An integrated management plan for the control of *Opuntia stricta* (Cactaceae) in the Kruger National Park, South Africa

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Opuntia stricta is the most problematic alien plant species in the Kruger National Park (KNP) where 30000 ha around Skukuza have been invaded by the weed. Control of *O. stricta* is expensive and time consuming and there are insufficient resources available for the task at present. Biological control using the moth *Cactoblastis cactorum* has only been partially successful and herbicidal control remains the main method for tackling the problem. In order to optimise the control operation against *O. stricta*, a management plan has been developed for the KNP. The infested region of the park has been divided into 18 management units, each of which will be treated in turn. During the first three years the control operations will clear *O. stricta* from the peripheral units, to prevent the spread of the weed into other areas of the KNP, after which the central units will be tackled. The objective is to destroy all mature fruiting plants and those nearing maturity to curb long-range (seed) dispersal of the weed. The small juvenile plants, which are difficult to detect, will be suppressed by *C. cactorum*. After five years the problem should be contained to the extent that an ongoing 'holding' programme will be sufficient to keep the weed in check. The success of the plan will depend on increased resources being committed to alien plant control in the Kruger National Park.

Additional keywords: alien species, invasive, sour prickly pear, weed.

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Introduction

Alien biota violate the principal objective of the Kruger National Park (KNP), namely to maintain the integrity of biodiversity within the region. Invasive alien plants are regarded as the single most important threat to biodiversity in the KNP and there are currently 213 alien plant species that occur within KNP (Anon 1997). The most problematic of the alien plants is a North American cactus, *Opuntia stricta* Haworth. In spite of ongoing control efforts since 1987, *O. stricta* has been spreading at an accelerating rate in the Skukuza area and the plant poses a considerable threat to the entire KNP.

A major problem for the control of alien plants within the KNP is a chronic shortage of resources. There are 2288 man-days per annum available for weed control in the KNP (11 labourers with appropriate equipment). This allotment is insufficient to cope with the *O. stricta* problem, let alone all the other alien plant species. There is a desperate need for additional resources to be allocated to alien plant control in KNP, but until a commitment is made the problems caused by

invasive plants will be compounded. Work will only be possible on the most problematic species, notably the terrestrial species *O. stricta* and *Lantana camara* and the aquatic weeds *Pistia stratiotes* and *Eichhornia crassipes*, even though the best time to tackle alien plants is at the inception of the invasion process when the problem is confined to manageable levels.

In order to rationalise the control of *O. stricta;* and to ensure that the best use is made of the limited available resources, a strategic management plan has been compiled. The outline of the plan is presented in this paper. Although the plan deals specifically with the situation in KNP, the approach that has been adopted will be applicable to other regions where *O. stricta* or any other similar weed species is a problem.

Opuntia stricta in Kruger National Park

The first records of *Opuntia stricta* in the KNP were made in 1953 (Zeller 1996) when plants were found in the staff village at Skukuza. By 1980, *O. stricta* had spread into approximately 1000 ha of the park around Skukuza. By 1990 the infested area had increased to almost 19000 ha (unpublished reports) and currently the weed occurs over more than 30000 ha, of which 2000 ha is densely infested, 17000 ha is moderately dense and the rest is relatively sparse (Lotter 1996). A survey during 1996 of one densely infested area (1.3 ha in extent) showed that *O. stricta* accounted for 16 % of the basal ground-cover, with 99 single plants and 68 impenetrable clumps (each up to 65 m² in extent and consisting of several hundred plants). In the same area there were 97 other woody plants >0.5 m in height.

Opuntia stricta is currently confined to the vegetation type known as Sabie/Crocodile rivers thorn thickets (Gertenbach 1983). The topography of the infested area is moderately undulating to relatively flat but is intersected by numerous transitory streams that drain into the perennial Sabie River. A few granite hillocks (koppies) occur in the area and the altitude varies between 200–350 m above sea level. The area is underlain by archain granite and gneiss intersected by dolerite intrusions and normally has shallow soils. Where the soils are deeper, they become saturated with sodium. The vegetation in the area is dominated by an *Acacia nigrescens/Combretum apiculatum* association, in which two variations are distinguished, namely *C. apiculatum*-dominated uplands and *A. nigrescens*-dominated bottomlands. Both variations have characteristically dense shrubbery with a sparse field layer which is generally heavily grazed, particularly by impala, and thus fires are infrequent (Gertenbach 1983). The average daily maximum temperature is above 31 °C for the months November to March while sporadic frost occurs in the winter in the bottomlands. The average rainfall is approximately 525 mm per annum.

In the KNP *O. stricta* is spread by rivers, especially during flood events, and the seeds are dispersed by baboons *Papio ursinus*, elephants *Loxodonta africana*, and birds (Malan 1989; Hoffmann *et al. in press* a). A study of the seed germination and biology of *O. stricta* is being conducted to verify predictions that the weed has the potential to invade the whole of the KNP (Zimmermann 1996).

Control options

Mechanical

Mechanical control, which would entail uprooting and removing *O. stricta* plants for subsequent destruction, is too time consuming and expensive to be considered as a method of control.

Herbicides

Along with other *Opuntia* species, *O. stricta* is controlled very effectively by the herbicide monosodiummethylarsenate (MSMA). The stems of large plants (>12 cladodes) are injected with a solution made up of equal parts of MSMA and water while smaller plants and loose cladodes lying on the ground are soaked with a mixture of 1 part MSMA to 30 parts water applied from knapsack sprayers (Malan 1989). Trials are being conducted to determine whether the plants will succumb to lower doses of the herbicide under the conditions in which the plants occur in the Kruger National Park.

The application of herbicides is laborious and time-consuming. Many small plants and plants that are concealed by surrounding vegetation are overlooked during spray operations and some plants are not treated with the correct dose of herbicide. These plants, along with seeds in the soil, form a reservoir that replenishes the weed infestations and necessitates frequent follow-up treatments in previously treated areas.

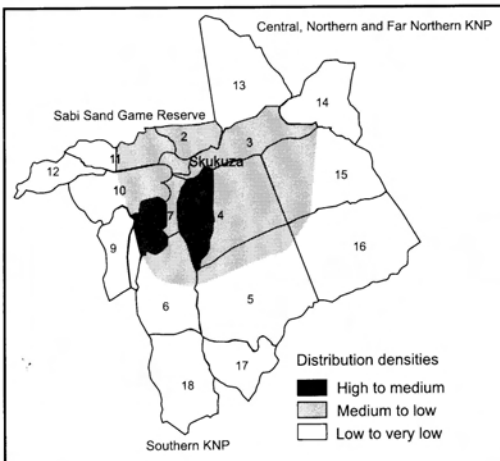
Biological control

The phycitid moth, *Cactoblastis cactorum*, was introduced into the KNP during 1988 in an attempt to control *O. stricta* biologically, as had been done so effectively using *C. cactorum* against *O. stricta* in Australia in the early part of this century (Dodd 1940). Although *C. cactorum* has been established on other *Opuntia* species in South Africa since 1934 (Pettey 1948), the infestation of *O. stricta* in the KNP was geographically isolated from other *Opuntia* infestations and *C. cactorum* had not dispersed into the KNP on its own. Following the release, *C. cactorum* readily became established in the KNP but, for reasons that are not clear, it has not reached levels of abundance that are needed to provide effective control of the weed (Hoffmann *et al. in press* a). However, the moth is playing an important role in areas that have been treated herbicidally because the larval damage is sufficient to curb the growth of the small plants, thereby slowing the rate of recovery of the weed infestations and extending the time it takes for the plants to reach fruiting size (>28 cladodes) (Hoffmann *et al. in press* b).

In an effort to enhance the biological control of *O. stricta*, a cochineal insect species, *Dactylopius opuntiae*, that has played a major role in the successful biological control of *O. ficus-indica* and *Opuntia lindheimeri* in South Africa, was also released in the KNP on at least three occasions, but without success (Zeller *pers. comm.*). In South Africa, *D. opuntiae* only occurs on *O. stricta* in regions where *O. stricta* grows sympatrically with *O. ficus-indica*. The occurrence of the insects on *O. stricta* is almost certainly a 'spill-over' from *O. ficus-indica* and *D. opuntiae* is unable to persist on *O. stricta* for more than a single generation. Efforts are currently underway to establish a more suitable strain of *D. opuntiae* in KNP. The new strain originates from North America and was instrumental in the biological control of *O. stricta* for many years in Australia, from where it was imported to South Africa during January 1997.

The management plan

Although the eradication of *O. stricta* from the KNP would be the most desirable situation, this objective cannot possibly be accomplished, and maintenance of the weed at acceptable levels is the only viable control option. Besides reducing the density of the weed, a primary aim is to prevent it from expanding its range within the KNP by preventing the plants from producing fruits. In the KNP *O. stricta* plants double in size on average each year and first produce fruit when they consist of 28 cladodes or are approximately five years old (Hoffmann *et*



Phase 1 (Block numbers in order of priority)

Main work force – 3, 5, 6, 8, 10, 11, 2
Reaction work force 13, 14, 15, 16, 17, 18, 9, 12

Phase 2
Main work force – 4, 7, 1
Reaction work force nascent – foci or small concentrations of adult plants reported. Otherwise, to integrate with main work force.

Phase 3
Follow up work and initial control of any new blocks which may become infested. To follow same sequence as initial control but must remain negotiable as the dynamics of the situation may change. New blocks may become infested. The guidelines for determining priority areas must by used to interpret the situation as it changes and to make appropriate adjustments to work schedules as and when necessary.

Control work never yet undertaken in blocks 3, 5, 6, 9 & 11–18. Total area of numbered blocks = 66961 ha.

Fig. 1. The configuration of the management units for control of *O. stricta* in KNP.

al. in press a). A primary objective is to destroy all mature, fruit-producing plants and then to maintain the plants in the residual populations of the weed at a size where no fruits are produced. To achieve these objectives, the following management plan has been developed. The constraints imposed by the limited resources that are currently available are addressed.

The first procedure was to divide the 30000 ha of infested land into 18 manageable units for control purposes (Fig. 1). The management units vary in size and the boundaries are demarcated by rivers, water sheds, roadways or fire-breaks. The status of *O. stricta* in each unit has been defined and rated according to the density of the weed, the size of the plants and the proximity of uninfested areas. This process enabled the different management units to be given a priority rating so that each could be tackled in sequence according to specified criteria (see below).

In each management unit, the initial herbicide applications will be applied principally to the large plants in order to prevent fruit production. The labourers will move relatively rapidly through the infested areas inoculating all the conspicuous plants. Small plants that are difficult to find will be ignored. This will enable coverage of greater areas and will ensure that the most problematic plants (i.e. those that are able to produce seeds) are removed from the populations. It will also ensure that a reasonable population of small plants is left to sustain a population of *C. cactorum* whose damage will curb the recovery of the weed population (Hoffmann *et al. in press* b).

Initially, the management units on the periphery of the infested region are to be treated as a priority as these areas provide most of the propagules that spread into uninfested areas. The northern periphery of the area mapped above will be treated before the southern areas, to prevent the spread of *O. stricta* into the greater portion of the KNP, which has extensive open, semi-arid areas where *O. stricta* has the potential to thrive and reach high densities. It is estimated that it will take three years to deal with the

peripheral units after which the infestations in the central management units will be given attention. The central area will take approximately two years to clear.

After each block has been treated, it will be monitored to determine when the residual plants are about to reach maturity (28 cladodes in size) and start to produce fruits. Hoffmann *et al.* (*in press* b) have shown that this will probably happen after 4–5 years. The block will then be treated with herbicides again, adopting the same procedure as that during the initial treatment (i.e. applying herbicides to the easily-located larger plants only). Follow-up treatments will be conducted predominantly during the dry winter months of the year when the vegetation is less luxuriant and the cactus plants are easier to detect. Wherever possible, recently-burnt areas will be treated before the planned schedule because the green cactus plants are easily located among the ashes and scorched vegetation and there is an increased likelihood of detecting and killing the plants.

Uninfested areas will be continuously monitored for the weed and newly-discovered isolated foci of *O. stricta* will be treated immediately. In these cases, all of the plants will be treated with herbicides to try to eliminate all the plants in the isolated infestations of the weed.

Control work schedule

At least twenty labourers are needed to achieve the first objective, namely the initial treatment of all of the management units within five years. For most of the time, the labourers will operate in two distinct groups. One group, consisting of at least two teams of seven workers each, will focus on the initial treatment of plants in the management units. The other group of six permanent labourers and any available part-time assistants (e.g. student and co-opted labourers from other operational units) will deal with follow-up treatments and treatment of isolated nascent foci that are detected. At times, the second group may be integrated with the first group to apply initial treatments. The arrangement of having two groups provides flexibility and will enable appropriate adjustments to be made to work schedules.

As control operations proceed, progress will be monitored to ensure that the objectives are achieved. Fixed point photographic records will be kept of selected densely-infested areas to record the 'before-and-after' effect of control operations. In addition, the numbers of *O. stricta* plants in different size categories will be counted along fixed transects. The control techniques that have been adopted will also be monitored to determine deficiencies in terms of rate of progress, labour requirements, ease of application and volumes of herbicide required.

The successful implementation of this Strategic Management Plan will depend largely on the support of all field staff within KNP, particularly the game rangers whose task it is to regularly patrol specified areas. The rangers will be required to locate and report on the occurrence of new foci and localised infestations in areas outside the current management units. The reaction work-force in particular will rely on reports received from the Rangers.

Five years after commencement of this management plan there should be no *O. stricta* plants setting fruit within KNP. Thereafter the *O. stricta* plants in residual populations of the weed will need to be prevented from reaching maturity through regular follow-up work to be carried out at intervals of approximately four years in each management unit. The success of the plan will depend on a commitment by the KNP management to allocate additional resources for alien plant control within the KNP for the next five years. The initial expenses are an investment

for the future because once the problem has been contained, the costs of keeping *O. stricta* under control will be minimal compared to those that are currently required.

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