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Historical costs and projected future scenarios for the management of invasive alien plants in protected areas in the Cape Floristic Region

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ABSTRACT

Scarce funds for conservation need to be optimally used, yet there are few studies that record the costs and projected outcomes of major conservation efforts. Here we document the historical costs and extent of efforts to control invasive alien plants in the protected areas of the Cape Floristic Region of South Africa, a biodiversity hotspot of global importance. We also estimate the resources that would be needed to bring the problem under control within a reasonable timeframe, under a range of scenarios of funding, rate of spread, and management effort. Trees and shrubs in the genera *Pinus*, *Acacia*, *Eucalyptus*, *Hakea*, *Leptospermum* and *Populus* were estimated to cover >66% of 750 000 ha at various densities in 2014. Historical costs of attempts to control these invasions over the past 20 years amounted to ZAR 564 million (~38 million US$), most of which (90%) was expended on *Acacia*, *Pinus* and *Hakea* in that order. The estimated cost to bring remaining invasions under control was between ZAR 170 and 2608 million (~1.3 and 174 million US$), depending on the scenario. Only substantial increases in annual funding under a scenario of low spread (4%), and removal of some taxa from the control programme, would allow for control to be achieved in <20 years. Even with increased spending, control would probably not be achieved under less favourable but more probable scenarios. Our findings suggest that, unless bold steps are taken to improve management, then a great deal of money would have been, and will continue to be, wasted. The essential element of an improved management approach would be to practice conservation triage, focusing effort only on priority areas and species, and accepting trade-offs between conserving biodiversity and reducing invasions.

1. Introduction

It is well known that the many needs for conservation action cannot be met by available resources (Murdoch et al., 2011), and conservation actions therefore need to be prioritized (Wilson et al., 2007). Prioritization alone is also not sufficient to ensure optimal outcomes, and conservation scientists need to shift some of their attention towards the design of effective policies and frameworks for action. In addition, there is a growing realization that using funds to set aside land in protected areas will not in itself achieve goals unless a sufficient proportion of the available funds are utilized to reduce threats, including legal and illegal harvesting of natural resources, pollution, climate change and invasion by alien species (Wilson et al., 2007). Moreover, we may need to practice conservation triage to achieve effective outcomes, by focusing sufficient resources on those priority areas where goals can be achieved. Following the basic principles of conservation triage should not be seen as a defeatist conservation ethic, but rather as being no more than the efficient allocation of resources, and that by failing to follow the basic principles of triage, we would simply be wasting resources (Bottrill et al., 2008). Finally, although many existing conservation frameworks claim to emphasize efficiency or wise investment, few have examined the actual costs of interventions, leading to calls for conservation biologists to make a major effort to include and record the costs of conservation actions, so that returns on investment can be demonstrated (Murdoch et al., 2011).

The establishment and management of protected areas are key components of global strategies to conserve biodiversity. South Africa's Cape Floristic Region (CFR) is one of the planet's recognised biodiversity hotspots (Mittermeier et al., 2011), and detailed plans have been developed to expand the network of protected areas in the CFR, to capture and conserve a representative sample of the region's biodiversity (Cowling et al., 2003; South African Government, 2008). However, once proclaimed, protected areas need to be actively managed if the biodiversity of these areas is to survive the multiple threats that they face. In the CFR in particular, invasive alien species are arguably the largest of

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these threats (van Wilgen, 2013). Over 1000 indigenous plant species are threatened by invasive alien species in the CFR (Raimondo et al., 2009), and if invasions were to reach the full extent of their potential distribution, overall biodiversity (expressed as a biodiversity intactness index, Scholes and Biggs, 2005) in the region could be reduced by as much as 40% (van Wilgen et al., 2008). In addition, most of the region's watersheds lie within protected areas, where ongoing invasion by trees and shrubs threatens to reduce surface water runoff by as much as 36% (if allowed to reach the full extent of their potential distribution), with substantial economic impacts (van Wilgen et al., 2008).

In response to concerns about the loss of water resources and biodiversity, the South African Department of Water Affairs launched a large programme to clear invasive alien plants in 1995 (Koenig, 2009). This programme, Working for Water, operates at a national scale, and within the CFR it provides funding for the control of invasive alien plants both inside and outside of protected areas. In places where the programme has been active in the CFR, there are indications that the area occupied by invasive alien plants has been reduced by almost 50% (McConnachie et al., 2016), but the programme has only reached a small proportion (4–13%) of the total invaded area (van Wilgen et al., 2012). Importantly, at the scale of the CFR's protected areas, there has been no attempt to date to accurately quantify the magnitude of the problem, or the cost of control, nor has it been possible to assess progress towards reducing invasions due to the lack of a monitoring programme (van Wilgen and Wannenburgh, 2016). The study described here therefore set out to assess these issues. We sought to quantify the magnitude of the invasive alien plant problem in the major protected areas of the CFR; to document the extent and costs of substantial control efforts over the past two decades, and to estimate the resources that would be needed to reduce the problem to a maintenance level at which it could be managed sustainably (see Section 2.5 for a definition of maintenance level). We use the findings to support suggestions for changes that should improve the effectiveness of management.

2. Methods

2.1. Study sites

Our study was conducted in 25 protected areas (3 National Parks and 22 Provincial Nature Reserve complexes) covering approximately 750 000 ha in the CFR (Table 1; Fig. 1). The Nature Reserves are managed by the provincial authority (CapeNature), and the National Parks by South African National Parks (SANParks). The natural vegetation is dominated by fynbos shrublands that vary according to substrate (sandstone, granite, limestone or shale), as well as other shrubland types (renosterveld and strandveld). There are also smaller areas of Afro-temperate forest; these are not extensive except in the Garden Route National Park. The topography varies from relatively flat (mainly coastal) areas, to rugged mountainous areas, and all are invaded to a lesser or greater degree by invasive alien trees and shrubs (Fig. 2). Alien plant control programmes were initiated in these areas in the 1970s (Fenn, 1980) or earlier (Macdonald et al., 1989), and in 1995 they were substantially expanded with the initiation of the Working for Water programme, in response to growing concerns about impacts on water resources and biodiversity. Working for Water provides management capacity and labour to control invasive alien plants in protected areas, in collaboration with the responsible authorities, and with the dual goals of managing invasive alien plants and creating employment opportunities (van Wilgen and Wannenburgh, 2016).

2.2. Extent of alien plant invasions

The Nature Reserves managed by CapeNature are divided into management units of between 5 and 200 ha. In each management unit, we estimated the cover of invasive alien trees and shrubs in the genera *Pinus* (pine trees introduced from North America and Europe), *Acacia* (Australian wattle trees), *Eucalyptus* (Australian gum trees), *Hakea* (Australian shrubs), *Leptospermum* (Australian myrtle trees) and *Populus* (North American poplar trees) in 2014. These six genera account for almost all of the invasive alien plant cover in the protected areas assessed here. We estimated the percentage cover of each genus in each management unit in collaboration with experienced reserve staff, using a range of products, including high-resolution satellite imagery, aerial photography, and Google Earth. In some cases, where there was uncertainty about the estimates, they were verified in the field. Similar procedures were used to estimate cover in the Table Mountain and Agulhas National Parks, except that management units were larger (up to 1250 ha) in some cases. In the Garden Route National Park, we used alien plant cover data collected by Vromans et al. (2010), who divided the area into homogenous vegetation units, using 1:10 000 orthophoto maps as a base. The percentage

Table 1
Salient features of 25 protected areas in the Cape Floristic Region, South Africa.

Protected area	Area (ha)	Centre point	Location and topography	Dominant vegetation (after Mucina and Rutherford, 2006)
Agulhas National Park	21 693	34° 48′ S; 19° 59′ E	Coastal	Strandveld; sandstone fynbos
Cederberg Nature Reserve	33 717	32° 30′ S; 19° 00′ E	Inland; mountainous	Sandstone fynbos
De Hoop Nature Reserve	34 151	34° 28′ S; 20° 30′ E	Coastal	Limestone fynbos; dune strandveld
Gamkaberg Nature Reserve	39 307	33° 40′ S; 22° 00′ E	Inland; mountainous	Sandstone fynbos
Garden Route National Park	115 782	34° 00′ S; 24° 00′ E	Coastal; mountainous	Sandstone fynbos; southern coastal forest
Genadendal Nature Reserve	26 619	34° 00′ S; 19° 30′ E	Inland; mountainous	Sandstone fynbos; shale fynbos
Goukamma Nature Reserve	2282	34° 10′ S; 22° 50′ E	Coastal	Southern Cape dune fynbos
Grootvadersbosch Nature Reserve	26 044	33° 55′ S; 20° 50′ E	Inland; mountainous	Sandstone fynbos; southern Afrotemperate forest
Groot Winterhoek Nature Reserve	27 512	33° 00′ S; 19° 10′ E	Inland; mountainous	Sandstone fynbos
Hottentots-Holland Nature Reserve	30 519	34° 10′ S; 19° 10′ E	Inland; mountainous	Sandstone fynbos; shale fynbos
Jonkershoek Nature Reserve	15 397	34° 00′ S; 19° 00′ E	Inland; mountainous	Sandstone fynbos; granite fynbos
Kammanassie Nature Reserve	27 056	33° 35′ S; 22° 51′ E	Inland; mountainous	Sandstone fynbos; shale fynbos
Keurbooms Nature Reserve	898	33° 58′ S; 23° 25′ E	Coastal	Sandstone fynbos; southern Afrotemperate forest
Kogelberg Nature Reserve	24 508	34° 16′ S; 19° 00′ E	Coastal; mountainous	Sandstone fynbos
Limietberg Nature Reserve	44 804	33° 31′ S; 19° 09′ E	Inland; mountainous	Sandstone fynbos; granite fynbos
Marloth Nature Reserve	13 752	34° 00′ S; 20° 20′ E	Inland; mountainous	Sandstone fynbos; shale fynbos
Matjiesrivier Nature Reserve	12 806	32° 25′ S; 19° 20′ E	Inland	Quartzite fynbos
Outeniqua Nature Reserve	38 902	33° 52′ S; 22° 36′ E	Coastal; mountainous	Sandstone fynbos
Riverlands Nature Reserve	1716	33° 30′ S; 18° 40′ E	Inland	Granite fynbos; dolerite renosterveld
Robberg Nature Reserve	186	34° 08′ S; 23° 25′ E	Coastal	Sand fynbos; seashore (azonal) vegetation
Swartberg Nature Reserve	131 557	33° 21′ S; 22° 19′ E	Inland; mountainous	Sandstone fynbos; shale renosterveld
Table Mountain National Park	26 554	34° 09′ S; 18° 23′ E	Coastal; mountainous	Sandstone fynbos; granite fynbos
Vrolijkheid Nature Reserve	1963	33° 50′ S; 19° 55′ E	Inland	Shale renosterveld
Walker Bay Nature Reserve	8647	34° 30′ S; 19° 20′ E	Coastal	Dune strandveld
Waterval Nature Reserve	32 044	33° 21′ S; 19° 05′ E	Inland; mountainous	Sandstone fynbos