# Alien plant species list and distribution for Camdeboo National Park, Eastern Cape Province, South Africa

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## ABSTRACT

Protected areas globally are threatened by the potential negative impacts that invasive alien plants pose, and Camdeboo National Park (CNP), South Africa, is no exception. Alien plants have been recorded in the CNP since 1981, before it was proclaimed a national park by South African National Parks in 2005. This is the first publication of a list of alien plants in and around the CNP. Distribution maps of some of the first recorded alien plant species are also presented and discussed. To date, 39 species of alien plants have been recorded, of which 13 are invasive and one is a transformer weed. The majority of alien plant species in the park are herbaceous (39%) and succulent (24%) species. The most widespread alien plant species in the CNP are *Atriplex inflata* (= *A. lindleyi* subsp. *inflata*), *Salsola tragus* (= *S. australis*) and cacti species, especially *Opuntia ficus-indica*. Eradication and control measures that have been used for specific problematic alien plant species are described.

**Conservation implications:** This article represents the first step in managing invasive alien plants and includes the collation of a species list and basic information on their distribution in and around the protected area. This is important for enabling effective monitoring of both new introductions and the distribution of species already present. We present the first species list and distribution information for Camdeboo National Park.

## INTRODUCTION

Protected areas globally are under threat from invasive alien plants (Pauchard & Alaback 2004), as they change habitats and threaten resources, ecosystem services and indigenous species. Alien plants enter parks in various ways; they are brought into the parks by people, wildlife, wind, water and vehicles (National Park Service 1996). Further, alien plant species with established populations on park boundaries frequently encroach into the parks. For these reasons, a number of South Africa's national parks, for example Table Mountain National Park (Alston & Richardson 2006) and Kruger National Park (Foxcroft 2007), have been shown to be threatened by invasive alien plants.

The Eastern Cape Province of South Africa falls within the Albany Centre for Endemism, which has the highest number of plant extinctions, mainly as a result of agriculture, overgrazing, urbanisation and invasive alien plants (Smith & Wilson 2002). Of the 4.7% of formally protected land in the Eastern Cape, 2.1% is located in the Camdeboo Municipality (Smith & Wilson 2002). Although there are major data deficiencies, invasive alien plants are believed to cover between 0.15% and 0.79% of the Eastern Cape surface area (CSIR 2004). Climate change and invasive alien plants are regarded as the major threats to Camdeboo National Park (CNP), the largest protected area within the Albany Centre of Endemism (Camdeboo National Park 2006).

Very few records of alien plants existed prior to 1981, and it is thus important to document alien plant introductions into the park to enable park management to prevent or mitigate the impact of alien species. Of serious concern to CNP management is the fact that it is surrounded by a variety of land use types, including suburban areas, garbage disposal sites, quarries, and agricultural areas, all of which are likely sources of propagules of invasive alien plant species. Moreover, a river runs from the town of Graaff-Reinet through the CNP, and the park includes an artificial impoundment (Nqweba Dam). These water bodies and associated disturbances are also likely to transport and promote alien plant invasion.

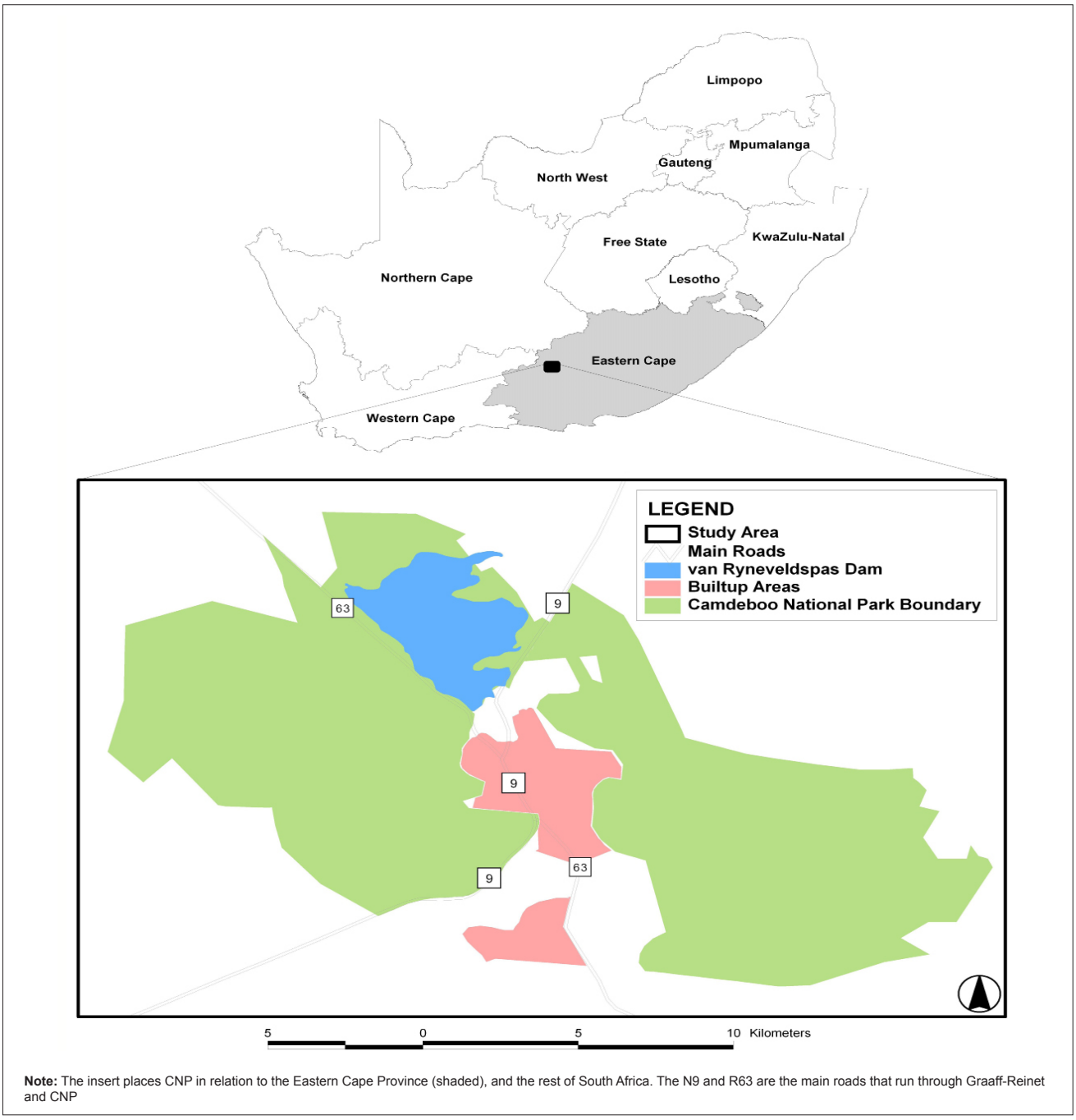
A species list provides a baseline for monitoring and managing alien plants that may threaten conservation management. Species checklists are used by biologists to keep records of the numbers, types and categories of species groups in a defined area, and are a starting point towards effective management of either problematic indigenous or alien species (Foxcroft *et al*. 2003) in a specific habitat, area, region, ecosystem, biome or country.

The aims of this article are to present a species list of alien plants for the CNP, together with distribution maps for 15 alien plant species recorded between 1981 and 2008, and to examine changes in species distribution patterns over this period.

## METHODS

### Study site

CNP surrounds the town of Graaff-Reinet (Figure 1), located in the Camdeboo Municipality of the Eastern Cape Province of South Africa. The CNP lies at the foothills of the Sneeuberg range, with a small section of low-lying plains included within the boundaries, and ranges topographically between 740 and 1480 metres above sea level. The climate is semi-arid, with 32% of the average annual rainfall of 336 mm occurring during the hottest months of the year (February–April). The CNP also experiences snow, fog and frost, with a maximum summer temperature of 43°C and a minimum temperature of –3 °C in winter. The hydrology of CNP is determined by its location at the edge of the Great Escarpment, which has six seasonal rivers (Sundays, Gats, Melk, Camdeboo, Pienaars and Erasmuskloof Rivers) draining into the Nqweba Dam in the central area of the park.




**Note:** The insert places CNP in relation to the Eastern Cape Province (shaded), and the rest of South Africa. The N9 and R63 are the main roads that run through Graaff-Reinet and CNP

**FIGURE 1**
Location and extent of the CNP and Graaff-Reinet in the Eastern Cape Province of South Africa

Proclaimed in 2005, the CNP is one of 22 protected areas proclaimed under the management of South African National Parks. However, it was first proclaimed as a provincial reserve (Karoo Nature Reserve) in 1979. Prior to 1979, the CNP area was used as town commonage with tenants grazing their livestock, thus contributing to overgrazing and erosion of some areas (Burdett 1995). Prior to colonial settlement, the land was used by the early, mid and late Stone Age people, as well as the Khoisan hunters and herders in the late Stone Age. The Inqua tribe occupied the park area in the mid-1600s with their cattle and fat-tailed sheep. White farmers settled on the Camdeboo Plains and Sneeuberg in 1770 and introduced merino sheep and angora goats, as well as alien plants (Burdett 1995). In the ensuing years, overgrazing and the effects of alien plants resulted in soil erosion and an increase in woody species and unpalatable plants (CNP 2006).

The geological systems of CNP consist of very thick layers of near horizontal strata of sedimentary rocks, with the largest parts covered with alluvium, gravel, sand, mud and wash stone of recent origin. These tertiary to quaternary deposits are an important feature influencing the vegetation of the Nama Karoo Biome, and they comprise the growth medium for many dwarf shrubs in the region (Lovegrove 1993). The soils are generally calcareous duplex forms of secondary nature, having been deposited as alluvium on the impermeable sandstone. They are subject to sheet and gully erosion, which is aggravated by a reduction in vegetation cover.

The vegetation of the CNP falls into three biomes, namely the Albany Thicket, Grassland and Nama Karoo (Mucina & Rutherford 2006; Palmer 1989). There is also Azonal Alluvial vegetation around the Nqweba Dam. The vegetation has been divided into three distinct physiognomic classes of vegetation,

namely the Shrubland, Succulent Thicket and Dwarf Shrubland (Palmer 1989). The Shrubland is dominant in sandstone uplands above 1300 meters elevation. Grasslands separate the shrubs growing in moist conditions from the dwarf shrub vegetation in the drier areas. The Succulent Thicket is a distinctive vegetation class dominated by shrubs and succulents of subtropical affinity, while the Dwarf Shrubland is restricted to bottomlands which may be grassy, succulent or degraded, depending on the surface substrate, the frequency of precipitation and recent land use history. To date, 336 plant species from 71 families of flowering plants have been recorded (Palmer 1989). The following families are important components of the region's flora: Asteraceae (daisy family with 55 species), Poaceae (grass family with 36 species), Liliaceae (lily family with 25 species) and Crassulaceae (crassula family with 16 species).

Other life forms include 43 species of mammals, consisting of, amongst others, disease-free buffalo (*Syncerus caffer*), kudu (*Tragelaphus strepsiceros*), springbok (*Antidorcas marsupialis*) and blesbuck (*Damaliscus dorcas phillipsi*), and thirteen carnivore species (CNP 2006). There are also 225 species of birds. The herpetofauna includes five frog, five tortoise, 19 lizard and 10 snake species. There are also ten species of fish, including two alien species of angling value, namely, carp (*Cyprinus carpio*) and barbell (*Clarias gariepinus*). The invertebrate fauna is largely unrecorded, but there are brown locust (*Locustana pardalina*) outbreaks, and Karoo caterpillar (*Loxostege frutalis*) and harvester termite (*Hodotermes mossambicus*) eruptions.

## Data collection

The data used in this study originates primarily from two sources. The first is an unpublished alien plant species list that was compiled in 1981, containing 15 species recorded within the park boundaries. Each of these species was plotted on a 1:50 000 map by the park manager and digitised in 2008. The data contained in the hand-plotted maps were digitised onto a 1:50 000 map to improve the visibility and quality of data, using ArcView GIS Version 3.1. The second dataset is based on ranger patrols that took place between April and December 2008 inside the CNP (Figure 1). Routine patrols were conducted by field rangers, on foot and by vehicle, using AIRIS Picket PCs with customised CyberTracker software (see Foxcroft *et al.* 2009 for a discussion on the CyberTracker programme). The collection of these and other environmental data by park rangers is ongoing.

In addition, in May 2008 a general survey was carried out and all new species encountered were added to the species list for the CNP.

### Presentation of the list

Families and species, respectively, are listed alphabetically within each of the major plant groupings of Pteridophyta (ferns and fern allies), Gymnospermae (gymnosperms) and Angiospermae (monocotyledons and dicotyledons). The date of the first record of the species indicates the year recorded by park authorities. The list further provides information on the status of the weed and its current impact in the CNP, methods for control, and legal status in South Africa.

Weed status is presented according to terminology described by Pyšek *et al.* (2004), who defined and classified weed status as follows. Casual alien plants (C) are those that may flourish and even reproduce occasionally outside cultivation in an area but eventually die out because they do not form self-replacing populations and rely on repeated introductions for their persistence. Invaders (I) are a subset of naturalised plants that produce reproductive offspring, often in very large numbers, at considerable distances from the parent plants, and thus have the potential to spread over a large area. Naturalised plants (N) are alien plants that sustain self-replacing populations for at least 10 years without direct intervention by people, or by recruitment from seed or ramets capable of independent growth. Potential invaders (P) means alien plants with the potential to reach invader status.

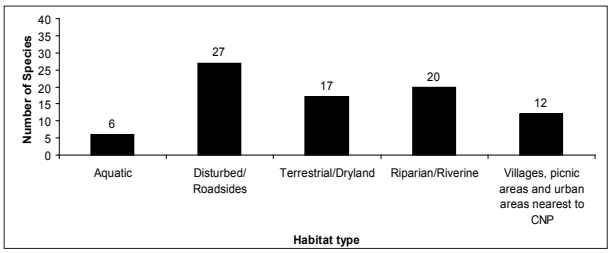



**FIGURE 2**
Number of alien plant species per habitat type recorded during the 2008 surveys (some species occur in more than one habitat type)

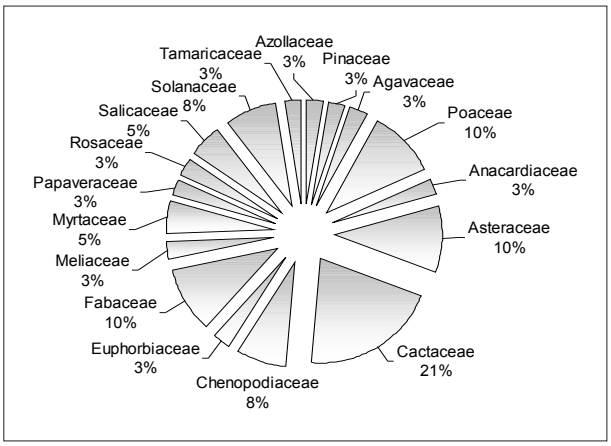



**FIGURE 3**
Families of alien plant species represented in Camdeboo National Park

The habitat types include all habitats within the park boundaries, and rivers, urban and rural areas within a 1-km zone from the park boundary. Almost all areas in the park have been exposed to agriculture, either through cultivation or livestock grazing, or both. The species observed and recorded in the CNP were found either in disturbed areas and roadsides (denoted by DR), villages and picnic areas in the CNP, urban and rural areas adjacent to the CNP (V), aquatic habitats (including Nqweba Dam, denoted by A), riparian or riverine areas in and adjacent to CNP (R), and terrestrial or dryland habitats (TD).

Control mechanisms utilised in CNP include chemical and mechanical techniques; there are no records of biological control. Mechanical clearing for the first, second and third time, respectively, is indicated by ME1–ME3. Chemical control is indicated in a manner similar to mechanical control (CE1–CE3), with the active ingredient of the herbicide used provided in brackets.

Legal status refers to the declared status of the species in terms of the Conservation of Agricultural Resources Act (Act 43 of 1983) regulations (as amended in 2001). Species are divided into three categories. Category 1 species are 'declared weeds', which are prohibited, and must be controlled or eradicated (DW1). Category 2 species are 'declared invaders', which comprise mainly commercial species that must be grown under controlled conditions by permit holders (DI2). Category 3 species are 'ornamental species', which may no longer be planted, except with a special permit, and must be prevented from spreading (DI3). For a full description of the regulations and details regarding individual alien plants see Henderson (2001).

## RESULTS

The first list compiled by the park manager contained 15 alien plant species, including one grass species (*Pennisetum clandestinum*), four herbaceous species (*Argemone ochroleuca* subsp. *ochroleuca*, *Cirsium vulgare, Salsola tragus* (= S. *australis*) [see

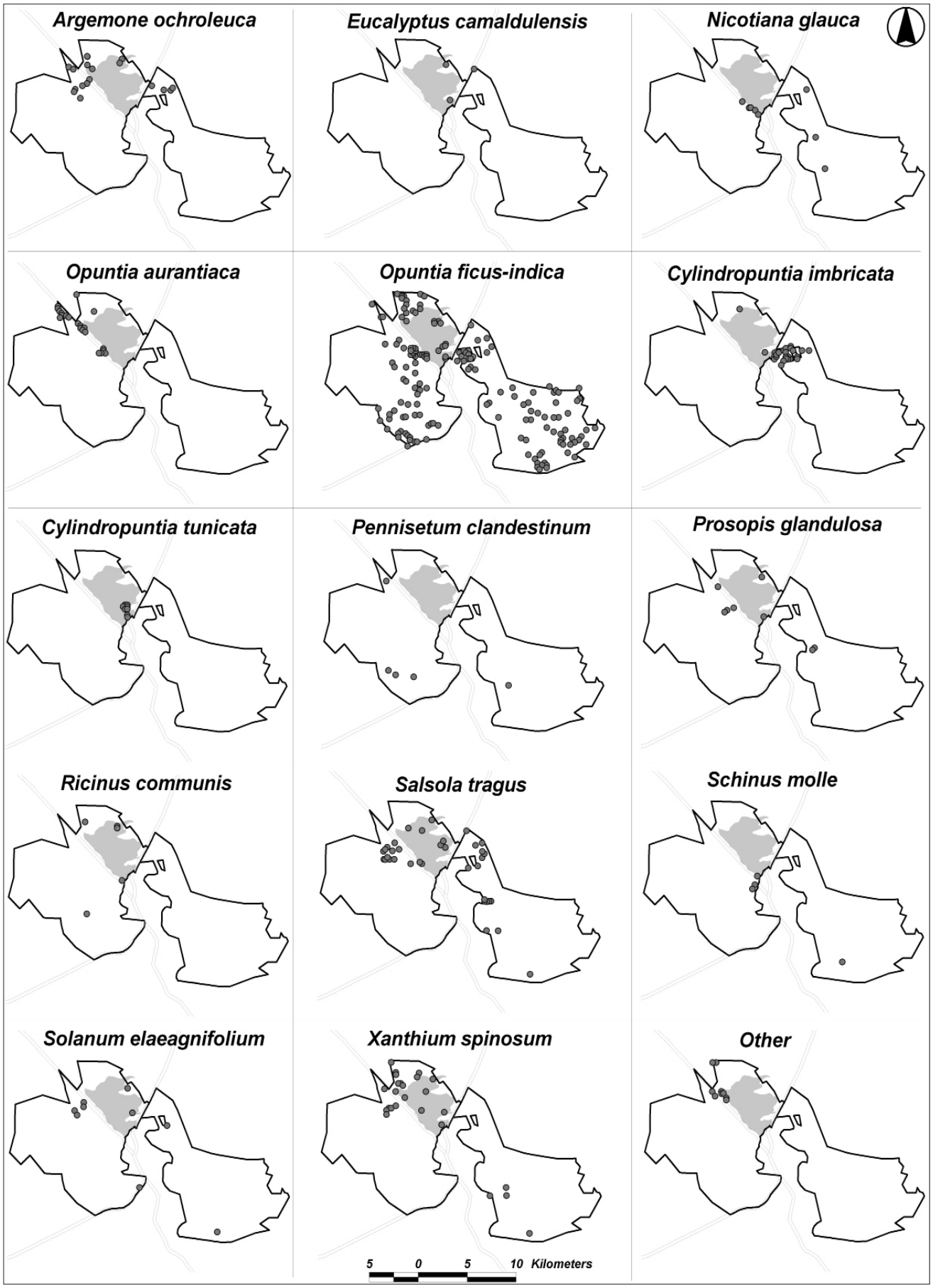



**FIGURE 4**
Distribution of alien plant species in Camdeboo National Park, compiled from data collected in 1981

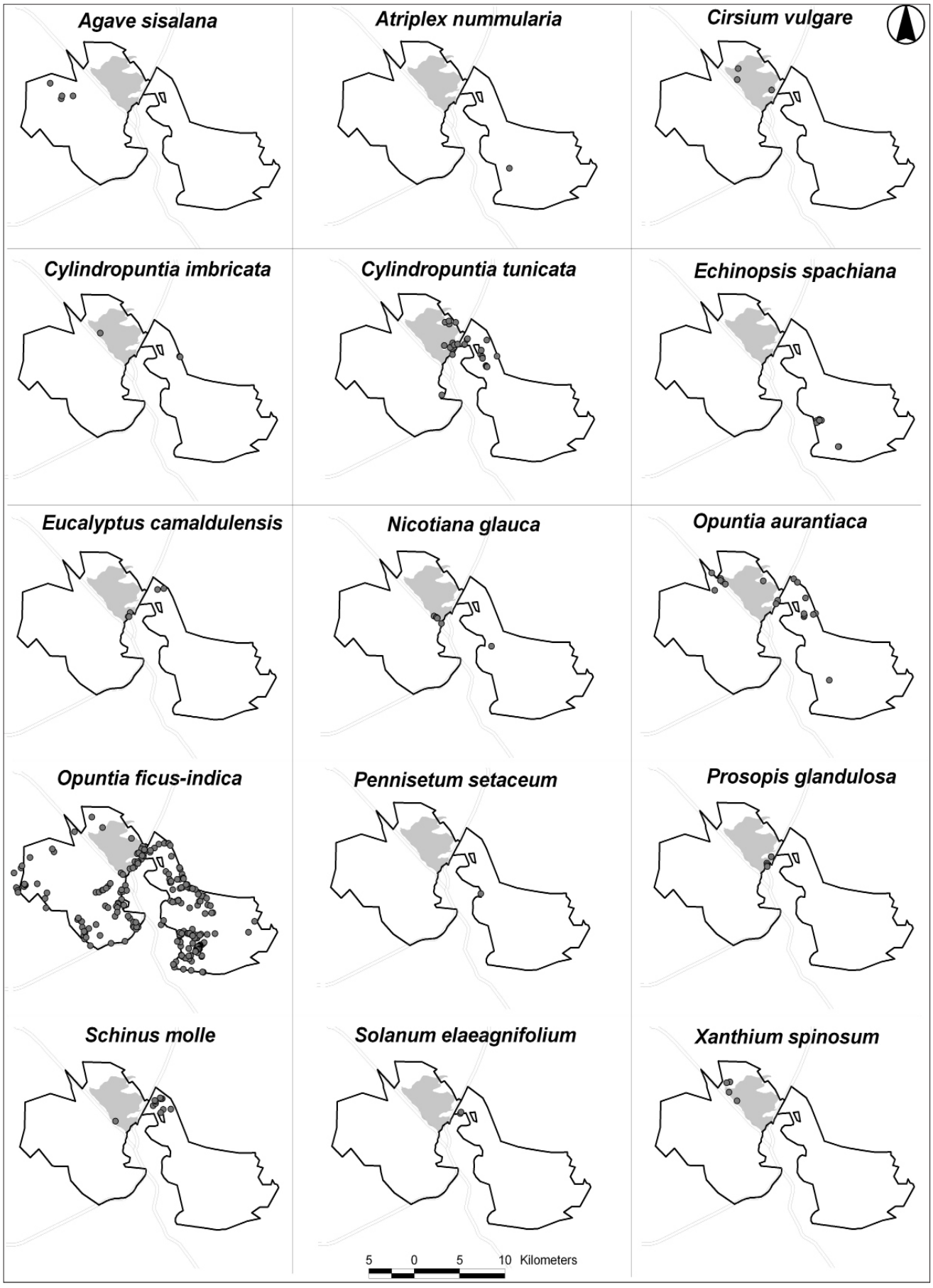



**FIGURE 5**
Distribution of alien plant species in the Camdeboo National Park, compiled from patrol data collected using CyberTracker, April–December 2008

**FIGURE 6a**
A selection of cacti at a cactus nursery in Graaff-Reinet

**FIGURE 6b**
A selection of cacti at a cactus nursery in Graaff-Reinet

**FIGURE 6c**
Various cacti along the street bordering the nursery (*Pennisetum setaceum* is also visible in the foreground)

**FIGURE 6d**
A cactus collection in an open space in Graaff-Reinet (Photographs: L.C. Foxcroft)

**Note**
Larger figures are available on the online journal

discussion on *S. tragus* by Hrusa & Gaskin 2008] and *Xanthium spinosum*), three shrubs (*Nicotiana glauca, Ricinus communis* and *Solanum elaeagnifolium*), three trees (*Eucalyptus camaldulensis, Prosopis glandulosa* var. *torreyana* and *Schinus molle*) and four cacti: *Opuntia aurantiaca, Opuntia ficus-indica, Cylindropuntia tunicata* (previously misidentified as *O. fulgida* or *O. rosea*) and *Cylindropuntia imbricata* (= *O. imbricata*). Although *E. globulus* was indicated in the early park records, this was most likely a misidentification, as the only *Eucalyptus* species from the area has been identified as *E. camaldulensis*. During the 2008 surveys a total of 24 additional alien plant species were added to the original alien species list (Table 1).

When the alien plants on the list are ranked according to weed status, the majority of the species (17) are invasive (46%) and 15 are potential invaders (41%). Two species are recorded as naturalised (5%), and the remaining three have a casual status (8%). Therefore, over 80% of the alien plants recorded either are, or pose, a potential threat to the vegetation types and ecosystems around CNP.

Among the successful invaders in and around CNP, the following are prominent: *Cirsium vulgare, Xanthium spinosum, Opuntia aurantiaca, O. ficus-indica, Cylindropuntia imbricata, C. tunicata* and *Eucalyptus camaldulensis. Tamarix ramosissima* is an invader with the potential to transform the aquatic edge habitat in CNP (especially the Nqweba Dam shoreline). *Atriplex inflata* and *Salsola tragus* are also widespread invaders in terrestrial drylands and disturbed areas in large sections of CNP. This is possibly due to earlier ploughing in almost all areas in and around the park.

Most of the alien plants have invaded disturbed areas, including areas that were previously heavily grazed and ploughed, as well as cleared areas along roadsides (Figure 2). Riparian habitat is the next most vulnerable to invasion, with the terrestrial or dryland areas appearing to be least vulnerable. When the Nqweba Dam overflows it results in an increase in the presence of especially *Tamarix ramosissima* and *Cirsium vulgare* (Charlotte Vermeulen [WfW Manager] pers. comm., 16 May 2008). *Solanum elaeagnifolium* occurs in all habitat types, and *Xanthium spinosum, Atriplex inflata, A. nummularia* subsp. *nummularia, Salsola tragus, Opuntia aurantiaca, O. ficus-indica, Cylindropuntia imbricata* and *Datura stramonium* occur in four habitat types.

The most highly invasive families of alien plants in the CNP (Figure 3) are the Cactaceae (21%), then Asteraceae (10%), Poaceae (10%), Fabaceae (10%), Chenopodiaceae (8%) and Solanaceae (8%). Of the cacti species, *Opuntia aurantiaca, O. ficus-indica, Cylindropuntia imbricata* and *C. tunicata* are highly invasive within a 1-km zone from the park boundary and within the park. *Cylindropuntia tunicata* and *C. imbricata* appear to be spreading from the areas where people live, into the disturbed areas and roadsides at the edge of the park.

The most widespread invader in the CNP is *Opuntia ficus-indica*. It was already widespread in the early distribution records obtained from 1981 (Figure 4) and is still currently widespread (Figure 5). Some alien plant species that are also known to be widespread but have not been comprehensively mapped are *Atriplex inflata, Salsola tragus and Tamarix ramosissima.*

The current distribution data (Figure 5) implies that some alien plant species have decreased in distribution when compared to the situation in 1981 (Figure 4). This is most likely due to the fact that the data collected for 2008 might not be extensive enough to have covered the entire area of the park, which was hand-mapped in 1981. It might also be because some individual plants have been mechanically or chemically controlled, and thus they now occur in lower abundance. Alien plant species that appear to have decreased in distribution are *Cirsium vulgare, Eucalyptus camaldulensis, Nicotiana glauca, Cylindropuntia imbricata, Solanum elaeagnifolium* and *Xanthium spinosum* (Figures 4 and 5). Of

**TABLE 1**
Alien plant species list of Camdeboo National Park

| ORDER AND FAMILIES | SPECIES | COMMON NAME | DATE OF FIRST RECORD | STATUS | HABITAT | CONTROL | LEGAL STATUS |
|---|---|---|---|---|---|---|---|
| Order: Pteridophyta | | | | | | | |
| Family: Azollaceae | *Azolla filiculoides* Lam. | red water fern | 2001 | I | A R | The biological control agent *Stenopelmus rufinasus*, while not intentionally released into CNP, is most likely present | DW 1 |
| Order: Gymnospermae | | | | | | | |
| Family: Pinaceae | *Pinus halepensis* Mill. | Aleppo pine | 2000 | C | TD | None | DI 2 |
| Order: Angiospermae: Monocotyledonae | | | | | | | |
| Family: Agavaceae | *Agave sisalana* Perrine | sisal | 2006 | N | V TD R | CE1 (MSMA) ME1 | DI 2 |
| Family: Poaceae | *Arundo donax* L. | giant reed/Spanish reed | 2008 | I | R | None | DW 1 |
| | *Nassella trichotoma* (Nees) Arechav. | nassella tussock | 2008 | P | DR TD | None | DW 1 |
| | *Pennisetum clandestinum* Chiov. | kikuyu grass | 2006 | I | DR V TD | None | Proposed DW 2 |
| | *Pennisetum setaceum* (Forssk) Chiov. | fountain grass | 2008 | P | DR R | None | DW 1 |
| Order: Angiospermae: Dicotyledonae | | | | | | | |
| Family: Anacardiaceae | *Schinus molle* L. | pepper tree | 1986 | C | DR V | ME 1 | Proposed DI 3 |
| Family: Asteraceae | *Bidens pilosa* L. | common blackjack | 2008 | N | DR V | None | na |
| | *Cirsium vulgare* (Sari) Ten | spear thistle/ Scotch thistle | 1986 | I | A R | CE1 (Imazapyr) | DW 1 |
| | *Xanthium spinosum* L. | spiny cocklebur | 1981 | I | A DR TD R | CE1 Unknown | DW 1 |
| | *Xanthium strumarium* L. | large cocklebur | 1981 | P | DR | None | DW 1 |
| Family: Cactaceae | *Cereus jamacaru* DC. | queen of the night | 2008 | P | DR | Unknown | DW 1 |
| | *Cylindropuntia imbricata* (Haw.) Knuth (= *Opuntia imbricata* (Haw.) DC. | imbricate prickly pear | 1981 | I | DR TD R | CEI MSMA | DW 1 |
| | *Cylindropuntia tunicata* (Lehm.) F.M. Knuth | thistle cholla | 1986 | I | DR TD V | CE3 MSMA | na |
| | *Echinopsis spachiana* (Lem.) Friedrich & Rowley | torch cactus | 2008 | P | DR R | CE1 | DW 1 |
| | *Opuntia aurantiaca* Lindl. | jointed cactus | 1981 | I | DR V TD R | CE3 MSMA | DW 1 |
| | *Opuntia ficus-indica* (L.) Mill | sweet prickly pear | 1981 | I | DR V TD R | CE3 MSMA | DW 1 |
| | *Opuntia humifusa* (Raf.) Raf. | large flowered or creeping prickly pear | 2008 | P | TD V | CEI MSMA | DW 1 |
| | *Opuntia stricta* (Haw.) Haw. | sour prickly pear | 2008 | I | DR TD | None | DW 1 |
| Family: Chenopodiaceae | *Atriplex inflata* F. Muell. (= *A. lindleyi* subsp. *inflata* (F. Muell.) P.G. Wilson | sponge-fruit salt bush | 1986 | I | DR TD | CE1 (Fluroxypyr-meptyl) | DI 3 |
| | *Atriplex nummularia* Lindl. subsp. *nummularia* | old man salt bush | 1989 | P | DR TD V | None | DI 2 |
| | *Salsola tragus* L. (*S. kali* L. misapplied in SA) | Russian tumbleweed | 1986 | I | DR TD R | None | na |
| Family: Euphorbiaceae | *Ricinus communis* L. | castor oil plant | 1986 | I | DR R | None | DI 2 |
| Family: Fabaceae | *Gleditsia triacanthos* L. | honey locust | 2008 | P | DR R | ME1 | DI 2 |
| | *Parkinsonia aculeata* L. | Jerusalem thorn | 2008 | P | DR R | None | na |
| | *Prosopis glandulosa* Torr. var. *torreyana* (L.D. Benson) M.C. Johnst. | honey mesquite | 1986 | T | DR | ME1 | DI 2 |
| | *Robinia pseudacacia* L. | black locust | 2008 | P | DR R | None | DI 2 |
| Family: Meliaceae | *Melia azedarach* L. | seringa, syringa, Persian lilac | 2006 | C | V R | None | DI 3 |
| Family: Myrtaceae | *Eucalyptus camaldulensis* Dehn. | red river gum | 1986 | I | V R | ME1 | DI 2 |
| Family: Papaveraceae | *Argemone ochroleuca* Sweet subsp. *ochroleuca* (*A. subfusiformis* G.B. Ownbey misapplied in SA) | white-flowered Mexican poppy | 1986 | I | DR | None | DW 1 |
| Family: Rosaceae | *Pyracantha angustifolia* (Franch.) C.K. Schneid. | yellow firethorn | 2008 | P | DR | None | DI 3 |
| Family: Salicaceae | *Populus* x *canescens* (Aiton) Sm. | grey poplar | 2008 | P | R | ME1 | DI 2 |
| | *Salix babylonica* L. | weeping willow | 2008 | P | R | None | DI 2 |
| Family: Solanaceae | *Datura stramonium* L. | common thorn apple | 2008 | P | A DR TD R | None | DW 1 |

**TABLE 1 (continued...)**
Alien plant species list of the Camdeboo National Park

| ORDER AND FAMILIES | SPECIES | COMMON NAME | DATE OF FIRST RECORD | STATUS | HABITAT | CONTROL | LEGAL STATUS |
|---|---|---|---|---|---|---|---|
| | *Nicotiana glauca* Graham. | wild tobacco | 1986 | P | DR | ME1 | DW 1 |
| | *Solanum elaeagnifolium* Cav. | silver-leaf bitter apple | 1986 | I | A DR TD | CE1 (Imazapyr) | DW 1 |
| Family: Tamaricaceae | *Tamarix ramosissima* Ledeb. | pink tamarisk | 2006 | I | A R | ME1<br>CE1 (Imazapyr) | DW 1 |

**Codes used:**
Date: first year of record in the park
Status: as in CNP currently; C=casual; I=invader; N=naturalized; P=potential invader
Habitat type: includes rivers, urban and rural areas adjacent to CNP; A=aquatic, includes Nqweba Dam; DR=disturbed area/roadside; R=riparian/riverine; TD=terrestrial/dryland; V=urban areas around Graaff-Reinet adjacent to CNP
Control: mechanical stage of clearing from 1st to 3rd=ME1 until ME3; chemical stage of application from 1st to 3rd with the name of the chemical in bracket=CE1 until CE3
Legal status according to CARA (Act 43 of 1983, as amended in 2001): DW 1=declared weed category 1; DI 2=declared invader category 2; DI 3=declared invader category 3

these species, *Cirsium vulgare, S. elaeagnifolium, Cylindropuntia imbricata* and *X. spinosum* have been chemically controlled while the other two have been mechanically removed. The chemicals used here include Monosodium Methanearsonate (MSMA) on *Cylindropuntia imbricata,* and Imazapyr on *Cirsium vulgare* and *S. elaeagnifolium.*

There was an apparent increase in the distribution of *O. ficus-indica, O. aurantiaca, C. tunicata* and *Schinus molle* (Figures 4 and 5). *Schinus molle* has increased in distribution although some individual species have been mechanically removed. The three cactus species (*O. ficus-indica, O. aurantiaca, C. tunicata*) are persistent invaders, as efforts to reduce these species have been unsuccessful, even though there have been more than two chemical controls and follow-up operations (Table 1). The fact that different species of Cactaceae utilise a variety of methods to invade (easily dispersed seeds and vegetative dispersal by ramets) makes them difficult to eradicate.

Alien plant species that were recorded in 1981 but were not found in the 2008 general survey data include *Argemone ochroleuca* subsp. *ochroleuca, Pennisetum clandestinum, Prosopis glandulosa* var. t*orreyana, Salsola tragus* and *Ricinus communis*. Plants recorded only in 2008 include *Echinopsis spachiana* and *Pennisetum setaceum,* both of which have invaded the eastern section of the CNP, presumably having spread from the nearby urban area. It is anticipated that more alien plant species will be recorded at the edges of the park as further surveys are carried out. The rivers that flow through the town and into the park are a source of many woody and shrubby alien plant species, and present a substantial management challenge.

## DISCUSSION

Our knowledge on the current distribution of invasive alien plant species in the CNP is still relatively limited; the focus has mainly been on individual plant species and the distribution has not been frequently updated. This article reports on efforts that have been made to improve our knowledge of the extent of invasive alien species by assessing the distribution of 18 of the most important and persistent species. While this is a start, it should be recognised that monitoring and recording the distribution of alien plants should remain an ongoing process. This paper only provides a picture of where specific alien plant species are common; detailed structured maps at relevant spatial scales should be compiled in the near future.

Effective management of invasive plants is based on thorough knowledge of the species' locations and distribution, modes and rates of spread, potential and known effects, and control methods (Crimmins *et al*. 2008). An inventory of the invasive species, invasion processes and management history provides management with a valuable baseline. This updated list contains a total of 39 alien plant species, an increase of 24 species from the 15 initially recorded and mapped before the CNP was proclaimed.

### Cactaceae as invaders in the Karoo

Most of the important alien plant invaders of the Karoo biomes are succulents (Richardson *et al.* 1997). The unique shapes and sizes of cacti results in these species being planted widely in gardens by people. This is done mainly for ornamental and aesthetic reasons. There is a large cactus nursery in Graaff-Reinet, on the edge of the Sundays River (which runs from the town into the park), which sells many types, shapes and forms of cacti (see Figures 6a–d). A number of cacti species appear to have been dumped into the adjacent river, which will promote invasion in the Camdeboo municipality.

Many species spread through vegetative reproduction, and their fleshy fruits are consumed by a host of animals, which assists their distribution into natural areas. Prickly pear (e.g. *Opuntia ficus-indica*) seeds are often dispersed to perch sites by birds (particularly crows) and to riverbeds and woodlands by primates (humans, vervet monkeys and baboons) that eat the sweet, watery fruit (Milton & Dean 1998; Richardson *et al*. 2000). *Cylindropuntia imbricata* and *O. aurantiaca* also appear to be dispersed by similar agents. Birds are major contributors to the spread of cacti to shaded sites below perches on trees and cliffs (Milton *et al*. 2007). *Opuntia ficus-indica* can be seen at the Valley of Desolation hanging from cliffs as well as under *Acacia karroo* in drainage lines. *Opuntia aurantiaca* is common only under *A. karroo* and *Pentzia incana*. However, as *Acacia karroo* and *Pentzia incana* are the most common indigenous plant species in the Karoo (Palmer 1989), these cacti species pose a risk to the species richness and diversity in the *Acacia karroo-Pentzia incana* plant communities if nothing is done to reverse the situation.

The four major cacti invaders are *Opuntia aurantiaca*, *O. ficus-indica*, *Cylindropuntia imbricata* and *C. tunicata*. The worst invader in CNP and the surrounding municipality remains *O. ficus-indica*. This species was originally introduced in the early 1700s as fodder for sheep and cattle. It survived and spread effectively to become not only a problem plant in the semi-arid Karoo and savanna, but to cause one of the worst agricultural catastrophes in the history of South Africa (Annecke & Moran 1978; Moran & Annecke 1979). The extent of the problem can be seen in old photographs, and its invasion of protected areas in the savanna (Foxcroft 2007; Macdonald & Frame 1988; Wells *et al*. 1986; Zimmermann and Moran 1982; Milton *et al*. 2007) and the Karoo (Dean & Milton 2000; Milton & Dean 1998) is discussed in various places in the literature.

Records for CNP indicate that *O. ficus-indica* has been treated mechanically and chemically using MSMA until it was visibly reduced. Ongoing follow-up treatment is important for the successful eradication or more likely, maintenance at low levels, of the species. The fact that follow-up control operations were not carried out continuously has resulted in the species returning in large numbers and still occurring as the most widespread species in the area. Although not specifically released in the CNP, the biological control agent *Dactylopius opuntiae*, a cochineal insect, has substantially reduced the density of *O. ficus-indica* in South

Africa (Moran and Zimmermann 1991; Zimmermann *et al.* 1986). The other biological control agent *Stenopelmus rufinasus*, also not specifically released into CNP, is most likely controlling the red water fern (*Azolla filiculoides*) infestations in dams, ponds and rivers on the Camdeboo Municipality.

### Invasive trees, shrubs and herbs

Alien plant species recorded in the Karoo Nature Reserve (now CNP) by Palmer (1989) include *Tamarix ramosissima, Salsola tragus (S. kali misapplied), Atriplex inflata* (= *A. lindleyi* subsp. *inflata*), and *Argemone ochroleuca* subsp. *ochroleuca* (*A. mexicana* misapplied by Palmer). *Tamarix ramosissima* is a major invader of rivers throughout the world (Loope *et al.* 1988), and has invaded the shores of Nqweba Dam in CNP. The rivers in the Camdeboo municipality have further been invaded by a range of alien plant species, with *Eucalyptus camaldulensis* already producing large numbers of seedlings and saplings. The other alien trees invading semi-arid areas are *Schinus molle* (Iponga *et al*. 2008) and *Prosopis glandulosa* var. *torreyana*. These species, although present, do not appear to be highly invasive in the CNP at present. However, according to Iponga *et al*. (2008), *S. molle* has the ability to out compete *Acacia tortilis* and thus poses a considerable threat to CNP.

A higher proportion of herbaceous alien plants are to be expected in the Karoo (Brown & Gubb 1986; Milton & Dean 1998; Richardson *et al.* 1997; Dean & Milton 2000) and the common invasive herbaceous alien plant species found in this study were consistent with other studies in the Karoo (Lloyd 1999; Milton *et al.* 2008; Milton *et al.* 1999; Weiersbye *et al.*, 2006;). These included *Atriplex inflata, Salsola tragus, Pennisetum clandestinum* and *P. setaceum*. Although present in CNP, *P. setaceum* has not yet spread along the major rivers, as it has done in the Karoo National Park (Milton *et al.* 2008). However, it clearly has the potential to become problematic, which may further promote fire, thereby threatening biodiversity among indigenous succulents. *Nassella trichotoma*, a grass species, is spreading from Nqweba Dam into the surrounding natural vegetation. The herbaceous species *Atriplex inflata* and *Salsola tragus* were found across different habitat types and sections of the park. These species were common in almost all areas or habitats, including along the rivers running through Graaff-Reinet. This is most likely because most sections of the park were previously ploughed.

### What needs to be done?

Ongoing distribution data collection is required to assist efforts to prioritise and manage the threats posed by alien plants to ecosystem function and structure in the Karoo. The precise point locality data collected through the use of the CyberTracker system can be used at a later stage to determine frequency or abundance per unit area. The unit area, or resolution of the grid cell in which abundance can be assessed, can then be determined relative to the extent of the area under consideration (Foxcroft *et al.* 2009).

Very little is known about the impacts of alien plants on the biodiversity (whether compositionally, structurally or functionally) of CNP and this should be given urgent attention. As understanding of the impacts improves, the modes of invasion used by species with the highest impact in CNP should also be examined and used to inform control measures. The influence of the different land use types on invasion by these plants will help identify areas of higher risk. Human impacts and the lack of sufficient knowledge and awareness of alien plants should be investigated for the Camdeboo Municipality. Control and rehabilitation to improve the natural vegetation condition will be of utmost importance for areas that are highly invaded. In areas where transformation by alien plants has persisted for a long period, the assumption that the system would self-repair following alien plant removal does not always hold true (Esler *et al*. 2008). Management should attempt to restore basic ecosystem functions through providing vegetation cover that is resistant to further invasion (Holmes *et al*. 2008). For example, in the case of CNP, the indigenous *Malephora* sp. might out-compete *Atriplex inflata* and *Salsola tragus*. This mat-forming succulent plant may therefore stabilise the soil to prevent erosion and further spread of other herbaceous alien plant species, in the areas or communities where it naturally occurs.

## CONCLUSION

The first step has been taken by collating a species list and distribution maps to monitor both new introductions of alien plants and the distribution thereof. It is highly likely that the area invaded and densities of alien plants will increase in the CNP and adjacent municipal areas. The aggressively invasive cacti, herbaceous weeds and certain woody species in the rivers will also present serious management challenges to CNP. A control programme will require concerted efforts from CNP management, Working for Water (invasive alien plant clearing programme) and the people of Graaff-Reinet.

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