Biological Conservation 148 (2012) 28–38

Contents lists available at SciVerse ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/biocon

An assessment of the effectiveness of a large, national-scale invasive alien plant control strategy in South Africa

Brian W. van Wilgen [a,*], Greg G. Forsyth [a], David C. Le Maitre [a], Andrew Wannenburgh [b], Johann D.F. Kotzé [c], Elna van den Berg [c], Lesley Henderson [d]

[a] *Centre for Invasion Biology, CSIR Natural Resources and the Environment, P.O. Box 320, Stellenbosch 7599, South Africa*
[b] *National Working for Water Program, Department of Environmental Affairs, Private Bag X4390, Cape Town 8000, South Africa*
[c] *Institute for Soil, Climate and Water, Agricultural Research Council, Private Bag X79, Pretoria 0001, South Africa*
[d] *Plant Protection Research Institute, Agricultural Research Council, c/o SANBI, Private Bag X101, Pretoria 0001, South Africa*

ARTICLE INFO

Article history:
Received 26 August 2011
Received in revised form 30 November 2011
Accepted 16 December 2011
Available online 18 February 2012

Keywords:
Adaptive management
Biological control
Biological invasions
Ecosystem services
Invasive alien species
Working for Water

ABSTRACT

This paper presents an assessment of a large, national-scale alien plant control program that has operated in South Africa for 15 years. We reviewed data from three national-level estimates of the extent of invasion, records of the costs and spatial extent of invasive species control operations, assessments of the effectiveness of biological control, and smaller-scale studies. The 19 most important invasive taxa, mainly trees, in terrestrial biomes were identified. The effectiveness of control efforts on the extent of invasion of these taxa was assessed. Control costs over 15 years amounted to 3.2 billion rands (US$457 million), more than half of which was spent on 10 taxa, the most prominent being in the genera *Acacia*, *Prosopis*, *Pinus* and *Eucalyptus*. Despite substantial spending, control operations were in many cases applied to a relatively small portion of the estimated invaded area, and invasions appear to have increased, and remain a serious threat, in many biomes. Our findings suggest that South Africa's national-scale strategy to clear invasive alien plants should be substantially modified if impacts are to be effectively mitigated. Rather than attempting to control all species, and to operate in all areas, a more focused approach is called for. This would include prioritising both the species and the areas, and setting goals and monitoring the degree to which they are achieved, within a framework of adaptive management. A greater portion of funding should also be directed towards biological control, where successes have been most notable.

1. Introduction

Alien plant invasions are a large and growing threat to ecosystem integrity in many parts of the world, where they change the structure and functioning of ecosystems, with negative consequences for the conservation of biodiversity and the delivery of ecosystem services (Mooney, 2005). There are several examples of high-level strategies to deal with the problem of invasive alien species, both at global (McNeely et al., 2001) and national levels (Federal Interagency Committee, 1998; Anonymous, 1999). These strategies all call for reducing the risk of new introductions of invasive species, the control of existing invasions to mitigate impact, and the establishment of management and legislative capacity to guide implementation. Interventions that give effect to national strategies are often a major component of the management of terrestrial ecosystems (Wittenberg and Cock, 2005), and attempts to control invasive species can and have brought about substantial levels of mitigation (Simberloff et al., 2011).

In South Africa, the strategy over the past 15 years has been to implement a large, national-scale, government-sponsored alien plant control program (van Wilgen et al., 1998, 2011a; Koenig, 2009). Known as 'Working for Water', the program has adopted a comprehensive approach to alien plant control, characterised by several distinguishing features. The program combines mechanical and chemical control of all invasive alien plant species in targeted areas with the provision of employment to people from impoverished rural communities as its main thrust. This has been supplemented by (1) the development of biological control options that target selected priority alien plant species (Zimmermann et al., 2004; Moran et al., 2005); (2) the promulgation of legislation that requires landowners to deal with the problem (van Wilgen et al., 2011a); and (3) the encouragement of systems of payment for ecosystem services that will generate funding to support control programs (Turpie et al., 2008). Few countries have implemented similar control programs, and we are not aware of any that have

* Corresponding author. Tel.: +27 21 888 2400; fax: +27 21 888 2693.
E-mail address: bvwilgen@csir.co.za (B.W. van Wilgen).

0006-3207/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
doi:10.1016/j.biocon.2011.12.035

assessed the effectiveness of such operations at a national scale over one and a half decades.

When Working for Water was initiated in 1995, an attempt was made to quantify the extent of invasions at a national scale (Versfeld et al., 1998), to provide inputs for management planning (see, for example, Le Maitre et al., 2002), to assist in the quantification of impacts (Le Maitre et al., 2000), and to serve as a baseline against which to assess trends. Working for Water has since spent 3.2 billion rands (expressed as 2008 rands, approximately 457 million US$) on alien plant control. Whether or not the correct, top-priority, species are being targeted, and whether or not progress has been made in reducing the extent of invasions, remains uncertain. While Working for Water has kept records of expenditure per species and geographic area since 2002, the ability to address questions regarding the effectiveness of their operations is limited because the program has not implemented an effective system of monitoring and evaluation (Levendal et al., 2008). A preliminary assessment of progress (Marais et al., 2004) was made by comparing the rate of clearing to the rough approximations of invaded area in 1996. Marais et al. (2004) concluded that, at the prevailing rates of clearing, and depending on the species, it would take between two and 83 years to clear the most important species, but with the important, albeit unrealistic, assumption that no further spread would take place during this time.

Working for Water has taken several steps to assess trends and changes in the situation. These include the commissioning in 2005 of a second national-scale assessment of the extent of invasion (Kotzé et al., 2010), providing ongoing financial support to a national-scale atlas project (Henderson, 2007), and supporting (or acting as a catalyst for) several finer-scale research projects. The study reported in this paper used information from all of the above sources to assess the effectiveness of Working for Water in suppressing and controlling invasive alien plants in South Africa, and we propose improvements that could increase efficacy and success.

2. Methods

2.1. Studies by biome

Working for Water is a national-level initiative in South Africa, operating in all nine of the country's provinces and across all major terrestrial biomes. The country's indigenous vegetation is diverse, including nine terrestrial biomes, and high levels of endemism are a feature of several biomes (Mucina and Rutherford, 2006). We used biomes as a basis for our assessment, as each biome is characterised by particular features (e.g. fire and rainfall regimes, and levels of herbivory), and is invaded by distinctive suites of alien plant species (Table 1). Much of the natural vegetation remains untransformed, and provides important ecosystem services in the form of livestock production from rangelands, water production from mountain catchments, and conservation and tourism benefits from protected and other areas. All of these services are under considerable threat from invasive alien plants (van Wilgen et al., 2008a). While invasive alien plants can bring benefits, these benefits are, by and large, outweighed by the negative impacts (see, for example, De Wit et al., 2001; van Wilgen et al., 2011b).

2.2. Extent of invasions

There have been three national-scale, and several smaller-scale, estimates of the extent of alien plant invasion in South Africa, compiled over the past 15 years. We used these estimates to identify the most important species involved and to assess, within the limits of the data (see Section 2.6) the extent to which they have impacted on the terrestrial biomes of South Africa.

The first estimate was initiated in 1994 through the Southern African Plant Invaders Atlas (SAPIA, Henderson, 1998). SAPIA is an ongoing project, which aims to collate information on the distribution and abundance of invasive and naturalised alien plants in southern Africa. Initially, the atlas was populated with data collected during roadside surveys, but was later broadened to accept inputs from volunteers, who were supplied with survey sheets to ensure the standardisation of inputs. By 2011, the SAPIA database contained approximately 72,300 records of alien plant species presence and abundance within quarter degree squares (a grid of approximately 25×25 km). Henderson (2007) used the SAPIA database to estimate a prominence value for each species, calculated as $P_i = A_i/A + R_i/R$ where P_i = the prominence of species i in a particular area, A_i = the abundance of species i, A = the abundance of all species, R_i = the total number of records of species i and R = the total number of records of all species.

The second estimate was made in 1996 (Versfeld et al., 1998; Le Maitre et al., 2000). Data on the extent and location of the areas invaded by all important invasive alien plant taxa were obtained from a variety of sources for this survey, including some detailed field mapping, mainly at a 1:250,000 scale, with some at 1:50,000 and at 1:10,000. The species data were captured, together with estimates of their density for each of the mapped areas, in a GIS database. We converted these density estimates to 100% equivalent cover ("condensed ha") for comparison to other surveys, using the formula $C = d/100 \times A$, where C is the area expressed as condensed ha, d is the density (% cover), and A is the area in ha within which the density was assessed. The authors of the survey noted that the findings were approximations, and needed to be interpreted with caution.

A third estimate in 2008 mapped 27 alien plant taxa (Kotzé et al., 2010). Species in the genera *Pinus* and *Eucalyptus* and some *Acacia* were mapped collectively. Prior to the survey, the entire country (excluding most of the arid biomes – Desert, Nama karoo, succulent karoo, and arid portions of the grassland and savanna biomes – and the Kruger National Park) was divided into homogenous environmental units (HEUs), based on unique combinations of three classes of rainfall, soil depth, clay content in the B-horizon of the soil, and two classes of terrain in each tertiary (3rd order) catchment. Those portions of HEUs that had been transformed were excluded. The remaining portions of the HEUs were then sampled at 32,330 points. Points were allocated to HEUs in proportion to their area, and then located at random within HEUs. At each sample point, the percentage cover of the three dominant alien plant taxa was estimated from low-flying fixed-wing light aircraft or helicopters on 100×100 m plots by observers who were familiar with invasive species in the area. A second set of 25,260 sample points were located on a grid of 1600×1600 m in a subsample of 205 quaternary (4th order) catchments (about 10% of the country), and results from this survey were used to verify broad levels of invasion detected in the national survey. Survey data were used to estimate mean percentage cover and coefficient of variation for each of the taxa in each HEU in each catchment. Areas were expressed as equivalent to 100% canopy cover (condensed ha, see above).

We obtained estimates of the extent of invasion per biome by creating subsets of the spatial databases described above using Mucina and Rutherford's (2006) biome boundaries. In the case of the SAPIA database, a biome-scale analysis of the data was already available (Henderson, 2007). Our analysis excluded the arid portions of the grassland and savanna biomes, which were not covered by Kotzé et al.'s (2010) survey. A recent estimate of the extent of invasion by *Prosopis* species was available for the Northern Cape Province (which includes large portions of the succulent karoo, Nama karoo, arid grasslands and arid savannas) (van den Berg, 2010). Control in these biomes has focussed almost entirely on