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Biological invasions in South African National Parks

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Objectives: A core objective in South African National Parks (SANParks) is biodiversity conservation and the maintenance of functional ecosystems, which is compromised by alien species invasions. The 2016 Alien and Invasive Species Regulations of the *National Environmental Management: Biodiversity Act (*NEM:BA) requires landowners to develop management plans for alien and invasive species, as well as report on the status and efficacy of control.

Method: To compile the species list, we started with the 2011 SANParks alien species list. Name changes were updated and SANParks ecologists and park managers contacted to verify the species lists and add new records. Species reported by external experts were added in the same manner. The management programme costs and species controlled per park per year were extracted from SANParks' Working for Water programme database.

Results: SANParks has listed 869 alien and extra-limital species, including 752 plants and 117 animals, increasing from 781 alien species in 2011. About R 590 million has been spent by the Working for Water/Biodiversity Social Programmes since 2000/2001. Of the species recorded, 263 are listed by NEM:BA, including 12 Category 1a species, 184 Category 1b species, 28 Category 2 species and 39 Category 3 species.

Conclusion: While large clearing programmes have been maintained since at least 1998, improving prioritisation is necessary. We provide a short synopsis of (1) what alien species are present in SANParks, (2) the species and parks that management has focused on, (3) the implications of the NEM:BA Invasive Alien Species Regulations and (4) future developments in monitoring.

Introduction

The South African National Parks (SANParks) estate includes 19 national parks across South Africa, covering about 39 000 km^2, which includes fynbos, forest, arid and sub-tropical savanna (Figure 1). SANParks' primary mandate is biodiversity conservation and the maintenance of heritage assets and thereby providing human benefits (SANParks 2015). The role protected areas (PAs) are required to play in maintaining biodiversity and ecosystem services is becoming increasingly important as landscapes become progressively fragmented (Watson et al. 2014). Changes in land use types surrounding PAs lead to habitat transformation that is not always compatible with conservation. Higher human population density in areas surrounding SANParks' PAs has been shown to be a significant predictor of invasions (Spear et al. 2013). These source populations around urban centres drive continual input into the system, increase propagule pressure and ultimately heighten the risk of impacts to PAs.

The insidious nature of invasions, typical lag phase (Crooks 2011) and the difficulty of detecting the resulting ecological change mean that concerns are often only raised and actions taken once the invasion is well advanced. Moreover, more quantitative data are needed to show that the observed impact on response variables (e.g. on plant richness) manifests as an impact on ecosystem processes (Hulme et al. 2013). Nonetheless, there are numerous examples that can be used as indicators of how alien species impacts may effect PAs, which should be used to illustrate concerns and motivate for control in the early stages. Studies in PAs that are considered intact natural ecosystems show that invasive alien plants (IAPs) dominate and displace native species and communities, alter fire regimes, directly or indirectly alter biogeochemistry and nutrient cycles and can use significantly more water than native vegetation because of the densities they reach (Foxcroft et al. 2013; Le Maitre, Versfeld & Chapman 2000).

Chromolaena odorata in Hluhluwe-iMfolozi Game Reserve (South Africa), for example, has affected spiders and mammals. In invaded areas, native spider assemblages changed in abundance, diversity and estimated species richness, but these changes were reversed following clearing (Mgobozi, Somers & Dippenaar-Schoeman 2008). Both small and large mammals had higher

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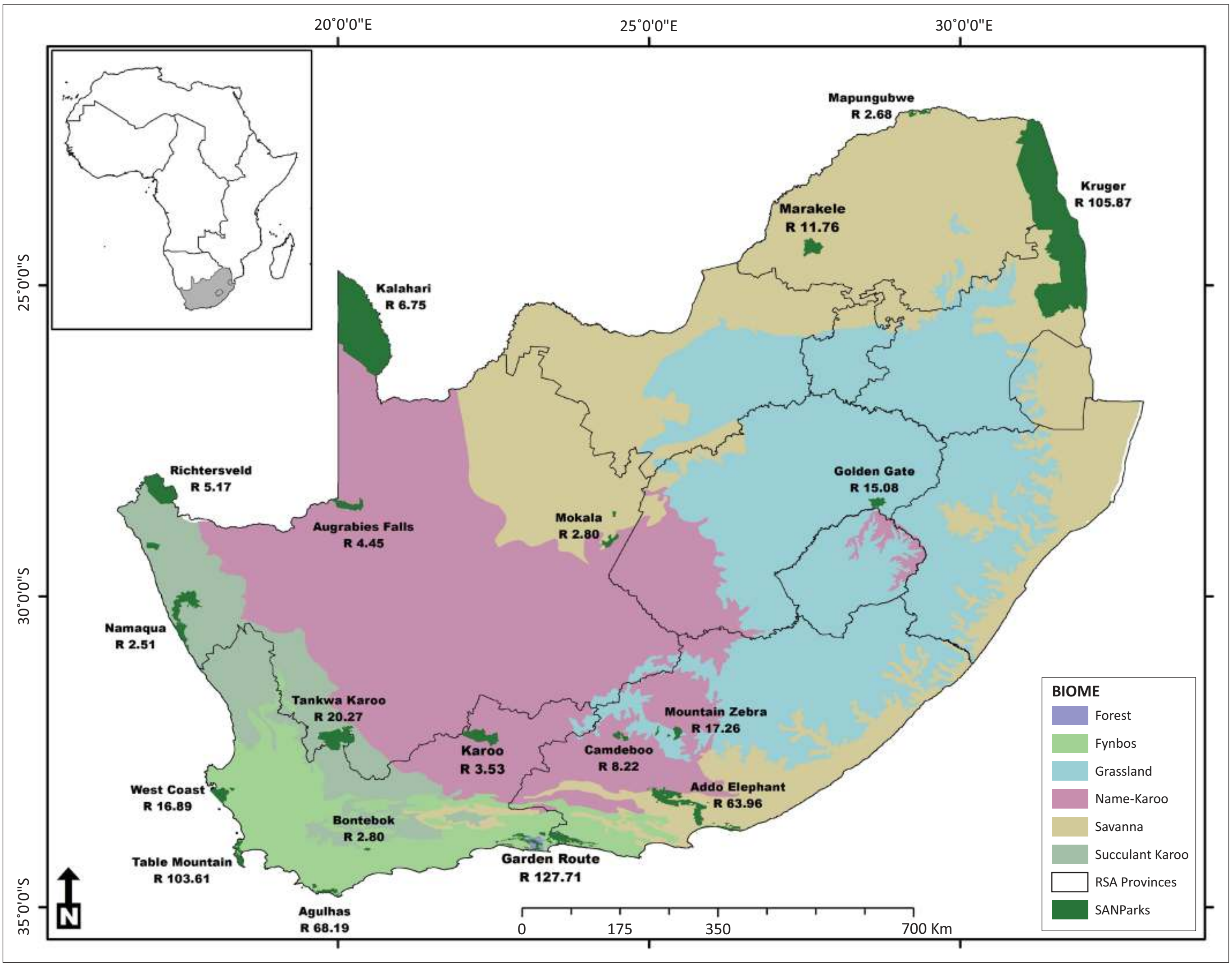


Source: Courtesy of S. MacFadyen

The values indicate annual funding spent by Working for Water (Biodiversity Social Projects) in SANParks between the 2002/2003 and 2015/2016 financial years, in ZAR millions.

FIGURE 1: Distribution of South African National Parks' 19 protected areas.

species richness and diversity in uninvaded sites compared with invaded sites (Dumalisile 2008). Similarly, *Opuntia stricta* in Kruger National Park (Kruger; all parks hereafter given by name) significantly altered beetle assemblages (Robertson et al. 2011). Although now successfully under biological control, the example illustrates the species level effects that *O. stricta* could have if not managed. In the fynbos biome, the presence of IAPs alters the fuel load as well as the horizontal and vertical connectivity of fuel. This can increase fire intensity and spread (Chamier et al. 2012) with serious implications for ecosystems and the ability to manage fires and human safety (Van Wilgen, Forsyth & Prins 2012). The effects of invasive alien fish are well documented, often resulting in irreversible change to native species communities and ecosystem function (see Ellender & Weyl 2014 for a review in South Africa) and, therefore, the presence of 17 alien fish species across at least 10 parks is of great concern. Some of these species include bass (*Micropterus* spp.), common carp (*Cyprinus carpio*), Nile tilapia (*Oreochromis niloticus*) as well as its hybridised form with the indigenous Mozambique tilapia (*Oreochromis mossambicus*) (Woodford et al. 2017). Feral animals are problematic in almost all parks. Although currently with low incidence, the potential of feral cats (*Felis silvestris catus*) to hybridise with African wild cats (*Felis silvestris lybica*) (Le Roux et al. 2015) is concerning. These examples paint a worrying picture of how invasive-species-led habitat transformation, ecosystem function impairment, loss of native biodiversity or genetically pure species could undermine the ability of SANParks to achieve its objectives and compromise its status.

The highly complex biophysical context of SANParks makes managing invasive alien species (IAS) across its PAs difficult, for example, the vast area, number of parks, the distribution across South Africa's biomes and the degree to which they are invaded makes planning challenging. Decisions about when, where and how to implement actions, therefore, need to be prioritised in line with available resources (e.g. Forsyth et al. 2012; Roura-Pascual et al. 2009), across parks and within key areas within each park (Forsyth & Le Maitre 2011), although current funding provision processes complicate prioritisation. Management also needs to take into account the complexities of species' distribution, abundance, spread, and the multiple interacting environmental and socio-economic factors (Roura-Pascual et al. 2009). Difficult decisions need to be made to trade-off benefits against losses for different ecosystems and different species, thereby accepting the fact that some negative impacts are inevitable in some areas or parks. An initial Analytical Hierarchy Process-driven assessment highlighted important criteria that should be considered in SANParks and recommended species that should receive management (Forsyth & Le Maitre 2011). While plants can be controlled, because of the kinds of species and ecosystems inhabited other taxa such as fish cannot in most cases be managed, posing substantial threats to ecosystems and indigenous species.

The process of developing management strategies requires two sources of information, namely accurate species lists and distribution data (Pyšek et al. 2013; Tu & Robison 2013). These data are needed to assess priorities and focus on species posing the greatest threat. As part of the strategic adaptive management (SAM) culture in SANParks (Roux & Foxcroft 2011) assessing past practices provides insights for continuous improvement. Here we focus on (1) what alien species are present in SANParks, 2) the costs and parks that management has focused on, (3) listed species and implications of the *National Environmental Management: Biodiversity Act* (NEM:BA) Invasive Alien Species Regulations and (4) future developments.

TABLE 1: Total alien plants and animals recorded across SANParks estate, reported by class.

Species	Total
Plants	**752**
Dicots	568
Monocots	152
Pinophytes	18
Ferns (Pteridopsida)	11
Cycads	3
Animals	**117**
Vertebrates	**54**
Mammals	26
Fish	17
Birds	9
Amphibians	1
Reptiles	1
Invertebrates	**63**
Slugs and snails (Gastropoda)	19
Insects (Insecta)	13
Collembola and relatives (Entognatha)	11
Crustaceans (Maxillopoda and Malacostraca)	5
Earthworms (Oligochaeta)	4
Sea squirts (Ascidiacea)	3
Bivalves (Bivalvia)	2
Millipedes (Diplopoda)	2
Spiders (Arachnida)	2
Anthozoa	1
Centipedes (Chilopoda)	1
All species	**869**

Methods

To compile the species list, we used the list in 'Alien species in South Arica's national parks' (Spear et al. 2011) as a starting point (data collection methods are provided in Spear et al. 2011). All the species were checked for name changes and then verified. SANParks botanists, ecologists and park managers were contacted and new species that had been positively identified since 2011 were added. Species reported by external experts were verified and added in the same manner. The control costs were extracted from SANParks' Working for Water programme database, as well as the species controlled per park per year.

Alien species in South African National Parks

The first comprehensive account of alien and invasive species in SANParks documented 781 species (including extra-limital and feral species, but excluding biological control agents as 'alien', Spear et al. 2011). The list comprised 655 plants and 115 animals. Current revisions based on (1) new species introductions, (2) updated nomenclature and (3) correcting for misidentified species have increased the list to a total of 869 species (Table 1). Of these, 752 are plants and 117 are animals (Table 1). The number of mammals (26) and insects (13) has not changed substantially. Two of the three parks with the highest number of plants changed marginally, while the number of listed plants in Garden Route increased from 171 to 251. Kruger's numbers increased to 363 plants (from 348) and Table Mountain to 243 species (from 239). In total, there are 1878 records across all parks, of which 1622 are plants and 256 are animals (see Online Appendix 1 for full species lists per park, including kingdom, class and family, and Online Appendix 2 for a list of species, indicating subspecies, common names and class). At least 18 plant species occur in 10 or more parks; fortunately only a third of these represent major concerns, for example, *Pennisetum setaceum*, *Arundo donax*, *Lantana camara*, *Melia azedarach* and *Schinus molle*. Of greater concern is that except for four parks (Kalahari Gemsbok [3], Richtersveld [6], Namaqua [8] and West Coast [8]), almost all parks have large numbers of 'transformer' species (sensu McGeoch, Chown & Kalwij 2006; Richardson et al. 2000). Furthermore, even in the parks with few transformer species, the species present are often highly invasive. For example, *Parkinsonia aculeata*, *Prosopis glandulosa* and *S. molle* in Kalahari Gemsbok; *P. glandulosa* and *S. molle* in Richtersveld; and *Acacia cyclops* and *Acacia saligna* in West Coast (predominantly a problem in new sections that are in the process of being added to the park) (Online Appendix 1).

Management

Effectiveness, costs and challenges of invasive alien plant control

As early as the 1940–1950s, there have been efforts to control plant invasions in some areas now falling within SANParks' estate, for example, Table Mountain and Kruger. In what is now part of Table Mountain, control was initiated in 1941 but by the 1970s efforts were still considered unsuccessful (Macdonald et al. 1988). By the mid-1980s, 40% of the Cape of Good Hope Nature Reserve's (now incorporated into Table Mountain) annual budget was being used for IAP control, but the distribution continued to expand (Macdonald et al. 1988). In 2015/2016, the budget for alien plant clearing in Table Mountain totalled about R 22.7 million (Figure 2). As Table Mountain falls in a species rich region with about 2285 indigenous plant species, of which 158 are endemic and 141 appear on the Red Data List (SANParks 2016), ongoing efforts attest to the importance placed on bringing the IAPs to maintenance control levels, which has had substantial success in certain areas. For example, the current density of IAPs at Cape Point in Table Mountain (uninvaded to scattered individuals; Appendix 1, Figure 1-A1, TMNP Management Plan, SANParks 2016) are lower than previous decades, where up to 25% of the area was densely invaded with *A. cyclops* and related species (Taylor & Macdonald 1985; Taylor, Macdonald & Macdonald 1985). However, the inflexibility of clearing programmes to respond quickly to changing priorities (e.g. following fires) undermines attempts to reduce the density of IAPs (Van Wilgen & Wannenburgh 2016).

In Kruger, small-scale efforts date back to the mid-1950s, focusing on the control of *Melia azedarach*. In the early 1980s, Kruger created an Alien Plant Control Officer post and a team of 10 people to control the IAPs. However, the size of the problem proved too large and species such as *Lantana camara* and *O. stricta* continued to invade (Foxcroft & Freitag-Ronaldson 2007). The programme started expanding with funding from the Royal Netherlands Embassy who provided R 3 million between 1997 and 2000, and then with the initiation of the Working for Water programme in Kruger in 1997.

While individual parks provide resources from their own operational funds for the control of IAPs, the overriding majority of funding comes from the Expanded Public Works Program, through the Department of Environmental Affairs Natural Resource Management Program (Working for Water). Since the start of the 2002/2003 financial year, from when more detailed records have been kept, about R 590 million has been spent in SANParks on IAP control (Figure 2). Between 2011/2012 and 2014/2015, the annual budget fluctuated between R 60 million and R 75 million, with a R 42 million increase in 2015/2016 to a total of R 114 million (Figure 2). Between 2002/2003 and 2015/2016, about 80% of the total funding was spent across five parks, namely Garden Route (R 127 million), Kruger (R 105 million), Table Mountain (R 103 million), Agulhas (R 68 million) and Addo Elephant (R 64 million) (Figure 3). For the last 6 years (since 2009/2010), Garden Route has accounted for about 20% of the annual budget, increasing to 29% in 2015/2016. The IAP control programme for Kruger constituted about 46% of the total budget for 2002–2004, which decreased to 13.5% in 2015/2016 (Figure 4).

It would be disingenuous not to acknowledge the problems that have arisen and in a programme operating at such a large-scale are inevitable, but need to be addressed promptly. For example, a recent assessment of the costs of controlling IAPs in 25 PAs (not only SANParks) in the Cape Floristic Region argued that without careful prioritisation and substantial increases in funding, the likelihood of achieving successful control is low (Van Wilgen et al. 2016; Van Wilgen & Wannenburgh 2016). In addition, evidence from the Garden Route suggests that significant management intervention is required to increase the impact and effectiveness of funds that are available (Kraaij et al. 2017). Additional challenges arise from the numerous parcels of land being added to national parks as part of the PA expansion strategy. In many instances, alien species have not previously been managed on the new land, which is also often transferred without accompanying financial resources for IAP management or at best a once-off payment

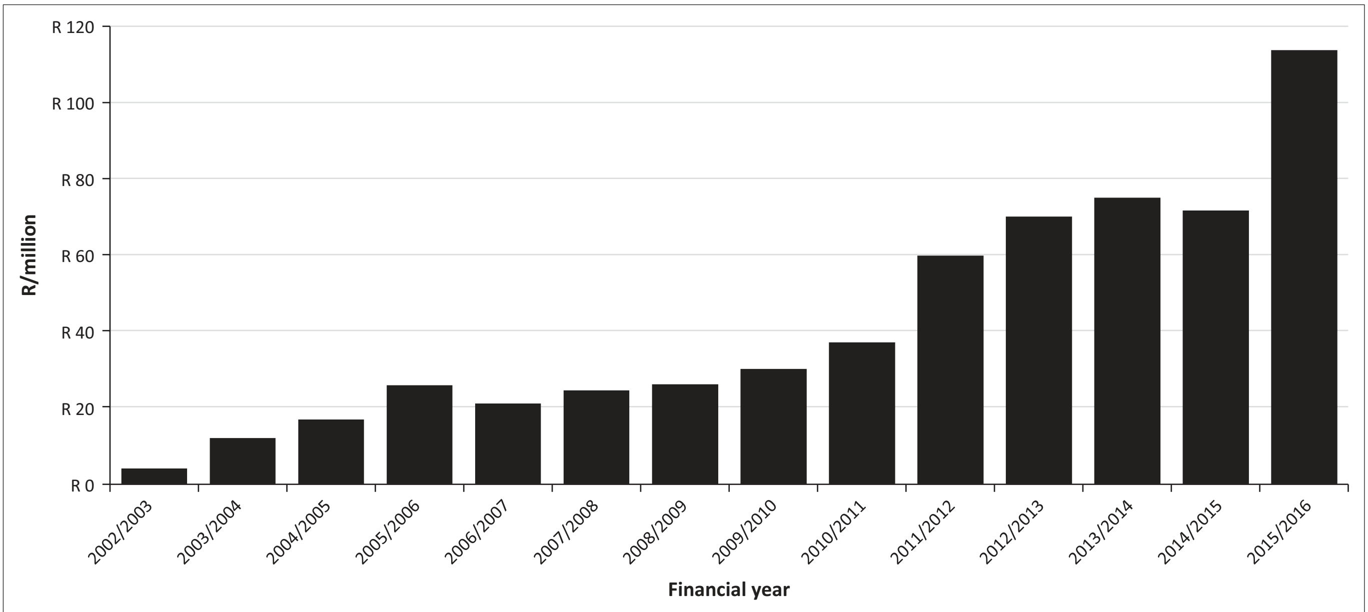


FIGURE 2: Annual funding spent by Working for Water (Biodiversity Social Projects) in SANParks between the 2002/2003 and 2015/2016 financial years.

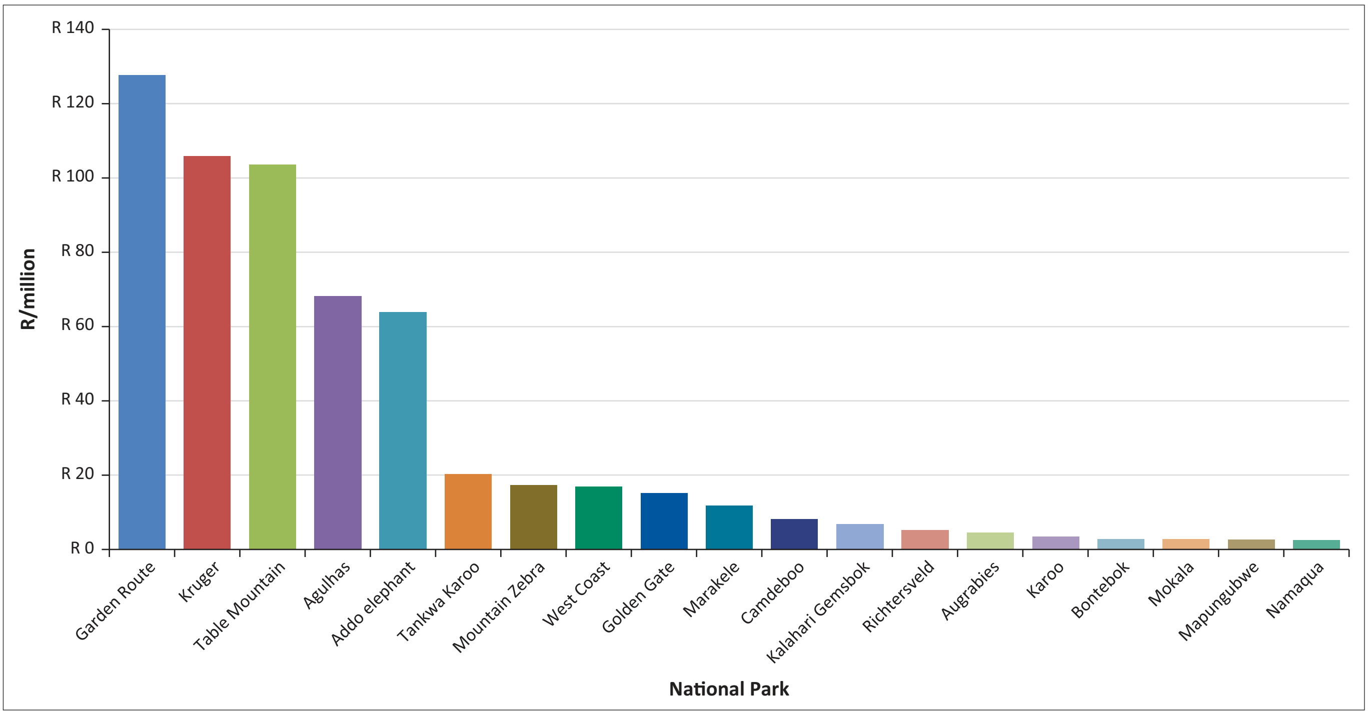
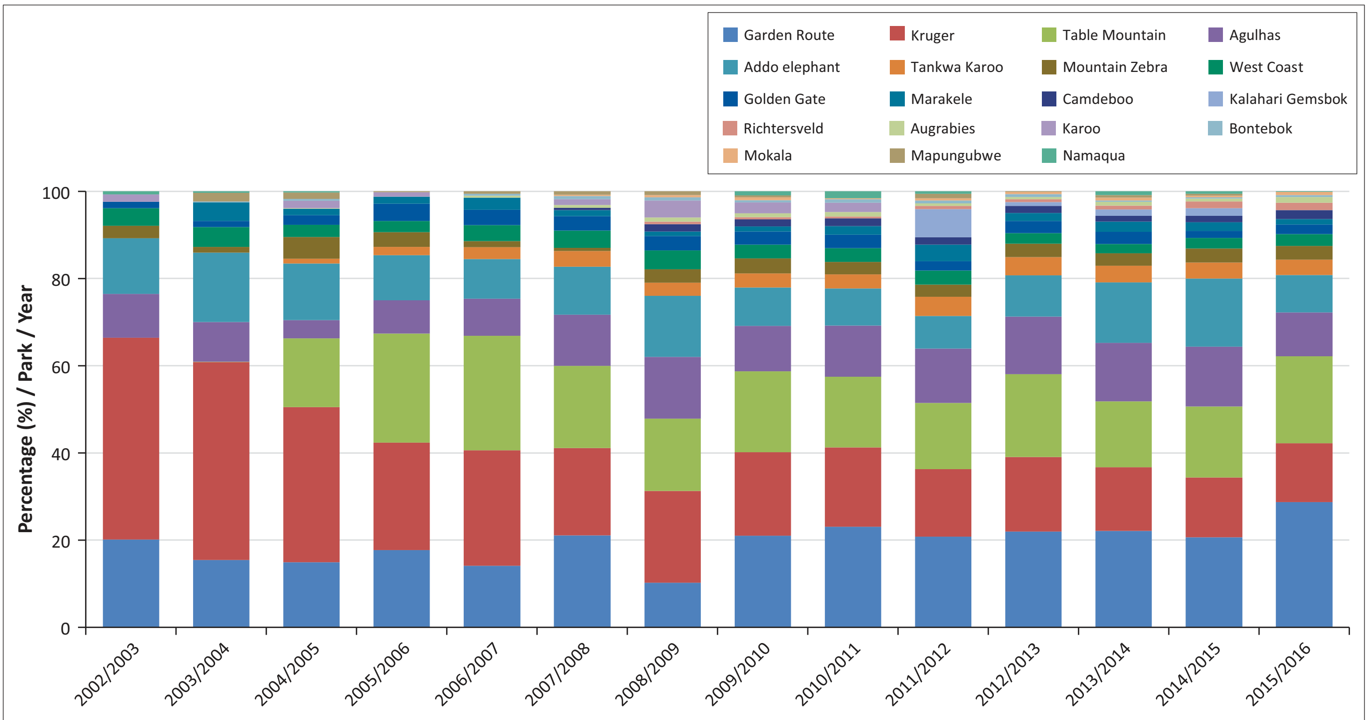


FIGURE 3: Total funding spent between 2002/2003 and 2015/2016 by Working for Water (Biodiversity Social Projects) in SANParks per national park.



The colours shown in the legend for each park correspond to Figure 3

FIGURE 4: The percent of the total funding spent in each park per financial year.

for short-term management. For example, in the large areas where commercial forestry is withdrawing from the Garden Route, a once-off amount of R 5.335 million (plus R 4.438 million outstanding) was received from the landowners when transferred to SANParks; however, no additional funds for long-term management have been made available. A similar situation exists in Tokai, Table Mountain, where the problem had been exacerbated by fires in 2015, which burnt most of the remaining plantation areas. Funding is also required to take advantage of these unexpected events as fire stimulates the germination of seeds and burning after 1 to 2 years kills seedlings before they mature (Van Wilgen, Forsyth & Prins 2012). Despite numerous challenges, the need to revise and align management plans with the NEM:BA regulations, along with improved species lists, increasing distribution data on key species and assessments of past programmes provides the opportunity to strategically plan future directions.

Biological control of invasive alien plants – Introduction and efficacy

Biological control is an essential component of any long-term IAP management programme and perhaps more so in PAs where there is resistance to the use of herbicides (Van Driesche & Center 2013). In addition manual or chemical control of IAPs over extensive areas may not be feasible even where large amounts of funding are provided. There are also numerous successes around the world and especially in South Africa (Moran, Hoffmann & Zimmermann 2005; Zachariades et al. 2017). In light of this, biological control of IAPs is potentially the only control option available to many PAs. In SANParks, 38 biological control agents (35 invertebrates and 3 fungi), totalling 47 records across all parks, have been released for the management of IAPs (Online Appendix 3). Of these, 23 have been released in Kruger, 12 in Garden Route and 5 recorded in Camdeboo. In some parks, for example, Kruger, biological control has been used since the mid-1980s, where it has been highly successful in the management of *Pistia stratiotes* (water lettuce) (Foxcroft & Freitag-Ronaldson 2007; see also Hill & Coetzee 2017). Additionally, biological control using *Dactylopius opuntiae* (cochineal) together with *Cactoblastis cactorum* (cactoblastis moth) is the primary control method for *O. stricta* (Paterson et al. 2011), with chemical control used in new foci outside of the core management zones (cf. Kaplan et al. 2017). Similarly in Camdeboo and Addo Elephant, biocontrol using *Dactylopius* spp. is one of the core management approaches for the cacti. Biocontrol agents have been released on invasive *Acacia* spp. in Addo Elephant, Agulhas, Garden Route and Table Mountain.

Management of extra-limital, alien and invasive animals

Of the alien animals in SANParks, 23 are extra-limital species (which we defined as species that are indigenous to South Africa but that have been introduced into national parks outside their historical ranges, Spear et al. 2011). Programmes are underway to remove species, for example, nyala (*Tragelaphus angasii*) and blesbuck (*Damaliscus pygargus*) have been removed from Marakele (SANParks 2014). Blue wildebeest (*Connochaetes taurinus*), springbuck (*Antidorcas marsupialis*) and gemsbok (*Oryx gazella*) are planned for removal from West Coast, while annual culling of warthogs (*Phacochoerus africanus*) takes place in Addo Elephant. As animals are removed from the parks, ongoing surveillance is required to ensure that no animals were missed and that reinvasions do not occur. However, in many instances eradication of invasive alien animals is likely to be impossible, for example, invertebrate species such as collembola (springtails) that occur in the soil and which are further complicated as native taxa are often poorly described. Some species require specialised training to assist in control operations, for example, in the case of highly aggressive German wasps (*Vespula germanica*) where Table Mountain has collaborated with specialists from The City of Cape Town in the removal of nests (L. Stafford [Environmental Resource Management Department, City of Cape Town] pers. comm., May 2016). Few alien animals have been introduced into SANParks, with some present prior to park proclamation, often for many decades, for example, Himalayan tahr (*Hemitragus jemlahicus*), sambar (*Rusa unicolor*) and grey squirrel (*Sciurus carolinensis*) in Table Mountain (Online Appendix 1). Vertebrates have been shown to have a high probability of becoming invasive once introduced (Jeschke & Strayer 2005). Once they have become invasive, the ability to control them is usually extremely difficult, labour intensive (e.g. fish; Ellender & Weyl 2014) and often compounded by fierce public resistance [e.g. the case of mallard ducks (*Anas platyrhynchos*) in Cape Town, Erasmus 2013].

NEM:BA listed species and implications for SANParks

The management of IAS in SANParks is governed by two primary policy instruments: the *National Environmental Management Protected Areas Act* (No. 57 of 2003), which requires alien species to be included in park management plans, and the *National Environmental Management: Biodiversity Act* (Act No. 10 of 2003, hereafter NEM:BA), which through its associated Alien and Invasive Species Regulations (2016) requires landowners to develop specific plans for the control, eradication and monitoring of alien and invasive species.

Of the 869 species in SANParks (including extra-limital and feral species), 263 are included in the NEM:BA alien and invasive species regulations (Table 2). This poses significant challenges for the management of IAS in the organisation (1) in the complexity of developing strategic plans for the numerous listed species across 19 national parks and (2) because of these extensive species lists, implementation thereof, even where the best available strategies have been developed. The NEM:BA regulations include four categories that aim to prevent introduction, manage existing species populations and regulate the use of commercially important but potentially IAS. Specifically, Category 1a includes 'Invasive species which must be combatted and eradicated' and 1b includes 'Invasive species which must be controlled and wherever possible, removed and destroyed'. The SANParks list includes 12 Category 1a species and 184 Category 1b species (Table 2). Table Mountain, Kruger and Garden Route each have more than 75 Category 1b species present. Since 2001/2002, these parks have however only focused on a small number of NEM:BA listed species, for example, 47 species (60%) in Table Mountain and 37 species each in Kruger (40%) and Garden Route (51%); typically less than half this number of listed species are worked on in any given year. For example, 15 (21%) and 29 (37%) Category 1b species were worked on in Garden Route and Table Mountain in 2015/2016, respectively. Category 2 species are 'Invasive species, or species deemed to be potentially invasive, in which a permit is required to carry out a restricted activity' and Category 3 species may only be allowed under specific terms. Category 2 species are generally used in commercial plantations and being granted exemptions under Category 3 is, as a PA agency, highly unlikely. This in effect adds 28 and 39 species to Category 1b, which then requires control in the same manner as Category 1b. Therefore, with the current funding of about R 110 million per year (Figure 2), SANParks will not be able to expand the current programme to eradicate or actively control

TABLE 2: The total number of alien species per park and the number of these species listed in each Category of the NEM:BA regulations.

Park	Total species per park				NEM:BA listed species										
	# species	# plants	# animals	# biocontrol	Total spp.	Total plants	1a plants	1b plants	2 plants	3 plants	Total animals	1a animals	1b animals	2 animals	3 animals
Addo Elephant	149	124	24	1	69	63	2	52	6	3	6	0	3	1	2
Agulhas	95	82	10	3	55	50	0	38	6	6	5	0	3	2	0
Augrabies Falls	59	54	5	0	31	29	0	24	3	2	2	0	0	0	2
Bontebok	95	80	15	0	37	28	0	23	5	0	9	0	4	2	3
Camdeboo	56	45	6	5	35	34	0	28	5	1	1	0	1	0	0
Garden Route	283	251	20	12	110	98	2	72	11	13	12	0	3	4	5
Golden Gate Highlands	89	77	12	0	63	57	0	44	9	4	6	0	2	1	3
Kalahari Gemsbok	21	18	3	0	11	9	0	8	0	1	2	0	0	0	2
Karoo	35	22	13	0	23	19	1	14	4	0	4	0	0	1	3
Kruger	415	363	28	22	130	118	1	93	7	17	12	0	9	0	3
Mapungubwe	49	40	9	0	33	29	0	27	2	0	4	0	1	0	3
Marakele	28	20	8	0	24	18	0	14	2	2	6	0	2	1	3
Mokala	34	27	6	1	22	21	0	16	2	3	1	0	0	0	1
Mountain Zebra	111	101	8	2	49	45	1	36	6	2	4	0	1	0	3
Namaqua	23	18	5	0	14	13	0	10	2	1	1	0	0	0	1
Richtersveld	21	15	6	0	15	12	1	9	1	1	3	0	0	0	3
Table Mountain	295	243	51	1	126	114	8	78	13	15	12	0	4	4	4
Tankwa Karoo	33	27	6	0	20	18	0	13	4	1	2	0	0	0	2
West Coast	36	15	21	0	19	11	0	8	1	2	8	0	0	2	6

Total spp., species per park.

many listed species (Table 2 and Online Appendix 2) and some form of prioritisation and triage will be necessary. However, strategies at the corporate level and park management plans have been developed and are being revised to determine the best approach for each park or group of listed species.

An additional point in the NEM:BA regulations, which states that any 'form of trade, propagation or planting is strictly prohibited', also applies to SANParks, especially with regard to nurseries selling native plants in some parks or the use of ornamental species in tourist facilities and staff accommodation. Ornamental species are well known to be an important pathway of invasion into PAs (e.g. in Kruger; Foxcroft, Richardson & Wilson 2008). These pathways can, however, be managed and nurseries are restricted to indigenous species only. For example, ornamental alien plants and landscaping in Kruger are strictly regulated and should be followed by the other national parks. The revised standard operating procedure allows only those indigenous species naturally occurring within a particular landscape for use in the tourist camps, while other non-invasive but alien ornamental species are being phased out (Kruger National Park [KNP] 2015). Follow-up control and awareness will have to remain a key part of the programme in the long term. However, from 1999 when the first comprehensive ornamental plant survey was conducted in Kruger, significant progress in managing the species used in camps and staff gardens has been achieved (Foxcroft, Richardson & Wilson 2008).

Future developments – Monitoring and indicators

Two key processes that have been lacking or only partially developed in some parks are outcomes or ecologically based monitoring and standardised operating procedures or guiding frameworks. A core element of the SAM approach that SANParks has adopted is monitoring and the concept of thresholds of potential concern (TPC) (Roux & Foxcroft 2011). The TPC approach has guided management interventions and drawn attention to important potentially invasive species, highlighting new or potential introductions and new foci of a species in a park (e.g. Foxcroft 2009). For example, where the TPCs were implemented in Kruger, a new introduction or increase in distribution of a species would breach a pre-defined threshold. This would trigger a process whereby the Kruger Conservation Management department was officially notified, the most appropriate course of action determined, implemented, and feedback given to the department until satisfactorily dealt with (Foxcroft & Downey 2008). In addition, as part of SANParks' biodiversity monitoring programme (McGeoch et al. 2011) an IAS monitoring programme was developed (Foxcroft & McGeoch 2011). This programme provides seven headline indicators against which progress in management of invasive species is measured over time, frequently a 3- or 5-year period. These include (1) the number of alien species in a park, (2) the number of populations, (3) the coverage or density of each species per park, (4) the total area of park invaded, (5) the number of species of special concern threatened by IAS, (6) the percentage of invasive species being actively controlled and (7) the percentage area controlled with abundance maintained at an acceptable threshold. These indicators can be disaggregated into finer level indicators, for example, for number of alien species in a park, temporal trends in changes to species can be listed by taxon, status, transformer or extra-limital species (Foxcroft & McGeoch 2011). Detailed monitoring of change and response to IAS on ecosystems will likely be implemented in the form of focused scientific studies, for example, using indicator species at a fine spatial scale. Successful implementation of the indicators is, however, contingent on extensive and detailed monitoring and will not be possible without the requisite resources.

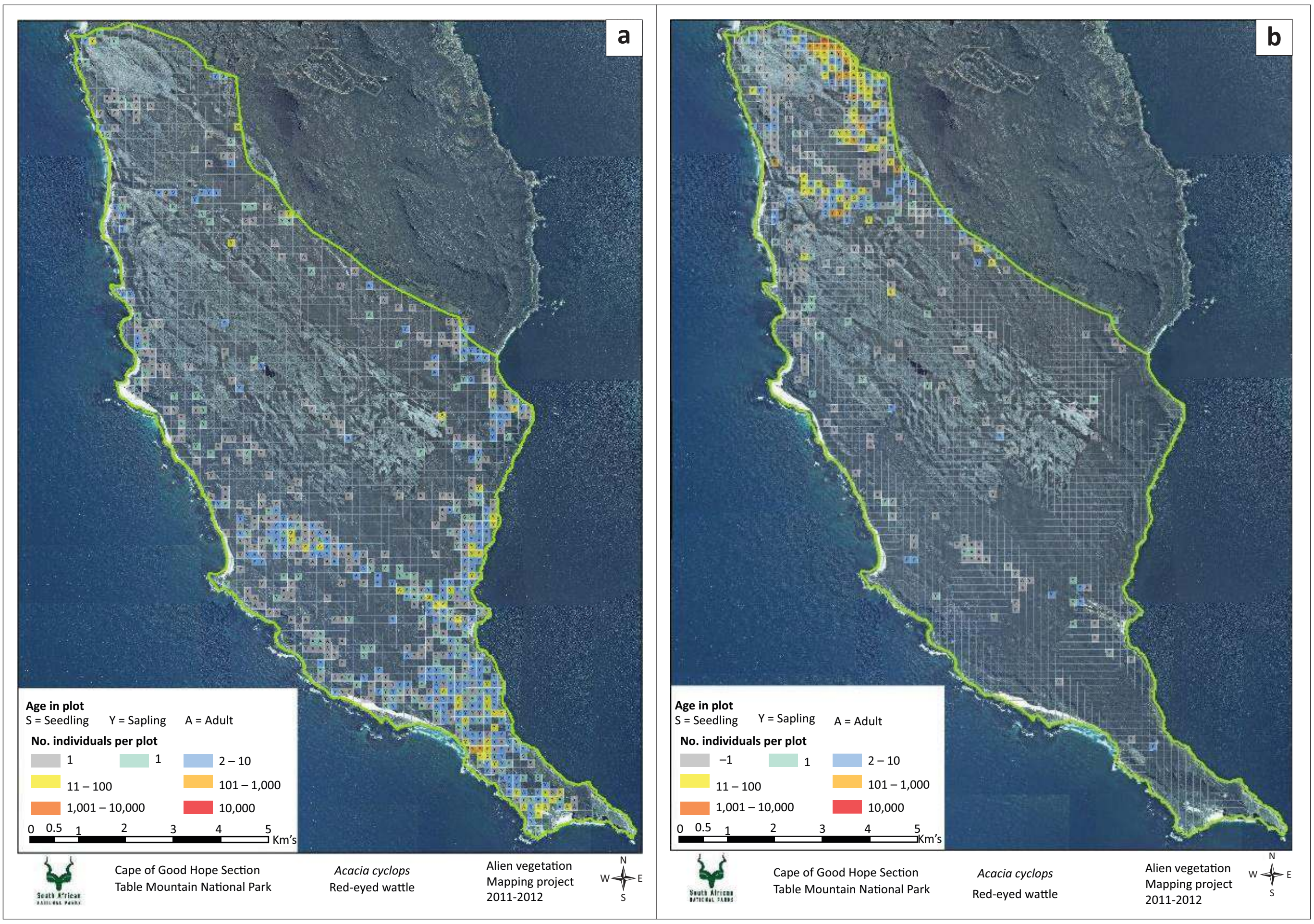
The collection of baseline data on species distribution and abundance at a fine scale using stratified sampling methods has been initiated in some parks (e.g. Table Mountain, Bontebok, Agulhas and West Coast). The data include species, age class, abundance and control status, for example, in Table Mountain and Bontebok (e.g. Figure 5a–d). Species-specific distribution monitoring for priority species is also conducted, for example, *Parthenium hysterophorus* (Figure 5e) and *O. stricta* (Figure 5f) in Kruger, which is used to inform preparation of management plans. This form of data is highly valuable not only in planning but also in monitoring the impact of management interventions. Baseline data collection beyond the parks mentioned and repeated monitoring will, however, require sustainable funding and dedicated human capital, which should be accounted for in future budgeting and funding applications.

Conclusion

Alien species management in SANParks is at an important junction, providing not only many opportunities but also substantial challenges and threats. The NEM:BA regulations provide an opportunity for much needed reorganisation and prioritisation of key targets, whether priority species or areas. However, increases in the number of alien species that are mandated to receive attention mean that difficult decisions are required to determine optimal allocation of funds. It is likely that additional funding streams will be required to maintain the status of areas currently being managed, as well as resources for the new species and areas that will be prioritised. The threat however is that should funding be reduced or reallocated, some areas that were under control will return to an invaded state without some level of follow-up or maintenance control.

Protected areas form a nexus between conservation and society. With a broad constituency across the 5.2 million annual visitors (SANParks 2015), SANParks should play a large role in creating awareness of alien species invasions. For South African visitors, SANParks should also be a source of awareness and information not only of the threat of IAS but also the NEM:BA regulations to gain additional support for implementation.

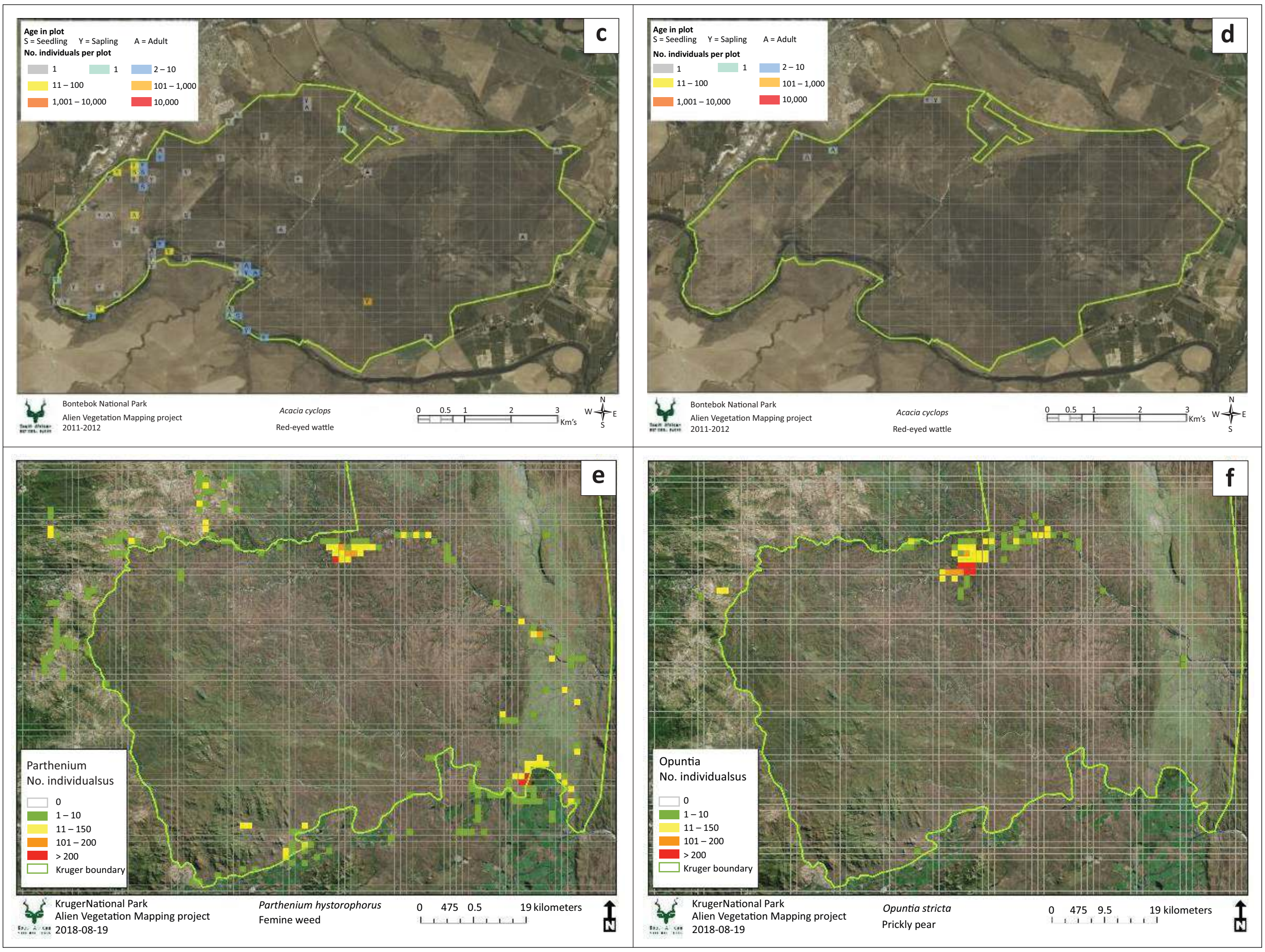
Globally, PA organisations are recognising the risk posed to the biodiversity entrusted to their care and the severe state of invasions already found in some PAs (see examples in Foxcroft et al. 2013). While there are many challenges that PAs may face in trying to implement management programmes (Tu & Robison 2013), there are numerous tools



Source: Figure a–d courtesy of C. Cheney; e–f courtesy of S. MacFadyen

(a) *Acacia cyclops* and (b) *A. saligna* in Table Mountain, (c) *A. cyclops* and (d) *A. saligna* in Bontebok, (e) *Parthenium hysterophorus* and (f) *Opuntia stricta* in Kruger.

FIGURE 5: Invasive alien plant distribution surveys.



Source: Figure a–d courtesy of C. Cheney; e–f courtesy of S. MacFadyen

(a) *Acacia cyclops* and (b) *A. saligna* in Table Mountain, (c) *A. cyclops* and (d) *A. saligna* in Bontebok, (e) *Parthenium hysterophorus* and (f) *Opuntia stricta* in Kruger.

FIGURE 5 (Continues...): Invasive alien plant distribution surveys.

and examples that can be used to assist managers in developing approaches to managing IAS. However, even where management approaches are in place, an ubiquitous problem is the lack of monitoring and the basic data, such as species lists and distribution data, required to inform programmes and assess progress. Unless larger proportions of funding are allocated to formal monitoring programmes, with long-term commitments, the sustainability of large control programmes may be in jeopardy.

SANParks is in the unenviable position of having recorded 869 alien species, with extensive alien plant lists such as 251 species in Garden Route and 363 in Kruger. Moreover, 263 species found in SANParks are listed in the NEM:BA alien and invasive species regulations. However, SANParks is acutely aware of the status and has been implementing a large-scale management programme in a bid to minimise the potential impacts to biodiversity. The organisation is instituting processes and frameworks to assist in improving planning and implementing monitoring programmes to determine trends in future progress. This review can therefore be used in various ways by providing an updated status and species list against which indicators can be assessed for detecting trends in invasion, providing the information required as part of the National Status Report and providing a basis for evaluating management implementation with a view to ongoing improvements (Wilson et al. 2017).

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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

L.C.F. was the project leader, collected and checked species data and led the writing of the manuscript. N.J.v.W. collated and corrected the species lists, analysed the lists and wrote the manuscript. J.A.B. collated data and checked the species lists. N.S.C. provided data on costs of control and list of species controlled by Biodiversity Social Projects.

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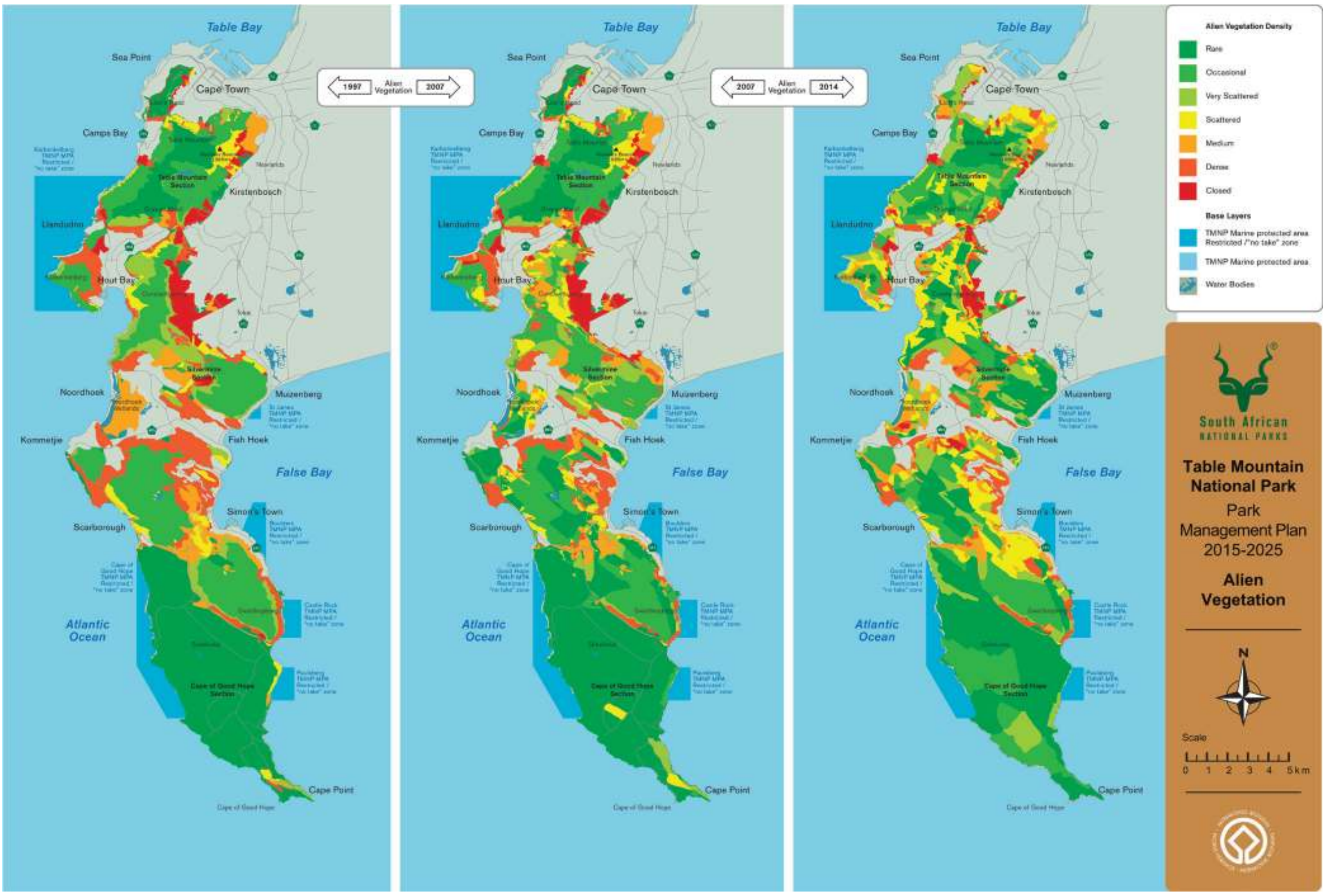
Appendix 1



Source: TMNP Management Plan, SANParks 2016

FIGURE 1-A1: Alien vegetation density of Table Mountain National Park over the past decades.