

Population changes of alien invasive plants in the Lower Kuiseb River

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Abstract

The status of six alien invasive plant species was investigated along the Lower Kuiseb River. The focus entailed a comparison of plants surveyed along transects located at five settlements of a rural community, with additional transects located between these settlements. While most living alien plants occurred in or adjacent to the main channel of the river, additional seed banks were noted in river areas further away from the channel. *Nicotiana glauca* was clearly on the increase along the length of the study area, while *Argemone ochroleuca*, *Ricinus communis*, *Datura stramonium* and *D. inoxia* appear to be declining, and *Prosopis* continues to be confined. While changing surface hydrology and near-surface geohydrology may underlie the increase in *N. glauca*, trampling action by increasing livestock numbers could perhaps explain the decreases by other species. More detailed studies and long-term monitoring are required to improve management of alien plants in the Kuiseb and other ephemeral rivers.

Keywords

wild tobacco, Topnaar community, ethnobotany, alien plant eradication, ephemeral rivers, livestock trampling

Introduction

The past thirty years has seen a growing awareness of and action on alien species and their impacts on ecosystems and processes. Alien invasives are non-indigenous species recently translocated into new areas by anthropogenic causes where they grow and reproduce particularly quickly and (potentially) cause changes to existing ecosystems, habitats and communities of indigenous species, and may stress economic systems (Van Wilgen *et al.* 2001; Venter 2002; Bethune *et al.* 2004). Some alien invasives have good uses, this being one of the reasons for their introduction, the other being incidental importation, e.g. with fodder (Brown & Gubb 1986; Smit 2004). Craven (1999) listed 156 alien plant species in Namibia. Of these, about 37 are invasive (Brown *et al.* 1985; Muller 1985; Barnard *et al.* 1998; Bethune *et al.* 2004).

However, alien invasive plants have seldom been demonstrated to be a serious problem in Namibia, although they may impact people and their livelihoods (Van den Eynden *et al.* 1992) as well as ecosystems or ecological processes at a local level (Bethune *et al.* 2004), and some of them are therefore justifiably flagged as members of the “nasty nine” (Steenkamp & Smit 2002) which should be the focus of management efforts (Shine *et al.* 2000; Venter 2002). Alien invasive plants often concentrate in or near riverbeds or drainage lines (Bethune *et al.* 2004). In the ephemeral rivers, seasonal floods play an important role in dispersing seeds of alien plants (Jacobson *et al.* 2000), colonising in particular areas which have been disturbed either by anthropogenic or natural causes (Boyer & Boyer 1989).

The Namib Desert is crossed by twelve westward flowing ephemeral rivers that originate in the highlands to the interior (Jacobson *et al.*, 1995). The Kuiseb River in the Central Namib separates the Namib Great Sand Sea from the gravel plains. The river extends from the Great Escarpment with a length of 440 km to the Atlantic Ocean (Stengel 1964). This river with its comparatively abundant water and vegetation resources has for centuries been the focus of activities of wildlife and people (Shackley 1985). Currently, livelihoods of the rural people continue to be founded on seedpod production of the indigenous Anatreas (*Faidherbia albida*) and Camelthorns (*Acacia erioloba*). The apparent increase in the occurrence of alien invasive plants and their effects on indigenous fauna and flora (Macdonald & Nott 1987; Boyer & Boyer 1989; Jabs 1991; Jacobson *et al.* 1995) are a matter of concern for management of the Kuiseb Basin, to the Namib-Naukluft Park, and to communal farmers of the Lower Kuiseb River.

According to Boyer (1989), alien invasive plants in the Namib-Naukluft Park get established in two kinds of locations. One kind is located in ephemeral rivers that originate in the Khomashochland and flow westwards across the Great Western Escarpment into the Namib Desert. The second kind of location comprises places that have been disturbed by people, livestock and game on farms and parks. This concurs with the study by Wells *et al.* (1986) that the areas in southern Africa most susceptible to the proliferation of alien invasive plants are riverine ecosystems and anthropogenically disturbed areas.

The current study investigates the spatial distribution of alien plants along the Lower Kuiseb River. We compare their abundance at settlements with that away from settlements as a test of Boyer’s (1989) hypothesis that some alien invasive plants grow preferentially at or near anthropogenically disturbed places, while other alien invasive plants suffer under anthropogenic impacts such as livestock trampling (Vinjeveld *et al.* 1985). Through interviews we attempted to establish the effects rural people may have on alien plants by using or eradicating them. The primary objective of this study was to establish a framework for future monitoring and management of alien species and factors that affect their abundance and distribution along the Kuiseb River.

Materials & Methods

Study Area

Fieldwork was conducted for 10 days during June 2004 in the Lower Kuseb River, with study sites located along a 60 km stretch between Homeb and Armstraat (close to Rooibank).

Climate data were collected at Gobabeb (23°33'S; 15°02'E), located 56 km inland. The mean annual temperature is 21.1°C (range 1.0-44.9°C) (Lancaster *et al.* 1984). Median annual rainfall is 11 mm (range 2-115.1 mm) and mean fog deposition is 33.5 litres.m⁻² (range 7-77 litres.m⁻²). The riverbed varies in width and a central channel is fringed by higher flood banks. From Homeb (23°38'S, 15°10'E) to Narob (23°30'S, 14°58'E) the riverbed is relatively narrow, from Narob to Swartbank (23°20'S, 14°51'E) the riverbed widens and from Swartbank to Rooibank (23°10'S, 14°38'E) it is at its widest and shallowest and many mid-river sandbanks occur.

Socio-economic survey

The study area contains 16 settlements or groups of households where Nama-speaking Topnaar community members live (Henschel *et al.* 2004) and keep cattle, goats, sheep, donkeys and horses (Table 1). Since some settlements are no more than 1-2 households, for the sake of the current study we grouped places together as follows: Homeb is grouped with Tatamutsi and Oswater; Natab-1 with Natab-2; Soutrivier with Gobabeb; Klipneus

Table 1: Numbers of livestock owned by residents at the study settlements and by Topnaars at all settlements along the Lower Kuseb River (survey of 2002, Directory of Engineering and Extension Services, Ministry of Agriculture, Water and Forestry)

Name	Cattle	Goats	Sheep	Donkeys	Horses	Total
Armstraat	0	50	0	19	0	69
Goadanab	0	132	0	4	0	136
Ururas	11	467	0	20	0	498
Utuseb	83	256	0	35	0	374
Swartbank	33	353	0	92	0	478
Klipneus	10	156	0	28	0	194
Soutrivier	0	258	8	25	0	291
Natab	2	525	0	21	0	548
Homeb	17	826	102	29	12	983
Total	156	3023	110	273	12	3571

alone; Swartbank alone; Utuseb with *Tsaraxa-aibes*; Ururas with Steekgras; Goadanab with Dawedraais; Armstraat alone.

We interviewed 13 people at 5 settlements, namely Homeb, Natab, Swartbank, Utuseb and Armstraat, concerning their usage of alien invasive plants and perceptions of changes in the occurrence of these plants. An interview was also conducted at the Namwater office at Rooibank, adjacent to Armstraat.

Plant surveys

Alien plants were recorded along 20 m wide transects oriented perpendicular to the river course. Five transects were positioned 200 m apart at each settlement, with one being across the middle of the settlement and two to the east and two to the west of the settlement. Similar sets of five transects were laid between the settlements well away from any human habitation and outside the daily foraging range of livestock. Lengths of transects were variable, depending on the width of the band of riparian vegetation. There were usually nine microhabitats along each transect:

- (1) gravel plains adjacent to the river;
- (2) gravel plain – river transition (sparse vegetation and a mixture of gravel and fine sand);
- (3) northern riparian forest (mainly comprising *Faidherbia albida*, *Acacia erioloba*, *Tamarix usneoides*, *Salvadora persica*, and *Euclea pseudebenus*);
- (4) northern bank of channel (sparse vegetation mostly tree seedlings);
- (5) main river channel (path of most recent river flood with sparse vegetation and topped with a cracked silt crust);
- (6) southern bank of channel;
- (7) southern riparian forest;
- (8) dune – river transition (large sandy hummocks around scattered vegetation);
- (9) dune field adjacent to the river.

Plant assessments

Our study focused on the six most common alien invasive plants that occur near Gobabeb (Henschel *et al.* 2006), namely, *Argemone ochroleuca* (Mexican poppy), *Datura inoxia* (downy thorn apple), *D. stramonium* (common thorn apple), *Nicotiana glauca* (wild tobacco), *Ricinus communis* (castor-oil bush), and *Prosopis* sp (mesquite). The species of *Prosopis* were not positively identified in this study, but *Prosopis glandulosa* var *torreyana* (honey mesquite) has previously been identified in our study area (Seely *et al.* 1980; Van den Eynden *et al.* 1992). Six *Prosopis* species have been introduced into Namibia, and they often hybridise (Smit 2004). In this study we refer to it as *Prosopis*. It was noted whether the plant had been damaged due to herbivory or trampling. Seeds were counted from 10-66 seedpods per species that were collected at random. No seeds were counted for *Argemone ochroleuca* as it did not bear seeds during our study.

Results

Socio economic surveys

Interview respondents indicated that the population of each settlement varied depending on the time of year and formal census information confirmed this. The total numbers of stock also proved to be difficult to determine as most respondents claimed to be unaware of their herd sizes.

Stock figures for 2002 were obtained from Directorate of Engineering and Extension Services of the Ministry of Agriculture, Water and Forestry (Table 1). These showed that there were about 3 600 livestock, 85% of them goats, along this 60 km stretch of river. Given that there is still game present in this area of the Namib-Naukluft Park, particularly springbok (no recent census figures are available), plants are exposed to high levels of potential herbivory.

Interviews at five settlements revealed a variety of uses for and problems with the alien plants under question (Table 2). The people reported that they do not apply any control measures to these plants, as they believe that destroying them locally will have no effect and is a waste

Table 2: Uses or problems of alien plant species by people and their livestock as reported in the current interviews

Species	by people	by livestock
<i>N. glauca</i>	wood for building, firewood	browse but not favoured
<i>Prosopis</i>	shade	shade, browse, pods as fodder
<i>R. communis</i>	medicinal seeds & leaves	browse, toxic seeds
<i>Datura spp.</i>	avoided, toxic	browse seedlings, mature plants toxic
<i>A. ochroleuca</i>	none	rash in mouth, bloating, blue meat

of time, due to the strong seed bank promoting persistence. When asked what changes they perceived in the numbers of plants and their distribution over time, the respondents indicated that there was no change, the plants had been there as long as they could remember and only increased in number with floods. The Namwater staff at Rooibank did not perceive the alien plants in the Kuisieb as a problem as they were not a threat to their infrastructure. Namwater also did not have a control program to prevent alien plants from being transferred from one basin to the next via transferred equipment.

Plant Surveys

The highest number of individuals of all alien plant species was found between Natab and Swartbank (31% of the total count) while the least was at Swartbank with 3%. Of the six plant species surveyed, only *Nicotiana glauca* was present at all locations (Table 3). It constituted 69% of the total alien plants at all sites. *Prosopis* constituted only 0.2% of the total count, and we only recorded it at the western extreme of our study area. *Argemone ochroleuca* was only found at Natab and only one individual plant was present at the site.

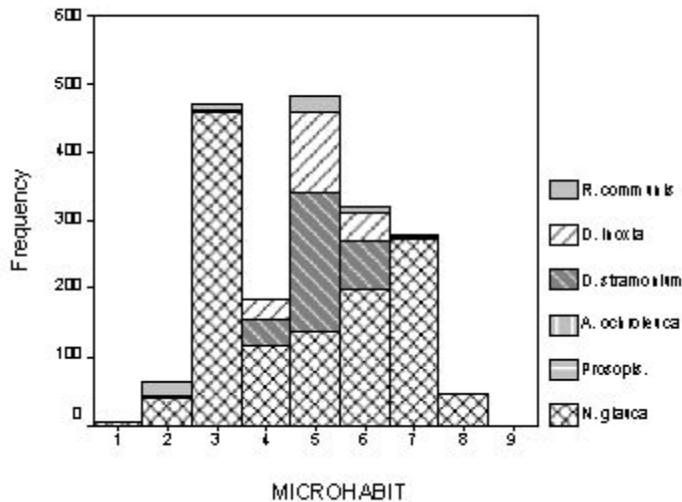


Figure 1: Occurrence of alien plant species in different microhabitats, which are numbered as follows: 1=gravel plains; 2=gravel-river transition; 3=northern riparian forest; 4=northern floodbank; 5=main channel; 6=southern floodbank; 7=southern riparian forest; 8=dune-river transition; 9=dunes.

Ricinus communis,

Datura stramonium and *D. inoxia* were widely distributed and constituted 3.7%, 17% and 10% respectively. *Nicotiana glauca* had about 986 ± 327 seeds per pod ($n=66$). *Datura inoxia* ($x=272 \pm 151$, $n=10$), *D. stramonium* ($x=237 \pm 123$, $n=10$), and *Prosopis* ($x=19 \pm 8$, $n=15$) are next in terms of numbers of seeds per pod. *Ricinus communis* always produces only 3 large beans per pod. Most alien plants grew in the main channel (Fig. 1). *Datura* spp. were confined to this area and the adjacent banks. *Nicotiana glauca* grew in all the habitats, with the highest number found in the northern riparian forest. *Ricinus communis* also grew in all habitats, but in small numbers. *Prosopis* grew on the banks of the channel.

All six plant species were present at Topnaar settlements (Table 3). *Nicotiana glauca* were common at all sites, and there were no significant differences between sites at settlements

Table 3: Alien plants recorded on sets of five transects at each location

Plant species	Homeb	H-N'	Natab	N-S	Swartbank	S-U	Utuseb	U-A	Armstraat	Total
<i>N. glauca</i>	149	112	202	74	55	252	233	80	115	1272
<i>Prosopis</i>								2	1	3
<i>R. communis</i>		4		8				9	47	68
<i>D. stramonium</i>				314		1			1	316
<i>D. inoxia</i>				187		2	1	1	1	192
<i>A. ochroleuca</i>			1							1
Total	149	116	203	583	55	255	234	92	165	1852

* letters separated by hyphen designate sets of transects between settlements, e.g. H-N is between Homeb and Natab

and sites away from settlements (sign test, $P > 0.05$). Though less abundant, there also did not appear to be a clear association or disassociation of *R. communis* with settlements, although none were observed as settlements with high stock numbers. *Datura* spp. were patchily abundant away from settlements and were almost absent from settlements, indicative of disturbance. There was therefore no evident relationship between numbers of livestock and numbers of alien plants, except for the possible negative relationship with *Datura* spp. and *R. communis*.

At settlements, livestock evidently caused damage to 31.2% of *N. glauca* that were trampled, 71% of *R. communis* that were browsed, and *Prosopis* that were apparently all browsed (casual observations of trees off transects confirmed this). Three solitary individuals of *D. inoxia*, *D. stramonium*, and *A. ochroleuca* found at settlements were undamaged, but the paucity of these species is indicative of heavy impact.

Discussion

All six of the previously documented dominant alien plants (Seely *et al.* 1980; Macdonald & Nott 1987; Boyer & Boyer 1989; Jabs 1991) were encountered in this survey. The plants were encountered in the highest frequency along the edges of the most recent flooding and in the main river course. This can probably be attributed to increased water and nutrient availability in these areas after flooding. However, the occurrence of dormant stands (dead plants bearing seedpods) up to the fringes of the river may have implications for periodic irruptions after floods. Short-term surveys therefore have limitations in determining the general status of aliens.

Nicotiana glauca was the most dominant species at all nine study sites. Although this plant has a strong smell and toxin as defence mechanism, it is occasionally browsed. A higher degree of damage is caused by trampling, and the persistence of *N. glauca* at settlements is indicative of its resilience despite damage. We counted up to 2,400 pods on older plants, amounting to a production of up to some 2 million seeds per plant. One-quarter of the plant individuals were still small (<1 m), and had probably germinated during the previous flood a few months prior to our study; 25% recruitment reflects a high rate of reproduction. Our study indicates an increase of *N. glauca* compared to previous studies (Boyer & Boyer 1989; Jabs 1991). We suggest that these fast-growing large-leaved plants, so unlike the slow-growing small-leaved indigenous Kuiseb plants, may impact the near-surface soil moisture.

We casually observed that there were large stands of dead *N. glauca*, bearing many seedpods, in the marginal habitats at the river boundary with the gravel plains and the dunes. Although seed viability was not tested, they probably bear a good seed reserve. These large peripheral stands indicate that *N. glauca* grows most vigorously and extensively in very high-flood years when it is widely distributed across the whole riverbed of the Kuiseb. It is during these high flood years that it acts as a possible competitor to indigenous plants.

Interviews showed that Topnaar people use wild tobacco but are not dependent on it. Although the use of its wood for construction and firewood is not confined to *N. glauca*, the ready availability of this wood may help reduce the pressure on indigenous trees. In a previous survey, the revitalising effect to people of leaf bandages was reported (Van den Eynden *et al.* 1992). We have frequently observed that dusky sunbirds favour the nectar of wild tobacco, and the abundance of this plant may therefore maintain high sunbird populations in the Kuiseb during times when other nectar sources are scarce.

Ricinus communis was found at four of the nine study sites, three away from settlements and one at the settlement with the lowest number of livestock (Table 1 & 3). We observed that livestock and other herbivores browsed this plant irrespective of location indicating that other herbivores also utilise the plant. Browsing did not appear to impact plant condition, and some *R. communis* grew isolated, others in stands. Most plants occurred close to the main river channel. Outlying plants most likely established themselves during high flood years. Seed production is far lower than for *N. glauca*, with an average of 9 seeds (maximum 219) per *R. communis* plant. Recovery from eradication may be slow, as few *R. communis* re-established themselves at Gobabeb in the 20 years since eradication (Boyer & Boyer 1989; pers.obs.). In a survey conducted at Gobabeb in 2007, only 0.3% of the over 600 alien plants in sample plots were *R. communis* (Isak Kaholongongo pers.comm.). The Topnaar people use the seeds and leaves for a range of medicinal purposes, and this invasive alien is therefore regarded as beneficial. During the time of our survey (mid-2004), we noted that in its native South America, castor-oil beans sold for US\$315 per kg. Perhaps there is potential to harvest and sell castor-oil products from the Kuiseb, but the likely effect may be an increase due to gardening and not a decrease of this invasive alien species.

We found *Datura innoxia* and *D. stramonium* only on transects downstream of Natab. We estimated the seed production of *Datura* spp. to range from 1,000 to 50,000 per plant; an average of 5 pods per plants with about 271 seeds each. *Datura* spp. have decreased compared to the situation in 1987 and 1991 (Boyer & Boyer 1989; Jabs 1991). During our study period we made casual observations in the Kuiseb canyon 40 km upriver of Gobabeb, and found a high abundance of *Datura* spp at Sarib. The current localised distribution may indicate that seeds do not disperse easily (as noted by Jabs 1991), while seedlings do not establish readily at existing plant stands and need to disperse. Livestock owners reported their dislike of this plant as they believe that its toxicity leads to livestock deaths. Even though they reported that they did not undertake eradication efforts against any alien plants, heavy trampling impacts at settlements may explain the lack of *Datura* there in agreement with Vinjevoold *et al.* (1985) concerning the impact of goats. Personal observations during the course of this study indicate very heavy browsing of young *Datura* plants, but that only flowering and seed-producing plants were avoided by goats. By contrast, *Nicotiana* plants of all ages and sizes were avoided by browsing goats, even within heavily browsed *Datura* stands. It is possible that *Datura* experience difficulties in re-establishing after eradication, e.g. at Gobabeb two decades ago (Boyer & Boyer 1989). This interpretation may contradict that of Bethune *et al.* (2004) concerning the inevitability of re-invasion after eradication of *Datura*; the question of population recovery of this species warrants further investigation.

Argemone ochroleuca have a scattered distribution across the lower Kuiseb and occurs at Gobabeb, but only one individual was recorded on our transects. It no longer appears to be as important in the Kuiseb as it was in the past, when Boyer & Boyer (1989) expressed concern about dense infestations that would be difficult to eradicate. For instance, only small patches of these plants are currently seen at Gobabeb (pers.obs.). Interviewed Topnaars reported that these plants are toxic to goats and also render their meat useless. The status of *A. ochroleuca* should be monitored in the Kuiseb and compared with other rivers. By ascertaining reasons for its changing abundance, insights valuable to management may be gained for this special effects weed which has the potential to choke surfaces (Henderson 2001).

Extensive research has been conducted on *Prosopis* spp. as they are thought to be the alien plants that pose the greatest threat to biodiversity in southern Africa, as well as a range of benefits to livelihoods (Smit 2004). The concern is that it could transform the Kuiseb River ecosystem as has occurred in, for instance, the Swakop River (Douglas 2008). We encountered only 3 specimens on our transects. In addition, we estimated that there are about 30 *Prosopis* trees in the immediate vicinity of Armstraat where they were previously recorded by Van den Eynden *et al.* (1992). Other observations (Seely *et al.* 1980; pers.obs.) indicate that there are a few scattered *Prosopis* trees elsewhere along the lower Kuiseb. We have also observed stands of *Prosopis* trees in tributaries of the upper Kuiseb (e.g. Djab), which pose a potential threat of spreading downstream. The local sources of seeds in the headstreams and near the lower end of the Kuiseb indicate that there is potential for *Prosopis* to invade

the Kuiseb. This plant should therefore be monitored closely. Plans should be made with the residents of Armstraat to control seed dispersal from there into the adjacent Kuiseb Delta where it may compete with !nara (*Acanthosicyos horridus*) for groundwater. The Topnaar people value *Prosopis* for its shade and food for livestock; they reported to Van den Eynden *et al.* (1992) that people, too, eat the pods. Collecting of all pods and crushing before consumption would be an effective means to decimate the seed bank while benefiting livelihoods as long as this is not copied for the use of *Acacia erioloba* and *Faidherbia albida* pods, where seed dispersal via livestock defecation should not be prevented.

Topnaar interviewees are of the opinion that alien invasive plants have not changed over time and have been there for as long as anybody can remember, implying that the first arrival of all of these species was many decades ago. Our observations indicate that the general status of alien plants in the lower Kuiseb seems to have changed during the past two decades, with an increase by *N. glauca*, and declines by *Datura* spp., *R. communis*, and *A. ochroleuca*. Our study obtained too little detailed information on *Prosopis* to tell, but we caution that the potential for invasiveness may be increasing. Whether and how several exceptionally high flood events in the past decade could have affected the status could not be established (positive: availability of water and seed dispersal, negative: plant destruction and flushing out of seed banks), and the increase of *N. glauca* appears to suggest a positive connection with surface hydrology following a decade with several good floods. It is possible that the increase of *N. glauca* promoted the decrease of the other species, as is so often the case with particularly fast-growing aliens (Versfeld *et al.* 1998).

We put forward that the general decline observed by us for several alien plant species can be attributed to the action of increasing densities of livestock. Livestock browsing has pronounced effects on many Kuiseb plants (Gabriel 1993). This browsing may sometimes include seedlings of otherwise unpalatable plants, such as *Datura* spp. and *R. communis*. Trampling potentially affects all small plants of any species, and this can be a formidable factor along the Lower Kuiseb (Moser 2006). A conservative estimate of 10,000 changes in hoof position per day per domestic animal outside its kraal and water point (walking only 1.2-2.5 km per day, most probably walk much further) would give 36-million trampling actions per day by the entire livestock population (some 10-20 ha of area daily under hooves), and this is highly concentrated around settlements. Topnaar livestock have about doubled in number since permanent boreholes were installed at settlements in 1979 (cattle: from 62 to 156, goats: from 1577 to 3023, donkeys: from 94 to 273; no sheep nor horses in 1979; Department of Veterinary Services), and the effects of insidious trampling by so many stock may now be telling by reducing survival and recruitment of small plants (Moser 2006), including alien invasives. *Nicotiana glauca* appear to have the highest tolerance.

Why are alien plants less dominant in the Kuiseb than in some other western ephemeral rivers of Namibia, such as the Swakop (Douglas 2008) or Omaruru (Moser 2006)? The

Kuiseb ecosystem could be in an ecological state that continues to favour indigenous vegetation over aliens, at least at certain canopy levels, giving it a degree of robustness (Moser 2006). Reasons may be physical characteristics of the Kuiseb riverbed, such as flood regime, geohydrology, nutrient availability and soil characteristics. Biological factors may include plant community conditions and inter-specific interactions, or could be affected by leaf- or seed-eating insects, birds or mammals. The type and level of uses and abuses by people and their livestock may play important roles, as could park management (e.g. eradication efforts). By examining reasons that underlie differences between the Kuiseb and other Namibian ephemeral rivers that are more affected by alien plants, important insights may be gained concerning the susceptibility of different habitats to invasion by aliens and the effectiveness of control measures.

A repetition of a complete survey of the Kuiseb river channel, such as undertaken in 1987, will enable direct comparison with previous surveys (Boyer & Boyer 1989). At shorter time intervals, e.g. every year, monitoring should be conducted at sample sites using the current transect approach and compare aliens in the riverbed at settlements with the riverbed well away from settlements. Species-specific studies should investigate plant responses to flooding, trampling, browsing and local eradication at different plant development stages as well as seed storage and dispersal. Causes for the declines of *A. ochroleuca*, *D. innoxia* and *D. stramonium* and the increase of *N. glauca* warrant investigation, as these may bear valuable lessons for management.

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