Identifying and protecting threatened freshwater ecosystems in the Cape Floristic Region, South Africa

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2.0 Acknowledgements

I would like thank the Rufford Foundation for funding this project, which was also the seed funding for my PhD. The START secretariat for a PhD bursary and the Water Research Commission for additional funding. The South African National Biodiversity Institute (SANBI), for providing a laptop computer.

Thank you to my supervisors Prof. Jenny Day and Dr. Mathieu Rouget, who were instrumental in the design and subsequent execution of this project. The members of the GIS Lab at SANBI, for technical advice. Jeanne Nel for data provision and project design.

Thanks to the Natural Areas Association (NAA), for a travel grant to their 34th Annual meeting in Cleveland, Ohio, where part of the results from this project were presented.

Photographs by Mao A. Amis

3.0. **Resulting publications**

Conference presentations

Part of the results from this project were presented at the 21st Annual meeting of the Society for conservation Biology (SCB) in July 2007, Port Elizabeth, South Africa. I became the first student from the African continent to receive an award from the Society for best student presentation.

M.A Amis, M. Rouget, M. Lotter, J. Day 2007. Do freshwater and terrestrial priorities overlap in Conservation Assessments? 21st Annual Meeting of the Society for Conservation Biology, Port Elizabeth, South Africa.

Part of the results from this project was also presented at the 34th Annual Meeting of the Natural Areas Association (NAA) in October 2007, Cleveland, USA.

M.A Amis, M. Rouget, M. Lotter, J. Day 2007. Integrating freshwater and terrestrial priorities in conservation planning: A scenario Analysis. 34th Annual Meeting of the Natural Areas Association, Cleveland, USA

Peer Reviewed Journals

Two papers are being written up for publication in a peer- reviewed journal.

Thesis

This project will go as a chapter in my PhD thesis, entitled *Freshwater Conservation Planning and Policy in South Africa.*

4.0. Project funding and expenditure

Grant received: £4661

Expenditure	
Car hire for field trips	1389
Fuel	370
Accommodation during overnight field trips	250
Field maps & ortho-photos	278
Expert workshops & consultations	536
Field equipment (camping tent & other outdoor requirements)	130
Office supplies & printing of large maps	110
Purchase of a GPS	300
Salary for field Assistants	1400
Miscellaneous expenses	169
Total	**4932***

* Project over budget by £**271**

5.0. Executive summary

This report summarises the findings of the project: *Identifying and protecting threatened freshwater ecosystems in the Cape Floristic Region, South Africa*. The aim was to develop a systematic conservation plan for the cape Floristic Region (CFR). The Cape Floristic Region (CFR) of South Africa is a region of global significance as a biodiversity hotspot. The CFR is home to the greatest concentration of non-tropical plants in the world, and is one of the 6 only floral kingdoms in the World. However, it is also highly impacted by anthropogenic disturbances due to agricultural activities, population increase and climate. Freshwater systems are especially very vulnerable in the region due to the low rainfall that has resulted in inter-basin water abstractions, flow modification through dam constructions and generally a high water demand. Alien invasive species especially alien fish and alien trees are also a major threat to indigenous species and water catchment areas respectively.

The objective of this project was thus to develop criteria for identifying threatened freshwater ecosystems in the Cape Floristic Region, and to develop a systematic plan for freshwater ecosystems in the region.

This project commenced in July 2006 and was completed a few months ago. It was undertaken as part of my PhD in Conservation Biology, for which I'm registered as a full time student at the University of Cape Town, South Africa. As a result I was the principle investor although I did collaborate with a several individuals and agencies undertaking similar projects in South Africa.

The project itself was divided into two phases:

i) The first phase comprised the development and testing of a criteria for effective integration of freshwater and terrestrial priorities in conservation planning
ii) The second phase involves the application of this criterion in the identification of priority freshwater ecosystems in the Cape Floristic Region.

This report is just a general overview of both components of the project, because my thesis is yet to be examined as a result, the dissemination of this information is still limited.

6.0. Introduction

Freshwater ecosystems are globally threatened due to human disturbance (**Saunders et al. 2002**), and its predicted that freshwater biota face extinction at a rate five times greater than that of terrestrial biota and three times that of coastal marine biota (**Ricciardi et al. 1999**). Yet freshwater ecosystems have been accorded the least protection compared to terrestrial and marine ecosystems (**Kingsford & Nevill 2005, Saunders et al. 2002**). The freshwater crisis is partly attributed to global environmental change; the principle agents of which are; land use, anthropogenic changes in biogeochemistry, and biotic additions and losses (**Lake et al. 2000**).

South Africa is experiencing severe water stress (**Arnell 2004**), and the situation is expected to worsen due to climate change (**van Dam et al. 2002, IPCC 1998**), population growth and changes in consumption patterns (**Scholes & Biggs 2004**). Despite this acute problem, most freshwater systems are not legally protected, apart from Ramsar sites designated for wetlands of global significance. Ramsar sites are not very effective in conserving freshwater ecosystems, because they are primarily designated for their importance as habitat for water dwelling species rather than for their significance as a representative ecosystem type.

Freshwater conservation planning seeks to identify and prioritize those freshwater systems that possess high level of biodiversity and harbour important ecological processes for conservation intervention (**Thieme et al. 2005, Higgins 2005**). But current methods of conservation planning do not take a holistic approach in identifying priority areas across terrestrial, freshwater and marine systems (**Abell 2002**), and also largely fail to incorporate emerging threats like global change (**Williams et. al 2005**). As a result the current network of protected areas appears to be biased towards terrestrial biodiversity at the expense of freshwater systems. Failure to incorporate the threat posed by global change may imply that areas that have been identified as priority for conserving biodiversity might be rendered ineffective in conserving species and habitats of most concern, thus leading to a squander of conservation resources (Williams et. al 2005).

The Cape Floristic Region, located in South Africa is a region of global significance for biodiversity as evidenced by its designation as one of 35 global biodiversity hotspots (**Meyers et al. 2000**). The CFR is also anticipated to be severely impacted by climate change (**Williams et al 2005**), with a resultant significant shift in the distribution of many species in response to climate change.

The objective of this project is thus to develop criteria for effective conservation of freshwater ecosystems, and to identify priority areas for conservation for freshwater ecosystems in the Cape Floristic Region (CFR), of South Africa.

7.0. Study area

South Africa has been designated into 19 water management areas (WMA) for ease of conserving freshwater ecosystems and for effective management. This study comprised of the three water management areas of the Berg, Breede and the Gouritz with a total area of 78933.1 Km sq (**Fig. 1)**. The area has a Mediterranean type of climate (**Davies et al 1995)** but with rainfall that varies considerably in the region.

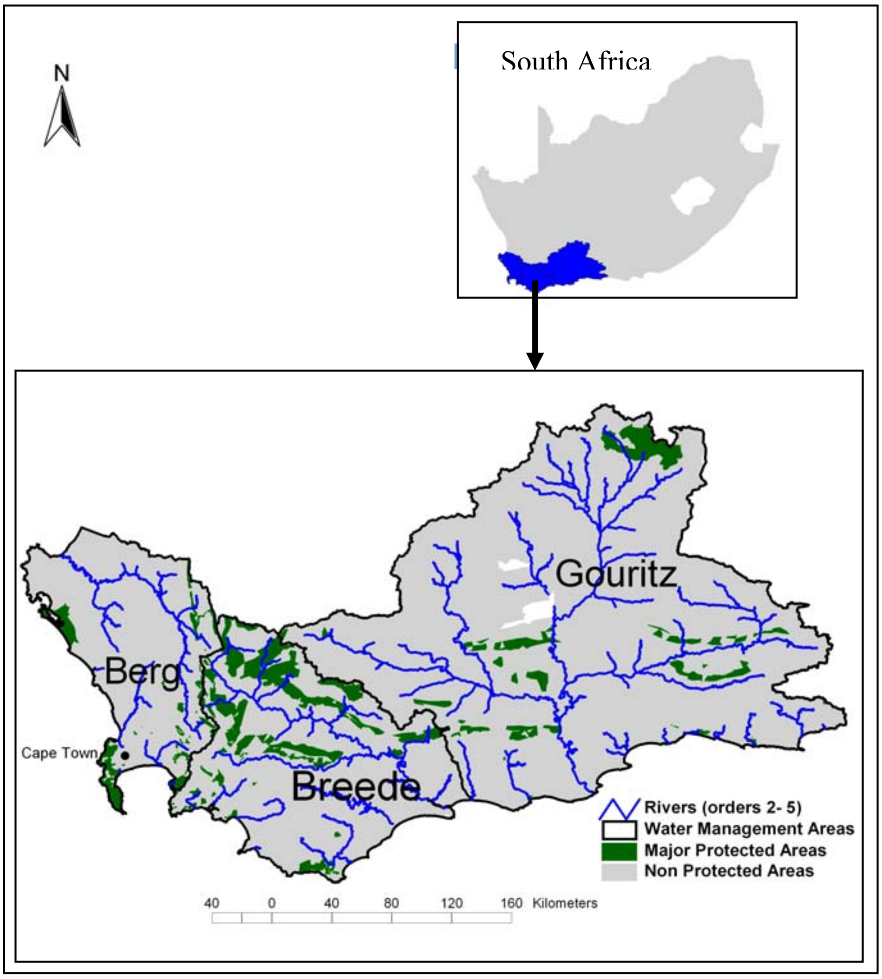

Fig. 1. **The study area showing the three water management areas, major river systems and protected areas (category I & II)**

All the three WMA's are located in the Cape Floristic Region (CFR), which has made them some of the most critical WMA's due to the importance of the CFR as a global biodiversity hotspot (**Myers et al 2000).** Biodiversity hotspots are those regions of the world that have an incredible level of biodiversity and their conservation is thought to be of global significance.

8.0. Freshwater ecosystems in the CFR

Freshwater ecosystems in the Cape Floristic Region also exhibit a very high level of species diversity and endemism similar to their terrestrial counterparts. These include several aquatic taxa such as invertebrates, amphibians and fish (**Wishart and Day 2003)**. For example there are about 19 indigenous fish species in the CFR out of which 16 are endemic to the region. The high level of endemism in freshwater biodiversity could be attributed to the unique Mediterranean climate and acidic waters to which many species have adapted **(Thieme et al 2005)**. In this study, only 6 fish species of special concern according to the IUCN REDDATA LIST were included due to paucity of datasets.

Wetlands form an important component of the CFR, but are by far the least studied of freshwater ecosystems in the region and South Africa at large (**Grenfell et al 2005)**. Yet wetlands perform important functions of regulating water quality and quantity and are thus important providers of ecosystem services. Wetlands also play an important role as habitat for water dependent species such as migratory birds, as a result five wetland systems in the CFR have been designated as Ramsar sites.

The key determinant of wetland distribution in the region is geomorphology and climate. Whereby, the flat and low lying areas of the CFR favour the formation of pans, whereas the moist areas favour the formation of perennial endorheic wetlands. The foothills favour the formation of wetlands along streams and seeps, while the coastal areas favour the formation of estuarine lagoons and salt marshes **(Van Nieuwenhuizen 2000).**

8.1. Threats to freshwater ecosystems in the CFR

Freshwater ecosystems are highly threatened by river bed and flow modification, alien fish and alien vegetation, urban and agricultural development (**Fig. 2)**. The lower and middle of the river systems are the most impacted by land use activities because these are the areas most suitable for agriculture and urban development. While the upper reaches of the river systems are relatively intact because of the rugged terrain which has made these areas unsuitable for human settle and agriculture.

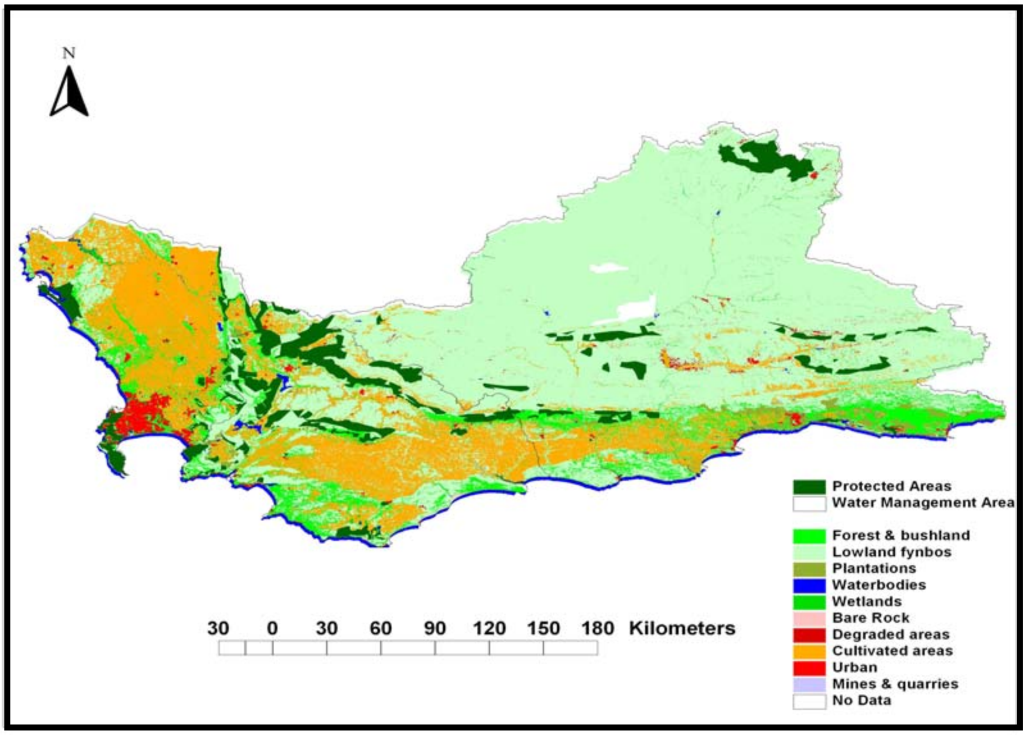

Fig. 2. Land use distribution and protected areas (category I & II)

More than 20% of the region has been cultivated, and thus agriculture and its associated activities is one of the major threats to freshwater systems in region (**Fig 3a)**. It has resulted in clearing of riparian vegetation in most of the impacted river systems (**RHP 2004).** Agricultural runoff has also given rise to eutrophication as pesticides find their way into the freshwater systems resulting in a build up of nutrients in the systems. This has impact on water quality and has been reported to have resulted in the loss of sensitive aquatic invertebrates such as stoneflies and mayflies (**RHP 2004).** Urbanisation is also a major threat to freshwater systems in the region, and is extensive in areas surrounding Cape Town. One of the major problems caused by urban settlements is wastewater discharges into freshwater systems.

Fig. 3a & 3b. Shows some of the major threats in the region of agriculture and dam construction respectively.

Water abstractions and inter-basin transfers is another major degrader of freshwater systems in the Cape Floristic Region. Due to the low rainfall in this region of South Africa there is very high demand for water during the dry summer months to supply the agricultural systems and for human consumption. Water abstractions and inter-basin transfers have a negative impact on in-stream habitats as they tend to decrease the base-flow which affects the function of the freshwater systems as it is dependent on water. For a long time water has been abstracted in this region indiscriminately regardless of the need to maintain the ecological functions of the system. This has had huge implication onfreshwater ecosystems in the region. Closely related to water abstractions and inter-basin transfers is flow modifications in the form of dam constructions. Due to the scarcity of water resources, dams have been widely used to capture water for agriculture (**Fig. 3b)**. But dams have negative implication on freshwater ecosystems as they interrupt connectivity of river systems which leads to disruption in the movement of aquatic biota.

Alien invasive fish species were introduced in many rivers in the region, and although many systems remain without alien fish, in some streams up to eleven alien fish species have been recorded (**Thieme et al 2005).** Alien fish species negatively impact on indigenous species through competition and predation (**Van Nieuwenhuizen 2000),** and sometimes they can temporarily change the physical characteristics of the river system by stirring up sediment and increasing turbidity (**Van Nieuwenhuizen 2000).** The most common invasive fish species in the CFR are the bass (*Microoterus* spp) and trout (*Oncorhynchus mykiss and Salmo trutta*), which have been reported to have eliminated several indigenous species of the genus *Pseudobarbus.*

8.2. Level of protection accorded to freshwater ecosystems in the CFR

The Cape Floristic Region is probably one of the few regions in South Africa that has had a long history of conservation. More than 10% of the region is under some form of protection according to the World Database on Protected Areas, and most of those areas lie in the IUCN categories I to IV. Most of the protected areas however lay in the mountain regions with very few protected areas in the lowlands (**Rouget et al 2003)**; as a result some of the most critically endangered vegetation in the CFR is found in the Cape lowlands, such as the renosterveld vegetation type.

In comparison to terrestrial biodiversity, freshwater systems are the least protected in the CFR, because the freshwater systems are generally species depauperate. Most of the protected areas were established for terrestrial biodiversity, even though some freshwater species are found in protected areas they have generally received inadequate protection. This is in disregard of freshwater systems being the driving force of biodiversity persistence in the region as it is a major limiting factor.

However, there are some remarkable freshwater conservation initiatives that have played an important role in securing freshwater ecosystems in the region. Most notable of these initiatives is the Working for Water Program (WFW) and the River Health Program (RHP). The WFW focuses on clearing alien vegetation along riparian areas of major catchments countrywide and has been very successful in restoring some river systems that were badly impacted by alien vegetation. Similarly, the River Health Program has been very successful in assessing the ecological integrity of river systems in South Africa. And in the CFR most water management areas have undergone this assessment. The shortfall of these conservation initiatives is that they are more opportunistic than systematic.

9.0. Systematic conservation planning

Systematic conservation planning has become an important aspect of biodiversity conservation in aiding decision makers to identify and implement good policy options (**Margules & Pressey 2000, Knight et al 2006, Sarkar et al 2006**). Systematic conservation planning involves the design and identification of a set of places to ensure biodiversity persistence (**Cowling & Pressey 2001**). The limited knowledge of the ecological systems has also highlighted the importance of systematic conservation planning as a strategy for effective biodiversity conservation (**Prendergast et al 1999, Crawley and Harral 2001, Groves 2003, Warman et al 2004**).

Box 1: Stages of systematic conservation planning (Adopted from **Margules & Pressey 2000**)

1. Compile data on the biodiversity of the planning region

2. Set conservation targets for the biodiversity features

3. Review existing conservation areas

4. Select additional conservation areas

5. Implement conservation actions

6. Maintain the required values of conservation areas

As stated above, most reserve systems in the CFR are located in mountainous regions, leaving most of the lowlands biodiversity vulnerable to anthropogenic impacts. This is mainly due to lack of planning in reserve design, which led to designation of reserves in isolated areas, unsuitable for human settlement and agriculture. Systematic conservation planning enables such anomalies to be eliminated because a strong emphasis is put on securing areas that are critical for conservation and working with stakeholders to ensure that such areas are protected.

The products of systematic conservation planning (maps of biodiversity priority areas) are widely used by local authorities for decision making on where developmental projects should be located and whether an environmental impact assessment will be required before authorisation to convert natural areas into other land uses. Systematic conservation planning products could also be used as a legal instrument in land use conflicts. For example if a privately owned land was identified as a critical biodiversity area, the landlord might have to comply with environmental regulations on what land use might be allowed in such an area.

One of the most important aspects of systematic conservation planning is that it allows the conservation goals of a region to be translated into quantitative terms and thus improve conservation efforts. For example if the conservation goal of a region is to ensure that all populations of critically endangered species are protected and should remain viable over the long term, systematic conservation planning approaches can translate this broad goal into a specific quantitative target based on species-area relationships and expert knowledge to identify the minimum area that should be set aside to achieve this goal.

9.1. Framework for integrating freshwater and terrestrial priorities in conservation planning

Freshwater and terrestrial biodiversity operate in fundamentally different ways to the extent that incorporating the interests of both systems in conservation planning has become a major challenge. Yet it is important that linkages between these systems are harnessed if biodiversity is to be effectively conserved. The uniqueness of freshwater systems is attributable to the fact that most freshwater species are highly mobile as a result of their liquid medium, the longitudinal nature of river systems and the location of freshwater systems at the lower end of the landscape.

However, current conservation planning practices do not integrate the different ecosystems of freshwater and terrestrial biodiversity. For example, a recent review of the conservation planning literature showed that more that 70% of conservation assessments were only based on terrestrial biodiversity, without consideration of freshwater or marine biodiversity whatsoever (**Amis, *in* prep**). This trend is worrying because freshwater and terrestrial biodiversity are intricately connected (**Palmer et al 2000**). Maintaining connectivity between freshwater and terrestrial systems is thus important for processes such as nutrient cycling and stream biotas that are highly dependent on adjacent terrestrial vegetation (**Palmer et al 2000; Grimm et al 2003**). The life cycles of many organisms also depend on both the aquatic and terrestrial habitat, such as nematodes **(Hanet & Janovy 2002),** and amphibians which require both terrestrial and aquatic systems to exist **(Semlitsch 2002).**

Recognising the lack of integration between freshwater and terrestrial biodiversity as a major impediment, this project thus undertook to develop and test a framework for effective integration of freshwater and terrestrial priorities in conservation planning. The aim of this component of the project was to develop and test a framework for integration in a region outside the Cape Floristic Region, and then use the CFR to validate its effectiveness.

Following extensive analysis of freshwater and terrestrial priorities areas in Mpumalanga province in South Africa, a framework was developed that could be used as a protocol for the effective integration of freshwater and terrestrial priorities in conservation planning (**Fig. 4)**.

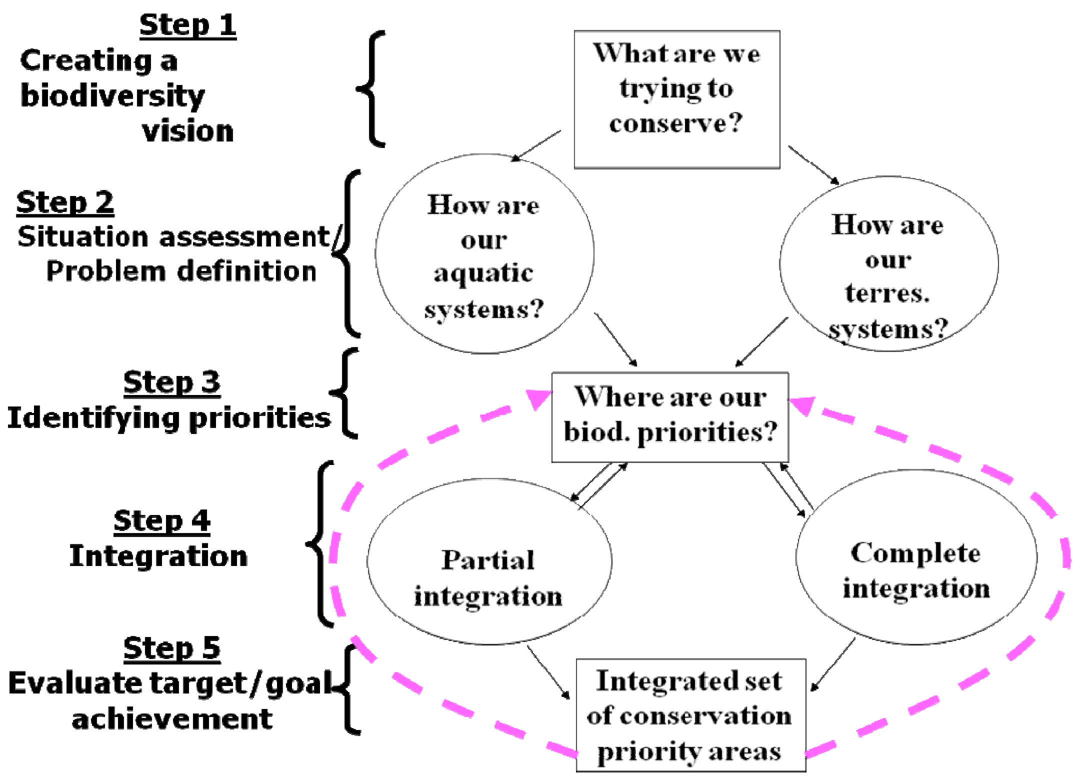

Fig. 4. A framework for integrating freshwater and terrestrial priorities in conservation planning.

Step 1: creating a biodiversity vision

Systematic conservation planning is essentially a strategy for realising a biodiversity conservation vision. Often times though, conservation assessments are carried out without stipulating specific goals that such an exercise should achieve in the long run. As a result such a conservation plan may become an end in itself and thus redundant.

Creating a biodiversity vision enables one to answer the question of, what it is that you are trying to conserve? This is a very basic question but it's the key determinant of the success of a conservation plan.

In the Cape Floristic Region the broad goal was to ensure that freshwater ecosystems are adequately protected, so as to maintain their ecological functions and to provide ecosystem services, and to restore those freshwater systems that have been impacted by anthropogenic disturbances back into ecologically functional systems.

Step 2: Situation assessment/problem definition

As stated earlier freshwater and terrestrial biodiversity operate differently, and to be able to overcome the challenges encountered in systematic conservation planning, it is vital that a situation assessment is carried out. A clear definition of a problem in systematic conservation planning will determine the success of the conservation action **(Knight et al 2006)**.

The situation assessment should specifically address the 'performance' of both freshwater and terrestrial ecosystems and this will determine how the systematic conservation plan is carried out. For example in the Cape Floristic Region, we know that freshwater ecosystems are a major limiting factor and have generally been accorded less protection. Therefore in our assessment freshwater ecosystems will be given precedent in designing the systematic plan for the Cape Floristic Region. But in Mpumalanga, where this framework was developed it was found that both freshwater and terrestrial ecosystems were not adequately protected, and to effectively integrate these systems, freshwater ecosystems should be assessed separately and then use the outcome of the freshwater assessment to influence the assessment of the terrestrial ecosystem.

<u>Step 3:</u> Identifying biodiversity priority areas

Only after a conservation vision/goal has been set and a situation assessment has been carried out should then the process of identifying priority areas for conservation commence (see Box 1 above).

<u>Step 4:</u> Integration

Depending on the outcome of Step 1 &2, the conservation planning approach will adopt an approach that will result in either complete or partial integration of both freshwater and terrestrial ecosystems. Complete integration is when both systems are given an equal weighting during the assessment, and this could be due to the fact that the situation assessment found that both freshwater and terrestrial biodiversity in the planning region are of equal importance or they both face the same level of threats. On the other hand when conservation efforts are biased towards a specific ecosystem, then partial integration should be adopted. Partial integration for example in terms of terrestrial assessment will ensure that freshwater priorities are used to influence the selection of terrestrial priority areas. However, it should be noted that in the testing of this framework, partial integration cannot be applied when assessing freshwater ecosystems, in other words terrestrial priorities cannot be used to drive freshwater assessment. This could be due to the fact that there are usually few options in terms of freshwater on where conservation targets for both freshwater and terrestrial priorities could be achieved.

<u>Step 5:</u> Evaluate target/goal achievement

The final step in the framework for integration involves target evaluation for both systems; the aim is to ensure that targets for both systems have been achieved. Integration could result in over or under representation of each system, it is therefore important to identify the gaps. If all areas selected do not meet targets, for example in terms of freshwater, it might require that additional areas are selected even though they do not meet the set criteria, but have a potential to be rehabilitated into an acceptable condition.

10.0. Mapping freshwater biodiversity priorities in the CFR

One of the key principles of systematic conservation planning is that it should result in the representation of the full suite of biodiversity in the planning domain (**Margules & Pressey 2000).** This requires that the best available data that represents the full diversity of the planning domain must be collated, so as to identify priority areas that are truly representative of the regions diversity. However, this presents a considerable challenge, because data is oven very patchy especially in regard to freshwater ecosystems. Since data for such analysis are collated from different sources, there is often a variation in the scale at which data was collected and in many instances there are gaps. To get around this predicament, systematic conservation planning has often relied on broad biodiversity data or surrogates based on physical characterisation of the landscape to represent the diversity of habitats that species occupy.

10.1. Delineation of planning units (sub catchments)

Systematic conservation planning requires that all data in the planning domain must be mapped at a specific scale, referred to as the planning unit. In the case of freshwater it was deemed suitable to use sub-catchments as the planning units, because they are more meaningful in terms of freshwater ecosystems and they help to achieve connectivity (**Moilanen et al 2007, Nel et al 2007**).

In this study sub-catchments were delineated using digital elevation models (DEM), and the 1:500, 000 maps of rivers of South Africa (**DWAF 2004**). Catchment boundaries were delineated around each river segment, defined as the stretch of river segment between confluences (Nel et al 2006). The delineation of the sub-catchments gave rise to 858 units, ranging in size from 184- 4,134 hectares.

10.2. River types

As discussed earlier, data availability is a major impediment in freshwater ecosystems and this has implications on how systematic conservation planning can be carried out. In this study we use the physical characterisation of the river system as a surrogate for biodiversity. This is based on the premise that, the diversity in the physical characteristics of a river system plays an important role in determining the type of habitat occupied by species. For example the rate of sediment transport is faster in mountain streams, than in lowland rivers (**Nel et al 2006**). The rate at which sediment is deposited in the river bed will determine the type of habitat instream species will occupy. The aim of delineating river systems is thus to capture as much diversity in the physical characteristics of river systems as is possible.

In this study river systems were delineated based on flow variability, ecoregions and longitudinal zonation of rivers . Ecoregions represent landscape scale characterisation of river systems, based on the assumptions that rivers that have similar ecological characteristics will have a similar species composition. The next level of river classification was based on flow variability, depending on whether the river is perennial, seasonal or ephemeral. The final classification of river types was based on whether the river is a mountain stream, upper foothill, lower foothill or lowland river (**Fig. 5**) (**Rowntree & Wadeson 1999**).

Fig. 5a & 5b. Examples of different river types, on the left is a lowland river, and on the right is an upper foothill river

The classification of river types as surrogate for biodiversity in the Cape Floristic Region gave rise to 164 river types. These were then used as surrogates for biodiversity in the assessment. To validate the river types generated in the desk top analysis, extensive 'groundthruting' was carriedout at randomly selected rivers, to determine the level of confidence in the river typing.

In the systematic conservation planning process a target of 20% was set for each river type. This implies is that in order to adequately protect freshwater ecosystems, a minimum of 20% of the length of each river type must be represented in the proposed portfolio of biodiversity priority areas.

10.3. Wetland types

Wetlands are some of the least studied freshwater systems in the Cape Floristic Region. The data availability is therefore relatively patchy, because of this a lot of time was spent in collating the best available data for the region. One of the major challenges in wetland conservation is that classification of wetlands is a very challenging task.
This study relied on a wetland database that spatially mapped all major and sensitive wetlands in the Cape Floristic Region. The problem with this database was that it did not classify the wetlands in to different types, and it also included dams.

Fig. 6. Different wetland types found in the study area

To capture the diversity of wetlands, they were classified based on ecoregions as a surrogate for biodiversity. A special consideration was also given to large wetland clusters of more than 1000 hectares, because such wetlands were thought to be critical for ecological functions and thus any conservation assessment should ensure that such wetlands were given a higher priority. Targets for wetlands varied based on the wetland type, size and ecological integrity.

10.4. Threatened fish species of the CFR

The diversity of fish species in the Cape Floristic Region is relatively low, but they are characterised by a very high level of endemism. As a result we took in account the species conservation status and endemism, but in the end only fish species of special concern were included in the assessment due to data available. In all there were six fish species that were included in the analysis of priority freshwater ecosystems, all of them listed under some form of threat according to the IUCN Red data list.

High water yield areas

Freshwater systems are not only important because they provide habitat for species, but they are also critical for the provision of ecosystem services to man. However, freshwater systems are often highly exploited in a very unsustainable manner. For example water abstraction and dam constructions have a major implication on the function of freshwater ecosystems. As a result in this study, special consideration was given to high water yield areas in the Cape Floristic. The aim is to ensure that any potential priority conservation area for freshwater biodiversity, should to secure those high water yield areas critical for securing flow.

The catchments that provide more than 50% of the mean annual runoff were assumed to be the catchments critical for maintain flow in the region. These catchments were flagged down, and we found that only 138 catchments (16% of catchments), were responsible for 50% of the total runoff in the study region. A target of 20% was set to capture all the high water yield areas.

10.6. Ecological integrity of the freshwater ecosystems

The determination of the ecological integrity of freshwater ecosystems is vital in systematic conservation planning; this is because biodiversity priority areas should be selected in catchments that are relatively intact and thus ecologically functional.

River systems

The ecological integrity of river system was determined based on land use (**Amis et al 2007)**, and the present ecological condition class (PESC). The assumption here is that adjacent land use will play an important role in determining instream conditions of river systems, example as a result of increased runoff into rivers due to erosion and direct effluent discharge. This led to characterisation of rivers into varies classes ranging from A- Z. A class of A implies that the river is in good condition with no alteration. While a class of Z implies that the river system has been irretrievably degraded, and cannot be rehabilitated into an acceptable condition. Ecological integrity was incorporated in the assessment, by ensuring that the selection of priority areas for biodiversity are biased towards those areas that of high ecological integrity.

Wetlands

Similar to river systems, wetland ecological integrity was based on land use, and in this case a buffer of 200 metres was created around each wetland and the percentage natural vegetation was determined. The underlying assumption here is that wetlands whose surrounding area is relatively intact, are of high ecological integrity and thus ecologically functional.

10.7. The use of MARXAN to identify priority freshwater ecosystems in the CFR

MARXAN is a robust and widely used tool in systematic conservation planning (**Sarkar et al 2006)**. It uses an objective function to assign a total cost to a chosen set of planning units depending on how good the set is as a potential reserve network. An optimisation method known as simulated annealing is then used to select a near optimal suite of potential conservation areas, by minimising the objective function (total cost). The objective function of MARXAN is described as: -

$$\textbf{Total cost} = \sum_{\text{PUs}} \textbf{PU costs} + \textbf{BLM} \sum_{\text{PUs}} \textbf{boundarylengths} + \sum_{\text{Species}} \textbf{CFPF} \times \textbf{penalty} \times \textbf{threshold penalty}$$

Where: -

PU are the planning units (sub-catchments). Cost can be the area of the planning unit, opportunity cost of not selecting the planning unit or an economic cost (e.g. the cost of land). The boundary length modifier (BLM) is a factor that ensures the selected planning units are not disaggregated to enhance connectivity. The conservation feature penalty factor (CFPF) is a penalty for failing to represent a conservation feature. The threshold penalty is associated with exceeding a set number of planning units or cost.

The planning unit cost feature of MARXAN enables the selection of planning units to be biased depending on the cost value. Planning units with low cost are selected preferentially to those with a higher cost if options exist. The cost function of MARXAN is mostly used to minimise the area required to achieve biodiversity targets. In this case the area of the planning unit is used as a cost, and the goal is to represent a specified number of biodiversity features at minimum cost (area) (**Oetting et al 2006; Shriner 2006; Carwardine 2007).** In this study the ecological integrity of the sub-catchments were used as the cost input in MARXAN. This was done to ensure that areas are selected preferentially in favour of sub-catchments of high ecological integrity.

10.8. Expert input in the identification of priority freshwater ecosystems.

An important aspect of systematic conservation planning that has not been discussed extensively in this report is the significance of expert input at all stages of the planning. Since most of actual identification of priority areas is a desktop exercise, it is vital that the priority areas identified are reviewed by experts who are familiar with the planning domain. A a workshop and several and consultations were undertaken in the course of this project to verify results of the assessment (**Fig. 7)**

Fig. 7. Expert review of priority freshwater ecosystems in the Cape Floristic Region

11.0. Results and discussion

11.1. Ecological integrity and target achievement of rivers

Ecological integrity of river systems in the Cape Floristic region varied widely **(Fig. 8 & 9).** About 40% of the total length of rivers was in the class A or B, implying that they are relatively intact from anthropogenic disturbances and are ecologically functional. The rivers in this category have at least 80% natural vegetation, which is critical for the functioning of the system. However, it should be noted that the intact rivers only made a contribution of 12% towards target achievement. This implies that even though these rivers were in good ecological condition, they have less diversity in terms of river types, hence the low contribution towards target achievement. The other reason towards the low contribution to target achievement could be attributed to the fact that most of the intact rivers occur in the northern part of the study area, which is mostly semi-arid and thus unsuitable for agriculture and human settlement. The semi-arid region also implies that rivers in those areas probably have similar classification in terms of ecoregion, flow variability, and longitudinal zonation.

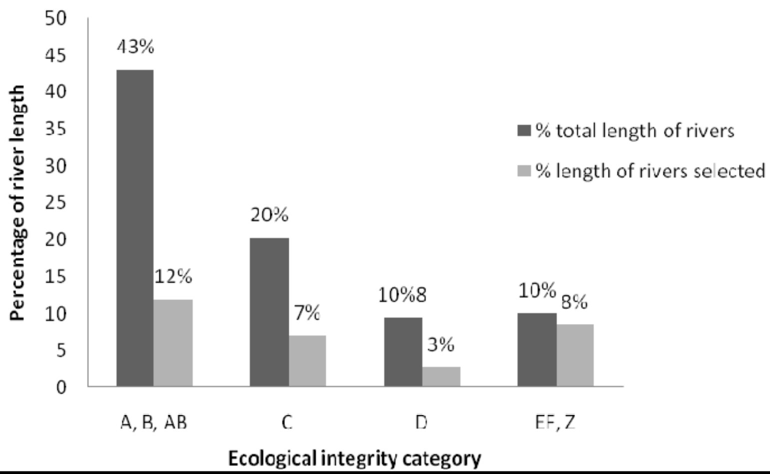

Fig.8. The ecological integrity of river systems and how much rivers were selected from each ecological integrity category to achieve conservation targets.

Category C and D rivers that are disturbed rivers, but still have a potential to be rehabilitated. This category contributed 10% towards target achievement. Whereas, rivers in category EF and Z, that are severely degraded were almost all required to achieve targets. This is alarming, because rivers in this category are those that were thought to be degraded to such an extent that rehabilitating them is thought to be infeasible. So if these rivers were excluded from the analysis it would mean that 8% of the target for rivers could not be achieved. The reason why these rivers were selected in the assessment was because there were no options in areas with high ecological integrity.

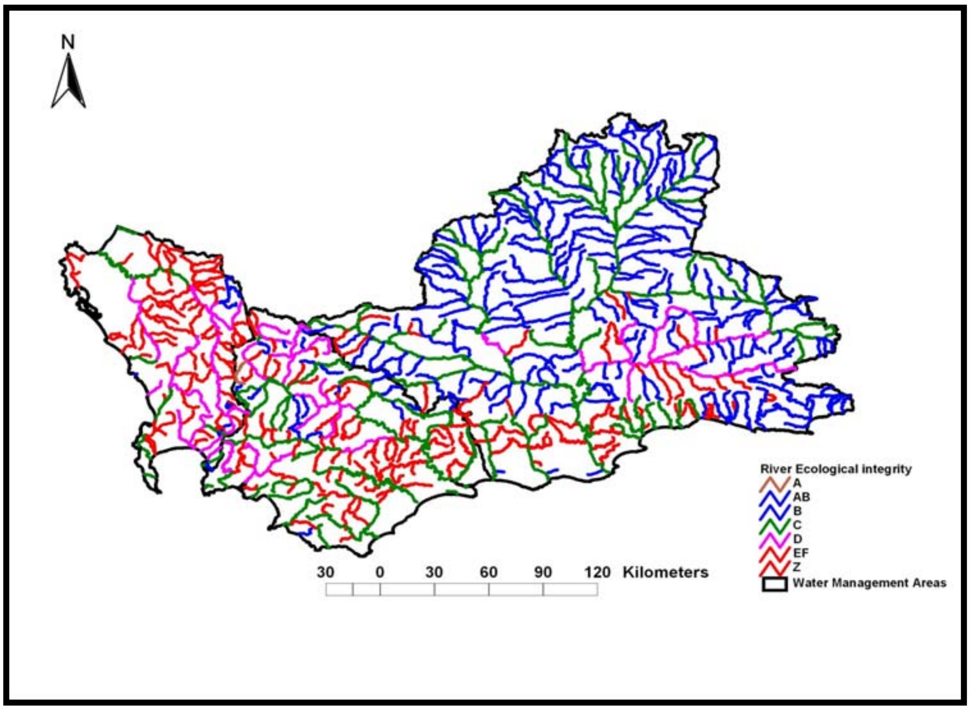

Fig. 9. The ecological integrity of river systems in the study area. Note that most of the intact rivers are found in the northern parts of the study area

11.2. Required sub-catchments

The number of sub-catchments required to achieve all set targets was 175 (20.4% of sub-catchments), which amounts to 25% of the total study area (**Fig.10)**. This is a relatively large area required to meet targets. However, it might be considerably reduced if the current network of protected areas is included in the analysis. Protected areas were not included in this analysis was, because many studies have found that many protected areas do not adequately protect freshwater ecosystems (**Roux et al *in press*, Keith et al 2000, Filipe et al 2004,).** This is mainly because most protected areas are designed for terrestrial ecosystems, with little regard to freshwater ecosystem. In the context of this study, during implementation it might be necessary to determine how much of the freshwater targets could be achieved inside protected areas, as a strategy to reduce the size of the area that would otherwise be required.

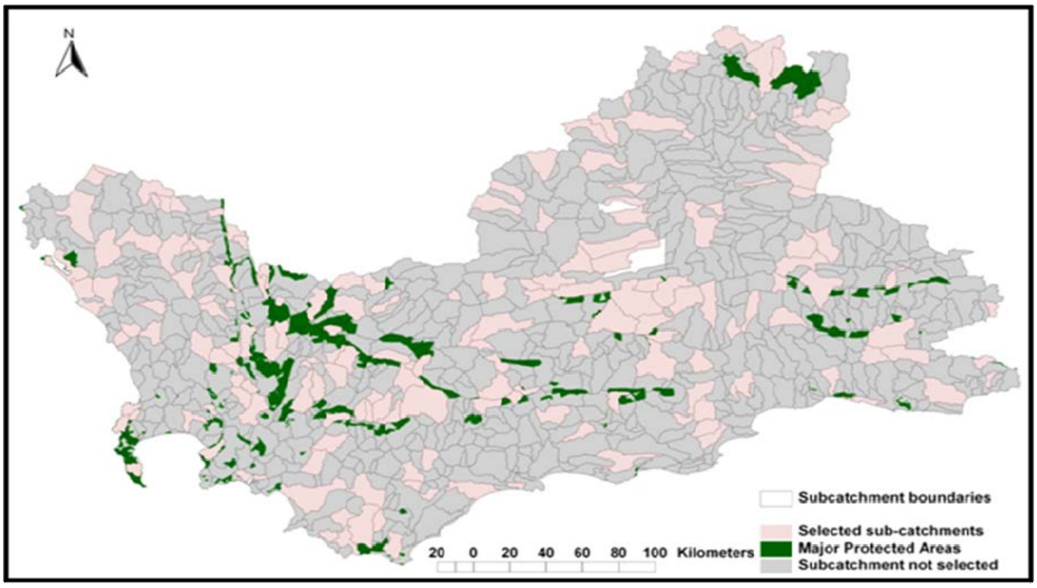

Fig. 10. Map shows sub-catchments that were selected to achieve targets (best output)

11.3. Freshwater irreplaceability

Irreplaceability is the likely hood that a site will be required to achieve targets (**Ball et al 2000, Linke et al 2007).** Irreplaceability was measured as a score ranging from 1 to 100, with a score of 100 being the most irreplaceable (**Fig. 11**). The significance of the irreplaceability is that it enables the evaluation selected priority sites. A good systematic plan should ensure that the final portfolio of priority sites should include highly irreplaceable sites as much as possible. In this study, we managed to secure more than 55% of selected sub-catchments with an irreplaceability of between 80- 100.

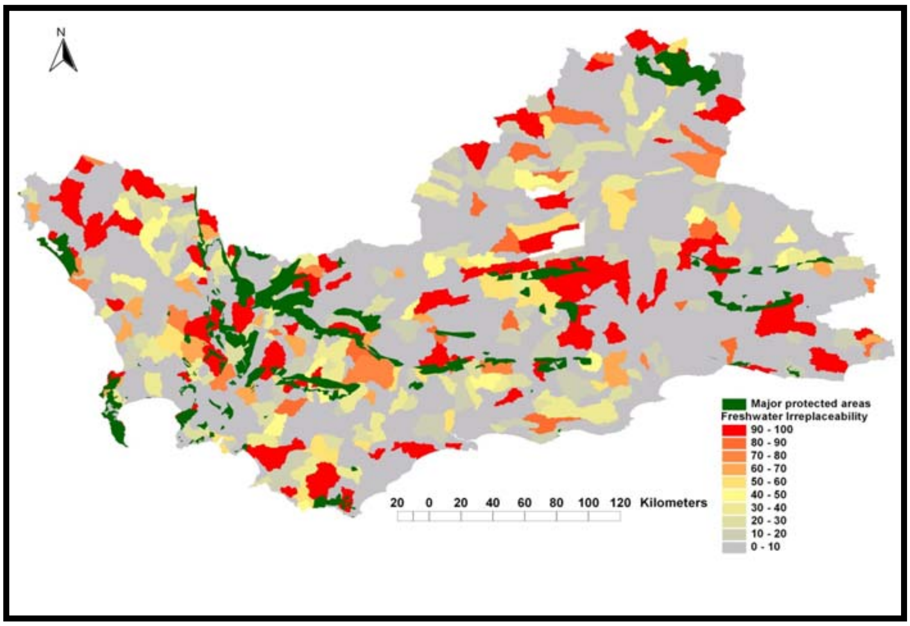

Fig. 11. Irreplaceability freshwater sub-catchments in the Cape Floristic Region.

12.0. Conclusions and recommendations

The outcome of this project is an important contribution to the conservation of freshwater ecosystems in the Cape Floristic Region, where conservation efforts have traditionally focused only terrestrial biodiversity. In the Cape Floristic Region, there are several major internationally funded conservation projects that are being executed, but all are based on the assessment of terrestrial biodiversity. This project will help to identify gaps in the current conservation efforts in terms of freshwater ecosystems, and recommend areas where additional attention might be required.

This project is a broad scale analysis of freshwater priority areas, but a common practice in systematic conservation planning is that to implement these priorities, further analysis should be undertaken at a finer scale. In the CFR for example, there are a couple of such fine scale conservation planning exercises that are being undertaken. These fine scale conservation planning are often very costly and time consuming. As a result one of the issues I would like to pursue further is how the priority areas identified in this project compare with those identified at a much finer scale. This is important, because if there is very little variation between the outputs of broad and fine scale conservation planning, it means that a lot of money and time will be saved when priorities for conservation are identified at a broad scale and implemented at a fine scale.

Further fieldwork also needs to be done to verify the priority areas identified in this project. Most of the field work undertaken in this project involved data collation and the verification of modelled and spatially collated data. So for this project to be truly useful, I will need to carry out extensive field surveys to assess the level of confidence in the priority areas identified. Although experts were involved through workshops in authenticating some of the outcomes, there were very few field visits undertaken to priority sites that were identified.

Finally, there is a need to mobilise stakeholders if the products from this project are going to be useful. This is because systematic conservation planning is essentially about implementing conservation decisions, and since conservation planners are not the main implementing agencies, it is thus paramount that conservation practitioners are made aware of the priority areas identified in this project and how this project might be useful in furthering their conservation goals. The main stakeholders that need to be mobilised include the Local Municipal authorities, the department of Waters Affairs, and the department of Environment and Forestry. Others include the local conservation agencies, that have conservation projects in the field but without clearly identified priority list of where conservation efforts are needed most.

In light of the issues identified above, a follow up project is being designed to pursue these issues, so as to give the much needed impetus, if this project is to be translated into a truly meaningful conservation effort.

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