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River management under transformation: The development of Strategic Adaptive Management as an approach to river management within the Kruger National Park, South Africa

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Abstract

Protected areas such as the Kruger National Park face many management challenges of which ensuring a healthy flow of rivers into the park is one of the most important. Although previous management policies isolated Kruger from its neighbours, this position has changed as the Park seeks to negotiate a respected 'place' for water and conservation in a competitive environment. A major catalyst for this re-orientation has been Kruger's response to the growing water crisis where its position needed to be seen within the wider catchment and policy context in South Africa. The aim of this paper is to present an overview of the transforming management practices of Kruger in a changing political, socio-economic and environmental context, seen through the lens of water resource security. It tracks the Park's management from one of inward looking, isolationist policies to one which adopts responsivity to major change factors. Viewing catchments within which the Park is embedded as dynamic, complex socio-ecological systems represented a major shift for both management and research. In recognition Kruger embarked on an approach that explicitly incorporates an experimental orientation and that sees management as adaptive by which one learns by doing. It is the co-evolution of these factors that is explored, as well as the extension of learnings and practice beyond water to other aspects of Park management, such as fire and herbivores. The main achievement for the Park has been the development of a new stewardship based on a stakeholder-centered vision and on management that has strong learning feedbacks. This has allowed a closer partnership between researchers, managers and field staff with buy-in and co-learning. Overall lessons are embodied in a number of fundamental principles which are discussed. Although developed through a focus on rivers, these can be embraced for the management of the ecosystem as a whole.

Introduction: A context under transformation

Protected areas such as the Kruger National Park (KNP) face many daunting management challenges of which ensuring a regular and healthy flow of rivers into the park is arguably one of the most important. Although previous management policies isolated Kruger from its neighbours, the Park is not an island (Pollard, Shackleton et al. 2003). Kruger's responses to the growing

water crisis needs are increasingly being referenced against the wider context of water management in South Africa which includes attention to the new water legislation and options for negotiating a respected 'place' for water and conservation in a competitive economic environment.

The aim of this paper is to present an overview of the transforming management practices of Kruger in a changing political, socio-economic and environmental context, from a water resource perspective. It tracks the Park's management of water from one of inward looking, isolationist policies to one which firmly adopts responsivity to major change factors. The paper is based on a synthesis of a number of research initiatives most notably the IUCN-EPP (Ecosystems, Protected Areas and People Project) and more recent work under the umbrella of the Shared Rivers Initiative. The purpose of the IUCN-EPP was to enable protected area managers to manage adaptively in the face of global change through a number of mechanisms, one of which was to document lessons from key case studies such as the KNP. As part of this the authors conducted research with a range of park staff regarding the changing nature of river research and management (Pollard and Du Toit 2006; 2007). The Shared Rivers Initiative examines the complexities of achieving compliance with the environmental water requirements (EWR) of the lowveld rivers that flow through the Park (Pollard and Du Toit 2009). In South Africa these EWRs, known also as the ecological Reserve, are used as benchmarks for assessing sustainability in freshwater resources (see for example Pollard and du Toit 2008). Sustainability is one of the cornerstones of the 1998 National Water Act that heralded a fundamental re-orientation to water resources management.

Water is an interesting lens to examine managerial transformation in the Park since, as a fugitive resource, it 'knows no boundaries'. This requires that for research and management to be meaningful, one must look beyond the boundaries imposed by administrative and political systems. In this regard the KNP is – within South Africa at least – the downstream user of all six major rivers that traverse or border the Park. A wider view recognises that South Africa and the KNP lie upstream of or adjacent to, international neighbours, Mozambique, Zimbabwe and Swaziland, with whom water must be shared and managed. Thus no account would be complete without consideration for the wider context within which KNP is embedded. An in depth account of the socio-economic profile and environmental profile has been given in various publications to which readers are referred for further details (see for example Pollard et al. 2003; Pollard, Biggs et al. 2008; Stadler 1994; Niehaus 2001; Dovie, Shackleton et al. 2006; Ramutsindela 2002) and here we provide only an overview to highlight major characteristics.

The KNP is located in the lowveld which comprises a 50 km wide stretch of land around it on its western border (see Pollard et al 2003). The rivers that traverse the Park cross into Mozambique, where the lowveld extends to coastal floodplains and estuaries. The landscape includes a rich variety of landforms, climate and vegetation, as well as cultures and land uses. The climate is tropical to subtropical, with drought being endemic to the region (Tyson, 1986). The Drakensberg escarpment, exceeding 1800 m.a.s.l descends rapidly eastward to the lowveld of Kruger and Mozambique with altitudes of 600 and 400m. Similarly rainfall declines from more than 1200mm a^{-1} along the escarpment to less than 450 mm at the eastern border with Mozambique.

At least 2 million people are settled within 50km of the western border of KNP and some 500,000 in Mozambique (Cumming and AHEAD 2004). There is a diversity of cultures and major groups include Tsonga, Vhavenda, Pedi and Swazi. In South Africa these groups were segregated under the apartheid government into the former bantustans of Gazankulu, Venda, Lebowa and KaNgwane from the late 1960s until the first democratic government in 1994.

In contrast to the adjacent sparsely settled (5–20 people km^{-2}) commercial farms historically owned largely by whites, these former homelands experienced densities as high as 300 people km^{-} as a result of forced removals (Pollard, Mendiguren et al. 1998). The legacy of Apartheid means that the former bantustan area are still characterized today by high levels of poverty with huge disparities in access to water, sanitation, education, employment opportunities as well as attendant environmental degradation as people tried to eke out a living on marginal land. In Mozambique which lies on the eastern border, which now forms part of the Great Limpopo Transfrontier Park (GLTP) and Conservation Area (GLTFCA) since 2002, people have also experienced a number of re-settlements due to colonial rule, the civil war and now the GLTP (Refugee Research 2002).

It is in this context that the democratic government is now re-orientating the management of water resources. The 1960s through to the 1980s was marked by a period of economic expansion, mainly in the form of commercial agriculture, including afforestation, and some limited mining (see Pollard, Riddell. et al. 2010). During this time water was considered only insofar as it was needed. In keeping with global practices, water deficits were dealt with through increased infrastructure such as dams and inter-basin transfers (Pearce 1992). Little concern was given to issues of sustainability or equity, and indeed this represented a period of uncontrolled development and one that was unconstrained by water resources.

By the early 1990s, South Africa was facing some major macro changes which were to have a direct impact on the Park (see Carruthers 1995; Pollard et al 2003; Pollard and du Toit 2007). The high densities of poor people on the western boundary lead to an environmental and economic situation that fostered conflict over land and resources (Stadler 1994). The collapse of the apartheid regime and the establishment of a democratic government in 1994 heralded the transformation of the politico-legal environment in South Africa. Land ownership and land reform meant that the future of the park and the definition of its boundaries are now embedded in a different socio-political climate. Protected area legislation underwent transformation, redirecting conservation endeavours to reflect the intentions of the Constitution. The old ‘parks’ legislation was replaced by the new Protected Areas Act in 2003. Legislation with regard to water resources underwent a fundamental re-orientation with the promulgation of the National Water Act in 1998 (NWA; RSA 1998) moving from a riparian system of rights to one in which there is no private ownership of water but rather where the state is the custodian. Underlying the transformation is the challenge of redressing past inequities and supporting development whilst ensuring the sustainability of the resource base upon which livelihoods and a healthy environment is founded. Sustainability was placed at centre stage together with equity with the recognition of the Reserve (a quantity of water to sustain basic human needs and to ensure the sustainability of the

resource itself) and as the first call on water (DWAF 2004). A major change was that water would be managed from a more holistic, catchment basis with stakeholder participation. This signaled a recognition of linkages - not only upstream-downstream and land-water but also of people-resource linkages- in water resource production and management.

Within the Park two key change factors frame today's management practices which are so fundamentally different from those of the past. The first was – and continues to be - the alarming decline in surface water quality and quantity, together with the associated biodiversity changes of the rivers that flow through the KNP (see later). The second is the recognition that lowveld savannas are not stable-state agricultural systems but rather an inherent characteristic is their heterogeneity and flux (Peel 1999; du Toit, Rogers et al. 2003). In retrospect, an interesting aspect of both of these is how closely interlinked their histories have been and some suggest that it has been their mutual influence that has transformed the management of KNP in the 15 years (see Pollard and du Toit 2005; van Wilgen and Biggs 2010). These factors had a number of implications.

Firstly because all of the five perennial rivers originate outside of the Park, the KNP has had to broaden its areas of focus and negotiation to a catchment-based perspective. This situation is not unique to the Kruger since many of the world's protected areas rely on rivers whose catchment areas are not co-incident with those of the park boundaries. Secondly, in recognition of the dynamic nature of ecosystems (and indeed the socio-ecological system, see Pollard, Biggs et al. 2008) Kruger embarked on an approach that explicitly incorporates an experimental orientation and that sees management as adaptive by which one learns by doing. It is the co-evolution and influence of these two factors that will be explored in the following sections. Another notable aspect to this story is how the practical "product" of an adaptive approach – the development of the objectives hierarchy, and thresholds of potential concern – has been extended way beyond the management of water alone and now frames all aspects of Park ecosystem management, such as fire and herbivores. It is this complete overhaul of a management approach from one of immutable goals and objectives based on stable-state ecosystem theory, to one based on learning-management iterations designed to maintain variability – a fundamental attribute of semi-arid savannas and rivers (Davies, O'Keeffe et al. 1995)- that we hope to elaborate. This progression is viewed through the lens of water resources management, an issue which often falls beyond the direct control of Kruger.

Historical Park management: taming variability

It was already in the 1970s that the then-warden of the Kruger realized that upstream impacts on the river systems were being felt within the Park and that these were likely to worsen. At that time his concerns focused principally on the potential loss of herbivore species because of insufficient water for game. Initially he prevailed upon government to act but soon adopted an inward looking approach, reasoning that the interests of irrigators and forestry were too pervasive and powerful to counteract. The resultant *Water for Game* programme was designed to support herbivore populations during drought through a network of reliable water points and the construction of weirs and sluices which were to mitigate upstream impacts by ensuring the

adequate flow of perennial rivers during droughts (Pienaar 1970). In total, some 400 boreholes, dams, sluices and weirs were built, but as Gaylard et al. (2003) note, the intended benefits did not materialize. As prudent as this policy may have seemed at the time, it was detrimental in two respects. Firstly, the numbers of game, especially of rare antelope like roan, did not improve - potentially because of the competition with escalating zebra populations and herbivore numbers continued to fluctuate (see for example Owen-Smith and Ogutu 2003). Secondly the use of surface water influenced faunal and hence vegetational distribution patterns at multiple scales since it the water point distribution ensured that the majority of the land was within 5 km of a permanent water source (Gaylard et al. 2003).

With the benefit of hindsight, it is perhaps easy to see the shortcomings of this policy but certainly then it was in keeping with the dominant management approaches of the time. All strongly interventionist in nature the strategies were designed to reduce variability and unpredictability (Mabunda, Pienaar et al. 2003). It is only in the past decade or so that new thinking that places heterogeneity at the forefront has really come into its own. A detailed account of this is beyond the scope of this paper but it instructive to note the breadth of this thinking detailed in the 2003 publication entitled *The Kruger Experience. Ecology and Management of Savanna Heterogeneity* (du Toit, Rogers et al. 2003).

Situation Analysis of the Lowveld Water Resources

Changes to the river systems have been evident since the 1970's (Pienaar 1970) and since then most systems have experienced progressive degradation in quantity, quality and the associated fauna and flora. Of the six river systems of the Park, five were perennial and one, the Shingwedzi, was naturally seasonal (O'Keeffe and Davies 1991). The first deterioration was evident some 45 years ago when the perennial Letaba ceased flowing and subsequent cessations have transformed this river into an annual system. A similar situation occurred in the Levuvhu River in the 1960s and later in the Olifants River. The Crocodile River has experienced flow constancy as well as a seasonal reversal as a result of regulation (see Pollard and du Toit 2010), and both the Crocodile and Olifants have suffered heavy pollution and invasion by alien plant species. The Sabie River is regarded as the least perturbed of the major rivers of the KNP, with relatively small distributional changes in fish species (Russell and Rogers 1988). In comparison, a net loss of species has characterised the other KNP rivers: the Letaba, Olifants and Crocodile Rivers have lost between four and six fish species, and the Luvuvhu River has lost nine species.

Agricultural abstraction is regarded as the primary driver for the increasing demands on the water resources (O'Keeffe and Davies 1991; Pollard, Riddell. et al. 2010) and, together with afforestation, and in some areas mining, has been implicated in the hydrological modifications evident today (Chunnett and Partners 1990; WRC 2001). This situation has been exacerbated by the past allocation inequities between the various user sectors, and has been accompanied by escalating conflict. For example, the Sand River Catchment boasts the highest percentage of afforestation of any catchment in South Africa, and the associated reduction in streamflow (Smith and Scott 1992), has led to disputes between timber growers and other downstream users during past dry cycles (Pollard *et al.* 1998). Recent studies have indicated that all catchments with the

exception of the Sabie are in water deficit or will be once the requirements for the Reserve are met (DWAF 2004; DWAF 2004; DWAF 2004; DWAF 2009; Pollard, Riddell. et al. 2010).

The aridity of the lowveld and the frequency of drought, coupled with current and projected population densities and water demands, means that there is insufficient water to meet current needs at the required assurance levels in most catchments (Pollard et al. 1998). This situation provided a drive for further water resource developments, mainly in the form of dams, although the enthusiasm for impoundments has waned somewhat since 1994, and has been replaced by a more cohesive integrated approach to water resource management, in which Kruger has been instrumental. Indeed in some cases this has meant that dams within the Park have been destroyed such as the Shimuwini Dam (Figure 2)

Challenges presented by declining river system integrity and institutional reform

If the length of rivers or area of catchments that fall within the Park are examined, the linkages and vulnerability of the Park to external influences are starkly apparent (Figure 3). From this it is quite clear that the extent of most of the rivers, together with their associated catchment areas fall largely outside of the Park boundaries. The most contained system is the Sabie which is relatively short with 110 km of its total length of 190 km falling within the Park. In the Olifants on the other hand, a severely degraded system, only a 100 km stretch of its entire 840 km length (or 11%) falls within the Park, accounting for a mere 8% of the catchment area. Only 25% of the catchments of the Crocodile and Letaba rivers fall within the Park, and some 36% and 18% of the river length respectively. Although 61% of the catchment area of the Levuvhu falls within the Park, this accounts for only 34% of the river length. Moreover, all the major river systems flowing eastwards through the Kruger National Park (KNP) ultimately feed Moçambique (Figure 1), and under international obligations South Africa is required to honour certain flows through to that country. Kruger thus sits between two realities: on the one hand it is the victim of upstream use and abuse and on the other it is the buffer for Mozambique downstream.

The precarious situation of the water resources of most of the rivers of the Park demonstrates just how vulnerable the Park is to the pervasive upstream influences. It is against this background then, that we explore the response of Kruger which, like the examples of fire and borehole provision, has transformed over time. What is distinctive to water resources however is that due to its fugitive nature, it forced Park management to look beyond its borders for potential solutions and to devise monitoring and management responses that were embedded in a wider socio-political landscape. This point is critical in understanding the Park's response. Had Kruger not undertaken, or at times initiated, engagement in the wider negotiations it is likely some of the mitigatory actions taken with respect to maintaining the flow of the Sabie during the 1992 and in the Letaba River would not have succeeded. Indeed the role of Kruger as 'watchdog' has been highlighted by Pollard and du Toit (2008) and essential to functional feedback loops.

Importantly in the political climate that has prevailed since 1994, stakeholder involvement, transparency and accountability are regarded as key tools for achieving equity and sustainability. This means that Kruger can no longer operate as an island since such policies compel Kruger to both involve and partake in wider stakeholder discussions within its expanded, albeit "informal"

borders for water resources negotiations. The National Water Act (1998) outlines institutional arrangements for the management of water through the Catchment Management Agencies operative for 19 Water Management Areas (WMA). Kruger straddles three WMA's (a) The Inkomati WMA: The Sabie and Crocodile rivers fall within the Inkomati River basin, an international drainage basin shared by South Africa, Swaziland and Moçambique; (b) the Olifants WMA and; (c) the Luvuvhu/ Letaba WMA. Both the Olifants and Levuvhu/ Letaba system form part of the Limpopo Basin in Moçambique. Only the Inkomati WMA has been gazetted thus far but what is precedent-setting is the composition of the board which reserves a seat for conservation. This places the onus for participation on Kruger, and affords the organisation with a much stronger voice than in the past.

The response: Developing a strategy to respond to the challenges posed by declining river system integrity

The Rivers Research Programme and adaptive management- still not enough

Up to the late 80s, the concerns of the KNP warden in the 1970s regarding changing river flows largely went unheeded by government until. Until then, the Park adopted internal strategies to mitigate the effects of declining and transforming flow regimes through an extensive network of surface water provision (see Gaylard, Owen-Smith et al. 2003). Importantly, river management *per se* was nearly non-existent other than asking the Department of Water Affairs and Forestry (now DWA) for releases. Nonetheless, by the late 80's the development of water quality guidelines seemed to signal a resurgence of belief that the Park could exert some pressure externally. At that time, releases were already being made from Tzaneen dam. Additionally, DWAF announced its intentions to allocate water for environmental flows in rivers in recognition that unchecked, the competing demands were compromising the integrity of rivers. Despite these intentions, estimates were limited to crude calculations and based on absolute amounts of water. Indeed, the first formal recognition of water for instream flow needs for South African rivers was by Roberts ((1983) who used an allocation to "conservation" of 11% of the country's MAR (later modified to 8% of the exploitable water resources by Jezewski and Roberts (1986). Roberts acknowledged that this figure was simplistic in that it was based on coarse, countrywide estimates of water for estuaries, lakes and nature reserves. As such it could not be used for individual rivers (see also Breen *et al.* 1994), but nonetheless provided the catalyst for future work. Researchers contested this figure and pointed to the paucity of understanding regarding lowveld river systems as a major challenge to their sustainable management. Ultimately a much more sophisticated and ground-breaking approach for calculating riverine water requirements was developed through the RRP and other research initiatives in South Africa (see later).

By 1988 the KNP RRP programme was conceptualised and initiated as a co-operative undertaking by resource-use managers, funding agencies and researchers (Breen, Dent et al. 2000). The RRP consisted of three phases (Appendix 1). Phase I (1989-1993), which ran for four years was largely limited to scientific research. The focus was on a range of research topics relating to environmental water requirements but was unstructured in detail (O'Keeffe and Coetzee 1996).

Moreover, a division still existed between researchers and managers within the Park who felt that in practical terms the research products was doing little to support the continuing management crises that they were experiencing (Biggs, Scientific Services, pers. comm.). In 1991, the newly-constructed Zoeknog Dam in the upper Sand catchment collapsed delivering a slug of sediment, (which continued for weeks) into the river and which persisted through the Park and into Mozambique (Weeks, Pollard et al. 1992). Such a patent demonstration of mis-management compelled the Park to respond through radio interviews and public criticism. It can be argued that this signaled the start of a more public voice for Kruger. It again highlighted the need for directed research which supported managers in their response to shorterm crises. Other research pointed to the fragility of the system. Work on the Sabie River during conditions of extreme drought, demonstrated that during this protracted period of low flow, an increase in predation both by certain fish species, and by birds, was documented as fish were trapped in shrinking pools *(*Pollard, Weeks et al. *1994)*. Further, the increasingly unfavourable conditions in pools resulted in a decrease in the condition of fish and an increase in parasitic infestations. Carter and Rogers (1989) documented reed-bed colonisation by woody riparian vegetation due to changes in channel morphology that have accompanied reduced flows in the Sabie River, South Africa.

A comprehensive review of Phase I recommended a second phase (1994- 1996) with greater emphasis on predictive capabilities and management action which was to be more intimately linked to a decision-making system. It was during this phase that collaboration between managers and researchers improved with some co-learning. Researchers responded to short-term crises experienced by managers, and managers benefited from the longer-term view provided by researchers. The political transformations that accompanied democratic transitions in 1994 were also major drivers for change, opening up windows of opportunity for effective international engagement that were previously denied to the research sector. In 1995 the RRP hosted an international conference on Integrated Catchment Management in Skukuza, a concept which was receiving increasing attention within the DWAF itself. This served to focus interests around holistic water resources management and interestingly raised the profile of international issues..

At about the same time, research interest was growing in complexity theory and adaptive management within natural resource management. These ideas arose as a critique of approaches based on averages, and the propensity to view nature as in balance, linear and predictable. It was highlighted that variability is in fact the key characteristic of semi-arid systems (Davies, O'Keeffe et al. 1995). Even where ranges were recognised (for example introducing a variation in elephant numbers between 7000 and 9000) this still did not appreciate that these savannas actually need the extremes to build resilience. This paradigm suggested that variation - and extreme events - is actually fundamental for biodiversity management. This idea was central to the determination of environmental flows where variation in flow regime was seen as a key driver of the system. The building-block approach (see later) introduced the concept of building in freshes into a flow regime which were seen as essential linkages to certain key biotic or abiotic events such as spawning or sediment flushing.

Other concerns at the time centered on the entrenched and 'command-and-control" nature of management within the Park (Biggs and Rogers 2003; du Toit, Rogers et al. 2003). The imperative of political transformation necessitated change from one of an insular approach of managing the Park as separate to its neighbours to one which attempts to embed the KNP within the socio-economic landscape and encourage wider participation, transparency and public ownership. Moreover, the entrenched science-management activities such as monitoring were being scrutinised against contemporary views that espoused a facilitatory, 'learning-by-doing' approach. The conservation of protected savannas in Africa has been dominated by a focus on charismatic species, and as mentioned, influenced by stable state concepts such as carrying-capacity without regard for scale or inherent ecosystem characteristics. However, this approach has been challenged for the failure to embrace spatial heterogeneity and flux in ecosystems and to recognize the compositional, structural and functional elements of biodiversity and ecosystems (Noss 1990). Indeed, the recent publication of a book on Kruger that is structured around the central theme of heterogeneity (du Toit, Rogers et al. 2003) bears testimony to this fundamental shift in thinking. This raised a number of questions and challenges for the research and management community.

- Firstly, what research was needed to elucidate the important characteristics of heterogeneity?
- Secondly, how was management to embrace such variability and flux as the norm and when would the 'variability norm' be unacceptably exceeded? As noted by Rogers (2005), adaptive management, and its associated objectives hierarchy, is the only widely recognised model for managing uncertainty in interactive social and ecological systems.

Adding to the catalysts for change was the fact that the management of rivers was in crisis at this time, since despite their degraded state, and the need to look upstream for solutions, cconventional management within Kruger hadn't internalized that river management was also part of their brief.

Interestingly, another important co-driver for the change in Kruger Park's management was the 'impasse' on elephant culling which came to a head at about the same time as the RRP was undergoing a major reorientation. Heated public debate and scrutiny called for reforms to the culling programme and a moratorium on culling was introduced (van Aarde, Whyte et al. 1999). This essentially set the scene for other programmes to be influenced by the thinking that had developed in the RRP. Notably, a conference to discuss elephant management was held in Skukuza and this provided an opportunity for participants to examine progress that had been made within Kruger's management framework. The key conclusions were that (a) the vision and objectives cascading from this needed to be improved and, (b) elephants are part of the ecosystem and need to be managed as such.

This led to the revision of the KNP management programme, staring with a visioning exercise, the learnings and elements of which were already available through the RRP. Under the theme of accountability, Kruger had to go public with its objectives. The RRP was at this time exploring and prototyping the concept of defining and operationalising the *Desired Future State, or DFS* of rivers (Rogers and Bestbier 1997). Through collaborative efforts between the Park and the RRP, the application of this concept was explored for use beyond river management alone. Much of

the philosophy behind the DFS is that as a public participation process which arrives at a joint agreement, much of the potential conflict is reduced. Having set clear objectives as an objectives hierarchy, questions arose as to what needed to be monitored to achieve these. A large collaborative meeting between managers and researchers in Kruger heralded the start of measurable endpoints, known as Thresholds of Potential Concern or TPCs (see for example Braack et al. 1997). As described elsewhere, these TPCs are intimately embedded in an adaptive management framework. Critically, they are set against background of complex systems, representing spatio-temporal flux, often with lower and upper limits.

The **third phase** of the RRP (1998-2000) was designed to enable the completion of first generation procedures and technologies that would support SAM of rivers, and to promote corrective action through the participation of stakeholders, especially the previously marginalized. By Phase III, the need for a more holistic approach also prompted creative thinking around the issue of integrated catchment management and the role that strategic adaptive management could place in this. It could be argued that given the leadership and close relationship between key individuals in the RRP, the national DWAF and the Water Research Commission (a body that funds water research in South Africa), a strong **learning alliance** was formed, albeit informal. Many of the ideas emerging out of the RRP and out of a water law reform process were echoed in WRC research reports and were mutually reinforcing. For example, today we see notion of SAM embedded within certain strategic documents and guidelines of DWAF. Moreover the approach is now firmly embedded in SanParks scientific services- as part of an ongoing process. Although not named as such, a new phase of work essentially building on that of the RRP, was initiated in 2007 as scientists and managers started to question the apparent lack of improvement in the status of the rivers despite advent of the new NWA. The intention was to understand if this was indeed the case and why this might – or might not – be the case. About a year later the Park also recognised the need to strengthen its own adaptive management of the rivers and also initiatited an associated project, both of which will now be discussed.

A new phase of research- linking outputs to management

The RRP was followed by a hiatus in programmatic river research until the conceptualization of two initiatives, both quite distinctive from the earlier rivers programme, and both strongly focused on action research and adaptive management processes. One of these, known as the Shared Rivers Initiative (Pollard and du Toit 2008), focused on understanding the factors that enable or constrain meeting the commitment to the ecological Reserve in six river systems flowing through the Park (Luvuvhu, Letaba, Olifants, Sabie-Sand, Crocodile and Komati). The intention is to build supportive programmes in Phase II due to commence in 2010. The other closely-linked project aims to consolidate the SAM process for freshwater management in the Park principally by operationalising the TPCs through effective science-management links (Biggs et al, this volume). Primarily as a result of findings from the Shared Rivers Initiative (SRI) which identified situations with potential for support, the current focus is on the Letaba and Crocodile rivers. In both cases there is strong evidence of feedback loops between key role players. Feedback loops and self organisation are considered to be essential components of resilient systems and adaptive management (Holling 2001; Gunderson and Holling 2002; Biggs and

Rogers 2003a). As recognition for this is growing so does the interest in what makes them successful (see Pollard et al. 2008). In the Letaba Catchment for example, a number of key feedback loops of self-organisation and self-regulation are evident (Figure 3). The KNP monitors flows against the Reserve requirements (albeit static until recently) and, on detecting problems, the Water Affairs manager (who manages the Tzaneen Dam), who in turn alerts the Groot Letaba Water Users Association to curtail use. They in turn inform users of curtailment rules and monitors this. Although not always popular the regulatory system is respected and adhered to by the WUA members. There are a number of causal factors behind the success of these two loops including the requirements of the law (the Reserve), the availability of benchmarks against which to monitor (the Reserve), the presence of a 'watchdog', the responsiveness of the manager and users and the ability to self organise. Whilst an in-depth analysis of these is beyond the scope of this paper and is examined by Pollard and du Toit (in prep), the role of Kruger as a 'watchdog' is critical. The SAM project is now developing, together with users, an adaptive monitoring-management system. The essence is that there are different levels of concern related to the status of a resource in question (e.g. river flow) and hence different management actions linked to each. The severity of the worry level is given via an indicator or TPC which is collaboratively determined. The important principle therefore is that there is an envelope of *levels of concern* – supported by clear rationale – and each linked to different management actions.

The SRI has demonstrated the requirements of the ecological Reserve are not being met in terms of quantity in all of the six rivers, despite an improved policy environment and the initiation of integrated water resources management (Pollard et al 2010). This can in part be attributed to lags that are *an inherent part of the process of reform and change* in a complex environment. Setting the Reserve today will not mean that it is met tomorrow. However it is important to consider which of these lags is unacceptable and what makes certain delays unacceptable. In many cases, especially in the northern WMAs, issues such as tardiness in authorisation, unlawful use, the lack of integration of water resources management and supply, weak monitoring and enforcement and the dearth of skills and capacity all need to be addressed as a matter of urgency. In others such as in the Crocodile and Komati rivers, recent advances in water resources management provide real possibilities for improvement. Again the Kruger has been an important roleplayer in this regard acting both as a catalyst for change and as a constructive stakeholder.

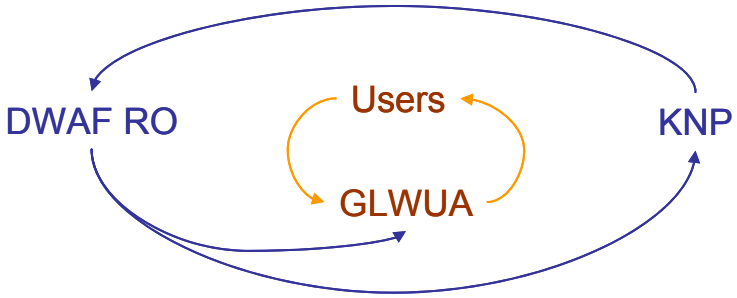


Figure 3 Functional feedback loops in the Letaba Catchment (adapted from Pollard and du Toit 2008). Feedback loops are evident when information that arises (discovered or learnt) as part of a management process is passed on to an (appropriate) body who takes (appropriate and effective) action and feeds this back. This is the basis for a learning and reflexive system. Where systems often fail is where any of these steps fail such as in cases where the learning is not passed on or is passed to an inappropriate body. DWA RO – Department of Water Affairs Regional Office; KNP = Kruger National Park, GLWUA = Groot Letaba Water User Association

Participation in wider catchment forums- the development of the CMS

The commitment to manage water holistically is captured in the new Water Act which requires that water resources are management from a catchment perspective. In some cases, such as that of the Crocodile River Catchment, the KNP has spearheaded the integrated approach by trying to involve all stakeholders in the catchment. Ultimately, Catchment Management Agencies or CMAs will take over the management of the water resources – especially, in terms of water allocation and protection of the resource. Representation is secured through various structures such as Catchment Management Committees (CMC) (CMF) and Water User Associations (WUA). In many cases, KNP has initiated forums that could be considered CMF precursors or prototype. A case in point is the Sabie River Working group which started in 1991. Today, the Park participates in fora that cover all major rivers entering the Park where awareness is used to garner support for KNP's views on certain decisions.

Earlier, the KNP's influence on DWAF was described but the Park's relationship or influence on the agriculture or forestry sectors are also worth mentioning. An example is the Sabie River Working Group that managed to save the Sabie River from a flow stoppage in the KNP during the 1992 drought. The KNP initiated this forum and was an active member but it was chaired by an irrigation farmer from the Hazyview area for many years. Another example is the Marula Weir which was to be constructed in the Crocodile River for irrigation purposes. Kruger managed to stop the building of the weir even though the foundation had been started. There was a strain in the relationship between the irrigation farmers and KNP as a result, but subsequently the two have managed to build a good relationship as mutual understanding improves. More recently, the Park supported the efforts of a local initiative – the Save the Sand Programme- in advocating the withdrawal of poorly-managed afforestation in the upper Sand River Catchment. The plantations, conceived as labour-creation schemes under the Bantustan regime, covered excessively steep slopes, wetlands and riparian zones causing reduced base flows and sediment problems (Figure

1). The support from KNP was less about actual effects which were most heavily felt before the Parks boundaries, but rather about the principle of wise use and management of natural resources.

Lessons emerging from learning in action

The main achievement for the Park has been the development of a new system of stewardship that is based on a clear mission informed by stakeholder involvement and on strategic adaptive management that has a strong learning feedback loop. This has allowed a much closer partnership to develop between researchers, managers and field staff with a strong sense of buy-in and co-learning (Pollard and du Toit 2005). Overall lessons are embodied in a number of fundamental principles which, although developed through a focus on rivers, can be embraced for the management of the ecosystem as a whole. Foremost, management should be directed towards *achieving a desired state* (Breen at al. 2000; Biggs and Rogers 2003). Indeed, this has fundamentally re-orientated the management of Kruger, and staff and resource allocations. As explained earlier, once this higher-order statement had been debated and captured in a vision, it provides the basis for the development of objectives and endpoints that can be tracked back to the vision with ease. An important adjunct is that in semi-arid savannas this desired state is not a stable state but is one which is based on a fundamental recognition of variability as an overarching characteristic which confers resilience. Thus judicious management is predicated on understanding the underlying ecosystem drivers and characteristics of the system in question. Moreover since river systems are dynamic and in a continual state of flux it is necessary to monitor conditions and to revisit management objectives. System dynamics need to be understood in the broader context of what is occurring inside and outside of the protected area.

Internally for the staff of KNP the process of re-orientation has been challenging but important. Pollard and du Toit (2007 IUCN) noted that the *collaborative role in developing TPCs* and the joint role of research and management in ensuring they are set and met has been cited as a powerful motivation for monitoring staff, such as rangers and wardens who then become a key link in the iterative SAM cycle. The role of involving field staff in setting management objectives cannot be underestimated in terms of developing commitment and buy-in. The TPCs are hypotheses and hence the TPCs and 'desired state' and TPCs, must be audited and refined in a reflexive manner.

Knowledge management is a challenge that needs to be addressed. Biggs and Rogers (2003) point out that after a TPC is tabled there is a tendency for several unpredictable threads of information to emerge as implementation proceeds. These threads may or may not be documented at the appropriate level of quality (i.e. everything is taken to be equally relevant). These authors recommend a continual 'roping together' of the information so that the organisation benefits as a whole, thus averting disparate and isolated approaches. The SAM approach is likely to generate a wealth of *field data that needs to be recorded, captured and made accessible*. This is seen as one of the challenges for Kruger. Today the park is developing a knowledge environment based on GIS as well as non-spatial databases. The intention is draw science and management together by putting data to productive use rather than archiving for

historical purposes only. Once the challenging aspects of knowledge management have been negotiated they lead to the need for *shared learning*. Here Kruger has experimented with the formation of communities of practice (Lave and Wenger 1991) from, initially, a core of enthusiasts whose task it is to continually rework and improve the SAM system and make it more accessible for use by others. Experience shows that there is a need for the *integration of programs* run by the Kruger so that by drawing on a wider variety of specialists and practitioner experiences it is thought that more realistic TPCs can be set in the future. Nonetheless, lessons for integrating new concepts such as ecosystems services and social ecology with more traditional approaches have yet to be learned.

Pollard and du Toit (2008) argue that the legislative environment for water resources management and the approach of integrated water resources management afford a particularly strong basis and coherent currency for the adaptive management of river systems. The approach in the Park thus complements – and puts into practice – the spirit and intent of the NWA. In the case of river management, an additional challenge has been to broaden horizons and deal with the realities of conflicting drivers and objectives. River systems are common-property resources (Pollard and Cousins 2008). In South Africa, there is no private ownership of water and flow through a portion of land does not confer inalienable rights on that land-owner. Moreover, that demand is viewed from a catchment-scale perspective of the total water resources, means that there will inevitably be tradeoffs and compromises to ensure equity and sustainability (Pollard and Toit 2008). These two factors necessitate that stakeholders, including protected area staff, participate in water resources management where different interests and demands on the water resources are used to negotiate water-sharing. Fortunately for Kruger, the new legislative environment has provided strong support for the concept of sustainability through the Reserve which not only provides a benchmark against which the Park can monitor, but which also carries legislative 'clout', making the Park's position as watchdog much stronger (Pollard and du Toit 2008). This is critical given that infringements of the ecological Reserve are evident in all rivers thrugh the Park (Pollard et al 2010). Importantly not only do the Kruger staff monitor but outputs are clearly linked to different actions according to the severity of the infringement; the transparency of which is important for monitoring staff (Pollard and du Toit 2005). Although the systems are still being strengthened and successful responsive action nonetheless varies, the basis for building feedback loops is in place. Indeed, as mentioned earlier, these feedbacks are essential for adaptive management for without these learning cannot happen (Pollard and Du Toit in prep).

In conclusion, it is important to remember that adaptive management is not an end in itself, it is a process that itself evolves as new learnings are brought to bear. As a result of the challenges confronted in addressing changes in rivers, the Park has charted new ground in management, research and outreach. The approach embraces the challenge of needing to manage a sensitive, complex system within a context where uncertainty is always an underlying factor. It encourages the 'first bold step forward' where and when implementation 'paralysis' can hamper decision-making under conditions that are complex and unclear. By using the best available information to set TPCs, it monitors trends and then demands reflection on collaboratively defined goals before agreed-upon action is initiated. The collaborative nature of implementing the SAM system forges

a partnership between science and management – an approach that is seen as a way forward for parks, conservation and science (Folke, Carpenter et al. 2002; van Wilgen and Biggs 2010).

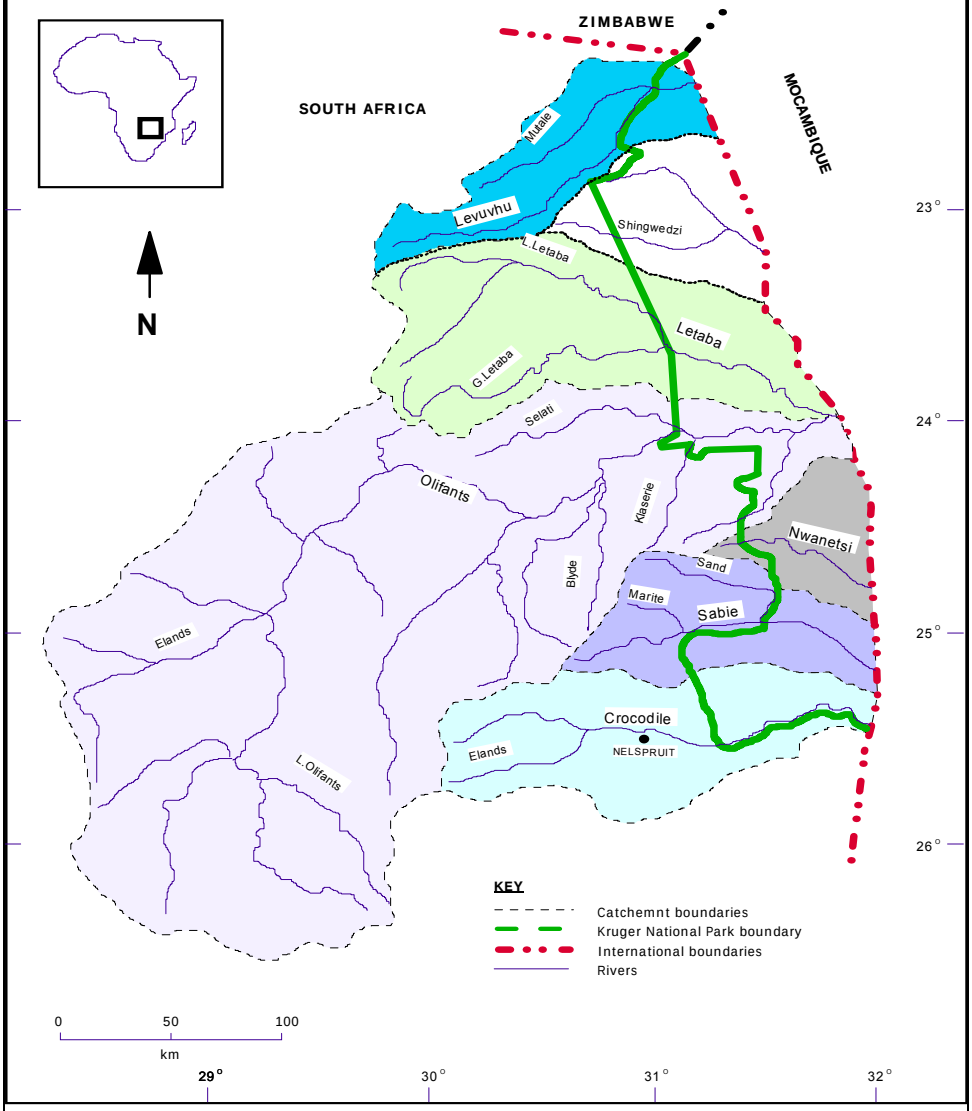
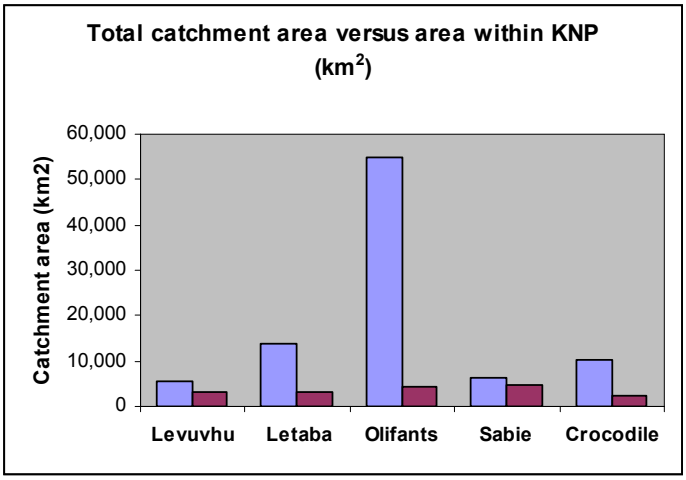


Figure 1 Map indicating the major river systems and associated catchments of the eastern escarpment, lowveld and Kruger National Park, South Africa. Anthropogenic changes have meant that of the six historically perennial systems, only the Sabie River has remained so.



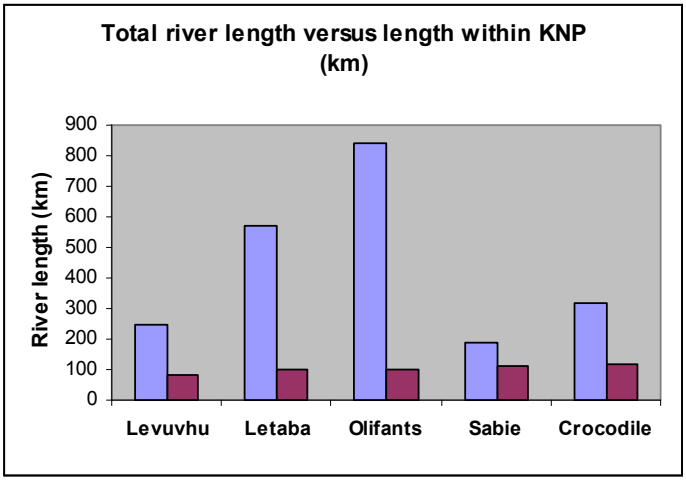


Figure 3 A comparison of (a) total catchment areas and (b) river lengths and that found within the KNP of the five perennial river systems (from Pollard and du Toit 2007)

Figure 2 The Shimuwini Dam and its removal in 2004 [Photo: F. Venter]

Appenidix 1

Timeline of the Kruger National Park Rivers Research Programme (KNPRRP), outlining goals and focus. DWA = Department of Water Affairs later to include Forestry (DWAF) and as of 2009 reverting nack to DWA. FRD = Foundation for Research and Development; SANParks = South African National Parks; DEAT = Department of Environmental Affairs and Tourism, WRC = Water Research Commission (from O'Keefe and Coetzee, 1996; Breen et al. 2000)

Date	Detail
1986	DWA indicated intentions to allocate water to sustain the natural environment. Increasing demands for water were compromising the integrity of SA rivers.
March 1987	KNRRP envisioned at a workshop convened by DWAF
Dec 1988	KNPRRP initiated jointly by DWAF, FRD (now NRF), WRC, National Parks Board (now SANParks).
1989 – 1993	**Phase I – Scientific research**
	Evaluation in 1992 commended KNPRRP for quality of scientific research but indicated the need for a more structured programme and proposed appointment of a Programme Managing Director, which was accepted. Questions as to whether activities lacked integration to achieve desired outcomes? Noted lack of explicit goals.
1994 – 1996	**Phase II**
	Management needed to be strengthened Focus on enhanced predictive capabilities and contextualising these within management in support of decision-making. Programme started with a Programme Description (Breen et al. 1994).
Focus:	Geographical focus on the Sabie River; conceptual focus on decision-support and development of predictive capabilities; - Research focus complemented these; - Capacity-building through participation in Programme.
Goals	1. To achieve a common understanding of water quality and quantity requirements to sustain the natural environments of rivers which flow through the KNP 2. To develop, refine and implement methods for predicting and monitoring the responses of the natural environments of rivers flowing through the KNP to fluctuating flow and variable water quality.
Research in support of decision-making	• Definition of a **desired state** • Need to identify **representative reaches** for monitoring • Need to improve and link **predictive capabilities** • Need for **integrated modelling** of catchment runoff and channel transformation • Need to develop a **meta database** • An integrated modelling system that incorporated **water quality** capabilities • **Monitoring and auditing** was recognised as a fundamental link in the iterative process of adaptive management.
Review: Strengths	Comprehensive review by O'Keeffe and Coetzee (1996) i. Existing information on rivers **synthesised** and easily accessed ii. A **decision-support system** was developed iii. **Protocols** for defining desired state and representative reaches were drawn up.

	iv.	**Predictive capacities** for biotic modelling were enhanced
	v.	**Linkages** between biotic and abiotic predictive models were developed.
	vi.	An **Integrated Catchment Information System** was developed and is being adopted by user agencies *(this is not so today)*
	vii.	Detailed **inventories and status** of certain components of Sabie River available
	viii.	Programme has advanced approach to rivers research in SA and pioneered development of an explicit **hydrology-hydraulic-geomorphology-biotic response framework**.
	ix.	Made significant contributions to assessment of **IFRs** of rivers
Weaknesses	i.	Failure to effectively engage DWAF and DEAT[1]. Government expectations insufficiently met.
	ii.	Weaknesses with internal and external communication.
	iii.	Intention to initiate research in water quality and to link this to predictive modelling was not effectively undertaken. (Noted good quality of Sabie River)
	iv.	Failure to effectively engage other interested researchers
	v.	The focus on building on existing knowledge resulted in few new projects, making the strengths gained vulnerable in certain areas.
	vi.	The decision-making hierarchy used to prioritise research programmes was unclear and led to discontent.
1997 – 2000	**Phase III**	
Overview	Complete first generation procedures and technologies for SAM of rivers Engage managers and stakeholders to promote information and technology transfer Promote corrective action to allow previously-disadvantaged to participate. A key difference was (a) the focus on broadening the base of understanding to River Forums and other stakeholders and (b) application of knowledge, understanding and tools to the management of river systems (Breen, Bestbier et al. 1997).	
Goals (as for Phase II +3rd added)	*3.*	*To achieve corrective action through enhancing individual and institutional capacity in the conceptualisation, implementation and management of trans-disciplinary research on river systems.*

[1] Noted however that **river systems** (ecosystems) were not acknowledged as **resources** and the structure of government departments did not facilitate river system management.

Subsidiary goals	1) Strategies and action plans for the integrated management of at least 3 rivers providing flow in KNP (Sabie, Olifants, Crocodile or Letaba). 2) Improved understanding and application of ecological, economic, social principles in management of natural environment of rivers flowing through KNP. 3) Strategies and action plans implemented for meeting national and emerging policy (e.g. CBD, Helsinki Rules, Agenda 21) on at least 3 river systems (Sabie, Olifants, Crocodile or Letaba). 4) An effective communication strategy 5) Partnership programmes developed and operationalised with 2 historically "Black" universities; 6) Previously marginalized researchers working in partnership with experienced sub-programme managers; 7) An effective education programme 8) River monitoring programmes for at least 3 rivers which enable stakeholders to evaluate whether goals and objectives are being achieved; 9) The sharing and exchange of principles and techniques derived in the programme with other regions and river basins in southern Africa;. 10) The formation of a Southern African Rivers Network to share information and exchange expertise; 11) The hosting of a conference on Integrated River Management.

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