

Assessment of the invasive status of newly recorded cactus species in the central Tugela River basin

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Background: Current distribution information on cacti in the Tugela River basin in KwaZulu-Natal, South Africa, is scant. Accordingly, surveys in this region substantially improve our understanding of regional invasions by this succulent group. The identification of new or extended invasions requires (re)assessments of their invasion status and consideration of possible management interventions.

Objectives: To identify and collect cacti either not previously recorded or poorly known in the central Tugela River basin, and to assess their invasion status.

Method: A 40 km section of tertiary road was travelled through the topocadastral square 2830 CC, from the R74 main road northward across the Bloukrans River towards the Tugela River. Herbarium specimens were collected to vouch for new instances of naturalisation of cacti, the colony sizes of which were estimated and invasion stages determined. An applicable weed risk assessment model was used to determine the threat status of one cactus species not previously evaluated for South Africa. Based on the South African Plant Invaders Atlas database records and field observations, management recommendations were suggested for six cacti species.

Results: The first naturalised population of *Opuntia microdasys* in KwaZulu-Natal was detected, as was the first confirmed South African record of *Echinopsis oxygona*. Four populations of *Peniocereus serpentinus* were also found, ranging in size from several square metres to 0.4 ha. *Echinopsis oxygona* generated a score that falls into the reject category of the risk assessment model used.

Conclusion: It is recommended that *E. oxygona* be added to the Species Under Surveillance for Possible Eradication or Containment Targeting list to investigate whether this species requires formal legal listing and the development of a specific eradication plan. Immediate action from local authorities is recommended for the manual removal of *P. serpentinus* and *O. microdasys* populations.

Introduction

The extensive and ongoing invasion by cacti in South Africa has been documented since the 20th century, when *Opuntia ficus-indica* (L.) Mill. occupied vast tracts of the Karoo (Henderson 2015). A recent global review of Cactaceae invasions identified South Africa as the second most invaded of all countries in respect of this largely New World family, with 35 taxa recorded (Novoa *et al.* 2014). This study identifies the bioclimatic equivalence of South Africa to the natural range of invading cacti as a factor key to their successful naturalisation on the subcontinent.

In 2008, the Working for Water programme of the South African Department of Environment Affairs funded the South African National Biodiversity Institute Invasive Species Programme (SANBI ISP). The SANBI ISP documents new instances of naturalisation, evaluates taxa on the Species Under Surveillance for Possible Eradication or Containment Targeting (SUSPECT) list, advises on the legal listing of taxa and develops specific eradication plans (Wilson *et al.* 2013).

Earlier surveys documenting the vegetation of Weenen County (West 1951) and the entire Tugela River basin (Edwards 1967) did not record any members of the Cactaceae, apart from the indigenous *Rhipsalis baccifera* (J.S. Muell.) Stearn subsp. *mauritiana* (DC.) Barthlott. However, by 1987 both *Opuntia ficus-indica* and *O. stricta* (Haw.) Haw. var. *stricta* were common in this area, with *O. aurantiaca* Lindl. recorded there since 1999 (Henderson 2007; Southern African Plant Invaders Atlas [SAPIA] database 2015).

The suitability of the central region of the largest catchment in KwaZulu-Natal (KZN), the Tugela basin, for colonisation by succulents necessitates ongoing surveys for new or extended invasions by cacti, the assessment of environmental risks posed by them and the formulation of possible management approaches. The objectives of this study were to survey the cacti in

the central Tugela River and to assess the invasion status of those not previously recorded in the area, as well as to make recommendations for the management of exotic cacti encountered during the survey, based on field observations and the SAPIA database.

Research methods

Field work in the central Tugela River basin near Weenen was undertaken in early December 2014 to gather cacti distribution data and specimens, particularly of *Peniocereus serpentinus*. A 40 km section of tertiary road was travelled

slowly by car through the topocadastral square 2830 CC, from the R74 main road northward across the Bloukrans River towards the Tugela River. Herbarium specimens were gathered and submitted to the KZN Herbarium.

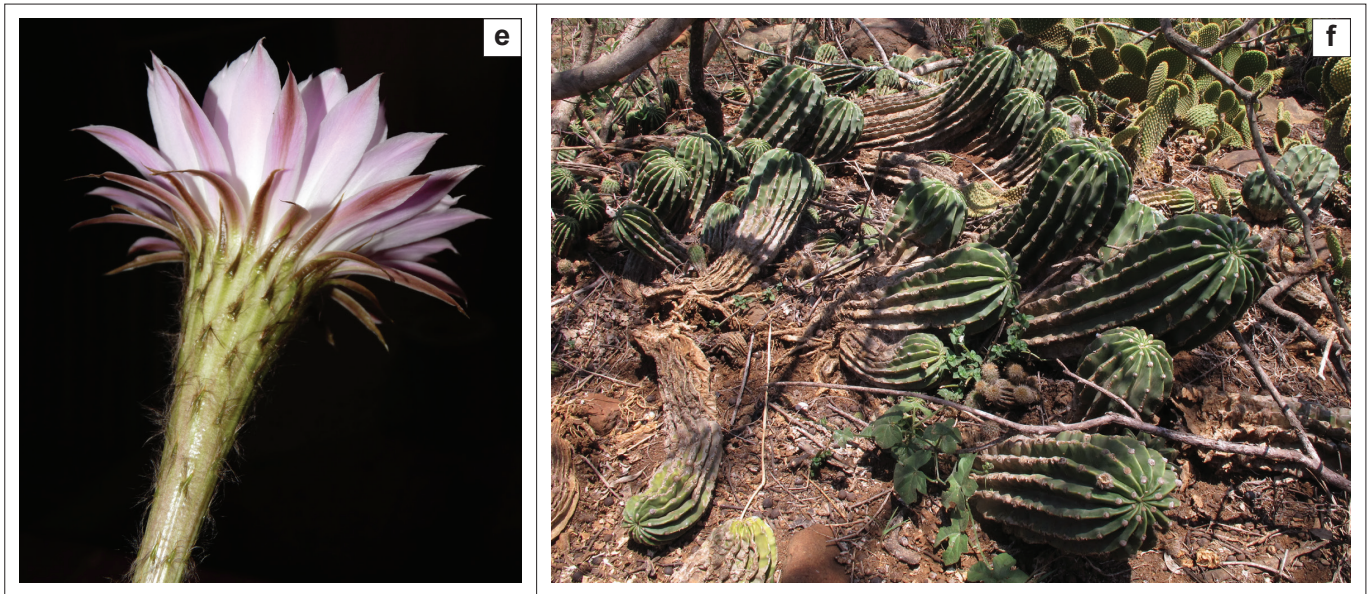
The invasion stages of three cacti species in the region were categorised according to Blackburn *et al.* (2011), following the interpretation of Wilson *et al.* (2014), with management recommendations formulated for all cacti encountered during the survey. A weed risk assessment (Gordon *et al.* 2010; Pheloung, Williams & Halloy 1999) was undertaken for one introduced cactus species not previously evaluated in South Africa.



Source: Figure 1 courtesy of Tanza Crouch

FIGURE 1: *Opuntia microdasys*: (a) Invasive population near Weenen; (b) Developing fruit, with prominent areoles bearing numerous glochids; and (c) Flowers orange, usually yellow elsewhere in South Africa. *Echinopsis oxygona*: (d) Flower, apical view, perianth segments spreading; (e) Flower, lateral view, funnellform, scales with long wool; and (f) Colony near Weenen, stems clustered, glaucous, subglobular to cylindrical-clavate.

Figure 1 continues on the next page →



Source: Figure 1 courtesy of Tanza Crouch

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Ethical considerations

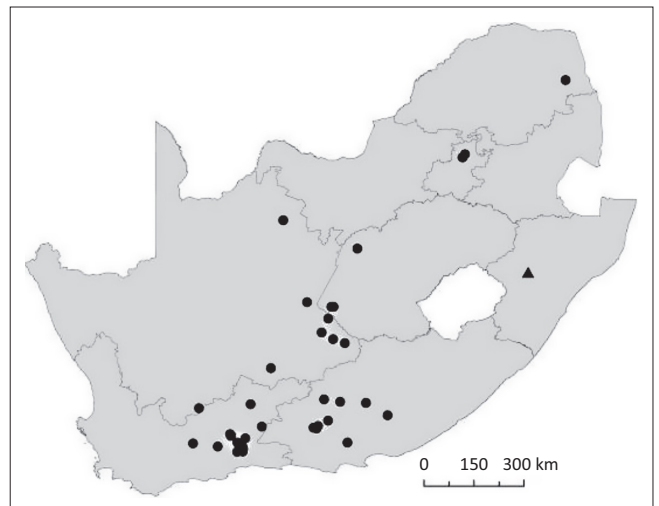
Material was gathered under permit number OP 967/2014 issued by Ezemvelo KZN Wildlife.

Results

The first record of *Echinopsis oxygona* (Link) Zucc. ex Pfeiff. & Otto outside of cultivation in South Africa was confirmed and the first naturalised population of *Opuntia microdasys* (Lehm.) Pfeiff. in KZN was documented. Four populations of *Peniocereus serpentinus* (Lag. & Rodr.) N.P.Taylor were encountered, ranging in size from several square metres to 0.4 ha.

The population of *O. microdasys* detected in the Tugela River basin (Figure 1) represents a significant range extension (± 410 km) into the KZN province (Figure 2). Previously, this species was known in South Africa from 45 sightings (21 localities) in 4 provinces: the Western Cape, Eastern Cape, Gauteng and Limpopo (SAPIA database 2015; Winter, Zimmerman & Mashope 2011). *Opuntia microdasys* is at the D2 stage of invasion, defined as being a self-sustaining population, outside of cultivation and with plants surviving and reproducing a significant distance from their original point of introduction (Blackburn *et al.* 2011) (Table 1).

Descriptions of *O. microdasys* in South Africa have previously been provided by Smith *et al.* (2011) and Winter *et al.* (2011). Smith *et al.* (2011) stated that in South Africa, plants of this species take a number of years to flower and, given that flowers and fruit were observed (Figure 1), the stand is evidently well-established, a notion supported by its expanse of ± 0.025 ha. No cochineal infestation was seen on *O. microdasys*, despite the presence of these insects on



Source: Map courtesy of Haylee Kaplan

FIGURE 2: Known distribution of naturalised *Opuntia microdasys* in South Africa, based on the Southern African Plant Invaders Atlas data (●), and recent field voucher (▲).

O. stricta var. *stricta* (Figure 3) and *O. aurantiaca* plants (Figure 3) growing in close proximity.

A small colony of *E. oxygona* (Figure 1) was detected adjacent to the *O. microdasys* population. As this remote site (Figure 4) showed no sign of abandoned habitations or cultivated lands, the manner in which this colony started is unknown. However, based on the size of the multiple stems (> 35 cm), it is evidently well-established.

A brief description of *E. oxygona sensu lato* has been provided by Hunt, Taylor and Charles (2006), with expanded descriptions of its synonymised elements published

TABLE 1: Categorisation of the invasion status of *Opuntia microdasys*, *Peniocereus serpentinus* and *Echinopsis oxygona* populations observed in the central Tugela River basin, KwaZulu-Natal province, South Africa, according to Blackburn *et al.* (2011), following the interpretation of Wilson *et al.* (2014).

Taxon	Reproduction and recruitment	Distance from known or putative site of original planting?			Invasion state
		< 2 x crown radius	Between 2 x crown radius and 100 m	> 100 m	
<i>Opuntia microdasys</i>	Are viable seeds or other propagules produced and dispersed?	Yes	Yes	Yes	D2
	Is there a long-lasting seed bank?	Not recorded	Not recorded	Not recorded	
	Are seedlings or vegetative offspring present?	Yes	Yes	Yes	
	Do seedlings or vegetative offspring survive for more than a year?	Yes	Yes	Yes	
	Is there survival to reproductive maturity?	Yes	Yes	Yes	
<i>Echinopsis oxygona</i>	Are viable seeds or other propagules produced and dispersed?	Not recorded	Not recorded	Not recorded	C3
	Is there a long-lasting seed bank?	Not recorded	Not recorded	Not recorded	
	Are seedlings or vegetative offspring present?	Yes	Yes	Yes	
	Do seedlings or vegetative offspring survive for more than a year?	Yes	Yes	Yes	
	Is there survival to reproductive maturity?	Yes	Yes	Yes	
<i>Peniocereus serpentinus</i>	Are viable seeds or other propagules produced and dispersed?	Yes	Yes	Yes	D2
	Is there a long-lasting seed bank?	Not recorded	Not recorded	Not recorded	
	Are seedlings or vegetative offspring present?	Yes	Yes	Yes	
	Do seedlings or vegetative offspring survive for more than a year?	Yes	Yes	Yes	
	Is there survival to reproductive maturity?	Yes	Yes	Yes	

elsewhere (Borg 1963; Britton & Rose 1963). The plants of the Tugela River basin possess somewhat glaucous, clustered stems that are subglobular. Later they are short, cylindrical-clavate, up to 65 cm high and 10 cm broad, and sprawling with many shoots at the base and along the sides. The 13 to 16 ribs are continuous, broad at the base and with deep furrows between them. The circular areoles are ± 2 cm apart, with whitish wool. Young shoots are distinctly spiny, whilst mature stems are relatively spineless. Flowers open at sunset, are narrow-funnelform, ± 20 cm long and 12 cm in diameter. The inner perianth segments have a spreading growth, and are translucent and rose-coloured. The axils of scales on the flower tube bear long, gray to blackish wool. The filaments and style extend a little beyond the throat, but are shorter than the perianth segments (Figure 1). The genus is reported by Borg (1963) to produce oval, fleshy, hairy berries, at maturity splitting on one side to reveal very small and minutely pitted seeds.

Echinopsis oxygona can be considered to be at the C3 stage of invasion, having a self-sustaining colony that is reproducing vegetatively and possibly sexually (flowering, although no fruit was observed) (Table 1). Following the weed risk assessment model of Pheloung *et al.* (1999), designed to screen primarily for invasive plant taxa, *E. oxygona* generates a score of 12, which falls into the reject category. This result is based on the answers to 49 questions that evaluate the plant's current biogeography, the impact of any undesirable attributes it may have and its ecophysiology (Pheloung *et al.* 1999). This means that an application for its import into South Africa should be turned down. As a first record for KZN, *O. microdasys* may still be restricted to a small region in the central Tugela River basin, although it will likely

spread in the absence of control interventions, which are suggested in Table 2.

Four *P. serpentinus* populations, which were over 1 km apart, were detected (Figure 3). These ranged from a few square metres to 0.4 ha in extent. The largest population, of a rectangular, polygon shape, was located at 28°48'24.5" S, 30°3'12.1" E. The most extensive infestation was surrounded by small satellite clumps that were less than 50 m away from the main clump. This taxon is now known from a total of seven localities in KZN and two in Limpopo province (Winter *et al.* 2011). The upright, clambering stems of *P. serpentinus* were observed to attain heights of up to 4.5 m, supported by the branches of trees through which they were growing, in conditions ranging from full sun to shade.

Given the distances between the known *P. serpentinus* populations, and that all but one of these had flowering plants, and in one case fruit, they are classified at the D2 invasion stage (Table 1). It is currently unknown what role people play in the dissemination of this species in the Tugela River basin, and its origin. However, given the rectangular shape of the largest population, it may originally have been cultivated as a barrier plant.

Discussion

Opuntia microdasys (teddy bear cactus) has a wide natural distribution from Texas to southern Mexico. It is considered to be invasive in Australia (United States Department of Agriculture 2015) and South Africa (Smith *et al.* 2011) and naturalised in the Iberian Peninsula (Sanz-Elorza, Sánchez & Vesperinas 2006). At a national level, *O. microdasys* is too

widespread and established to be considered an eradication target for SANBI ISP and is categorised as 1b (Department of Environmental Affairs 2014b), meaning that its control needs to form part of an invasive species management plan (Department of Environmental Affairs 2014a; Wilson *et al.* 2013).

According to the definition by Pyšek *et al.* (2004), *O. microdasys* can be considered naturalised in KZN as this self-sustaining population has likely existed for at least

10 years without direct human intervention, by recruitment from seed and ramets. Manual extraction and chemical control with herbicides should enable eradication at this site, but if the species is found to be more widespread in KZN, the feasibility of biocontrol should be considered.

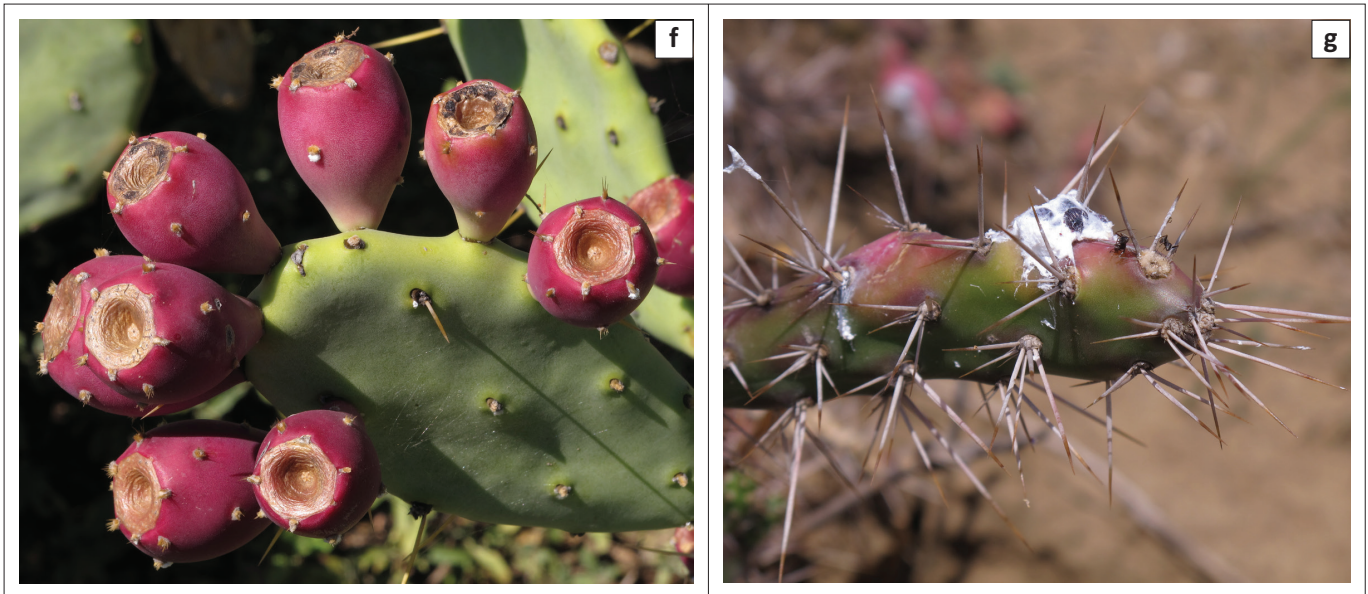
Echinopsis oxygona, the Easter lily cactus or sea urchin cactus, is indigenous to Brazil, Paraguay, Uruguay and Argentina (Hunt *et al.* 2006). It is listed in Brazilian state legislation as Vulnerable in the Rio Grande do Sul region (De Freitas *et al.*



Source: Figure 3 courtesy of Tanza Crouch

FIGURE 3: *Peniocereus serpentinus*: (a) Extensive invasion near Weenen, narrow scandent stems to 4.5 m supported by tree branches; (b) Developing fruit, turning red at maturity; (c) Flowers nocturnal, closed during day and reopening for a second night; perianth funnelliform, white; and (d) Shoot generation following adventitious rooting along length of prostrate stem. *Opuntia stricta* var. *stricta*: (e) Flowers yellow, pericarpel relatively smooth with few (up to 8) areoles; (f) Mature fruits purple, obovoid; and (g) *Opuntia aurantiaca*: cladode section, infested with cochineal.

Figure 3 continues on the next page →



Source: Figure 3 courtesy of Tanza Crouch

FIGURE 3 (Continues...): *Peniocereus serpentinus*: (a) Extensive invasion near Weenen, narrow scandent stems to 4.5 m supported by tree branches; (b) Developing fruit, turning red at maturity; (c) Flowers nocturnal, closed during day and reopening for a second night; perianth funnellform, white; and (d) Shoot generation following adventitious rooting along length of prostrate stem. *Opuntia stricta* var. *stricta*: (e) Flowers yellow, pericarpel relatively smooth with few (up to 8) areoles; (f) Mature fruits purple, obovoid; and (g) *Opuntia aurantiaca*: cladode section, infested with cochineal.

2010) and is one of several subjects in an *ex situ* conservation project in Transylvania (Stoie 2007). However, its global Red List status is Least Concern (International Union for the Conservation of Nature 2014).

The only species of *Echinopsis* Zucc. currently listed in the Alien and Invasive Species list (Department of Environmental Affairs 2014b) is the torch cactus, *E. schickendantzii* F.A.C.Weber (syn. *E. spachiana* [Lem.] Friederich & G.D.Rowley), although *E. chamaecereus* H.Friedrich & Glaetzle has recently been recorded outside of cultivation (SAPIA database 2015). *Echinopsis schickendantzii*, a category 1b invader, has naturalised extensively in the central dry interior of South Africa, and remains poorly controlled despite being declared an invader in 2001 (Department of Agriculture 2001). Its succulent fruits are believed to be distributed by both mammals and birds (Henderson 2015) and both of these are likely to also be the dispersal agents of *E. oxygona*.

The Easter lily cactus, *E. oxygona*, is naturalised in Spain (Laguna-Lombreras *et al.* 2014), the Galápagos Islands (Randall 2012) and Australia (McFadyen 2012). It was earlier noted (as *E. multiplex* Pfeiff. & Otto) as having been cultivated within the Kruger National Park and required removal (Foxcroft *et al.* 2003). In the early 19th century, various *Echinopsis* species were introduced into Europe (Mottram & Quail 2009), amongst them the 'pure species' *E. multiplex*, *E. oxygona*, *E. eyriesii* (Turpin) Pfeiff. & Otto and *E. tubiflora* (Pfeiff.) Zucc. ex A.Dietr.

Subsequent crossing of these forms resulted in what were perceived to be a multitude of hybrids of indeterminate parents, such that the pure species were considered to have largely disappeared from cultivation (Bertrand &

Guillaumin 1957). However, Hunt *et al.* (2006) subsequently placed *E. multiplex*, *E. eyriesii* and *E. tubiflora* in synonymy under *E. oxygona*, so circumscribing a much broader species concept under which the central Tugela River basin material is placed. This species has long been a horticultural subject in South Africa (Glen 2004; Pienaar & Smith 2011).

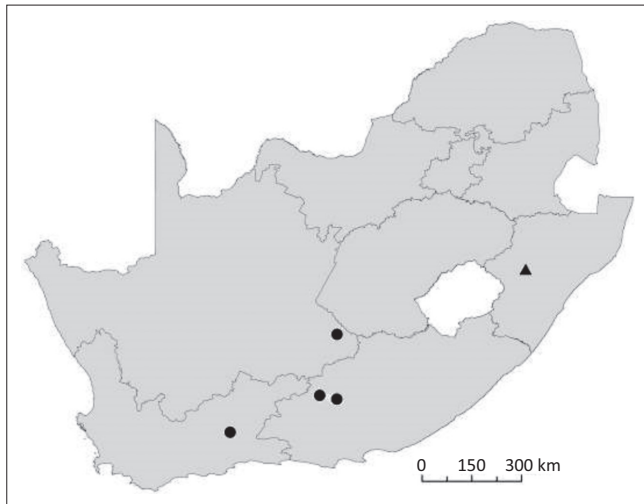
Within the last two years, several reports have been received by SAPIA of round, cushion-type *Echinopsis* colonies occurring in non-cultivated situations (Figure 4). In the absence of flowers, it remains uncertain whether all these are attributable to *E. oxygona*, or to various other taxa in this genus of ± 72 species (Hunt *et al.* 2006). The risk assessment score of 12 for *E. oxygona*, as determined in this study, leads to a recommendation that this cactus should not be imported into the climatically similar Australia, another cactus invasion hotspot (Novoa *et al.* 2014).

In considering the wide distribution of the congeneric *E. schickendantzii*, and observing that cushion-type *Echinopsis* naturalisations in South Africa occur in four different veld types across three biomes (Mucina & Rutherford 2006; SAPIA database 2015; Figure 4), *E. oxygona* likely has a much wider potential national distribution. An adequate sample size of distribution records of this species is currently unavailable on the Global Biodiversity Information Facility (2014) for a reliable distribution model (fewer than 20 with co-ordinates).

The lack of detailed native range data is common to many cacti and in view of such gaps, the South African Cactus Working Group recently proposed a ban on 'any cacti genera that contain invasive species' (Novoa *et al.* 2015). This approach was put forward by Novoa *et al.* (2015) as the most effective way of regulating the movement of invasive species,

without curtailing the horticultural industry unnecessarily. It is recommended (Table 2) that *E. oxygona* be placed on the SUSPECT list to establish whether its formal regulation is necessary.

Peniocereus serpentinus, the serpent cactus or snake cactus, is indigenous to Mexico, in the Sinaloa region and the states between Querétaro and Oaxaca (Arreola *et al.* 2013; Hunt *et al.* 2006). It has naturalised in Queensland, eastern Australia (Atlas of Living Australia 2015; McFadyen 2012). This species is cultivated globally as an ornamental plant (Arreola *et al.* 2013; United States Department of Agriculture 2015) and, under the synonym *Nyctocereus serpentinus* (Lag. & Rodr.) Britton & Rose, has been grown in South Africa since at least the mid-1960s (Rawé 1966). Individuals characteristically produce long, thick, turnip-like roots that comprise a substantial proportion of their biomass. The etymology of the generic name is a reference to the opulence of the root growth relative to the development of aerial parts. Winter *et al.* (2011) provide a description of



Source: Map courtesy of Haylee Kaplan

FIGURE 4: Known distribution of naturalised records of cushion-type *Echinopsis* in South Africa, based on the Southern African Plant Invaders Atlas data (●), and recently recorded locality of *Echinopsis oxygona* (▲).

P. serpentinus and a distribution map that remains largely unaltered by the current report. In South Africa, this species is noted as fast-growing under a range of light conditions (Rawé 1966), as observed in the Tugela River basin.

Peniocereus serpentinus is listed as 1b on the most recent national regulations (Department of Environmental Affairs 2014b), and therefore falls outside the ambit of SANBI ISP. However, given the observed tendency of *P. serpentinus* to spread and its current localised distribution in the central Tugela River basin, urgent action is required, with recommendations for control provided in Table 2.

Specimens examined

Opuntia stricta var. *stricta*

SOUTH AFRICA. **KwaZulu-Natal:** Alongside the R74, south of Bloukrans River, Tugela River basin, 28°49'32.2" S, 30°1'42.6" E, 901 metres above sea level (m.a.s.l.), 08 Dec. 2014, Cheek, M. 2272 (NH!).

Opuntia aurantiaca

SOUTH AFRICA. **KwaZulu-Natal:** Alongside the R74, south of Bloukrans River, Tugela River basin, 28°49'31.9" S, 30°1'41.5" E, 901 m.a.s.l., 08 Dec. 2014, Cheek, M. 2273 (NH!).

Opuntia microdasys

SOUTH AFRICA. **KwaZulu-Natal:** Alongside the R74, south of Bloukrans River, Tugela River basin, 28°49'16.8" S, 30°2'21.5" E, 859 m.a.s.l., 08 Dec. 2014, Cheek, M. 2275 (NH!).

Peniocereus serpentinus

SOUTH AFRICA. **KwaZulu-Natal:** Alongside the R74, south of Bloukrans River, Tugela River basin, 28°47'34" S, 30°3'22.7" E, 832 m.a.s.l., 09 Dec. 2014, in flower and fruit, Cheek, M. 2291 (NH!); alongside the R74, south of Bloukrans River, Tugela River basin, 28°46'50.1" S, 30°4'8" E, 726 m.a.s.l., 09 Dec. 2014, Cheek, M. 2289 (NH!); Zingela Game Reserve, ~200 m from

TABLE 2: Notes on and recommendations for the management of exotic cacti encountered during a survey of the central Tugela River basin. Information based on field observations and the Southern African Plant Invaders Atlas database (2015).

Taxon	Notes	Recommendation
<i>Opuntia microdasys</i>	45 SAPIA records from Western Cape, Northern Cape, Gauteng and Limpopo; the earliest two sightings were recorded in 1990 from the Swartberg Pass and Oudtshoorn areas. No SAPIA records for KZN prior to this survey. A 1b species on the NEMBA regulations (Department of Environmental Affairs 2014b).	Advise both uThukela District Municipality and KZN Working for Water programme on manual removal.
<i>Opuntia ficus-indica</i>	3231 SAPIA records dating back to 1979, representing the entire country. Recorded as frequent in the 2830 CC quarter degree square on SAPIA by 1987. A 1b species on the NEMBA regulations (Department of Environmental Affairs 2014b), with the spineless cultivars excluded.	ARC-PPRI to ensure that the correct cochineal biotype is present on plants in the Tugela River basin.
<i>Opuntia stricta</i> var. <i>stricta</i>	Frequent in the Weenen/Mooi River area since 1987, with cochineal infection seen on plants near Muden in that year. This species was frequently seen in this survey with cochineal infections on many plants. A 1b species on the NEMBA regulations (Department of Environmental Affairs 2014b).	ARC-PPRI to ensure that the correct cochineal biotype is present on plants in the Tugela River basin.
<i>Opuntia aurantiaca</i>	Recorded as present on SAPIA by 1999 for the Weenen/Colenso area. A 1b species on the NEMBA regulations (Department of Environmental Affairs 2014b).	ARC-PPRI to ensure that the correct cochineal biotype is present on plants in the Tugela River basin.
<i>Peniocereus serpentinus</i>	One record from Herberdsdale, Western Cape, and one from Dendron, Limpopo, on SAPIA. Three populations recorded by Winter <i>et al.</i> (2011) from the Tugela basin; four new populations added to SAPIA from this survey. Currently a 1b species on the NEMBA regulations (Department of Environmental Affairs 2014b).	Advise both uThukela District Municipality and KZN Working for Water programme on manual removal.
<i>Echinopsis oxygona</i>	No confirmed SAPIA records for this species prior to this survey. Four SAPIA records of <i>Echinopsis</i> sp. outside of gardens, in the vicinity of the towns of Prince Albert, Colesberg and Graaff-Reinet. Not listed on the NEMBA regulations (Department of Environmental Affairs 2014b).	Add to SUSPECT list for further investigation by SANBI ISP.

SAPIA, Southern African Plant Invaders Atlas; KZN, KwaZulu-Natal; NEMBA, National Environmental Management: Biodiversity Act 10 of 2004; ARC-PPRI, Agricultural Research Council Plant Protection Research Institute; SANBI ISP, South African National Biodiversity Institute Invasive Species Programme; SUSPECT, Species Under Surveillance for Possible Eradication or Containment Targeting.

Tugela River, 28°43'21.3" S, 30°3'57" E, 716 m.a.s.l., in flower, *Cheek, M. 2288* (NH!); alongside the R74, south of Bloukrans River, Tugela River basin, 28°48'24.4" S, 30°3'12.1" E, 831 m.a.s.l., *Cheek, M. 2277* (NH!).

Echinopsis oxygona

SOUTH AFRICA. **KwaZulu-Natal:** Alongside the R74, south of Bloukrans River, Tugela River basin, 28°49'17" S, 30°2'21.4" E, 860 m.a.s.l., 08 Dec. 2014, *Cheek, M. 2276* (NH!).

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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

Both M.D.C. (South African National Biodiversity Institute) and N.R.C. (South African National Biodiversity Institute) were involved in the fieldwork, subsequent research, assessment and drafting of the manuscript. M.D.C. and N.R.C. were responsible for the field survey, plant identification, weed risk assessment and assessment of the invasion categories and concomitant recommendations. M.D.C. made the herbarium collections.

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