Linking spatial planning, water resources management and biodiversity protection:

A case study for the systematic conservation of rivers in South Africa

Authors: Gillian A. Maree, Dirk J. Roux and Jeanne Nel

Introduction

Research into developing a planning tool for the conservation of freshwater biodiversity has shown that successful biodiversity planning and management is dependant on collaborative planning involving a number of actors and stakeholders (Driver et al, 2005; Margules and Pressey, 2000; Abell, 2001; Saunders et al, 2002). Managing South Africa's water resources is about managing shared responsibilities. The ability to integrate local priorities and national needs across a watershed is important to maintain the integrity of the catchment resources.

A global trend is that while many protected areas do include rivers they are dammed or stocked with alien species for fishing and tourism purposes (Saunders et al, 2002). There are only a few examples globally of protected areas that are designed to protect freshwater resources, however even these are often designated to protect a specific species, as opposed to the ecosystem, and are affected by land use changes and altered hydrology's (Sanders et al, 2002). A challenge for conservation ecologists is to overcome the lack of information on freshwater biodiversity to aid decision-making and planning processes (Abell, 2001).

Results from the National Spatial Biodiversity Assessment (NSBA) have highlighted the poor condition of South Africa's main rivers for conservation of biodiversity and that conservation efforts in South Africa have centred primarily on terrestrial systems (Driver et al, 2005). An integrated perspective (including linkages with wetlands and estuaries) is needed if biodiversity strategies and plans are to be successful. Ultimately, the conservation of freshwater biodiversity resources in South Africa will require an integrated approach to land and water management. This would require implementing agencies to align policy and strategies.

Background

Biological Diversity or 'biodiversity' is an umbrella term and is defined by the Convention on Biological Diversity as:

> *"the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems".*

Globally, the loss of species and fragmentation of ecosystems and landscapes is happing at increasing levels (The Living Planet Report, WWF, 2000 and Gleick, 1998). The protection of large of terrestrial species has traditionally received more attention than the loss of freshwater and marine species. However, it is estimated that the loss of freshwater animals is occurring at a rate five times higher than the loss of terrestrial species and three times higher than the loss of coastal marine species (Saunders et al, 2002, The Living Planet Report, 2000).

Noss (1990) takes the definition of biodiversity further to define attributes of biodiversity, each of these occurring over a hierarchy of organisational levels from the finer scale of genes to broad landscapes. Noss's attributes of biodiversity are commonly used in South Africa to describe and study freshwater systems, where:

- *composition* describes what is there and how abundant it is
- *structure* describes how the units are organised in space and time
- *function* describes the roles these different units play in maintaining ecosystem processes and dynamics.

In the past an emphasis by conservation efforts on structural and compositional biodiversity (e.g. species or habitats) has led to an inadequate consideration or even a disruption of fundamental ecosystem processes that maintain healthy ecosystem functioning. For long-term conservation of biodiversity, an integrated perspective of all three elements is required (Margules and Pressey, 2000).

Traditionally, protected areas have been used as method aimed at curbing extinction rates. However, these protected areas were often planned on an ad hoc manner and conservation was often not the primary consideration in their location (Pressey et al, 2004). Groves (2003) believes that protected areas have actually exacerbated the extinction problems. Furthermore, while the protection of terrestrial biodiversity has often proved difficult, the protection of freshwater biodiversity may not even have been a consideration. This shows that the use of Protected Areas alone as a means of conserving biological diversity is not enough to ensure sustainability. Rather, a range of strategies that consider the legislative framework at local and national levels should be included.

The need for systematic conservation of freshwater biodiversity

Roux et al (2005) identified three main constraints to the conservation of freshwater biodiversity. First, poor planning and designation of the existing protected areas has still resulted in a net loss of biodiversity. This is linked to the fact that often areas of the highest biodiversity value are also the areas of highest population and developmental pressures. Second, conservation efforts are generally biased toward terrestrial areas and species, and freshwater species are often only captured incidentally when meeting terrestrial targets. Furthermore, a poor understanding of the ecological integrity of freshwater resources may compromise biodiversity values. For example, protected areas may be designed and marketed around a dam were alien species can be fished in order to draw in tourists. Third, the linear nature of rivers, flowing from mountain catchments to the ocean, makes selecting whole river lengths for conservation extremely difficult, if not impossible.

The National Spatial Biodiversity Assessment for South Africa has shown that by considering main rivers only (excluding most tributaries), 82% of the different types of rivers are threatened (Nel et al, 2004(b)). This means that these rivers run the risk of irreversibly losing their ability to support the biodiversity features (habitats, biota, functioning) naturally associated with them. For 44% of these main rivers, this loss is in all likelihood already irreversibly.

A South African example is the Kruger National Park. Arguably, South Africa’s premier conservation area, the Kruger National Park runs in a north/south direction along the borders of Zimbabwe, Mozambique and Swaziland. Rivers however, flow in an easterly direction, cutting perpendicularly through the park as they flow through Mozambique ending in the Indian Ocean. These rivers flow through highly developed areas which have severely altered their ecological integrity before entering the park.

This raises the question of how effective a strategy protected areas are for freshwater biodiversity conservation and is an area that requires further research.

Shared responsibilities

Globally, it is increasingly being recognised that effective conservation of biodiversity, and its associated environmental goods and services, is dependant on an integrated and holistic understanding and subsequent management across the landscape (Abell, 2001, Saunders et al, 2002; Roux, 2005). This point can be demonstrated by looking at the responsibilities for managing South Africa's biodiversity.

Since 1994 policies, legislation and institutions have been changing at a rapid rate to reflect the needs of a new democratic state. A plethora of new laws and legislation, from a local to a regional level have been shaping the way decisions concerning the environment are made. The implications for freshwater biodiversity are that a wide variety of Acts like the National Environmental Management Act (No. 107 of 1998 – NEMA), the National Environment Management: Biodiversity Act (No. 10 of 2004), the National Water Act (Act 36 of 1998), the Municipal Systems Act of 2003 and so forth, will each impact the implementation of conservation strategies. Additionally, array of legislation is aimed at decision making at for spatial scales and this can give rise to uncertainty as to who is responsible for implementation and monitoring.

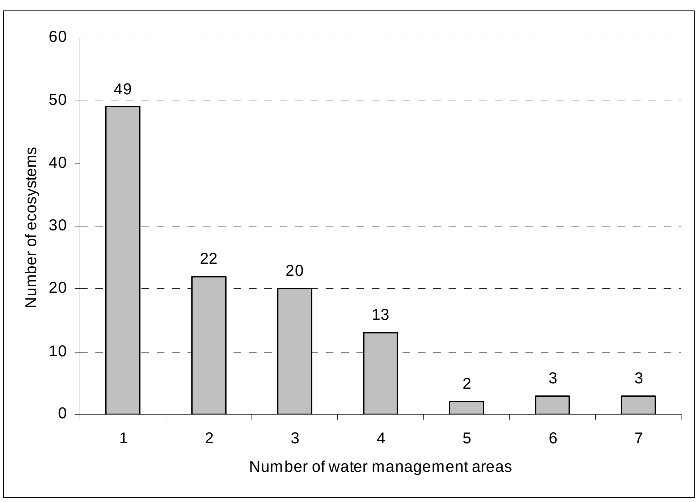

Figure 1: The degree of cooperation required between catchment management agencies for conserving river biodiversity in South Africa. Forty-four percent of the river ecosystems are

unique to a single water management area (i.e. occur in only one water management area). Conserving the rest of the ecosystems will require a coordinated effort between two to seven of the water management areas.

The management of freshwater biodiversity in South Africa can only be achieved by the shared responsibility and efforts of numerous government departments and stakeholders. The figure above demonstrates how managing catchments (from an ecological perspective) requires a great deal of cooperation. Add terrestrial, marine and social systems to this picture and the levels of complexity can become quite overwhelming.

Furthermore, resources available for conservation are limited and a systematic conservation planning approach seeks to ensure the most effective strategy and spatial configuration is chosen that meets a set of predetermined conservation goals (Margules and Pressey, 2000 and Driver et al, 2005).

Principles of systematic conservation planning

Systematic Conservation planning is a process whereby explicit, transparent targets and objectives are set for meeting biodiversity goals (Margules and Pressey, 2000). Principles of conservation planning include; having a clear delineation of biodiversity pattern (representivity) and process (ecological persistence), setting explicit targets, ensuring complementarity with existing conservation areas and having clear mechanisms for implementation. These principles are necessary to ensure that the best options for conservation are taken, and that decision makers can best understand the trade-offs that may need to be made.

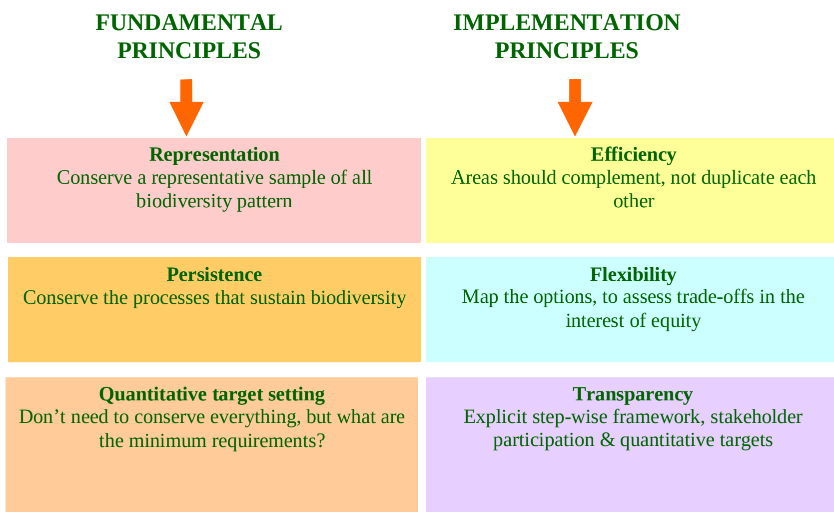

Figure 2: Principles of Systematic Conservation Planning (Nel et al, 2004(a))

The fundamental principles of systematic conservation planning ensure that a *representative* sample of the spectrum of biodiversity is conserved across the landscape. The ecological processes that sustain that sample of biodiversity should also be conserved to ensure long term *persistence* of the biodiversity features. One of the cornerstones of systematic conservation is to set an *explicit goal*. As it is acknowledged that conservation resources are limited and setting an explicit scientifically accepted goal of ‘how much’ to conserve can ensure that maximum biodiversity benefit is derived (Margules et al, 2001 and Driver, 2005).

The implementation principles aim to ensure that the areas selected for conservation complement each other for efficiency of the design. Providing options allow flexibility when considering other priorities within a planning domain. At all times, the planning process should allow for participation in a clearly explain process to make sure of transparency of decision making.

The systematic conservation planning approach for freshwater biodiversity

The process for the systematic conservation planning of freshwater resources is based on the accepted terrestrial systematic conservation planning approach (Margules and Pressey, 2000). The advantage of using a similar approach is that it allows for easier integration and interpretation of the assessment and planning process outputs.

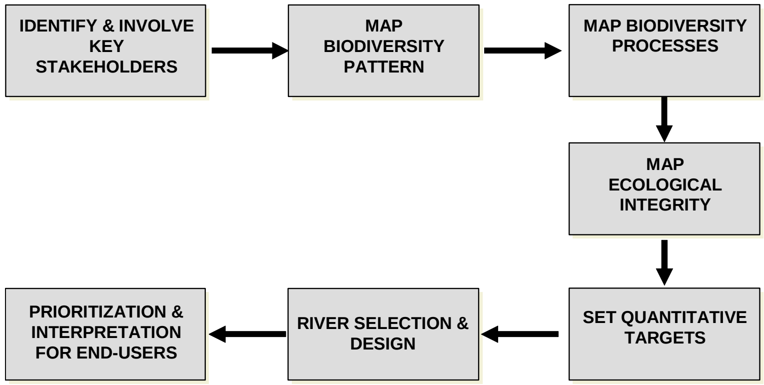

Figure 3: The systematic conservation planning process (after Margules and Pressey, 2000; Nel, 2004(a))

This simple, step-wise approach is designed in such a manner as to encourage participation and make the outputs clear and scientifically defensible.

'*Ecosystem management involves finding institutional and administrative, as well as scientific, ways of managing whole ecosystems instead of the often small, arbitrary management units that are found almost everywhere'* (Slocombe, 1998).

An ecosystem approach focused on managing water resources takes a catchment perspective at a large spatial scale.

Maintaining landscape connectivity

Maintaining connectivity across the landscape is essential for biodiversity conservation. For freshwater biodiversity conservation this means considering horizontal, vertical and lateral connectivity. Water resources management requires a catchment approach.

Horizontal connectivity refers to the connectivity between the source of a river and the river mouth that runs into the ocean. This is based on the river continuum concept that describes that habitat transitions through space and time that occur along a river (Poole, 2002). Maintaining this connectivity is important for processes like species migration. As an example eels spawn in the upper reaches of rivers, returning to the ocean until they reach maturity. The cycle is completed when these adults return upstream to breed. Creating barriers in a river (e.g. a dam) breaks this connectivity and can trap eels, preventing them completing their lifecycle. The consequences are the possible loss of the species, an altered species complement and ultimately an altered ecosystem.

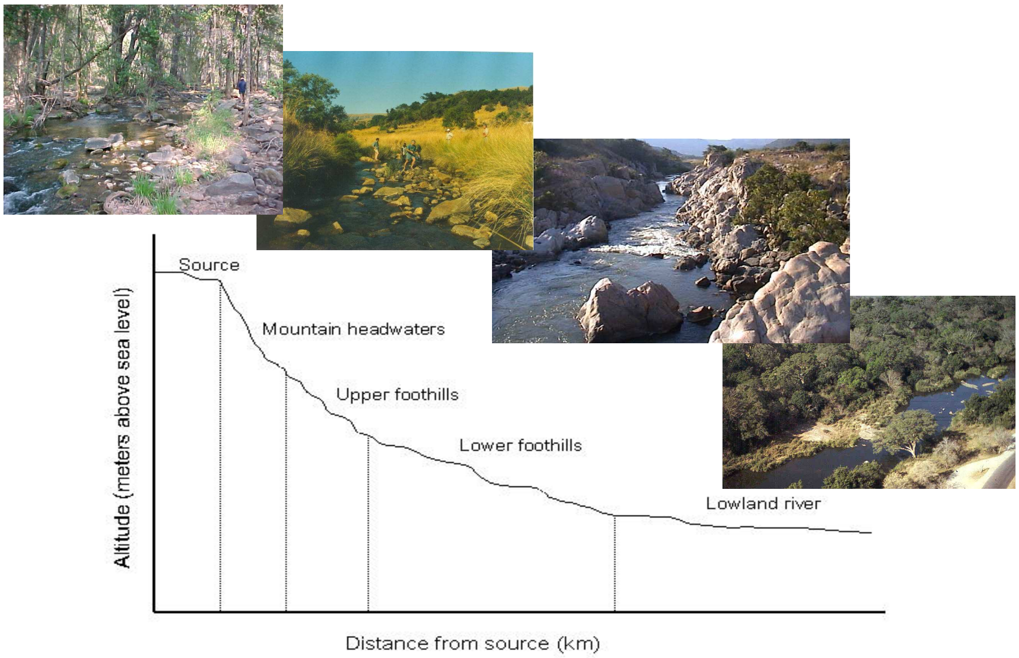

Figure 4: Longitudinal Zonations from the source of a river to the sea (after Rowntree and Wadeson, 1999)

Lateral connectivity is the connectivity between the instream and riparian components of a river or wetland. Riparian areas perform valuable services like acting as sediment and nutrient controls. The flow of a river fluxuates between wet and dry periods and during flooding riparian zones absorb the flow of water, distributing water and sediment and slowing flow (Saunders et al, 2002; Poole, 2002; Ward et al, 2002).

Vertical connectivity is the connectivity between surface and groundwater. Surface and sub-surface water is connected within the larger process of the water cycle. From a spatial perspective groundwater regions may be significantly larger than surface water catchments. Thus the effects of groundwater abstractions from one area may only be felt in a completely different surface region. This can have major implications on how transboundary water management policies are structured.

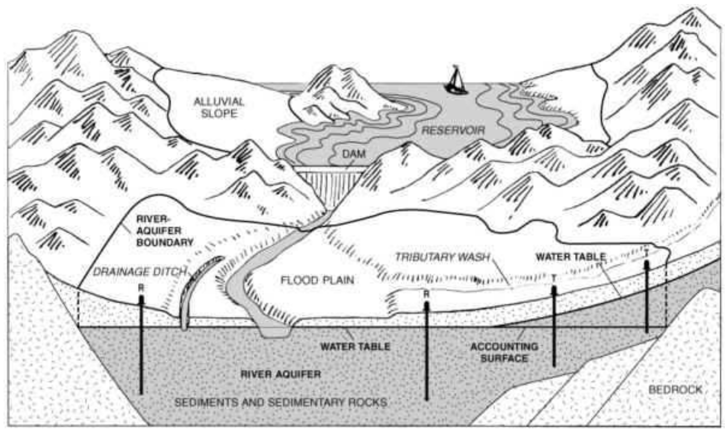

Figure 2. Schematic cross section of the river aquifer and accounting surface.

Figure 5: Cross-section of a river showing lateral and vertical connectivity (USGS, downloaded from http://az.water.usgs.gov/factsheets/ofr_93-405.html, 5/02/2006)

The implications of water resources management for spatial planning is that a large scale, holistic perspective that takes into account longitudinal, lateral and vertical connectivity is needed. Developments planned within a local area, may have impacts in another area within the catchment area.

Challenges and future directions

Protected areas are only one tool to be used to ensure biodiversity conservation. Freshwater biodiversity requirements highlights that effective conservation strategies require a holistic picture of a catchment and decisions made upstream can affect downstream users.

Whole catchment management is necessary to protect freshwater resources and watershed boundaries should be used to define the planning domain (Saunders et al, 2002; Driver, 2005 and Roux et al, 2002). In South Africa where many of the catchments extend over extremely large parts of the country, protecting large catchments is impractical (Figure 6). In these cases, understanding river functioning and the river continuum concept, which accounts for the connectivity from headwater to estuary mouth, can assist in defining those river reaches most in need of protection (Saunders et al, 2002). In all cases though, a riparian buffer should be maintained in a natural condition, something that has not necessary been followed. Strategies that balance use and protection that are designed around understanding the limits of the ecosystem extraction are needed.

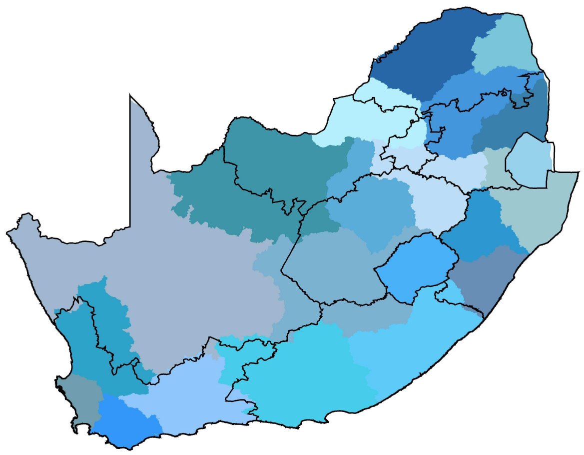

Figure 6: Map showing the Water Management Areas (shaded colour) and provinces (solid black lines)

Maintaining natural flows within rivers remains a challenge for freshwater biodiversity protection. The alteration and control of hydrological regimes through impoundments (including flow regulation), diversions for irrigation, groundwater extraction and land use changes (e.g. deforestation and agriculture) affects the water temperature, dissolved oxygen levels, nutrient availability and the physical habitat structure (Saunders et al, 2002; Ward et al, 2002). Ultimately, this can impact the ability of certain species to survive within the river (e.g. migratory species) and these changes can fundamentally alter the ecological functioning of the river. The relative water scarcity experienced in South Africa, coupled with increasing water demands to meet developmental goals means that most of the main rivers in South Africa are already regulated with altered ecological functioning and are unsuited to conservation purposes. To this end, the smaller tributaries are most likely to be needed to meet freshwater biodiversity conservation goals (Nel et al, 2004(b)). There is a need for a multi-scaled, collaborative study of land use planning, ecological connectivity and its impacts at a variety of scales.

The future of water resources planning and management is dependant on understanding the shared responsibilities and roles across a landscape or catchment. Within South Africa, the Department of Water Affairs and Forestry and at a regional level the Catchment Management Agencies (CMAs) have the responsibility for protecting South Africa’s water resources. However, decisions made by other departments, at a local or national level, can affect the future of water resource availability and its ecological integrity (Figure 6). This relates to differing hierarchical scales of decision making; local, provincial and national government versus the catchment boundaries delineating CMAs for water resources decision making.

Co-operative government is a fundamental principle of the South African constitution (Act No. 108 of 1996). Effective freshwater biodiversity management can not be achieved without successful cooperative governance. The future of natural resources planning is dependant on the development of tools for monitoring implementation of legislation as well as performance indicators in line with the goals of biodiversity conservation.

Slocombe (1998) states that the greatest challenge facing an ecosystem management approach is to identify and articulate meaningful goals that relate to both the planning and science processes. The future of effective planning for water resource management will require working within a conceptual framework that allows continual evaluation of the planning and management methods in line with ecological principles.

Integrated Development Plans (IDPs) are regarded as a means to bring all the necessary elements for development together into a single vision. The National Water Resource Strategy (2004 - NWRS) requires that DWAF integrates its goals and vision into these IDPs. However, criticism has been raised over the ability of IDPs to integrate the huge variety of plans and priorities into a single practical application (Friedman, 2005). From a freshwater biodiversity conservation perspective, a range of tools and mechanisms through a consultative process need to be explored to enable effective conservation. Difficulties with the large areas of land that will be required to protect freshwater biodiversity resources means that increasing emphasis will be placed on managing land use practices.

Legislative changes in South Africa have given rise to a new set of challenges for implementation of policies and planning will need to respond in an innovative way to these complex social and ecological changes. A critical success element for freshwater biodiversity planning and management is the ability to integrate shared responsibilities across the landscape and for spatial composition to influence decision making. Friedman believes this means that *'the traditional concern with land use needs to be brought into relation with sustainable economic growth, social diversity and justice, and the stewardship of the Earth … ultimately, it will require both a changed approach to planning education as well as to official planning practice'* (Friedman, 2005, pp 215). Increasingly, the challenges of planning within contemporary society relate to the social, economic and environmental aspects of sustainability.

Westley (1995, pp 396) sees planning as the bridge that will link knowledge to action and raises and important question as to how we use planning – as a bridge or a barrier across boundaries (spatial, institutional and professional).

> 'Planning, in all its forms, is a structure of signification, functioning primarily as a means of organizational sense-making. Ideally, the planning process reduces equivocality of information so that choice is possible. … But as a technology for sense-making and choice generation, its form is fundamentally determined by the myths or paradigms that dominate a given organization, determining the perceptions of the environment and of the organization's role in that environment. *So planning acts as an intervening variable between knowledge and action in large, complex systems. But under which circumstances is it a barrier and under which is it a bridge.* '

Conclusions

Globally, freshwater ecosystems are some of the most impacted with higher species losses than terrestrial or marine systems. Methods for the systematic conservation planning of river biodiversity are based on terrestrial models and our current knowledge of freshwater systems. The spatial assessment of inland freshwater systems is a relatively new field that can greatly add to our understanding of the functioning and value of goods and services derived from a landscape.

Freshwater resources will continue to be impacted by development as land uses change. A pragmatic approach that sets conservation goals and considers the whole landscape for the most suitable placement of scarce conservation resources can help minimize this impact. Additionally, a whole catchment perspective that manages the changes in land use and links the social system with the ecological system will be required for strategic planning processes. The challenge for planning is to link these ecological requirements to social, development priorities within existing spatial and institutional planning frameworks.

References

Abell, R. (2001) 'Conservation Biology for the Biodiversity Crisis: a Freshwater Follow-up', *Conservation Biology,* Volume 16, No. 5, 1435-1437

Department of Water Affairs and Forestry. (1997) *White Paper on a National Water Policy for South Africa*. Department of Water Affairs and Forestry, Pretoria. 37pp.

Department of Water Affairs and Forestry, Pretoria. DWAF. (2004) *Blueprint for survival: National Water Resources Strategy for South Africa*. RSA

Driver, A., Maze, K., Rouget, M., Lombard, A.T., Nel., Turpie, J.K., Cowling, R.M., Desmet, P., Goodman, P., Harris, J., Jonas, Z., Reyers, B., Sink, K. and Strauss, T. (2005) National Spatial Biodiversity Assessment 2004: Priorities for Biodiversity Conservation in South Africe. *Strelitzia 17*. Pretoria, South African National Biodiversity Institute.

Gleick, P. (1998) The World's Water. *The Beneficial Report on Freshwater Resources 1998-1999,* Washington, D.C. Covello, California.

Margules, C.R. and Pressey, R.L. (2000) Systematic conservation planning. *Nature* 405: 243-253.

National Water Act, (1998) Act 36 of 1998, Department of Water Affairs and Forestry.

National Environmental Management Act. (1998) Act 107 of 1998. Republic of South Africa.

National Environmental Management: Biodiversity Act. (2004) Act 10 of 2004, Department of Environmental Affairs and Tourism.

Nel, J.L., Gelderblom, C., Roux D.J., Kotze, I., Smith-Adao, L., 2004 (a). Underlying Philosophy And Principles Of Conserving Freshwater Biodiversity: Developing a common understanding between water resource management and systematic conservation planning. Stellenbosch: Council for Scientific and Industrial Research

Nel, J., Maree, G., Roux, D., Moolman, J., Kleynhans, N., Silberbauer, M. & Driver, A. 2004 (b). South African National Spatial Biodiversity Assessment 2004: Technical Report. Volume 2: River Component. CSIR Report Number ENV-S-I-2004-063. Stellenbosch: Council for Scientific and Industrial Research.

Noss, R.F. (1990) Indicators for monitoring biodiversity: a hierarchical approach. *Conservation Biology* 4: 355-364.

Poole, G.C. (2002) Fluvial landscape ecology: addressing uniqueness within the river discontinuum, Freshwater Biology, 47, 641-660

Pressey, R.L., Johnson, I.R. & Wilson, P.D. 1994. Shades of irreplaceability: Towards a measure of the contribution of sites to a reservation goal. *Biodiversity and Conservation* 3: 242–262

Rowntree KM, Wadeson RA. 1999. *A hierarchical geomorphological model for the classification of selected South African river systems*. Water Research Commission Final Report. Water Research Commission, Pretoria. 334 pp.

Roux, D., de Moor, F., Cambray, J. and Barber-James. H. (2002) Use of landscape-level river signatures in conservation planning: a South African case study. *Conservation Ecology* 6(2): 6. [online] URL: http://www.consecol.org/vol6/iss2/art6

Roux, D., Nel, J., MacKay, H., Maze, K. and Pienaar, H. (2005) Developing cross-sector policy for the systematic conservation and management of South Africa's freshwater biodiversity, paper presented at *IAIAsa Annual Conference, August, Bloemfontein*

Saunders, D.L., Meeuwig, J.J. and Vincent, C.J (2002) 'Freshwater Protected Areas: Strategies for Conservation', *Conservation Biology*, Volume 16, No.1, 30-41

Slocombe, D.S. (1998) 'Lessons from experience with ecosystem-based management', *Landscape and Urban Planning*, 40, 31-39

The Living Planet Report 2000. WWF-International, UNEP-WCMC, Redefining Progress, Centre for Sustainability Studies, Gland Switzerland.

Ward, J. V., Tockner, K., Arscott, D. B. and Claret, C. (2002) Riverine Landscape Diversity, *Freshwater Biology*, 47, 517-539

Westley, Frances. 1995. Governing Design: The Management of Social Systems and Ecosystems Management. In *Barriers and Bridges to the Renewal of Ecosystems and Institutions*, pp. 391-427. Edited by Lance Gunderson, C.S. Holling, and Stephen S. Light. Columbia University Press, New York.