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Monitoring consumptive resource use in South African national parks

Authors:
Wessel Vermeulen[1]
Nicola van Wilgen[2,3]
Kyle Smith[4]
Mbulelo Dopolo[2]
Louise Swemmer[5]
Wendy Annecke[2]
Hugo Bezuidenhout[6,7]
Graham Durrheim[1]
Nick Hanekom[4]
Howard Hendricks[8]
Melodie McGeoch[2]
Ntombizodwa Ngubeni[1]
Alexis Symonds[8]

Affiliations:
[1]Garden Route Scientific Services, Conservation Services, South African National Parks, Knysna, South Africa

[2]Cape Research Centre, Conservation Services, South African National Parks, Steenberg, South Africa

[3]Centre for Invasion Biology, Stellenbosch University, South Africa

[4]Garden Route Scientific Services, Conservation Services, South African National Parks, Sedgefield, South Africa

[5]Savanna and Arid Research Unit, Conservation Services, South African National Parks, Phalaborwa, South Africa

[6]Savanna and Arid Research Unit, Conservation Services, South African National Parks, Kimberley, South Africa

[7]Applied Behavioural Ecology and Ecosystem Research Unit, University of South Africa, South Africa

[8]Conservation Services, South African National Parks, Pretoria, South Africa

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Monitoring is an essential component of measuring the performance of protected areas. This requirement led to the development of a biodiversity monitoring system for South African National Parks (SANParks). The system comprises of ten major programmes, each focusing on a core area of conservation biodiversity monitoring, with resource use being one of the focal areas. With the growing appreciation of the importance of natural resources for the socio-economic well-being of communities and other stakeholders, sustainable resource use is an important component of the management of natural areas and national parks. To gauge sustainability, a sound monitoring and research programme that fits within the context of the SANParks' adaptive management approach towards social-ecological system management is required. The purpose of this article was to define the context and scope in which consumptive resource use takes place within SANParks and to outline the criteria necessary for developing a sound monitoring programme to assess the sustainability of such use. The monitoring programme is structured in view of the fact that sustainable resource use is achievable only where all dimensions of sustainability (social, economic and ecological) are considered simultaneously. In terms of the social and economic dimensions of sustainability, the programme provides for assessing stakeholder needs, trends in resource use and the social and economic impacts of resource use. Monitoring that relates to the ecological dimension of sustainability of biological resource use deals with the rate of turnover and population dynamics of target species, as well as harvest impact. In terms of abiotic (non-renewable) resources, monitoring deals with sound management practices to minimise impact on the environment, and to optimise benefits through responsible use.

Conservation implications: The resource use monitoring programme is intended to ensure that monitoring relating to the harvesting of natural resources from national parks is scientifically sound and conducted in a structured way, towards meeting the objective of sustainable use and compliance with national legislation. The article illustrates how SANParks meets its obligation to monitor biodiversity conservation while at the same time meeting the needs for the consumptive use of resources.

Background

The primary mandate of protected areas is the conservation of biodiversity both for its intrinsic value and for the conservation-related benefits for people. Although protected areas provide a wide range of opportunities from which many stakeholders benefit, they are under increasing threat from a range of external and internal factors. As a result, protected areas are under pressure to do more in terms of their ecological, social and economic contributions than ever before (Ervin et al. 2010). Monitoring is an essential component of both measuring the performance of protected areas and ensuring their sustainability. The requirement for biodiversity monitoring in national parks is specified in national legislation and international policy, as well as by South African National Parks' (SANParks) own adaptive management philosophy. These guiding frameworks and principles have led to the development of a biodiversity monitoring system (BMS) for SANParks (McGeoch et al. 2011). This system comprises ten major programmes, each focusing on a core area of conservation biodiversity monitoring. Resource use has been identified as one of these areas, together with, for example, freshwater and estuarine systems, habitat representation and rehabilitation, species of special concern, invasive species, disease and climate.

Corresponding author: Wessel Vermeulen, wessel.vermeulen@sanparks.org

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With an increasing population and high unemployment levels in South Africa (Stats SA 2017), the demand for access to natural resources (subsistence, recreational and commercial purposes) within protected areas is growing (Van Wilgen & McGeoch 2014). With the greater appreciation of the importance of natural resources for the socio-economic well-being of people (Clarke & Grundy 2004; Shackleton, Shanley & Ndoye 2007; Twine 2011), sustainable resource use is an important aspect of the management of natural areas and increasingly also national parks. As such, the importance of resource use in national parks is embedded in the SANParks' mission (SANParks 2016a):

> To develop, expand, manage and promote a system of sustainable national parks that represents biodiversity and heritage assets, through innovation and best practice for the just and equitable benefit of current and future generations. (p. 10)

While access to resources has the potential to provide varied benefits to people, overharvesting and/or the illegal or unauthorised harvesting of resources has been identified as an international threat to biodiversity and ecosystem services and is a driver of global change, particularly in the marine environment (Butchart et al. 2010; Millennium Ecosystem Assessment 2005; Pauly 2008; Van Wilgen & Herbst 2017). In South Africa, uncontrolled and illegal harvesting from both terrestrial and aquatic ecosystems in many areas and the lack of harvesting systems that ensure the sustainable use of resources are of growing concern (Ouédraogo 2001; Ticktin 2004; Van Wilgen & Herbst 2017). Overharvesting and unsustainable use not only challenge meeting biodiversity management objectives but also threaten sustained social and economic benefits undermining system sustainability. Paradoxically, a lack of access to harvest resources (under-harvesting) may similarly impact system sustainability. The challenge for protected areas is therefore to put resource harvesting systems in place that can facilitate equitable, legal and controlled access to resources inside national parks that enhance social relevance (through impacting positively human well-being), and in so doing build a vested interest in conservation while maintaining ecological integrity and economic viability (Swemmer, Mmethi & Twine 2017).

This article provides a brief overview of the resource use monitoring programme adopted by SANParks (Vermeulen et al. 2011) and describes how a sound, holistic resource use monitoring and research programme can contribute towards the sustainability of protected areas through more effective social, economic and ecological system management. As the monitoring framework is based on an established, generic process for harvest system development, and consolidates the ecological, social and economic aspects of sustainability, it can be replicated by other conservation and management agencies in South Africa and further afield. Although the context in which it is applied may differ, the system is flexible enough to accommodate different challenges and focus areas. Its wider application would contribute to consistency in resource use monitoring and reporting. Two case studies are presented to illustrate challenges and success in implementing the programme in SANParks.

Scope and context

Local context

Natural resources play a significant role in the well-being of millions of South Africans. Despite widespread electrification, low household income levels result in a significant number of people in the country still relying on firewood as a primary fuel source or using a combination of fuel sources (Department of Energy 2013; Uhunamure, Nethengwe & Musyok 2017). Timber, thatching grass and other resources are widely used for building material, while many people rely on natural pastures for livestock fodder. Millions of people use a wide variety of plants and animal products as medicines (Mander et al. 2007; Van Wyk, Oudtshoorn & Gericke 2009) and natural foods (plants, animals and fish) are harvested on a wide scale around the country (Paumgarten, Locatelli & Witkowski 2018; Shackleton & Shackleton 2004).

South African National Parks manages 19 national parks in South Africa, ranging in size from approximately 50 km^2 (Bontebok National Park) to roughly 20 000 km^2 (Kruger National Park) and covering nearly 40 000 km^2. Four parks also have marine-protected areas (MPAs) adjoining protected land, and collectively, the parks span eight of the nine biomes present in South Africa.

Historically access to parks and their resources has been confined to exclusive groups. Some open access parks, such as Agulhas National Park and Garden Route National Park (GRNP), have experienced more unregulated extractive use than others, such as Kruger National Park (KNP), that have hard boundaries. As a result of this inequality in access, many people are resentful about the lack of resources and access to them that they experience. Parks are embedded within a significant array of diverse social, political, historical and economic contexts, some with a history of forced removals of local residents during the establishment of parks and others with a history of restricted access policies that did not allow black visitors until South Africa became a democracy in 1994. As such SANParks are fraught with contrasts both in terms of constituency and visitation (Biggs et al. 2014) as well as stark contrasts in land use on either side of park boundaries. Such contrasts pose a number of biological and social threats to biodiversity, providing important context for implementing locally appropriate resource use projects and programmes. Threats include the introduction of alien species (Spear et al. 2013), pollution of freshwater entering parks (Roux & Nel 2013) and spread of agriculturally relevant diseases or genes between plants and animals inside and outside of parks (see, e.g., SANParks [2016b] for threats to the Cape mountain zebra *Equus zebra zebra* in this regard). In some cases, increasing contrasts in natural resource abundance and diversity inside and outside parks reinforces the historical alienation that many people living adjacent to certain national parks feel at not being able to access resources within protected areas. Many of these threats are further exacerbated by climate change impacts (Van Wilgen et al. 2016), while also impacting the livelihoods of people living outside of

national parks. As such, with biodiversity threats increasing outside of parks, the resources within parks are increasingly important not only for conservation but also as resources for livelihoods and to meet social and cultural needs.

While the formal unemployment rate is reported at 26.7%, non-participation in the labour force means that of 38 million people of working age in South Africa, only 43.5% are employed (Stats SA 2018). This extremely high level of unemployment increases reliance on natural resources, which can serve as an entry point into the informal economy in terms of the traditional medicine trade (Petersen et al. 2014). In general, people or communities living near more isolated or rural parks tend to have limited employment opportunities compared to urban parks. Table Mountain National Park (TMNP), for example, is situated within the city of Cape Town, where 3.7 million people (growing at ~2%; 2011 census data) live on the park periphery. This calls for a relatively strict control and regulation of resource harvesting from the park. The TMNP-MPA is located adjacent to communities for whom fishing forms part of their livelihoods and who are in competition with more expansive commercial operators for the limited resources. Resentment over the allocation of fishing licenses and quotas (not administered by SANParks) contributes to illegal resource harvesting, including rock lobster and abalone. Overall, good progress has been made with the co-management of resources within parks (e.g. the harvesting of mopane worms, thatching grass and sour figs in some parks) (Scheepers, Swemmer & Vermeulen 2011; Swemmer et al. 2015a). However, the same cannot be said of co-management of parks, with the exception of the Richtersveld National Park that is situated in a very remote and sparsely populated part of the country, typified by desert landscapes with very few permanent residents. This is also the only park that is jointly managed by SANParks and local communities in its entirety, with co-owners having considerable authority and responsibility. Livestock graze freely in the park, providing an important contribution to local livelihoods through resource access. The Makuleke concession agreement in the KNP also claims some successful components of co-management, while the Khomani San co-management agreement in the Kgalagadi Transfrontier Park has yielded few benefits for the majority of the San.

The KNP has a particularly complex history with a legacy of forced removals of residents to outside of the park during its establishment as well as policies of restricted access to certain cultural groups. Furthermore, a large portion of the western boundary of the park is bordered by former homelands (Bantustans) where thousands of people were forcibly moved to live from other areas in the country. As such, not only does the KNP have approximately 2 million people living within the eight municipalities that border the western boundary of the park, but the 1074 km of perimeter is adjoined by segments of industry, urban settlements, and private, communal and public nature reserves, as well as state-owned communal land. Unemployment rates in all eight adjacent municipalities are higher than the national average (Swemmer & Mmethi 2017). As such, many people living next to the park rely on natural resources (Shackleton 2000). This offers significant opportunity for positive well-being and constituency building as a result of controlled resource use from the park. The vast area covered by the various parks, the wide variety of biodiversity within them and the complexity of the range of stakeholders involved mean that there are a large number of resources within parks that are sought for a variety of purposes (Van Wilgen et al. 2013).

Defining resource use

Resource use is either consumptive or non-consumptive, while indirect use-values (e.g. ecosystem services such as soil and water conservation, genetic resources and landscape aesthetics) are also recognised (Lawes, Obiri & Eeley 2004). Non-consumptive use refers to the passive or intangible value of resources and includes activities such as the tourism experience (often commercial ventures) and cultural practices of a non-extractive nature. Consumptive use implies the removal or withdrawal of all or part of the natural resource from its origin. Natural resources are both biological and renewable (i.e. able to be replenished in the course of natural events within the limits of human time) or abiotic and non-renewable (i.e. cannot be produced, grown or generated on a scale that can sustain their consumption rate) (Symonds 2010). The extractive use of biological resources is broad in scope and includes parts of individual plants and animals such as leaves and bark, or by-products from animal activities (e.g. honey), as well as entire plants or animals and their different life-history stages, such as seeds, flowers and eggs (Lawes et al. 2004), each of which has a unique social, economic and ecological impact.

Consumptive use may either be for commercial gain (e.g. game sales, to support the tourism industry and fishing) or for domestic (often traditional) purposes, such as subsistence and recreational use (e.g. medicinal plant harvesting and recreational fishing), with SANParks and/or external stakeholders as the beneficiaries. Consumptive use could also include the removal of plants and animals (or products thereof) as by-products of management actions or interventions (e.g. game stock reductions and plants and cultural artefacts collected for research purposes). The monitoring programme outlined in this article deals specifically with the consumptive use of biotic (living, e.g., thatching grass and fish) and abiotic (non-living, e.g., rocks and minerals) resources from terrestrial and aquatic ecosystems as the broader biodiversity monitoring framework was established within the context of direct threats to biological resources. The importance of non-extractive use of resources is acknowledged, but is beyond the scope of the programme and this article.

Legislative and policy context

Having policies, laws and institutions in place at all levels of governance with effective linkages between them is one of the Addis Ababa principles for the sustainable use of biodiversity (CBD 2004). Relevant South African legislation,

as well as international agreements and conventions relating to resource use, is provided in Vermeulen et al. (2011). The South African *National Environmental Management*: *Protected Areas Act* (Act No. 57 of 2003) states that one of the purposes of protected areas is to provide for the sustainable use of natural and biological resources. Various components of the *Marine Living Resources Act* (Act No. 18 of 1998) and the International Convention on Biological Diversity are also relevant.

Implementation of and compliance with legislation dealing with resource use is directed by internal SANParks policies, in particular, the SANParks Resource Use Policy (SANParks 2010). Some key principles that relate to this policy, and which potentially impact on monitoring, include the following:

- The consumptive use of renewable resources is allowed, provided that the use is sustainable and does not threaten the resource, nor any other resource, ecosystem functioning or element of biodiversity dependent on it.
- A complex system view is adopted and therefore a certain amount of change to ecosystems (including that brought about by resource use) is acceptable, provided that the change remains within the limits of natural variation exhibited by the ecosystem.
- South African National Parks follows an approach of adaptive management based on (1) a combination of science and traditional or local knowledge, (2) iterative, timely and transparent feedback derived from adequately monitoring the resource and (3) adjusting the management of the resource based on feedback from monitoring.
- South African National Parks supports interdisciplinary research (including the development of internal expertise and harvesting systems) into the ecological, social and economic opportunities and constraints of resource use.

The effective implementation of the policy requires that resource use takes place according to principles of sustainability, and without compromising the integrity of ecosystems and other services that it sustains.

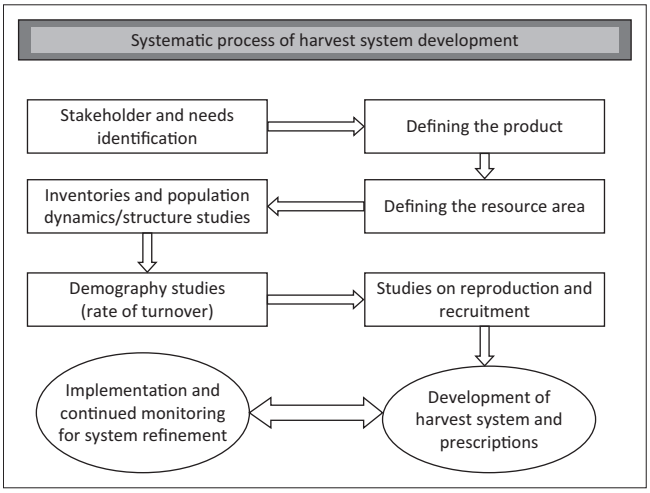
Monitoring system

Sustainability is of overriding importance in the context of sound conservation management. As such, the development of a robust, goal-orientated monitoring programme must consider the interdependent social, economic and ecological dimensions of sustainability, within a political or policy framework (Cunningham 2001). The SANParks resource use monitoring programme is therefore structured in view of the fact that sustainable resource use is achievable only where all dimensions of sustainability are considered simultaneously and where investment in assessment and monitoring of these dimensions, including the trade-offs within and between them (Swemmer et al. 2015a), is in place to ensure that sustainability objectives are achieved. Ecological sustainability, as defined in the *National Environmental Management: Biodiversity Act* (Act No. 10 of 2004), involves the use of a biological resource in a way and at a rate that does not lead to its long-term decline, does not disrupt the ecological integrity of the ecosystem in which it occurs and ensures its continued use to meet the needs and aspirations of present and future generations. Social sustainability refers to social justice and equity and stresses community participation, paying particular attention to the most vulnerable people in society (DEA 2002). Economic sustainability refers to economic viability and integrity and focuses on economic growth that is viable and fair, and which occurs at a rate that does not exceed the ability of natural and social systems to support this growth (DEA 2002).

The SANParks resource use monitoring programme, described in detail by Vermeulen et al. (2011), follows the generic process for harvest system development (Figure 1) and is summarised in Table 1. Two case studies provide examples and challenges in programme implementation (see section 'Implementation and adaptive management'). The first case study deals with medicinal plants in the GRNP and the second case study covers recreational and subsistence line fisheries.

Monitoring the social and economic dimension of sustainability

The overall objective of this component of the programme is to (1) assess the extent to which SANParks meets legislative and internal objectives pertaining to the promotion of access to social and economic benefits from resource use and (2) to monitor the extent to which having access to resources impacts the perception of stakeholders regarding the value of conservation and protected areas. To this end, the programme entails assessing the resource use needs of key stakeholders, the status and trends of resource use in protected areas managed by SANParks, and the social and economic impact thereof (see Table 1). Also the development of alternative resources is of relevance not only to address needs where demand exceeds supply, but also to build more robust systems and reduce vulnerability.



Source: Adapted from Peters, C.M., 1996, *The ecology and management of non-timber forest resources*, World Bank Technical Paper No. 322, The World Bank, Washington, DC

FIGURE 1: Flow diagram indicating the generic process for the development of harvest systems and management prescriptions for sustainable resource use.

TABLE 1: Components of the South African National Parks resource use monitoring programme for the three dimensions of sustainability.

Monitoring programme component	Specific objectives	Methods	Frequency	Examples of indicators/data collection
Social and economic dimension				
Stakeholder needs	Assess stakeholder needs in terms of resource use to develop baselines and assess trends in these needs over time to monitor outcomes.	Formal appraisal techniques	Would depend on the stakeholder dynamics for specific parks	Species, plant or animal parts used, volumes required, seasonality of use, motivation for harvest, commercial or domestic use, number of people wanting to harvest the resource, product quality requirements, level of dependence on the resource, acceptance of alternatives
Broad-scale status and trends in resource use in SANParks	Assess status and long-term trends in legal and illegal resource use in SANParks including species and amounts of resources harvested, income generated, numbers of people directly involved.	Data collection, record keeping and data analysis over time; questionnaire-based surveys	Annual for authorised use; every 5 years for full assessment	Range of products harvested, total harvest volumes per species or resource, domestic or commercial use, quality and quantity of products harvested, satisfaction of participants, number of households/people directly involved, value of harvested resources, income generated, incidences of illegal harvesting
Social and economic impact of resource use	Assess social and economic impact or consequences of resource use	Social and economic impact studies	Depends on specific project objectives and the stakeholder dynamics of the park	Economic impacts at individual, household and community level; well-being indicators; monitoring of indicators against co-defined objectives in terms of monetary and non-monetary resource use values (how people live, their beliefs and customs, community cohesion, available services and facilities, livelihoods and well-being)
Ecological dimension (biological resources)				
Rate of turnover or population dynamics of target species or products	Determine status and distribution of available resources; determine the rate of turnover or recruitment of targets species or products to feed into harvest systems for sustainable use (sustained yield); assess long-term trends in population dynamics	Establishment of permanent plots or monitoring sites; census of animal species and application of appropriate ecological models; experimental harvesting; inventories; fishery-independent biomass estimates (e.g. mark – recapture); fishery-dependent biomass estimate surveys; recruitment monitoring	Depends on species and product harvested (longer for slow recruitment or rate of turnover); monitoring protocols may vary but should be robust enough to detect biologically significant shifts in resource abundance	Depends on species and product harvested, for example: in plants – regeneration and recruitment, ingrowth and mortality, increment, rate of leaf or fruit production, bark regrowth; for fish – trends in numbers and mass of fish caught, time spent harvesting and catch per unit effort
Harvest impact: products	Assess trends in quantity and quality of product harvested from the same harvest area	Record keeping; measurements	Aligned with harvest rotation of specific product	Depends on species and product harvested, for example: quantity – number of plants, number of bundles of reeds, weight of mushrooms; quality – length of leaves, thickness of bark, colour of wood, horn length
Harvest impact: population health	Assess trends in population health of target species in harvest areas and where necessary compare to undisturbed sites	Permanent plots; inventories or surveys or censuses; comparisons with undisturbed areas	Aligned with harvest rotation of specific species or products; dependent on life-history traits	Depends on species and product harvested, for example: Quantity – number of plants or animals or fish or invertebrates, including population size and sex structure (where applicable); Quality – length of leaves, size or age class distributions, condition factors (fish)
Monitoring the impact of harvesting of abiotic resources				
See the text under this section 'Monitoring the impact of harvesting of abiotic resources'	-	-	-	-

SANParks, South African National Parks.

Local stakeholder resource uses and needs

Baseline information on the history of the park and the people living in proximity to park, as well as local stakeholder needs for and uses of various natural resources, provides useful context with which conservation organisations can frame specific resource use projects and programmes. Stakeholder needs and uses are dynamic; hence, ongoing engagement is required to maintain the relevance of resource use programmes in the context of changing needs. Data to be collected would be context-specific depending on the type of resource, but some useful variables may include species (fauna and flora) used, parts harvested, the motivation for harvest, type of use (domestic or commercial), quantity used, product quality requirements, number of people to be involved in the harvesting, level of dependence on the resource and acceptability of alternative resources should demand exceed supply (see Case study 1 in terms of medicinal plant harvesting and surveys with traditional healers).

Broad-scale status and trends in resource use

Broad-scale status of and trends in resource use are useful for assessing the degree to which strategic objectives for resource use are being met, as well as for long-term monitoring of resource use dynamics to inform an adaptive approach to management, specifically in relation to threat identification. The known status of resource use in SANParks is provided by Van Wilgen et al. (2013) and forms the baseline for monitoring long-term trends in resource use (in terms of species and products harvested, volumes harvested, user groups, etc.) as does the annual SANParks resource use report (see, e.g. Symonds 2014 and 2018 for the reports for 2013/2014 and 2017/2018, respectively). Broad-scale trend indicators to monitor the extent of resource use and the benefits accrued include quality and quantity of products harvested, satisfaction of participants, income generated and number of stakeholders directly involved. Setting easy-to-measure species or group-specific indicators of quality is an important step when new projects are set up. For the forest fern *Rumohra adiantiformis*, for example, it involved recording the number and length of ferns fronds with < 10% blemish, harvested during successive harvest cycles (Vermeulen 2009). The programme also includes indices for illegal, unreported and uncontrolled harvesting (see Case study 1).

Local-scale social and economic impact of resource use

Monitoring the simultaneous social and economic impact of resource use enables identification of costs and benefits at multiple stakeholder levels, as well as between stakeholders and the natural environment, in support of a net benefit outcome at most levels (Swemmer & Taljaard 2011; Swemmer et al. 2015a). Examples of social impacts include developing or maintaining social cohesion and continuity as well as changes that occur in people's way of life (i.e. how they live, work, play and interact with one another on a daily basis), their culture (i.e. shared beliefs, customs and values) and their community (i.e. its cohesion, stability, character, services and facilities) (Lahiri-Dutt, Nair & Dowling 2008). Not only does the SANParks resource use programme aim to promote access to resources but it also aims to build support for conservation through the creation of both positive relationships and vested interest in national parks (Swemmer et al. 2017). Monitoring the economic impact of resource use on the user at various scales (e.g. individual, household and broader scales) is equally important. Identifying indicators for social and economic objectives is not easy because in most cases the outcomes are both quantitative and qualitative. Detailed monitoring of the social and economic aspects is not always needed on an annual basis. Numerous generic well-being indicators exist, but indicators are context-specific in that they must be seen as legitimate by all parties involved. This is best achieved through co-defining programme objectives and indicators through multiple stakeholder lenses together with resource harvesters (Swemmer et al. 2015a). A lack of cohesion and formal representation of user groups, for example, limited inclusion of resource users in developing indicators within the GRNP line fisheries (Case study 2) and will require novel methods to ensure inclusivity in the future. In contrast, the Rastafarian community was directly involved in the monitoring of *Bulbine latifolia*, a plant used for medicinal purposes (Case study 1) within the park. Monitoring of the indicators is determined at a project level based on local context and should be based on needs, resources and expertise available. The use of community-based monitors has proven successful in natural resource-based programmes (Swemmer et al. 2015b). For example, community monitors employed through South Africa's Expanded Public Works' Environmental Monitor Programme patrol certain boundary fences of the KNP, including areas where there have been historical incidents of illegal harvesting of high-value medicinal plants. The community monitors both come from and work in the areas adjacent to the park. Despite advantages of using community monitors (local expertise, connections with community and buy-in to the project) funding for salaries can be a challenge (Swemmer et al. 2015b).

Monitoring the ecological dimension of sustainability (biological resources)

The overall objective of this component is to ensure the ecological sustainability of resource use by providing a scientific basis for harvest system development and refinement, and implementing relevant monitoring of key aspects of target species for continual assessment of and feedback to adaptive management. Of specific relevance here are baseline data to support sustainable yield determination and harvest system development, including (1) species distribution and populations status (locally and nationally) and (2) rate of recruitment or replacement (i.e. rate of turnover) of the target species or product. Harvest impact on the resource must be assessed to allow for harvest system refinement (Table 1). Although monitoring is an integral component of specific, formal resource use projects and concessions cognisance must be given to the potential impacts of illegal and unauthorised use of resources. Where necessary, monitoring of relevant population dynamics should be compatible with and be able to feed into national monitoring programmes. This could be particularly important within the aquatic environment where fish stocks are assessed, and species-specific regulations are generated on a national basis (Case study 2).

Rate of turnover and population dynamics of target species or products

Quantitative, field-based resource inventories or other relevant methods (e.g. life tables for animal populations, biomass estimates for fish and size–class distributions for timber – see Table 1) can provide baseline data on how much of a resource targeted for use is available. Data on the rate of production, which depend on the demography of the target species or the parts harvested, are crucial in determining the sustainable off-take of the available resource. For example, in the case of *B. latifolia* harvested for medicinal purposes in the GRNP, the size–class distribution of the population and monitoring data on the growth rate of the species were used to formulate harvest prescriptions in terms of harvestable size and harvest rotation, reflecting the sustainable off-take, while rate of bark regrowth was used to assess options for sustainable medicinal bark harvesting (Vermeulen 2009, Case study 1). Population transition and other mathematical models could also be used to determine the potential yield or to assess harvest impact (Ngubeni 2015; Pfab & Scholes 2004) for harvest prescription development and refinement. Where necessary (e.g. large mammals), ecological complexity should be incorporated into the decision-making process and population management should seek heterogeneity favouring biodiversity and ecosystem resilience (Ferreira & Hofmeyr 2011). Indicators of turnover would depend on the species or products harvested, for example, diameter or length growth for whole plants, recruitment and regeneration (including coppice growth), fruit or leaf or bark production for specific plant parts and catch per unit effort for fish.

Harvest impact

The impact of harvesting according to specific harvest intensities on the target species, as well as on other components of the ecosystem, is an important component of monitoring. Two approaches are followed here: monitoring trends in quality and quantity of the product harvested from the same harvest area and the health of the population after harvesting. Data collection depends on the specific species and product harvested and could include the number or volumes harvested (quantity) and size (or any other measures

that define the quality, e.g., condition factor) of the individuals or products harvested. Monitoring population health entails assessing the quantity and quality of the remaining product in the harvest area, as well as the population status as a whole. For example, in the GRNP, monitoring included assessing tree response to bark stripping and susceptibility to insect and fungal damage following bark stripping (Case study 1). In some instances, population parameter monitoring should be implemented within areas where resource use occurs, and also in 'no-take' areas to provide an indication of population trends independent of anthropogenic influence. For example, target populations of various fish species are known to show natural fluctuations in population abundance (Götz et al. 2008), while a natural decline in *R. adiantiformis* fern populations has also been recorded (Vermeulen 2009), which may need to be taken into consideration.

Monitoring the impact of harvesting of abiotic resources

As abiotic resources are considered to be non-renewable, sustainable use (e.g. the harvesting of rock, gravel and sand from quarries) in this context refers to sound harvest and management practices to minimise the impact on the environment, and to ensure the responsible use of the resource in terms of its availability to optimise social and economic benefits. This includes assessing the needs and trends in the harvesting of non-renewable resources from national parks in terms of products, volumes and frequencies, as well as whether sound management practices and measures are in place to minimise environmental impact. In line with policy directives (SANParks 2010), the total available original quantity of the resource would need to be determined and its use should be curtailed such that only a minor portion of this original quantity is used and no ecosystem process or biodiversity is threatened by the use.

Implementation and adaptive management

In terms of ecological sustainability, the programme has been implemented at different levels in different parks for specific resource use projects, while a baseline has been established to monitor trends in resource use and benefits accrued (Swemmer & Mmethi 2016; Van Wilgen et al. 2013). Lessons learnt are that the precautionary principle should apply with the formulation of harvest prescriptions when limited monitoring and research data are available and that roles and responsibilities in project implementation are clearly defined, including that of external beneficiaries. Also, new projects may fail if the necessary financial and human resources are not available to support the development of harvest prescriptions and associated social, economic and ecological monitoring. Depending on the nature of the resource use project, different role-players in SANParks are responsible for the successful development and implementation of the programme. These include scientists (working in the biology and social science fields), park management staff and resource users.

In line with SANParks strategic adaptive management approach (Biggs & Rogers 2003), management intervention could be required in terms of both the socio-economic (resource use trends, benefits accrued and social impact) and ecological dimensions (e.g. harvest impact) of sustainability, based on monitoring results. Adaptive management lies on the concept of thresholds of potential concern (TPCs), which defines acceptable upper and lower levels of change (Biggs & Rogers 2003). Such TPCs could also be developed for resource use to close the adaptive loop, and be linked to park management objectives. Science–management interface meetings are the ideal platform for the development and refinement of such TPCs. This approach allows for the setting of conservative harvest levels where data deficiencies exist, to be refined as monitoring results become available. Examples of applying adaptive management in resource use in SANParks are provided in the two case studies, but also include the harvesting of seven-weeks fern (*R. adiantiformis*) in the GRNP, medicinal bark from the Pepper-bark tree (*Warburgia salutaris*) in the KNP and Sour fig (*Carpobrotus acinaciformis*) in Agulhas National Park (Scheepers et al. 2011). Applying a holistic, sustainability-based focus on the application of strategic adaptive management of resource use (social, ecological and economic) has the potential to reduce the risk of resource use project failure. Ensuring the maintenance of ecological integrity (through ecological harvest system development), promoting economic viability (by identifying, monitoring and managing the cost–benefit trade-offs within and between stakeholder groups) and establishing social relevance (by facilitating access to resources using governance processes and promoting shared decision-making) are key requirements. Also, as lessons are learnt with the implementation of the monitoring programme, the programme itself could be adapted and refined to ensure that it remains appropriate and practical to adequately serve its purpose within a specific context.

Case study 1: Demand and access for medicinal plant harvesting in the Garden Route National Park

Context

The overharvesting of resources has been identified as an international threat to biodiversity and ecosystem services and as such a driver of global change (Van Wilgen & Herbst 2017). This is no different in SANParks where the demand for medicinal plants is increasing (Van Wilgen et al. 2013), particularly so in the GRNP where demand for forest and fynbos medicinal plants species is exacerbated by the nature of the open access park, changes in stakeholder dynamics and commercialisation (Vermeulen 2009).

Assessing demand and monitoring harvesting

Table 2 summarises Garden Route projects in terms of monitoring objectives, methods, frequency of monitoring and important indicators. A baseline inventory of medicinal plant harvesting was provided by Van Wilgen et al. (2013), while local traditional healers were surveyed to determine

TABLE 2: Monitoring projects and surveys relating to the sustainable harvesting of medicinal plant products from the Garden Route National Park.

Objectives	Methods	Frequency	Indicators and data collection
Social and economic dimension: Stakeholder needs and trends			
Project 1. Medicinal plant harvesting in the Garden Route National Park (Ngubeni 2015).			
To assess specific needs in terms of access to medicinal plant products.	Structured interviews with traditional healers.	Frequency not set, but the need has been identified for follow-up surveys as the stakeholder dynamics and needs in the region are changing.	Species, uses, plant or animal parts used, volumes required, seasonality of use, commercial or domestic use, and so on.
Project 2. Inventory of natural resources harvested from national parks (Van Wilgen et al. 2013).			
To gather information on natural resources harvested from the SANParks estate.	Questionnaires, completed by park managers and scientists.	Recordkeeping of natural resources harvested from national parks is ongoing to feed into annual reports on resource use.	Users, species and products harvested, parts of resource harvested, use of the resource, numbers or volumes harvested, whether for domestic or commercial use, and so on.
Project 3. Monitoring incidences of unauthorised resource use from the Garden Route National Park (Vermeulen 2018; Vermeulen et al. 2015).			
To assess the extent and trends in the unauthorised harvesting of terrestrial plants from the park.	Data are collated from reports on incidences of illegal harvesting submitted monthly by park management, in terms of field observations and the confiscation of plants harvested illegally.	Recording of incidences ongoing, with monthly data collation.	Confiscated plants: user information, plant species, number and/or weight, harvest location, uses; field observations: locality, species harvested, uses, extend of damage, and so on.
Ecological dimension: Population dynamics and rate of turnover			
Project 4: Sustainable harvesting of the medicinal plant species, *Bulbine latifolia* from the Garden Route National Park (Vermeulen 2009).			
Gain insight in the demography and reproductive biology of *B. latifolia* to inform harvest prescriptions.	Permanent plots in representative plant populations.	Six-monthly re-measurements for period of 2 years.	Rate of corm diameter and length growth, ingrowth and mortality, seedling establishment, and so on.
Project 5. Experimental medicinal bark harvesting in the GRNP (Vermeulen 2009; Vermeulen et al. 2012).			
To assess the response of selected trees species to bark stripping and the extent and rate of bark regrowth, to inform management options for suitable bark harvesting.	Trees in forest research area selected for experimental bark stripping.	Initially, 6 monthly; annually after 2 year.	Extend and rate of bark regrowth through edge (from edge of wound) and sheet (on wound surface) development, extend of fungal and insect damage on exposed wood.

GRNP, Garden Route National Park.

their requirements for plant species in the region (Ngubeni 2015). Medicinal tree bark was identified as a high priority, considering the demand for bark for private and commercial use, and the destructive nature of strip harvesting. Tree response to bark stripping and the rate of bark regrowth were assessed (Vermeulen 2009). Monitoring of *B. latifolia*, also a species in high demand and subjected to overharvesting, was aimed at assessing the rate of growth and population turnover to inform harvest prescriptions for sustainable use (Vermeulen 2009). This monitoring was conducted in consultation with the Rastafarian community as an important user group. A project was initiated to monitor the increasing unauthorised use of medicinal and other plants (Vermeulen et al. 2015).

Summary of results

A wide range of medicinal plant species and products are in demand (Ngubeni 2015; Vermeulen 2018). Users seem to be receptive to exploring alternatives to assist sustainability (Ngubeni 2015). Harvest prescriptions have been formulated for high-demand species such as *B. latifolia*, which is slow growing with a low rate of turnover of populations in the wild (Vermeulen 2009). However, a sustainable supply of *B. latifolia* can be provided by growing this in gardens and engagements are underway with stakeholders to facilitate this. For medicinal tree bark, harvest prescriptions have been developed for *Ocotea bullata*, but for most other species, little scope exists for sustainable strip harvesting because of poor bark regrowth, and susceptibility to fungal and insect damage (Vermeulen 2009; Vermeulen, Geldenhuys & Esler 2012). Harvesting bark as by-product from timber harvesting or full-tree harvesting under sustainable timber harvesting systems (see Seydack et al. 1995) would be more viable options than strip harvesting.

Management actions and challenges

Managing unauthorised resource use in a fragmented and open access park, such as the GRNP, requires pro-active engagement with stakeholders together with law enforcement and vigilant monitoring of population health. Improved understanding of stakeholder dynamics and needs enable research and monitoring to focus on priority species and products, and assess to what extent needs could realistically be addressed. Achieving inclusive engagement with all plant harvesters is key but difficult because many are not members of a user group. Park management needs to drive a more structured effort to identify stakeholders because the demand for medicinal plant products is expected to increase.

Case study 2: Monitoring the recreational and subsistence line fisheries occurring within the Garden Route National Park

Context

Recreational fishing managed nationally under the *Marine Living Resources Act* (1998) has been primarily top-down and subsistence (or small-scale) fisheries, in particular, were historically marginalised and neglected within policies and management systems (Sowman 2006). Recreational and subsistence fishing occurs within the GRNP, but little

information about participants or trends in fishing effort and catches was available to management.

Monitoring related to recreational and subsistence fishing

To evaluate the sustainability of marine and estuarine fishing, a monitoring programme was implemented in 2008. Two estuaries and two coastal sections were selected as monitoring sites through a prioritisation exercise. Objectives, key questions and hypotheses were co-developed by scientists and park management. Sustainability indicators along with trends, performance criteria and TPCs were set within the ecological and social domains. Indicators were standard between estuarine systems and coastal areas but reference points were area specific. For example, in estuarine systems, targeted catch per unit effort (*cpue*) for Cape stumpnose is an indicator but the TPC differs between systems.

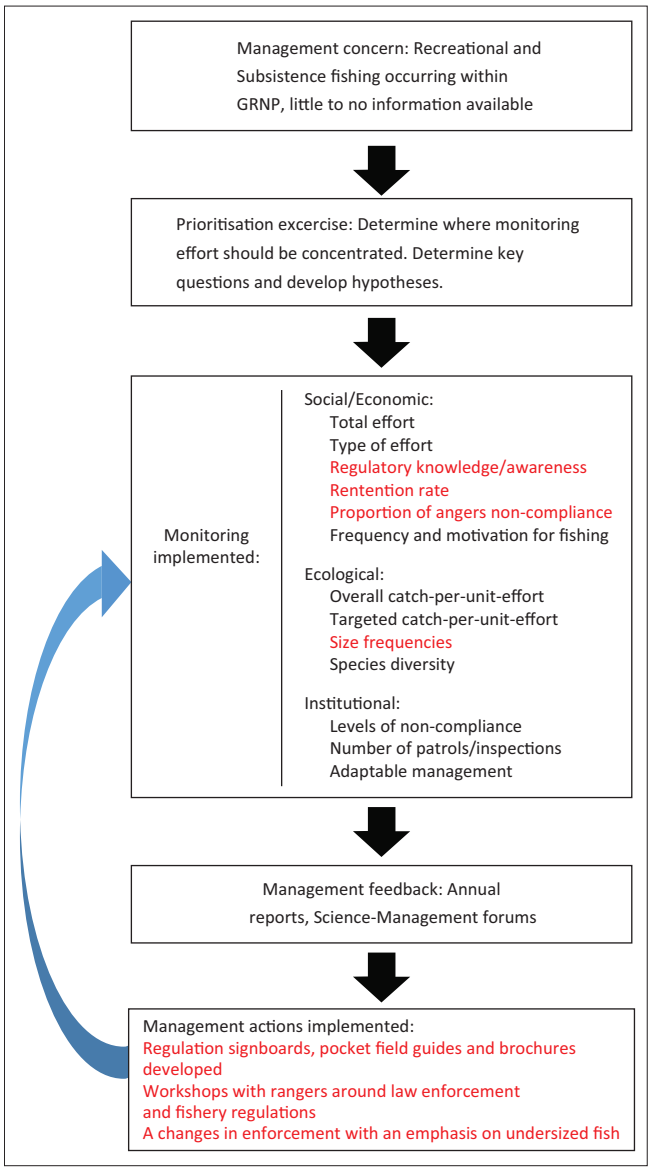
Feedback and challenges

The programme provides spatially explicit information including catch rates, proportion of different user groups, *cpue*, retention rates, proportion of undersized fish, number of patrols and annual estimates (e.g. total fishing effort and total catch). Results are fed into the adaptive management loop and used to guide management interventions and identify further research questions (Figure 2). For example, monitoring highlighted a large proportion of undersized fish being retained, and as a result, research is being conducted regarding the drivers of angler behaviour and non-compliance, while management increased its emphasis on law enforcement. Similarly, poor angler awareness and knowledge of fishery regulations resulted in management interventions, including the development of illustrative and locally relevant fishery signboards, pocket field guides and brochures. The influence of these interventions is currently being re-assessed on a 5-year basis.

Currently, the monitoring programme is in partial compliance with the desired resource use monitoring system. The impact on the targeted populations and biodiversity is less well covered and, in particular, social and economic indicators need to be developed in collaboration with the local anglers. Future research and monitoring should strengthen the interdisciplinary nature of the work, with the aim of gaining greater understanding on how recreational and subsistence fisheries respond to socio-ecological change. Of particular importance is further engagement with local fishermen and enabling their input into the monitoring framework and future refinements. This is a challenge as most anglers do not belong to a club and, in particular, subsistence fishermen are not well organised or represented.

Conclusion

The monitoring programme needs to be supported by applied research on selected target species and products to ensure sustainable use and optimise benefits. The resources required to develop harvest systems for sustainable use and to conduct initial and ongoing monitoring to support this are often underestimated (Cunningham 2001; Vermeulen 2009).



GRNP, Garden Route National Park.

FIGURE 2: Example of how the monitoring framework has been adopted in the Garden Route National Park recreational and subsistence line fisheries. Text in red shows how areas of concern (identified through monitoring key indicators) were addressed in management actions. The impact of these actions is then re-assessed through the monitoring programme.

Costing for a specific project would be possible, but a detailed costing of the programme would be difficult as this would be influenced by, for example, diversity of species and products harvested, number of users and stakeholder dynamics, further impacted on by the precision and accuracy of inventories and monitoring required, and the spatial and temporal scale at which monitoring needs to be conducted (Cunningham 2001). Constraints on the availability of resources (financial and human resources) could potentially hamper the successful implementation of the programme. In many cases (as described in the different examples and the two case studies), components of the programme have already been implemented, integrated with park management activities and as part of the established SANParks research and monitoring programme (SANParks 2014). However, prioritising monitoring and resource use projects is essential.

These are influenced by sociopolitical or institutional factors (including political and societal values and regulatory frameworks for resource use), economic factors (such as the economic status of local communities and the demand for and value of the resource), as well as user group and local community factors (e.g. the nature of the demand and history of use, dependence on the resource and the availability of alternatives). Also, the ecological factors such as the status and availability of a resource and the characteristics of the target species are of importance (SANParks 2011).

Considering the long-term nature of the monitoring programme, the development of in-house skills and expertise is essential, while partnering with research institutions such as universities, is also important. In terms of commercial resource use projects, the costs of monitoring and research should ideally be covered by the commercial venture.

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Competing interests

The authors declare that they have no financial or personal relationships that may have inappropriately influenced them in writing this article.

Authors' contributions

W.V., together with N.v.W., K.S., M.D., L.S. and W.A., conceptualised the article. W.V. drafted the manuscript with input from N.v.W., K.S., M.D., L.S. and W.A. Further comments and editorial input for the article were provided by H.B., G.D., N.H., H.H., M.M., N.N. and A.S. All authors formed part of a working group that developed the monitoring system.

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