Agulhas National Park/Private	Conservation, agriculture	WQ similar or possibly improved in terms of nitrogen	**C**	**Deteriorated**	Abstraction, sediment, nutrients from

Wetland name and area		Present "Ecological Health"						Trajectory of Ecological Health	Major cause of change
		HGM type	Land-use	Conservation status	Major impacts	Change in water quality	Ecological Health score		
				land		levels.			u/s Nuwejaars River. Alien veg.
	Soetendalsvlei Ditch	Not a wetland. No longer in existence.							
	Voelvlei	Freshwater lake depression	Agricultural lands	Private land	Grazing, agricultural activities.	No historical nutrient data. Phosphates currently high.	**B/C**	**Deteriorated (probably)**	Encroachment of agriculture
	Waskraalsvlei (Modder Valley)	Freshwater lake depression	Agricultural lands/conservation	Private land	Grazing, agricultural activities.	No historical nutrient data. WQ currently good.	**A/B**	**Improved**	Good buffers, better management
	Wiesdrif	Channelled valley bottom	Agricultural lands	Private land	Grazing, churning by tractor along edge. Upstream abstraction, pollution?	WQ currently good. Possibly increase in salinity and phosphates.	**B/C**	**Slight deterioration**	Still largely intact. But increasing impacts u/s?
	Varkensvlei	Depression	Agricultural lands	Private land	Grazing, tractor tracks along edge.	Possible increase in nitrates	**B**	**Same**	
Agulhas – Groot Hagelkraal	Groot Hagekraal Upper	Floodplain depression	Conservation	Agulhas National Park	Alien veg being removed. Track crossing upstream	WQ currently very good	**A**	**ND**	Couldn't locate original wetland
	Groot Hagelkraal Lower	Unchannelled valley bottom	Conservation/Esko m	Conservation/ Eskom	Alien veg being removed. Track crossing upstream. Farm infrastructure (historic homestead). Flower harvesting.	WQ currently very good	**B**	**ND**	Couldn't locate original wetland
	Pearly Beach	Depression (with river inflow and outflow to sea)	Vacant land/natural vegetation.	Private land	Limited infrastructure (house and road). Massive alien infestation. Decrease in extent of open water (Phragmites).	ND (no access to open water)	**C**	**Deteriorated**	Alien veg. Encroachment of emergent macrophytes

Wetland name and area		Present "Ecological Health"						Trajectory of Ecological Health	Major cause of change
		HGM type	Land-use	Conservation status	Major impacts	Change in water quality	Ecological Health score		
Mossel Bay and Riversdale	Riversdale (excluding the Kruis River)	Unchannelled valley bottom	Agriculture/conserved	Private land/conservancy	Drainage, excavation, grazing, burning. Alien veg, erosion channels from Kruis R. Erosion channel upstream.	No historical nutrient data. Probably similar. WQ currently good.	**B/C**	**Deteriorated (probably)**	Erosion, alien veg. But WfW active in upper area.
	Gouriqua	3 X freshwater seeps	Conservation/low level development	Private land	Infrastructure development (conference centre, few holiday houses) – not currently much used.	ND (dry)	**B**	**Deteriorated (probably)**	Infrastructure
	Blinde Estuary	Estuary	Natural and very low density residential	Private land	Septic tanks. Upstream WQ impacts	N.D. for nutrients	**NA**	**N/a (riverine)**	Mossgas
	Blinde River	River	Natural/low level agricultural	Private land	Upstream pollution impacts.	Marked increase in salinity	**NA**	**N/a (riverine)**	Mossgas

An ecological health score could not be assigned to approximately 10% of the wetlands for various reasons:

- Those wetlands no longer in existence – Pinelands crossing, Yzerfontein Inflow, (Soetendalsvlei ditch), the upper part of Platdrif, lower Verrekyker area of Kluitjieskraal and effectively the lower part of Belsvlei.
- Cape Corps, Peters Bog, and Groot Hagelkraal wetland which we were unable to locate.
- Lake Michelle (formerly known as Noordhoek Salt Pan) and Rooipan which have changed completely in terms of ecological character (Section 2.2).
- The ecological health of the Blinde River and Estuary and the Ratel River were not assessed in any detail because they are riverine/estuarine systems rather than wetlands.
- Witzand Aquifer Recharge wetland (because it is completely artificial).

The extent to which the study wetlands are representative of wetlands in the Fynbos Biome is unclear. According to the original researchers, the choice of study wetland was based on the presence of wetlands indicated on the 1: 50 000 maps. The researchers would travel to an area for a week and visit the surrounding wetlands. But logistical details were also important (wetlands needed to be fairly easy to access, for instance). Furthermore, no classification system was available for South African wetlands in the 1980s, so the attempt by Silberbauer and King to choose a variety of wetland types must have been fairly subjective. Given the fact that the current South African wetland cover has not been ground-truthed, it is not possible to be sure that the study wetlands are indeed representative of all types and all sizes of wetlands in the region.

Furthermore, it is unclear to what extent the distribution of ecological health scores shown in Table 7-2, is indicative of the general condition of wetlands in the Fynbos Biome and whether there is a bias towards un-impacted wetlands. National statistics for wetland condition arising from the NFEPA project (Nel *et al*. 2011) report that 44% = good; 18% = moderately modified; 9% = heavily modified and 36% = critically modified. The above statistics can be compared with the ecological condition of the study wetlands (Table 7-2) in which 49% = good (Ecological Health score = A or B); 24% = moderately modified (Ecological Health score = B/C, C or C/D) and only 9% = critically modified (Ecological Health score = D or E). These results suggest that the "picture" painted by the results from the present project is better than the national situation. We suspect that this is possibly because a large proportion of the study wetlands have been incorporated into conservation areas. Further work is required to investigate this hypothesis, however, and ground-truthing of the results from the NFEPA project required. It would also be useful to explore the results from other "historical" wetland surveys from other parts of the country (*e.g*. the work of Beggs 1986-1989 in Natal) and compare them with present condition in a manner analogous to this project.

One of the strengths of this project is the fact that the wetlands investigated were pre-chosen and independent of partiality on the part of the present sampling team. The wide range of wetland types raises some interesting questions around wetland benefits and assessment of ecological condition. For example, the Witzand Aquifer Recharge wetland is completely artificial and was designed to take the stormwater and purified domestic sewage effluent from Atlantis. Because it is artificial it is difficult to compare it to the baseline "natural" condition and yet the wetland is undoubtedly carrying out important ecosystem services (principally water quality amelioration and the provision of habitat for birds). Another example is Noordhoek Salt Pan[5] (now called "Lake Michelle"). It is difficult to establish the exact environmental condition of the Noordhoek Salt Pan when it was visited by King and Silberbauer 25 years ago. From descriptions available it would seem that the wetland was already highly modified, salt had been mined there previously and then sewage effluent pumped into the excavated areas (Volume 2: Wetland Status Reports). The area had also been used as a car-racing track and was degraded with extensive encroachment of alien vegetation. Despite this, at that stage urban development had not encroached extensively within the area and there was potential for rehabilitation. Now there has been extensive encroachment by informal settlements and a shopping mall built to the east of the wetland. Within the immediate area of the wetland itself dense development of up-market residential properties has occurred, enclosing the open-water areas. Nevertheless, the most recent phase of the development (unlike the first) has strict regulations governing gardens and pesticide use and only indigenous plants are allowed. Not only that, artificial wetlands have been created so that run-off from the developed, eastern and north-eastern sides of the catchment, including that from the informal settlement, is filtered and the entire wetland development forms a buffer area protecting the downstream un-impacted Noordhoek Wetlands. The development prides itself on being an "eco-estate" and water quality is monitored. The water quality in the wetland appears to be good and otters *Aonyx capensis* (a Red Data species) are now regularly been seen there. It is thus very difficult to assess the environmental condition of the wetland relative to the reference (natural) and to its historical condition.

7.5 CHANGE IN CONSERVATION STATUS

Any change in the conservation status of the wetlands over the intervening period was recorded. It was found that for the study wetlands the conservation status of:

- **51%** of the wetlands have **improved**
- **38%** of the wetlands are the **same**
- **2%** wetlands have **deteriorated**

For the remaining **9%** the change in conservation status is either unknown or not applicable (wetland no longer in existence).

One of the major factors leading to an improvement in the conservation status has been the establishment of conservation areas, some of which were created specifically to protect wetlands. On a large scale, the proclamation of the Table Mountain and the Agulhas National Parks has helped to conserve many wetlands. On a smaller level, efforts of the City of Cape Town to protect some wetlands, *e.g.* declaration of the Khayelitsha Wetland Park, Kenilworth Conservation Area, Witzand Aquifer Recharge area, Silvermine River (floodplain) have resulted in improved protection. Similarly, the Overstrand Municipality has created the Vermont Pan Conservation Area. Initiatives from private land-owners noticeably the Nuwejaars Special Wetland Management Area, and the conservancy agreement due to be

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[5] A co-sampler with King and Silberbauer was Deborah Hall, whose PhD overlapped the historical study occasionally. Hall, D. 1993. The ecology and control of *Typha capensis* in the wetlands of the Cape Flats, South Africa. Ph.D. thesis, Freshwater Research Unit, Department of Zoology, University of Cape Town, Rondebosch, South Africa. (Dr Mike Silberbauer, DWS, *pers. com*., Nov. 2014).

formalised between private landowners, CapeNature and the Worcester Municipality for Papkuils (Bokkekraal wetland) have also resulted in improved protection for some wetlands. The conservation status of the Gouriqua wetlands has deteriorated in the intervening 25 years. It was state land in the late 1980s belonging to Kernkor and an environmental plan was drawn-up to manage the wetlands (King unpublished). The land was subsequently sold, developed as a private conference/holiday centre but is currently unused.

7.6 TRAJECTORIES OF CHANGE IN ECOLOGICAL HEALTH

An analysis of the change in environmental condition for the study wetlands for which an ecological health score could be assigned (*i.e.* comparison of Tables 7-1 and 7-2) over the past 25 years shows that:

29% wetlands are in a **better/slightly better** category
24% wetlands are in the **same** condition
8% wetlands show a **slight deterioration**
23% wetlands have **deteriorated significantly**

In addition, three entire wetlands from the original set and two/three portions of existing wetlands have effectively been lost, two have changed completely in ecological character, and a small number of wetlands were not sampled (making up the 16% not accounted for above). The results shown above are considerably better than those considering WQ alone (Chapter 4) where only 3% of the wetlands are considered to have improved. The discrepancy arises because the change in water quality was only one of the factors considered in assessing the change in ecological health.

Impacts that have caused deterioration

It was not always easy to establish the trajectory of change in ecological health, because quite often, as can be seen from Table 7-1, wetlands were already impacted when surveyed historically and it is difficult to be certain if particular impacts have increase in magnitude or extent. There are some threats, however, that need to be highlighted.

As reported in Chapter 5, in several wetlands there has been a proliferation in the extent of the indigenous wetland plant species *Typha capensis* and *Phragmites australis*, indicatating nutrient enrichment and stabilized water levels. Alien vegetation also seems to have flourished markedly in some areas and has had a severe impact on ecological health, for example Pearly Beach and the lower reaches of the Groot Hagelkraal River (where the infestation of Acacia spp. is so dense it is very difficult to get to the open water), Gans Bay (although according to Dr Mike Silberbauer, DWS, pers. com. Nov. 2014, infestation was already fairly dense in the late 1980s), Yzerfontein Salt Pan (and the inflow area), Suurvlakte, Elias Gat (sites A and B). Associated with the infestation of alien vegetation, is reduced run-off, reduced biodiversity and an increase in the potential for erosion. As reported in Chapter 2, reduction in the amount of water at Pearly Beach Site D and Yzerfontein Inflow was likely to have been exacerbated by dense alien vegetation. The erosion channel forming Salmonsdam Site E, whilst probably not caused by the infestation of acacia in the surrounding area is certainly not helped by it (Volume 2: Wetland Status Reports). In some areas land-owners are making concerted efforts to control alien vegetation (e.g. Groot Hagelkraal lower – owned by Eskom), Groot Hagelkraal upper – managed by SANParks, Witzand Aquifer Area – City of Cape Town). Within the Nuwejaars Special Wetland Management Area, a group of private land-owners have diverted considerable effort and budget towards eradicating alien vegetation, but it is a significant and on-going problem in the area. Biocontrol of *Sesbania* at the Papenkuils (Bokkekraal) wetland, on the other hand by weevils over the past few years has been very successful (Dr Donovan Kotze, UKZN, pers. com., Dec. 2014). Not all landowners seem to be aware of the threat from alien invasive plant species, however, and when we visited the Hemel-en-Aarde wetland in September 2013 we found that one of the land-owners in the upper part of the wetland had recently planted Eucalyptus saplings along the border of the wetland!

In several sites located in agricultural areas cultivation has infringed into the wetland. Some of this intrusion was recorded in the historical project, but in several wetlands this has occurred subsequently. For example, comparison of aerial photographs for the Wagenbooms River Wetland shows clearly that centre-pivot crop irrigation has gradually encroached into wetland area over the intervening 25 years. In the near-by Die Vlakte wetland the upstream portion of the wetland has been effectively destroyed by removal of wetland vegetation, infilling and encroachment of cultivation and ploughing up to the channel edge. In some cases, however, such as Driehoek wetland in the Cederberg, cultivation into the wetland has ceased and a buffer area between the wetland and agricultural lands is being established.

Development of housing has of course also been a major impact to urban wetlands – most noticeably Khayelitsha Pool and Lake Michelle where dense residential (and also industrial in the case of the former) development has taken place. For the coastal lakes, Vermont Pan, and the three Betty's Bay wetlands of Malkopsvlei, Groot Rondevlei and Groot Witvlei, although there are buffer areas around the wetland (probably not as wide as they should be, but at least present), housing around the wetlands is gradually becoming denser, with the accompanying increase in pollution, change in hydrology and isolation of the wetlands from surrounding areas of biodiversity.

Pollution has affected many of the wetlands. A notable example is the Blinde River – which because it is riverine rather than a wetland system, was not one of our major sampling sites (Volume 2: Wetland Status Reports) and a formal assessment of ecological health (*e.g.* using SASS) was not carried out. Nevertheless, water chemistry samples were taken and compared with the limited data from the historical project. There has been a 100-fold increase in electrical conductivity at the site which originates from the upstream Mossgas (PetroSA) Refinery which has been built in the intervening 25 years[6]. This contention is supported by other reports of saline discharges originating from PetroSA, *e.g.* WMS sites 188713, 191105, 191106, 191235 (Dr Mike Silberbauer, DWS, *pers. com*., Nov. 2014).

Water quality issues are also a problem in Silvermine Wetland (lower), Khayelitsha Pool, and many wetlands in agricultural areas, *e.g*. Die Vlakte and Kiekoesvlei.

[6] The discovery of natural gas fields off the Southern Cape coast in 1980 and of the nearby EM field in 1983, led to the development of the Mossgas gas-to-liquids refinery (commissioned in 1987 and renamed the PetroSA Refinery in 2002). (Wikipedia/www.petrosa.co.za).

Factors that have cause an improvement in ecological health

From Table 7-2, the following factors appear to be linked with an improvement in the ecological health of the wetlands:

- Improvement in ecological health seems to frequently arise from better management of vegetation in and around the wetland (e.g. Kenilworth), especially removal of alien infestations (e.g. Witzand Aquifer Recharge area, Salmonsdam Site A, Cederberg area), which as noted above is a significant threat to many wetlands.
- Unsurprisingly, improvement of ecological condition seems to usually be in conjunction with better management which arises from an improvement in conservation status. As noted previously, there have been some significant improvements in conservation efforts in the Fynbos Biome over the past 25 years which have resulted in improved protection of some wetlands, namely: proclamation of the Table Mountain and the Agulhas National Parks, and formalisation of the Greater Cederberg Conservation Area in addition to local initiatives: the Khayelitsha Wetland Park, Kenilworth Conservation Area, Witzand Aquifer Recharge conservation area, Silvermine River (floodplain), and the Overstrand Municipality – Vermont Pan conservation area.
- As noted previously, initiatives from private land-owners noticeably the Nuwejaars Special Wetland Management Area, and the Papkuils conservancy agreement are important mechanisms for protecting wetlands in private ownership.
- Rehabilitation efforts by Working for Wetlands. At a few of the project wetlands namely; Goukou, Kluitjieskraal, the area around Agulhas Salt Pan, Ratel River, are or have been in the past the sites of rehabilitation interventions. Whilst this work has undoubtedly improved the ecological health of these sites, it is not always completely successful (e.g. Kluitjieskraal Wetland Status Report) and can only rehabilitate a few wetlands at a time.

Despite the positive efforts noted above, there is no doubt that some wetlands, all of which are in private hands, are in serious peril. The most noticeable ones of these are:

Gans Bay wetland due to alien vegetation

Pearly Beach due to alien vegetation

Lower Salmonsdam Site E due to erosion

Possibly Die Diepte Gat from erosion and alien vegetation invasion (at the lower end).

In general wetlands not in formally-protected conservation areas are at risk and there are indications that many land-owners are still unaware of the importance of wetlands and the need to protect them. Even for those wetlands that are in conservation areas, however, the ecological health is not always assured. For example, although Khayelitsha Wetland Park appears to be well-managed green area, the upstream development of the catchment and poor quality water entering the wetland, puts the ecological health of this system at risk.

7.7 IN SUMMARY

The results from this study investigating changes in ecological health of the study wetlands are quite mixed. A handful of wetlands have been lost, but this out of a total of ±65 wetlands, is lower than expected considering the significant loss of wetland that has already occurred in the country (Macfarlane *et al*. 2009). Indeed, 29% of the wetlands are in a better ecological condition, and a further 24% are in the same condition as 25 years ago which is very encouraging news. Undoubtedly that improvement arises from protection of these systems within new conservation areas – both at the national level and at the local level involving both state institutions and private landowners. .

Despite this progress, there is no room for complacency and the future of many wetlands located on private land is uncertain. Although some private landowners we spoke to were aware of the importance of the wetland on their property, some of them were not really interested and didn't see why wetlands should be conserved. There is an urgent need to investigate ways of incentivising land-owners to protect wetlands on their property in addition to educating them.

With regards to the impacts facing wetlands in the Fynbos Biome, there are probably few surprises. Invasion by alien plants (acacias, pines, eucalypts) is one of the most significant threats, and once invasives have established themselves removing them takes considerable commitment in terms of both time and resources. Urban development, agricultural development with the accompanying deleterious effect on water chemistry and biodiversity are also common impacts.

CHAPTER 8

SUMMARY OF THE MAJOR FINDINGS AND CONCLUSIONS

8.1 SURVIVAL OF THE WETLANDS

On re-visiting the 65 wetlands sampled by King and Silberbauer from 1987-1989, the following situation was encountered:

- The wetlands no longer in existence are: Pinelands crossing, Yzerfontein Inflow, and a very small artificial wetland, Soetendalsvlei ditch. Part of the following wetlands have been completely lost: Platdif (upper part), Kluitjieskraal (the lower, Verrekyker area), and the lower part of Belsvlei.
- Lake Michelle (formerly Noordhoek Salt Pan) and Rooipan are still in existence but have changed markedly in ecological character.
- We were unable to accurately locate Cape Corps, Peters Bog, and Groot Hagelkraal wetland, although we are fairly sure that they are still in existence.
- We were unable to access Sederhoutkop, Donkerkloof tributary in the Cederberg and Pearly Beach C on the Groot Hagelkraal River because of snow or flooding, but from Google Earth and other information both of the Cederberg wetlands are still there and likely to be in the same ecological condition. Pearly Beach C is also still there and may have increased in extent due to restriction of outflow arising from road construction.

8.2 IMPORTANCE AND BENEFITS OF THE WETLANDS

- The study wetlands differed in the benefits they supplied, depending on the hydrogeomorphic (HGM) type and the opportunity for providing the service.
- Goukou Wetland (Riversdale Wetland) scored the highest for hydrological services.
- The Ecological Importance and Sensitivity (EIS) was the highest contributor to the overall wetland importance and benefit score. This is because many of the wetlands are situated in un-impacted areas in vegetation of high importance.
- Direct Human Benefit scores were fairly low amongst the study wetlands, probably due to the low levels of subsistence use in the Western Cape and the fact that the wetlands were located almost exclusively on private land or in conservation areas. Many of the wetlands do contribute to Direct Human Benefits through provision of opportunities for tourism (especially avitourism) and through increasing the value of adjacent property (and thus increasing local municipal rates paid by the land-owner).

8.3 CHANGES IN ANTECEDENT RAINFALL/INUNDATION LEVELS

Comparing the antecedent rainfall for the hydrological year in which the historic and present-day sampling took (in addition to the average for the preceding decade) yielded the following results.

Cape Town area

- The hydrological year October 2011 to September 2012 was only slightly wetter than 1987/1988 so that the hydrological difference in the sampled wetlands as seen at the time of sampling was probably very small.
- The most recent decade appears to have been slightly drier than the decade prior to 1988 and both sampling years (2012 and 1988) were below average in rainfall.
- Groot Rondevlei, Kleinplaats West and possibly Klaasjagers Estuary are likely to

have contained considerably more water when sampled in 2013 compared to 1987/1988.

West Coast

- The study wetlands were probably slightly "wetter" and more extensive when sampled in 2012 compared to when visited by King and Silberbauer in 1988.
- The year 2012 was somewhat wetter than the previous decade.

Cederberg

- The Cederberg wetlands are likely to have been "wetter" when sampled in June 2013 compared to when sampled by King and Silberbauer (May 1989).
- For the Cederberg area, 2012/2013 was a much wetter year than the average for the previous decade (especially the latter portion of the hydrological year).
- Of interest is the reduced average rainfall for 2002/2003-2011/2012 compared to 1978/1979-1987/1988.

Ceres area

- Die Vlakte and Verrekyker are likely to have been wetter at the time of sampling for the present project compared to the historic sampling since the antecedent rainfall differs by roughly 200 mm. 2013 appears to have been an exceptionally wet year for the region around Ceres, above the average for the previous decade.
- During the sampling carried out by King and Silberbauer, the wetlands would have been slightly drier than average.

Worcester area

- Bokkekraal when sampled in June 2013 is likely to have been a lot wetter than when sampled in May 1988 since 1988 appears to have been a particularly dry year for Worcester and the surrounding region.

Betty's Bay and Vermont area

- At the time of sampling Malkopsvlei/Bass Lake, Groot Rondevlei and Groot Witvlei in April 2013, the wetlands are likely to have been wetter than in March 1989.
- For the wetlands in the Hermanus/Vermont area, sampling months for the historic and present projects were in May and October respectively, making comparison difficult. The wetlands are likely to have been drier in 2013 when sampled than in 1988.

Agulhas Plain

- The hydrological year October 2012-September 2013 was similar to average and slightly wetter than average only for the latter part of the wet season (August and September).
- 1988/1989 was a very wet year with the cumulative monthly rainfall for the entire period more than 200 mm in excess of average in the Point Agulhas region.
- 1986/1987 was slightly drier and 1987/1988 very much drier than the average calculated from the preceding decade.
- The average for the decade preceding the present sampling is slightly below that of the historical average.

Mossel Bay wetlands

- For this region, the average cumulative monthly rainfall for the last decade is higher than for the decade prior to the sampling by King and Silberbauer in 1988.
- 2013 was a "dry" year, but wetter than 1988 when the historic sampling was carried out in the area.

8.4 PRESENT WATER CHEMISTRY

Electrical conductivity

- Electrical conductivity (EC) in the present project varied from roughly 2 mS/m for Silvermine Dam inflow to 17170 mS/m for Koekiespan, although the EC for 80% of the wetlands lay between 5-4250 mS/m with a median EC of 57 mS/m.
- The results support the findings of Malan and Day (2012), namely that seeps exhibited the lowest EC followed by valley bottom systems, with depressions (specifically endorheic "pans") exhibiting the highest.
- There was little correlation of EC with the Present Ecological State (PES) of the wetland.

pH and water colour

- The wetlands were divided into three broad bands of "acidic"(pH< 6), "circum-neutral" (pH 6-8) and "alkaline" (pH >8). The majority of wetlands were in the circum-neutral group with roughly 25% of the wetlands being acidic and 10% being alkaline.
- All of the acidic wetlands were located in largely natural, fynbos vegetation, or fed by water from such a system. The alkaline wetlands are mostly saline pans – such as Vispan, Rooipan and Vermont.
- The highest values of water colour were usually linked with the most acidic wetlands. This was expected, since tannin-stained waters are usually acidic due to the presence of humic acids. The wetland systems that had the highest level of water colour were those associated with the Groot Hagelkraal River (including Pearly Beach), Salmonsdam and Hemel-en-Aarde.
- The saline, alkaline pans, *e.g.* Melkbospan, Vispan and Koekiespan often recorded low levels of water colour.

Phosphorus

- Water column phosphate concentrations ranged from below detection to a maximum value of 3.05 mg P/L (for Kiekoesvlei). The median phosphate concentration was 0.01 mg P/L and 25% of wetlands had phosphate concentrations below 0.005 mg P/L.
- There was a trend of increasing phosphate concentration with elevated levels of impact, but this was not clear-cut. The exorheic seeps and valley-bottom wetlands located in the mountains tended to record low phosphate levels. At the other end of the scale are the most impacted systems, which were often endorheic. The Khayelitsha Pool (extensive urban development) did, as expected, have the highest levels of phosphate.
- Many of the endorheic, saline wetlands (*e.g.* Yzerfontein Salt Pan, Rooipan, Vermont Pan, Agulhas Salt Pan) had the highest TP concentrations, the highest being Rhenosterkop in the Agulhas National Park, a largely un-impacted wetland (PES = "B").

Nitrogen

- Total Inorganic Nitrogen varied from less than 0.01 mg N/L (Driehoek, Kenilworth Racecourse, Silvermine Dam inflow), to more than 1.0 mg N/L (Koekiespan, Khayelitsha Pool, Witzand Aquifer Recharge, Platdrif and Die Vlakte). The median TIN value was 0.083 mg N/L.

- In general, high TIN levels could be explained by land-use in the area or by other impacts. The wetlands that had low TIN values were usually (but not always) mountain seep/valley bottom systems.

8.5 CHANGES IN WATER CHEMISTRY OVER THE INTERVENING 25 YEARS

On comparing WQ for each study wetland during the historical project and the present, it was found that in terms of water quality:

3% of the wetlands have **improved**
17% of the wetlands are the **same**
9% of the wetlands **likely to be the same (**but data are lacking)
9% of the wetlands have **deteriorated** (significantly)
17% of the wetlands show a **slight deterioration**
6% of the wetlands have **possibly deteriorated** but data are too limited/cryptic to be conclusive

The change in WQ for the remaining 39% could not be determined (lack of historical data or unable to sample in the present project for various reasons).

- Of the wetlands that show a significant deterioration in WQ, the most marked in the Blinde River where the level of EC in the river has increased 100 fold. Salinity seems to have increased in the Modder River, Papkuils (Bokkekraal) and Kluitjieskraal (Verrekyker) wetlands probably due to increased agricultural development upstream and for Kluitjieskraal, due to discharge from the town of Wolseley.
- Deterioration of WQ in the wetlands frequently took the form of increased levels of either (or both) nitrogen or phosphorus. In some wetlands only phosphorus levels have increased (*e.g.* Rooipan, Yzerfontein Salt pan, Gans Bay, Wiesdrif) and in others only nitrogen (*e.g.* Silvermine Lower, Belsvlei, Varkensvlei). General nutrient enrichment could usually be predicted from the change in land-use.

8.6 CHANGES IN PLANT COMMUNITIES

- Differences in sampling intensity and approach between the 1988/89 and 2012/13 surveys may have resulted in some inconsistency in vegetation sampling and may therefore have complicated the interpretation of results. It can be concluded for the study wetlands, however, that although HMG types cannot be identified by plant communities, plant communities can be used to describe HGM units. Several HMG units are recognized, each with characteristic plant communities and indicator species.
- Cluster analysis and MDS plots of the plant species data identified four main plant community groups historically and five in the present-day study. The main change seems to have been an increase in dominance of the reed *Phragmites australis* in several of the wetlands showing increased disturbance.
- Differences in species composition over time seem to be tied to changes in land-use although these changes were not strongly related to differences in the measured environmental variables. As such, the trajectories of change are not readily predictable from changes in simple physical and chemical attributes. The lack in most cases of the relationship between nutrient concentrations and plant communities was unexpected but similar results have been found in certain wetlands elsewhere.
- The majority of wetlands whose plant communities have changed are depressions, perhaps because depressions are often located in areas vulnerable to human

disturbance and because depressions tend to retain water and nutrients draining from their surroundings.

8.7 DIATOMS

- Strong correlations exist between certain, but not all, water quality variables and the indices calculated during this study.
- Despite the once-off sampling regime and the almost complete lack of knowledge of the diatom flora of the south-western Cape wetlands, the wetlands could be separated into water quality classes based on an analysis of their diatom floras. Bioassessment using diatoms therefore represents a potential tool for assessing the ecological condition of wetlands of the south-western Cape of South Africa.
- The Specific Pollution Sensitivity Index showed potential for describing water quality in freshwater wetlands but caution should be used in interpreting results for naturally occurring saline systems.
- It seems that the species identified in this study as “European species” do respond in the same way to water quality variables, suggesting that they are cosmopolitan species.
- While diatom samples from different substrata gave similar results, further investigations are needed into the effect of substratum on the “ecological condition” or water quality classes identified from diatom analysis.

8.8 ASSESSMENT OF CHANGES IN ECOLOGICAL HEALTH

- In terms of the assessment method used to evaluate ecological health, only the method of Duthie (1999) was found to be applicable to *all wetland types, and* was used since it is reasonably rapid, simple, flexible and fairly transparent.
- “Historical ecological health scores” were estimated for the study wetlands based on all available information, but are likely to be an educated guess. The majority of the wetlands (roughly two thirds) were in a natural/slightly impacted condition (*i.e.* A or B category). Some wetlands were already significantly impacted, however, and probably in a “C” or “D” category in terms of ecological heath. The most impacted of all the wetlands was probably Rooipan *(“D/E” score)*.
- With regard to the present ecological condition of the wetlands, 25% of the wetlands are in a natural (“A” category); 24% are in a “B” or slightly impacted category. A further 24% are fairly seriously modified (categories B/C, C and C/D) and 6% are in a “D” category or lower. Almost all of the wetlands in a natural condition included, unsurprisingly, wetlands in the conservation areas such as the Cederberg, Table Mountain National Park, or the Agulhas National Park. Exceptions to this are Januariesvlei (West Coast) and Waskraalsvlei (Nuwejaars River, Agulhas Plain) which are both on private land.
- The wetlands in the worst condition were Khayelitsha Pool (C/D), Kiekoesvlei (D) and Koekiespan (D). The former is impacted by extensive urban development and the latter two by agriculture. The lower portion of Belsvlei wetland was assigned a D/E as there is very little functional wetland area remaining.

8.9 CHANGE IN CONSERVATION STATUS

It was found that for the study wetlands the conservation status of:

51% of the wetlands have **improved**
38% of the wetlands are the **same**
2% wetlands have **deteriorated**

For the remaining **9%** the change in conservation status is either unknown or not applicable (wetland no longer in existence).

- The establishment of new conservation areas namely; the Table Mountain National Park and the Agulhas National Park and at a more local level, Khayelitsha Wetland Park, Kenilworth Conservation Area, Witzand Aquifer Recharge area, Silvermine River (floodplain) and Vermont Pan Conservation Area have resulted in improved protection for wetlands.
- Initiatives from private land-owners noticeably the Nuwejaars Special Wetland Management Area, and the conservancy agreement due to be formalised between private landowners, CapeNature and the Worcester Municipality for Papkuils (Bokkekraal wetland) have also resulted in improved protection for some wetlands.

8.10 CHANGE IN ECOLOGICAL HEALTH

An analysis of the change in environmental condition for the study wetlands for which an ecological health score could be assigned over the past 25 years shows that:

29% wetlands are in a **better/slightly better** category
24% wetlands are in the **same** condition
8% wetlands show a **slight deterioration**
23% wetlands have **deteriorated significantly**

For the remainder of the wetlands (16%), the change in ecological health either could not be determined or the wetland is no longer in existence. The results from this study investigating changes in ecological health of the study wetlands are quite mixed. Although some wetlands have been lost, the small number out of a total of ±65 wetlands is lower than was expected.

Impacts that have caused deterioration

With regards to the impacts facing wetlands in the Fynbos Biome, there are few surprises and these include: invasion by alien plants (acacias, pines, eucalypts), urban development, and agricultural development.

Factors that have cause an improvement in ecological health

Improvement in ecological health has arisen from protection of some wetlands within new conservation areas – both at the national level and at the local level involving both state institutions and private landowners.

SUMMARY

The overall conclusion from this project is that although good progress has been made with regard to the management and protection of wetlands, there is no room for complacency and the future of many wetlands located on private land is uncertain. There is an urgent need in this country to investigate ways of incentivising land-owners to protect wetlands on their property in addition to educating them about the importance of wetlands.

CHAPTER 9

RECOMMENDATIONS FOR THE NATIONAL WETLAND MONITORING PROGRAMME AND FOR THE NEXT 25 YEARS

An important output of this study was that the challenges and practical considerations that needed to be tackled during the implementation of the project be documented. This is so that the experience gained can be used to inform future wetland management, including he proposed National Wetlands Monitoring Programme (NWMP). Issues and recommendations that have emerged are discussed below.

General

- It is important to always keep in mind the reason for monitoring. Is it for biodiversity monitoring? To monitor the provision of ecosystem services to people? To provide long-term data series for some future purpose as yet undetermined? Or something else? This should guide the entire sampling programme and defines exactly what is sampled, how often and where.
- Depending on the answer to the above questions, rather than sampling biotic aspects such as diatoms, plants or invertebrates which can vary across a wetland (in addition to varying temporally) it may be better instead to rather monitor macro-changes in and around the wetland such as changes in land-use using remote-sensing.
- Ideally as many aspects as possible should be monitored, but there will always need to be a balance between the financial cost and sampling effort and what yields the most useful and relevant information.
- Following on from above it would be best to have an initial in-depth assessment of each wetland to prepare the baseline information. Any specific issues, such as threats to the environmental condition need to be highlighted for future monitoring. For each wetland a tailor-made sampling strategy should be prepared. This would include sampling of basic aspects (*e.g.* some water quality parameters, land-use change) and any specific issues (*e.g.* encroachment of reeds) that are relevant for that particular wetland and likely to pose a threat to the future ecological health.
- It was sometimes difficult to pin-point the exact location of the sampling site(s) used by King and Silberbauer, since this work was undertaken before the Global Positioning System (GPS) was commonly available. It is important for the NWMP that the exact position of the sampling sites is well-documented and that fixed-point photos are taken.
- Documentation/information pertaining to background issues for the historical project was of immeasurable use to the present project. Careful attention needs to be paid in future projects, including the NWMP, to archiving not just the sampling results but other background information that might be of use in the future. The exact nature of such needs cannot always be anticipated and because of this as much information as possible needs to be preserved. Paper records such as field data sheets, while fragile, may outlast digital records if no provision exists for curating the digital data (Dr Mike Silberbauer, DWS, *pers. com*. Nov 2014).
- .The experience from this project was that trying to organise coordinated sampling visits with multiple organisations/institutions is difficult because of differing schedules

and programmes. Nevertheless, coordination between sampling initiatives (*e.g.* CapeNature, SANParks) is important in order to maximize resources.

- Allied to the above, it was difficult to find out what work has already been done on a given wetland. This is especially so if the information is not on the Internet, if it is in the “grey literature“ or if lodged as institutional records. It is important that the data obtained through the NWMP be easily available to wetland scientists, managers and interested parties. A database (the “National Wetlands Inventory”) to store the data collected through the NWMP will be required, but in addition, the database should also act as a repository for existing data and have links (where possible) or refer to the available literature for a given wetland.

The role of the land-owner

It is important not to under estimate the role and importance of the landowner in planning a sampling programme.

- Firstly, identifying and contacting the landowners on which each wetland is located is time-consuming and yet is an essential step. Permission needs to be gained to visit each wetland and in addition it can be very illuminating to talk to landowners about their management strategy for each wetland and the history of utilisation. Some landowners in this project were rather unwilling to allow sampling (although none denied access).
- It is important to ensure that there is good communication with landowners and that they receive the results of the sampling in a format that is useful and understandable to them. One landowner stated that “students come and sample our wetland, but we never see the results and are told that the results will only be available in 3 years, when the PhD is finished”. Landowners need to be given frequent updates on the results from monitoring the wetlands on their land. This will ensure that the landowners through the process gain a better understanding of the wetlands that they “own” and will hopefully value and conserve them.
- There is an important “citizen-scientist” role that farmers can play if a suitable internet data-base can be developed and maintained for wetlands (see www.miniSASS.org as an example of a South African citizen-science project linked to river health). Land-owners could become involved in wetland monitoring by uploading data on aspects such as rainfall, bird migrations, inundation levels of wetlands, *etc.* This could also potentially be linked with Coordinated Waterbird Counts (CWAC) which are carried out at important wetlands nationally on a regular basis (http://cwac.adu.org.za/). Although, sadly at the time of this project the future of the CWAC database, was uncertain due to lack of funding (Dr Doug Harebottle, ADU, *pers. com*. July 2013).

Assessment of the wetland Present Ecological State

- It is important before starting any assessment of the Present Ecological State that the reference state of the wetland be described because this is the basis against which any changes or impacts are assessed.
- It is important that the NWMP considers not only once-off assessment of wetland environmental condition (as is usually carried out) but also the on-going monitoring of environmental condition.

- Allied to the above two points around the assessment of wetland environmental condition, is the problem of how to assess artificial wetlands or those highly modified from the original condition.

Assessment of wetland Importance and Benefits

The importance of the wetland and the benefits it provides need to be assessed and monitored. There is a tendency sometimes for these aspects to be left out and only environmental condition defined. Frequently, wetlands are artificial or radically changed from the reference state and so it is difficult to establish the PES and yet they provide critical benefits for people and should not be under-valued.

Packaging and disseminating the sampling results

- It is important that information (*e.g.* species lists, WQ data) collected during the sampling programme is made freely available to landowners. It is not just the data *per se* that is important but the interpretation of the data. This needs to be in a format that can be understood by lay-people. If budget allows, the information should be "packaged" in different ways for different users. Possibly this could be done in different languages also.
- There is a need to have simple "how to sample" guides for the different elements (*e.g.* sampling invertebrates, water quality, plants, etc.) so that there is a standardised sampling effort. Many of these may already be available through River Health Programme or DWS and require only slight modification for wetlands.

Sampling wetland water quality

- The question "how many WQ, invertebrate and diatom samples need to be taken per wetland?" is not an easy question to answer. It depends on the size of the wetland and the budget. Taking a pooled WQ sample, *i.e.* for example take 1 litre from 3 or more different sites in a wetland and combining them is a good way over ensuring representative sampling. In the case of systems with obvious inflow and outflow points – try to sample the inflow, outflow and in the middle. If this is not possible, take a pooled sample.
- When taking nutrient samples, take these in open water to reduce debris.
- The DWS need to re-examine the analytical techniques used for nutrients in wetlands (and perhaps rivers also). Depending on the aims of the monitoring programme, the current detection limits may be too low for effective detection of ecological change.

Sampling wetland vegetation

- Vegetation surveys should be based on more than presence/absence data. At the very least, once-off intensive sampling of wetland vegetation should be done. The use of permanent quadrat sampling allows for representative field data collection across subsequent years for monitoring purposes. The relevé method (listing of species) with cover, abundance and vegetation structure provides a comprehensive plant species list and provides records of rare, vulnerable and threatened species.
- The standard vegetation sampling protocol for future studies should follow the sampling protocol of Sieben (2011)/Corry (2012). Each HGM unit should be mapped and identified using the classification system of Ollis *et al*. (2013). A standardized

data sheet should be used to record all relevant and necessary data (*e.g.* that of Sieben 2003).

- The size of the wetland and the number of different vegetation stands will determine how many sample plots and/or quadrats are needed per wetland. Quadrats 2 x 2 m are commonly used for wetlands in the Fynbos biome (Corry 2012). Within each homogenous stand of vegetation a single permanent[7] sample plot can be developed as a relevé, in which all the plant species are listed. The number of relevés is dependent on the different number of homogenous and representative vegetation per wetland. Cover and abundance of each species should be recorded for each sample plot.
- For follow-on monitoring it is appropriate to collect presence/absence data within the same quadrat plot. Monitoring data can then be compared to determine if changes/shifts in plant communities have occurred over the years.
- Typically sampling should be conducted over two sampling seasons. Spring and early summer are the best time for sampling vegetation, as they coincide with flowering and fruiting of many graminoid species and overlap with the flowering of geophytes. This makes identification much easier for a non-specialist.
- Species not identified in the field should be collected for later identification. Specimens should be pressed and labelled immediately to preserve quality for identification purposes. Rare species should be photographed rather than being collected for identification.
- Soil samples for emergent vegetation, and water samples for floating and submerged vegetation, should be collected at each plot and/or site for analysis of associated environmental variables. Site descriptions of land-use should also be noted.

Sampling diatoms

Before the formal use of diatoms as biomonitoring tools for wetlands can be recommended, further field-work is required on the relationships between environmental variables and diatom communities in different types of wetlands in different geographical regions of the country (see below for specific recommendations). Objective analysis of the advantages and disadvantages of the practical implementation of a diatom biomonitoring scheme would also need to be carried out once more fundamental ecological knowledge has been gained. Only then will it be sensible to decide if diatom biomonitoring should be used as a routine biomonitoring tool within a NWMP.

FUTURE WETLAND MONITORING

The future monitoring of South African wetlands should and hopefully will, revolve around a national thrust (*i.e*. the NWMP) towards standardized collection of data which are archived in a central, easily-accessible database. As discussed previously, the data should be analysed and summarized in suitable packages applicable to a variety of users. Other aspects that need to be considered for future wetland monitoring are discussed below.

Further work into the use of diatoms for biomonitoring of wetlands needs to specifically:

- Investigate the degree of variability of results with season and hydroperiod.

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[7] A permanent sample plot can be marked and demarcated physically in the field by using flags or coloured pegs. Recording the GPS coordinates of the centre of each plot is also a practical way to safeguard the location of the plots for future.

- Investigate the relationship between plant nutrients (N and P compounds) and diatom indices given that very little correlation was seen between these variables in the current study.
- Develop an index for naturally saline systems.
- Investigate the use of artificial substrata.
- The study of diatom frustules attached to plant specimens collected by King and Silberbauer in the historic project did not form part of this project. However, it could potentially be an interesting and rewarding avenue of research.

Over and above the work of the NWMP, there is an urgent need in this country to investigate ways of incentivising land-owners to protect wetlands on their property in addition to educating them with regard to the benefits of wetlands. Furthermore, South African wetlands are generally small, remote and difficult to get to which makes them expensive to monitor through formal sampling programs. Thus “citizen-science” needs to be explored and developed. Ultimately, landowners need to understand the importance of these systems to themselves and others in the environment, and to contribute to monitoring and conserving them. Education, through NGOs, DAFF, schools and universities, is essential for individuals to realise the value of the wetlands under their control. Involving land-owners in the monitoring process, and providing them with rapid feed-back, should encourage them to regard wetlands as important and beneficial features of the landscape.

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APPENDIX A

AN ASSESSMENT OF WATERBIRDS AT VARIOUS WETLANDS IN THE WESTERN CAPE

By D Harebottle

INTRODUCTION

In the late 1980s some of the first research on South African wetlands was carried out by Jackie King and Mike Silberbauer from the University of Cape Town. They visited 70+ wetlands in the Western Cape and collected basic wetland data for each wetland (Dr Heather Malan, FRC, *pers. com.*, June 2013). These wetlands have now been revisited to observe and record any changes over the past 25 years as part of WRC project (Project K5/2183). Aspects that were investigated included: (a) how land-use has changed in the surrounding catchment, (b) changes in water quality, (c) changes in wetland plants and invertebrates, which included diatom analysis. The primary aim of this comparative study was to determine the types of pressures (*e.g.* pollution, encroachment by alien vegetation) that wetlands are being exposed to in South Africa.

BRIEF

Based on the above and a request from Dr Heather Malan, one of the leaders on this project, I was asked to undertake an assessment of the wetland avifauna at 45 wetland sites included in the above project. In terms of the assessment, I was required to determine the importance of each site for waterbirds. This component would add additional value to the overall biodiversity assessments being undertaken by the trajectory team.

DATA SOURCES AND METHODS

The following data sources were used to determine the wetland avifaunal importance at each site:

(a) Coordinated Waterbird Counts (CWAC) database curated at the Animal Demography Unit, University of Cape Town (http://cwac.adu.org.za). Quantitative data (counts) conducted at site level.

(b) Second Southern African Bird Atlas Project (SABAP2) database curated at the Animal Demography Unit, University of Cape Town (http://sabap2.adu.org.za). Occurrence (presence/absence) data at a pre-defined grid scale (5' latitude x 5' longitude, approx. 9 x 8 km grid referred to as a 'pentad').

(c) *Ad hoc* records/observations provided by members of the 'trajectory project' during visits to the wetland sites.

(d) Personal records from visits to some of the wetland sites and/or knowledge of the landscape in terms of waterbird occurrence.

CWAC data was considered as the primary and preferred data source but where quantitative data was not available, SABAP2 data was considered. However, due to the wide (~ 72 km^2) spatial coverage of the SABAP2 data caution had to be exercised with regards to determining the occurrence of important waterbirds at the actual site; data could often not be allocated to the actual site due to there being multiple wetlands in the pentad. In this regard, a probability value was assigned to each site which described how applicable the SABAP2 waterbird data could be to each site. This value was dependent on the size of the wetland, location of the site (notably in relation to access from public roads), the number of wetlands in the pentad or surrounding pentads and the occurrence of important waterbirds within the pentad.

Each site was given a score between 0 and 4, with 0 being of low significance (data deficient), 1 being of low significance (some spatial data but low probability species could occur at site), 2 being of some significance (spatial data available and fairly good probability species could occur at site), 3 being significant (spatial data available and high probability species could occur at site) and 4 being of high significance (count data available and important species present).

The score was based on available waterbird data, and considered aspects such as status (resident or migratory), conservation worthy species (Red Data species and/or species with localised populations in the Western Cape) and/or species with important populations. For the latter, the Ramsar 1% threshold and the 0.5% southern African Important Bird Area (IBA) thresholds were considered. The Ramsar threshold is the criteria used to designate Ramsar sites and states that a wetland should be deemed internationally important if it supports 1% of the global or bio-geographical population of a waterbird species (Kuijken 2006). In southern Africa, due to rainfall being erratic and unpredictable and many wetlands only being periodically inundated, a 0.5% threshold was used in order to designate IBAs (Barnes 1998). The Ramsar and IBA thresholds were only applied to sites for which CWAC data was available.

SITE ASSESSMENTS

A summary of the scores and additional waterbird data for each of the 45 wetlands is given in Electronic appendix A.1. Only two wetlands (Vermont Pan and Soetendalsvlei) could be assessed using CWAC data, but neither of these supported global or regionally important numbers of waterbirds. They did support up to seven Red Data species and some important species populations in the Western Cape and were the only sites to have a score of 4. Of the remaining sites, only SABAP2 data was used for the assessments; nine sites had a score of 3, eight sites a score of 2, 13 sites a score of 1, and 13 sites a score of 0.

Overall, 26 sites (58%) had scores of 0 or 1, *i.e.* they were considered least important for waterbirds; the remainder were considered to have at least some importance. Twelve sites were identified as priority sites for waterbirds; these are listed below in descending order of importance:

1. Soetendalsvlei
2. Vermont (Salt) Pan
3. White Water Dam
4. Peter's Bog
5. Voelvlei 2
6. Waskraalsvlei (Modder Valley)
7. Wiesdrif
8. Agulhas Salt Pan
9. Die Pan (Vispan)
10. Melkbospan

11. Rhenosterkop Pan
12. Khayelitsha Pool

DISCUSSION

Only two sites (Vermont Pan and Soetendalsvlei) were able to be robustly assessed and this was largely due to the availability of site-specific quantitative waterbird data. For the remainder (95%) of the sites, only presence/absence (SABAP2) data or *ad hoc* observations were available, and this limited the ability to make proper assessments on the importance of each site in terms of its waterbird community. In addition, there was a lack of available historical waterbird abundance and/or seasonal data for most sites which further limited thorough assessments to be carried out. However, in light of these shortfalls the results have provided a first baseline assessment for most of these sites and further investigations or observations are recommended to improve on the assessments presented here. Where actual census work can be undertaken, even as a once-off activity, this should be strongly encouraged in order for further assessments to be undertaken comprehensively.

It is recommended that sites that scored 2 or 3 should be considered for inclusion in the CWAC programme; this would allow further and ongoing monitoring of waterbirds at these sites, but this would be dependent on the availability of counters (volunteers) and other resources. There is a need to include these important sites in CWAC so that monitoring of important waterbird populations can add greater value to waterbird and wetland monitoring initiatives on national and regional scales. For some of the sites that scored 1 (e.g. Groot Rondevlei 1, Klaasjagers Estuary, Pearly Beach, Salmonsdam – Site E), additional surveys are recommended to evaluate the potential of these sites to support some of the important species highlighted from SABAP2.

Although the computation of the score was not completely objective and therefore not as robust as a ranking or index, the results did provide, in my opinion, an adequate first guide in determining if the site was important for waterbirds. Perhaps it should be considered as an outcome of this study that a more objective measure be developed when undertaking assessments of this nature, particularly where data sources are more qualitative than quantitative.

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APPENDIX B
LOCATION AND SAMPLING DATES FOR THE STUDY WETLANDS

Area	Wetland Name	Wetland Code	Historical project			Present project		
			Sampling date	Latitude	Longitude	Latitude	Longitude	Sampling date
Greater Cape Town	Cape Corps	G204/01A1	03/02/88	34. 1'. 59"	18. 41'. 59"	??	??	NS
	Groot Rondevlei (Cape Point)	G203/04A1	27/01/88	34. 13'. 59"	18. 22'. 59"	34 14' 18.719" S	18 22' 57.274" E	1/8/2013
	Kenilworth Race Course	G203/13A1	13/07/88	33. 58'. 59"	18. 28'. 59"	33 59' 55.6"S	18 29' 01.0" E	25/7/2012
	Khayelitsha Pool	G204/02A2	03/02/88; 04/05/89	34. 1'. 59"	18. 40'. 59"	34 02' 12.78S	18 41 02.19E	13/06/2013
	Klaasjagers Estuary	G203/05A1	27/01/88	34. 13'. 0"	18. 22'. 0"	34 13' 55.61" S	18 22' 52.69" E	1/8/2013
	Kleinplaas Dam/Kleinplaats West	G203/01A1	22/12/87	34. 10'. 0"	18. 22'. 59"	34 10' 17.32"	18 22' 56.79"	18/4/2013
	Lake Michelle/Noordhoek Salt Pan	G203/12A2	15/06/88	34. 7'. 0"	18. 22'. 0"	34 07' 12.5"S	18 22' 53.9" E	27/06/2012
	Silvermine Dam inflow	G203/18	06/09/88	34. 4'. 0"	18. 22'. 59"	34 04' 26.83S	18 23' 44.01E	26/9/2012
	Silvermine River (lower)/floodplain	G203/19A1	06/09/88	34. 7'. 0"	18. 25'. 0"	34 07' 43.83" S	18 25' 50.05" E	26/9/2012
	Pinelands – The Crossing	G203/20	02/02/89; 01/08/89	33. 55'. 59"	18. 28'. 59"	33 56 06.30S	18 29 29.83E	NS
West Coast	Burgerspan	G103/03	03/08/88	33. 16'. 0"	18. 19'. 0"	33 16' 09.37" S	18 19' 21.02 E	28/08/2012
	Januariesvlei (Rondeberg)	G201/04	04/08/88	33. 25'. 59"	18. 16'. 0"	33 26' 32.3" S	18 16' 26.3" E	29/08/2012
	Kiekoesvlei	G103/01A1	03/08/88	33. 15'. 0"	18. 22'. 59"	33 15' 50.14" S	18 23' 18.59" E	28/08/2012
We st	Koekiespan	G103/02A1	03/08/88	33. 13'. 59"	18. 19'. 59"	33 14' 10.24" S	18 20' 38.98" E	28/08/2012
	Modder River	G201/06A1	05/08/88	33. 28'. 0"	18. 21'. 5"	33 28' 35.8" S	18 21' 45.3" E	29/08/2012

Area	Wetland Name	Wetland Code	Historical project			Present project		
			Sampling date	Latitude	Longitude	Latitude	Longitude	Sampling date
	Rooipan	G201/01A1	02/08/88	33. 19'. 0"	18. 8'. 59"	33 19' 51.5" S	18 09' 49.1" E	27/08/2012
	Witzand aquifer recharge	G201/07A1	01/08/88	33. 37'. 0"	18. 26'. 59"	33 37' 48.3" S	18 26' 50.5" E	29/08/2012
	Yzerfontein Salt Pan	G201/02B1	02/08/88	33. 19'. 1"	18. 10'. 59"	33 19' 23.84" S	18 11' 02.85" E	27/08/2012
	Yzerfontein Salt Pan inflow	G201/08A1	02/08/88	33. 17'. 59"	18. 10'. 59"	33 18' 59.99" S??	18 11' 30.52" E??	NS
Cederberg	Blomfontein	E201/03A1	23/05/89	32. 25'. 59"	19. 13'. 0"	32 26' 07.36" S	19 13' 07.03" E	04/06/2013
	Donker Kloof (tributary)	E201/01A1	23/05/89	32. 22'. 59"	19. 8'. 59"	32 23 53.55S??	19 09 39.7E??	NS
	Driehoek	E201/06A1		32. 25'. 59"	19. 10'. 0"	32 25' 52.66 S	19 08' 54.66" E	04/06/2013
	Hoogvertoon	E201/05A1	26/05/89	32. 28'. 0"	19. 8'. 59"	32 28' 16.34" S	19 09' 25.97" E	05/06/2013
	Middelberg West	E100/01A1	28/05/89	32. 21'. 5"	19. 4'. 59"	32 21' 10.44" S	19 04' 57.38" E	6/6/2013
	Sederhoutkop	E201/02A1	23/05/89	32. 32'. 59"	19. 8'. 59"	??	??	NS
	Sneeuberg Hut stream	E201/04A1	26/05/89	32. 28'. 0"	19. 10'. 0"	32 28' 48.00"S	19 10' 04.9"E	05/06/2013
	Suurvlakte	E201/08A1	29/05/89	32. 36". 5"	19. 11'. 59"	32 36' 15.35" S	19 12' 13.31" E	07/06/2013
	Wagenbooms River	E201/09A1	29/05/89	32. 47'. 34"	19. 14'. 45"	32 47' 31.36' S	19 14' 47.39" E	7/6/2013
Tulbagh/Worcester	Die Vlakte	H101/06A1	11/05/88	33. 13'. 59"	19. 16'. 0"	33 14' 35.12" S	19 16' 33.99" E	07/06/2013
	Kluitjieskraal (Verrekyker)	H101/05A1	11/05/88	33. 25'. 59"	19. 10'. 00"	33 26' 10.93" S	19 10' 33.21" E	08/06/2013
	Papenkuils (Bokkekraal)	H101/01A1	09/05/88	33. 40'. 13"	19. 22'. 34"	33 40' 35.47" S	19 24' 09.67" E	20/06/2013
	Platdrif	H101/03A1	10/05/88	33. 38'. 59"	19. 16'. 59"	33 38' 33.95" S	19 17' 23.68" E	20/6/2013
Betty's Bay	Groot Rondevlei (Bettys Bay)	G401/02A1	19/03/89	34. 21'. 5"	18. 52'. 1"	34 21' 44.76" S	18 52' 48.22" E	11/4/2013
	Groot Witvlei	G401/03A1	19/03/89	34. 21'. 5"	18. 52'. 59"	34 21' 45.815 S	18 53' 29.04" E	11/4/2013

Area	Wetland Name	Wetland Code	Historical project			Present project		
			Sampling date	Latitude	Longitude	Latitude	Longitude	Sampling date
	Malkopsvlei (Bass Lake)	G401/01A1	19/03/89	34. 21'. 47"	18. 53'. 29"	34 21' 22.64" S	18 54' 20.86" E	11/4/2013
Vermont	Belsvlei	G403/04A1	24/05/88	34. 20'. 8"	19. 16'. 59"	34 21' 04.61" S	19 16' 33.56" E	08/10/2013
	De Diepte Gat	G403/05A1	25/05/88	34. 21'. 5"	19. 19'. 0"	34 20' 38.86" S	19 19' 35.36" E	08/10/2013
	Elias Gat (Vioolskloof) Site A	G403/03A1	24/05/88	34. 19' 59"	19. 28'. 0"	34 20' 40.80" S	19 27' 27.07" E	08/10/2013
	Elias Gat (Vioolskloof) Site B	G403/03A1	24/05/88	Not recorded		34 20' 54.17" S	19 28' 50.19" E	08/10/2013
	Hemel-en-Aarde	G403/02A1	23/05/88	34. 22'. 59"	19. 13'. 0"	34 23' 18.05" S	19 13' 46.76" E	07/10/2013
	Salmonsdam – Site A	G404/01A1	26/05/88	34. 25'. 59"	19. 37'. 59"	34 25' 56.34" S	19 38' 01.53" E	09/10/2013
	Salmonsdam – Site D	G404/01A2	26/05/88	Not recorded		34 26' 24.70" S	19 37' 10.51" E	09/10/2013
	Salmonsdam – Site E	G404/01A3	26/05/88	Not recorded		34 29' 26.218" S	19 35' 11.858" E	09/10/2013
	Vermont Pan	G403/01B1	23/05/88	34. 23'. 59"	19. 08'. 59"	34 24' 36.98" S	19 09' 41.12" E	07/10/2013
Agulhas – other wetlands	Agulhas Salt Pan	G501/06A1	07/08/87; 09/05/89	34. 43'	19. 55'	34 43' 11. 147" S	19 55' 24.00" E	4/7/2013
	Die Pan (Vispan)	G501/17A1	10/05/1989	34. 43'. 59"	19. 45'. 0"	34 44' 24.9" S	19 45' 21.0" E	5/7/2013
	Gans Bay	G403/09A1	19/09/88	34. 34'. 0"	19. 22'. 0"	34 34' 40.07" S	19 22' 20.01" E	30/08/2013
	Melkbospan	G501/16A1	10/05/89	34. 45'. 0"	19.45'. 0"	34 43' 27.9" S	19 45' 05.5" E	5/7/2013
	Ratel River Estuary	G501/15A1	06/08/87	34. 45'. 0"	19. 43'. 59"	34 45' 11.17" S	19 43' 48.03" E	5/7/2013
	Rhenosterkop Pan	G501/07A1	07/08/87	34. 45'. 0"	19. 55'. 1"	34 45' 34.187" S	19 55' 37.96" E	4/7/2013
	White water dam	G501/03A1	06/08/87; 11/05/89	34. 43'. 0"	19. 40'. 00"	34 43' 45.056" S	19 40' 52.579" E	6/7/2013
Agulhas – Nuwejaars	Farm 182 (Peters bog)	G501/21A1	12/05/89	34. 36'. 5"	20. 3'. 2"	34 37 09.76	20 03 32.12E	NS
	Soetendalsvlei	G501/08A1	07/08/87; 09/05/89	34. 44'. 18"	19. 58'. 18"	34 44 53.269S	19 58 47.558E	04/07/2013
	Soetendalsvlei Ditch	G501/19B1	11/05/89	34. 43'. 59"	19. 58'. 0"	34 44' 44.64" S	19 58' 28.11" E	NS
A g	Voelvlei	G501/05A1	07/08/87	34. 40'. 07"	19. 52'. 21"	34 40' 34.58" S	19 53' 03.669" E	27/8/2013

Area	Wetland Name	Wetland Code	Historical project			Present project		
			Sampling date	Latitude	Longitude	Latitude	Longitude	Sampling date
	Waskraalsvlei (Modder Valley)	G501/04A1	06/08/87	34. 38'. 59"	19.49'. 0"	34 39' 56.57" S	19 50' 05.38" E	27/8/2013
	Wiesdrif	G501/18A1	11/05/89	34. 40'. 29"	19. 54'. 15"	34 40' 56.53" S	19 55' 27.848" E	27/8/2013
	Varkensvlei	G501/20A1	12/05/89	34. 47'. 59"	20. 1'. 0"	34 38' 50.63" S	20 00' 59.22" E	21/10/2013
Agulhas – Groot Hagelkraal	Groot Hagekraal Upper	G501/09A1	08/08/87; 22/09/88	34. 40'. 0"	19. 34'. 59"	34 40' 18.555" S	19 35' 58.245" E	29/8/2013
	Groot Hagelkraal Lower	G501/14A1	22/09/1988	34. 40'. 8"	19. 35'. 28"	34 40' 52.398" S	19 34' 0.494" E	29/8/2013
	Pearly Beach site 1	G501/10A1	08/08/87; 21/09/88	34. 40'. 0"	19. 31'. 0"	34 40' 13.36" S	19 31' 39.58" E	26/8/2013
	Pearly Beach site 2	G501/10C2	08/08/87; 21/09/88	34. 40'. 0"	19. 31'. 0"	34 40' 14.50" S	19 32' 35.70" E	28/8/2013
Mossel Bay and Riversdale	Riversdale	H900/01A1	03/03/88	34. 2'. 59"	21. 19'. 59"	34 3' 40.769" S	21 20' 49.283" E	29/04/2013
	Gouriqua	H900/02A1	22/10/88	34. 22'. 0"	21. 45'. 0"	34 23' 02.77" S	21 45' 14.30" E	30/4/2013
	Blinde Estuary	K101/01A1	02/03/88	34. 12'. 1"	22. 0'. 0"	34 12' 29.954" S	22 00' 41.535" E	28/04/2013
	Blinde River	K101/04A1	02/03/88	34. 11'. 59"	22. 0'. 0"	34 10' 48.532" S	21 58' 58.659" E	28/4/2013

APPENDIX C

SCORE SHEET USED TO ASSESS PRESENT ECOLOGICAL STATE (FROM DUTHIE 1999)

Wetland Name:	**Map reference: SA 1:50 000**	**Position: Lat: Long:**	**Size (ha)**
Reference Condition:			
ASSESSMENT:			

Criteria and attributes	**Relevance**	**Score**	**Confid-ence**
		One score or mean per criterion	
Hydrologic			
Flow Modification	• Flows reduced by abstraction (surface and/or groundwater, upstream or within wetland) or impoundment (dams, weirs or spillways), alien plant infestation or silviculture; • Increased runoff from hardened catchment, agricultural drains, effluent disposal or change in watershed:wetland ratio; • Alteration in flow regime (timing, duration, frequency, volume or velocity); • Outflows constricted by vegetation; • Altered inundation pattern of wetland habitats resulting in floristic changes or incorrect cues to biota.		
Permanent Inundation	• Impoundment or water level regulation resulting in destruction of natural wetland habitat.		
Water Quality			
Water Quality Modification (nutrient loading and/or toxics and/or faecal pollution)	• From surface or groundwater point and/or diffuse sources (agricultural activities, human settlements, industrial or wastewater effluent); • Internal loading from accumulated sediments; • Aggravated by volumetric decrease in flow delivered to the wetland (scored under flow modification); • Change in ambient (desired) salinity as a consequence of altered freshwater or marine intrusion.		
Sediment Load Modification	• Reduction due to upstream retention by impoundment; • Increase due to land-use practices such as overgrazing, unnatural rates of erosion or in-filling, and resulting in atypical accretion and/or turbidity.		
Hydraulic/Geomorphic			
Canalisation/culverts	• Desiccation, shrinkage, altered inundation patterns and changes in habitats; • Point discharges as opposed to broad or sheet flows.		
Topographic Alteration/Habitat Fragmentation	• Consequence of infilling, ploughing, dykes, causeways, trampling, bridges, roads, railway lines and other substrate disruptive physical changes that alter wetland habitat either directly or through changes in inundation patterns.		

Wetland Name:	**Map reference: SA 1:50 000**	**Position: Lat: Long:**	**Size (ha)**
Reference Condition:			
ASSESSMENT:			

Criteria and attributes	**Relevance**	**Score**	**Confid-ence**
		One score or mean per criterion	
Biotic			
Terrestrial Encroachment	• Desiccation of wetland and/or encroachment of terrestrial plant species due to changes in hydrology, geohydrology or geomorphology, resulting in a change from wetland to terrestrial (upland) habitat and associated loss of wetland function.		
Loss of Shoreline (riparian) and/or fringing Vegetation (indigenous)	• Loss or reduction in herbaceous or woody vegetation cover, and/or increased distance between upland vegetation and permanent water; • Switch from macrophyte to algal dominance; • Loss of critical riparian or upland vegetation as a consequence of development, farming activities, grazing or firewood collection affecting wildlife habitat, overland attenuation of flows, input of organic matter or increased potential for erosion; • Loss of shading.		
Invasive Plant Encroachment	• Altered habitat characteristics through changes in community structure and/or water quality (oxygen reduction and shading).		
Faunal Disturbance/ Alien Fauna	• Faunal disturbance due to human presence, domestic animals, noise, light, footpaths, roadways, airports, electricity servitudes; • Presence of alien fauna affecting faunal community structure (*e.g.* top down imbalance due to coarse fish, excessive zooplankton grazing, etc.; bird predation; gerbils); • Atypical fauna due to human presence.		
Overutilisation of biota	• Overgrazing, fishing, mowing, burning or harvesting leading to alterations and imbalances in community structure and foodweb interactions.		
TOTAL SCORE **MEAN** (determined as Total Score / number of attributes evaluated)			
Scoring guidelines per attribute: Natural, unmodified = 5; Largely natural = 4, Moderately modified = 3; largely modified = 2; seriously modified = 1; Critically modified = 0. **Relative confidence of score:** Very high confidence = 4; High confidence = 3; Moderate confidence = 2; Marginal/low confidence = 1.			