Australian Government

Weed management

Managing for biodiversity in the rangelands

Tony Grice and Tara Martin

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Contents

Abstract	2
Introduction	3
Defining the term ‘weed’	6
Weeds of the Australian rangelands	7
Identifying weeds	14
The impact of weeds on biodiversity	17
Reducing the impact of weeds on biodiversity	21
The four phases of invasion	21
Prevention	22
Eradication	23
Containment	25
Control	26
Weed management strategies	32
Investment in weed management	33
A checklist for weed management best practice	35
Recommendations	37
Further information	40

Abstract

Weed invasions pose a major threat to Australian rangeland ecosystems. They threaten both individual native species and communities of native plants and animals, and they alter important ecological processes. More than 640 non-native naturalised plant species are found in the Australian rangelands and 14 per cent of these pose a serious threat to rangeland biodiversity.

Total expenditure on weeds in the rangelands between 1997 and 2004 is estimated at $80 million. The majority of weed funding in rangelands is spent on Weeds of National Significance (WONS). Some species that pose a great threat to biodiversity but have production benefits, such as buffel grass (*Cenchrus ciliaris*), have not been nominated by states and territories as potential WONS.

Strategies to manage problems caused by weeds aim to prevent, eradicate, contain or control the weeds. It is unlikely, however, that any rangeland weed problem can be solved with one-off treatments using a single technique. Rather, a strategic approach that effectively integrates available techniques is required. Integrated weed management combines chemical, mechanical, biological, and fire control options—the combination used depends on the biology of the weed(s) and the circumstances under which it is growing.

Each control technique has potential side effects for native flora and fauna. Clearly, a particular weed management regime must produce a better outcome for biodiversity than the weed invasion itself.

In this paper, we consider the threats to the biodiversity of Australian rangelands from invasive, non-native plant species. We identify the regions where the threat is greatest and provide advice about integrated weed management strategies.

We discuss weed management techniques in light of the diverse tenures and land uses, and the extensiveness of the rangelands. We provide a checklist for evaluating projects that address rangeland weed problems relevant to environmental or biodiversity management. Management recommendations for reducing the impacts of existing weed problems and minimising the risk of new weed problems arising are also included.

This paper is part of a series of related publications on Managing for Biodiversity in the Rangelands, intended to provide government agencies, land managers and others with relevant information on protecting biodiversity in the rangelands.

Introduction

Australia's rangelands cover a huge area of the Australian landmass, estimated at the time of writing to be about 70 per cent (6 million km2) of the continent. Land use and land tenure in the rangelands varies considerably. Pastoralism, mostly on leasehold land, is the most extensive land use, with over half of the rangelands used specifically for livestock production. Land tenure is diverse, with thirteen different tenures in the rangelands. Indigenous land occupies 16 per cent, conservation reserves and national parks cover seven per cent, unassigned state-owned Crown Land occupies around 13 per cent and non-indigenous freehold approximately eight per cent.

Rangelands support diverse and rich communities of plants and animals that are culturally, socially, ecologically and economically significant at national and international levels. Like many ecosystems across the world, Australian rangelands are threatened by invasions of pest plants and animals. Pest plant species—broadly called weeds—have an extensive impact, threatening individual native species and communities of native plants and animals, and altering the ecological processes upon which these communities depend.

Weeds have enormous consequences for the Australian continent. In 1994, the annual national economic impact of weeds was estimated at $3,554 – 4,532 million based on the cost of weed control and, more significantly for the rangelands, the value of lost production. While these figures are substantial, they are underestimated as they do not take into account the cost of losses in biodiversity, ecosystem function, or cultural value caused by weed invasions.

Weeds have a significant impact on the biodiversity of Australian rangelands. The rangelands have a high level of biodiversity; they include 53 of the 85 Interim Biogeographic Regions of Australia (IBRA), and five of Australia's 15 biodiversity hotspots. A hotspot is an area rich in plant and animal species, particularly many endemic species, which is under immediate threat from impacts such as land clearing, development pressures, salinity, weeds and feral animals. Five of Australia's 15 hotspots occur in the rangelands: 1) Einasleigh and Desert Uplands, 2) Brigalow North and South, 13) Carnarvon Basin, 14) Hamersley/Pilbara and 15) North Kimberley. The rangelands support 67 per cent of Australia's reptiles, 62 per cent of birds, 47 per cent of frogs, 33 per cent of mammals, and a diverse (and not fully known) range of invertebrates.

In this paper, we consider the threats to the biodiversity of Australian rangelands from weeds. We identify the weed management techniques that will be most effective given the diverse tenures and land uses, and the extensiveness of the rangelands.

This project

The purposes of the project, conducted by the Co-operative Research Centre for Australian Weed Management, were to:

- identify which weeds are a problem in Australian rangelands
- describe where those problems occur
- outline the threats that weeds pose for biodiversity in rangelands
- describe and evaluate current weed management practices in relation to biodiversity in rangelands
- summarise past weed management projects and their impacts
- evaluate current policies and regulations relating to weed management
- provide a checklist for planning and implementing weed management projects

The project used the experience and knowledge of an expert panel drawn from a number of organisations including CSIRO, the Queensland Government, the Australian Government, The University of Queensland, and Desert Channels Queensland.

A series of discussion papers produced over the course of the project is published in a special issue of *The Rangeland Journal* (2006).

Defining the term ‘weed’

The term ‘weed’ can mean a number of things. In this publication, we use the following definitions:

- A ‘weed’ is any unwanted plant, whether native or non-native species. Here, we do not tackle the issue of problematic native plant species although many of the principles discussed relate equally to native and non-native species. We accept that there are species native to Australia that are problematic from some perspective, either within their native range or in some other part of Australia.
- ‘Non-native species’, ‘introduced’ or ‘alien’ plants are species that are not native to the Australian continent and have been brought to Australia directly or indirectly through human activity.
- ‘Naturalised species’ are non-native species that reproduce consistently, without human intervention, and sustain populations over many life cycles.
- An invasive plant is any naturalised species that can spread in the area to which it has been introduced.

Weeds of the Australian rangelands

The Australian rangelands currently support more than 640 non-native naturalised plant species including a diverse range of trees, shrubs, grasses, forbs and aquatic plants, all at various stages of invasion. Many of these were introduced deliberately, either for primary production or as ornamental plants that found their way to the rangelands from botanical gardens and suburban backyards.

There are 92 non-native plant species that pose the greatest threats to rangeland biodiversity (Table 1). Of these, 43 per cent are trees or shrubs, 28 per cent are grasses, 22 per cent are forbs, while the remaining seven per cent are climbers or aquatic species.

Recent studies show there is significant connection between the traits of plant species and their potential to impact plant biodiversity—invaders tend to be highly habitat-dependant and context-specific. For example, in the sub-tropics, a perennial tall tussock or rhizomatous grass, with its main growing period in summer, is guaranteed to have a high impact on the richness of native herbaceous species.

Several non-native species that pose a threat to biodiversity are not included in current national ranking lists and, therefore, are not a priority for Australian Government funding. In particular, several non-native grasses pose significant threats to biodiversity. While most of these grasses were introduced as potential pasture species, current attitudes toward them vary greatly. Some, such as grader grass (*Themeda quadrivalvis*), are detrimental to both pastoralism and the environment. Others, such as buffel grass (*Cenchrus ciliaris*), are highly valued as pasture species but pose serious threats to rangeland biodiversity. Resolving these conflicts of interest is a major challenge.

While scores of non-native species currently pose a threat to biodiversity in the rangelands, there are others of high risk that have not yet arrived. Species such as *Aeschynomene paniculata*, *Azadirachta indica*, *Bracharia mutica*, *Brillantaisia lamium*, *Crupina vulgaris*, *and Echinochloa polystachya*, while not currently a problem, have the potential to greatly impact biodiversity if not managed.

Figure 2: Grazing Land Management Zones (GLMZ)

There is an urgent need to map the current and potential extent of several species that threaten rangeland biodiversity. Approximately 30 per cent of the species listed in Table 1 have been mapped at the national scale. A further 60 per cent have been mapped by state and national herbaria. These maps, however, are not comprehensive and only indicate where specimens have been collected and lodged with the herbaria. The current distributions of the other 10 per cent of species have not been mapped. Maps of 'potential distribution' exist for only 30 per cent of the species listed in Table 1.

Grazing Land Management Zones (GLMZ) provide a useful framework for the management of rangelands (Figure 2). Amalgamations of the Interim Biogeographic Regions of Australia (IBRA), they are based on biophysical characteristics, land uses, land modification and stocking characteristics in the rangelands. The zones containing the most weeds that pose serious threats to biodiversity are the Einasleigh and Desert Uplands, Highly Modified Rangelands (Brigalow North and South), Tropical Savannas, and Arnhem Land. Of the five biodiversity hotspots that occur within the rangelands, the ones that contain the most weeds are Brigalow North and South, and Einasleigh and Desert Uplands.

Grazing Land Management Zones

1. Arnhem Land and Tiwi Islands
2. Tropical Savannas
3. Mitchell Grass Downs
4. Einasleigh and Desert Uplands
5. Arid Deserts
6. Central Australian Cattle Grazing
7. Pilbara: Extensive Cattle Grazing in Tussock and Hummock Grasslands
8. Southern Australian Sheep and Cattle Grazing
9. Extensive Sheep Grazing
10. Highly Modified Rangelands

Table 1:

Weeds posing the greatest threat to rangeland biodiversity

#	Scientific Name	Common Name	Growth Form	Current GLMZ (potential GLMZ)	Biodiversity Hotspot
1	*Acacia curassavica*	redwood	shrub/ tree	1, 2, 3, 4, 5, 10	Einasleigh and Desert Uplands: North Kimberley
2	*Acacia catechu*	cutch tree	tree	2	none
3	*Acacia karroo*	karroo thorn	tree	5, 10	none
4	*Acacia nilotica*	prickly acacia	shrub/ tree	2, 3, 4, 5, 10 (6, 7, 8)	Einasleigh and Desert Uplands: Brigalow North and South: North Kimberley
5	*Achnatherum caudatum*	speargrass	perennial grass	10	none
6	*Aeschynomene paniculata*	panicle jointvetch	shrub	2	none
7	*Agave* spp.	agave	large perennial forb	2, 3, 8, 9, 10	Einasleigh and Desert Uplands: Brigalow North and South
8	*Agrostis capillaris*	browntop bent grass	perennial grass	4, 5, 8	none
9	*Alternanthera philoxeroides*	alligator weed	aquatic	8 (9)	Brigalow North and South
10	*Andropogon gayanus*	gamba grass	perennial grass	1, 2, 4, 6	Brigalow North and South: Hamersley/ Pilbara
11	*Annona glabra*	pond apple	tree	4 (1, 2, 10)	none
12	*Asphodelus fistulosus*	onion weed	perennial forb	4, 6, 8, 9, 10	Brigalow North and South: Carnarvon Basin: Hamersley/ Pilbara
13	*Azadirachta indica*	neem tree	tree	2, 4, 5	none
14	*Barleria prionitis*	barleria	shrub	2, 4, 5, 10	none
15	*Brachiaria mutica (Urochloa mutica)*	para grass	perennial grass	1, 2, 3, 4, 10	Einasleigh and Desert Uplands
16	*Bryophyllum daigremontianum x Bryophyllum delagoense*	mother-of-millions hybrid	perennial forb	2, 3, 4, 6, 9, 10 (1, 5, 7, 8)	none
17	*Cabomba caroliniana*	cabomba	aquatic	4 (1, 2, 8, 9, 10)	none
18	*Calotropis gigantea*	giant rubber bush	shrub	1, 2, 6	Brigalow North and South: North Kimberley
19	*Calotropis procera*	calotrope	shrub	2, 4, 5, 6 (3, 7, 8, 9, 10)	Einasleigh and Desert Uplands
20	*Carrichtera annua*	wards weed	annual forb	5, 6, 7, 8, 9	none

Table 1: continued

Weeds posing the greatest threat to rangeland biodiversity

#	Scientific Name	Common Name	Growth Form	Current GLMZ (potential GLMZ)	Biodiversity Hotspot
21	*Cascabela thevetia*	Captain Cook tree; yellow oleander	tree	1, 2, 4, 9, 10	North Kimberley
22	*Cenchrus ciliaris*	buffel grass	perennial grass	1, 2, 3, 4, 5, 7, 10 (6, 8, 9)	Einasleigh and Desert Uplands: Brigalow North and South: Carnarvon Basin: Hamersley/ Pilbara: North Kimberley
23	*Cestrum parqui*	green poisonberry	shrub	9, 10	Einasleigh and Desert Uplands: Brigalow North and South
24	*Chromolaena odorata*	Siam weed	shrub	3, 4, 8, 10	Einasleigh and Desert Uplands: Brigalow North and South
25	*Cirsium vulgare*	spear thistle	annual forb	3, 4, 8, 9, 10	Einasleigh and Desert Uplands: Brigalow North and South
26	*Citrullus lanatus*	Afghan melon	annual forb	2, 3, 4, 8, 9, 10	Einasleigh and Desert Uplands: Brigalow North and South: Hamersley/ Pilbara: North Kimberley.
27	*Coronopus didymus (Lepidium didymum)*	lesser swinecress	annual forb	2, 7, 8, 9, 10	Brigalow North and South:
28	*Cryptostegia grandiflora*	rubber vine	climber/ shrub	2, 3, 4, 6, 8, 10 (5, 7, 9)	Einasleigh and Desert Uplands: Brigalow North and South: North Kimberley
29	*Cuscuta planiflora*	small-seeded alfalfa dodder	annual forb	8, 9, 10	Carnarvon Basin
30	*Datura ferox*	fierce thorn-apple	annual forb	2, 6, 9, 10	Brigalow North and South
31	*Echinochloa polystachya*	aleman grass	perennial grass	1, 2, 4, 10	Brigalow North and South
32	*Eichhornia crassipes*	water hyacinth	aquatic	1, 2, 4, 9, 10 (3, 5, 6, 7, 8)	none
33	*Eragrostis curvula*	African lovegrass	perennial grass	8, 9, 10	Brigalow North and South: Carnarvon Basin
34	*Gmelina elliptica*	badhara bush	shrub	2	n/a
35	*Grewia asiatica*	phalsa	shrub	2, 3, 4	none
36	*Gymnocoronis spilanthoides*	Senegal tea	perennial forb	(1, 2, 4, 10)	none
37	*Harrisia martinii*	harrisia cactus	shrub	10	Brigalow North and South

Table 1: continued

Weeds posing the greatest threat to rangeland biodiversity

#	Scientific Name	Common Name	Growth Form	Current GLMZ (potential GLMZ)	Biodiversity Hotspot
38	*Hieracium caespitosum*	hawkweed	annual forb	2	none
39	*Holcus lanatus*	Yorkshire fog	annual grass	2, 6, 8, 10	Brigalow North and South
40	*Hymenachne amplexicaulis*	olive hymenachne	perennial grass	4, 10 (5, 8)	Einasleigh and Desert Uplands: Brigalow North and South
41	*Hyparrhenia hirta*	coolatai grass, tambookie grass	perennial grass	1, 2, 6, 8, 10	Brigalow North and South
42	*Hyparrhenia rufa*	thatch grass	perennial grass	2, 10	Einasleigh and Desert Uplands: Brigalow North and South
43	*Hyptis suaveolens*	hyptis	annual forb	1, 2, 4, 10 (3)	Einasleigh and Desert Uplands: Brigalow North and South
44	*Ibicella lutea*	yellow-flowered devil's claw	annual forb	2, 3, 4, 8	Brigalow North and South
45	*Ipomoea indica*	purple morning glory	climber	9, 10	Brigalow North and South: Carnarvon Basin
46	*Jatropha curcas*	physic nut	shrub	2	Einasleigh and Desert Uplands
47	*Jatropha gossypifolia*	cotton-leaf physic nut	shrub	2, 3, 4, 5, 10, (1, 7)	Einasleigh and Desert Uplands
48	*Juncus acutus* ssp. *acutus*	spiny rush	perennial forb	9	Einasleigh and Desert Uplands
49	*Koelreuteria elegans*	Chinese rain tree	tree	10	none
50	*Lantana camara*	lantana	shrub	2, 4, 10 (8, 9)	Einasleigh and Desert Uplands: Brigalow North and South: Hamersley/ Pilbara;
51	*Lantana montevidensis*	creeping lantana	shrub	10 (1, 2, 4)	Brigalow North and South
52	*Leucaena leucocephala*	leucaena	tree	1, 2, 3, 4, 10	Einasleigh and Desert Uplands: Brigalow North and South: Hamersley / Pilbara: North Kimberley.
53	*Lycium ferocissimum*	African boxthorn	shrub	3, 8, 9, 10 (5, 6)	Brigalow North and South: Carnarvon Basin
54	*Martynia annua*	devil's claw	annual forb	1, 2, 4, 10	Einasleigh and Desert Uplands: Brigalow North and South
55	*Melinis minutiflora*	molasses grass	perennial grass	1, 2, 3, 4, 5	Brigalow North and South
56	*Mimosa pigra*	giant sensitive tree	shrub	1, 2 (4)	none

Table 1: continued

Weeds posing the greatest threat to rangeland biodiversity

#	Scientific Name	Common Name	Growth Form	Current GLMZ (potential GLMZ)	Biodiversity Hotspot
57	*Nassella charruana*	lobed needlegrass	perennial grass	0	none
58	*Nassella hyalina*	cane needlegrass	perennial grass	0	none
59	*Nassella tenuissima*	Mexican feathergrass	perennial grass	0	none
60	*Nassella neesiana*	Chilean needlegrass	perennial grass	8, 10 (9)	Brigalow North and South
61	*Nassella trichotoma*	serrated tussock	perennial grass	10 (8, 9)	none
62	*Opuntia* spp.	prickly pear	shrub	3, 5, 6, 8, 9, 10	Brigalow North and South: Hamersley/ Pilbara
63	*Parkinsonia aculeata*	parkinsonia	shrub	1, 2, 3, 4, 5, 6, 7, 8, 9 ,10	Einasleigh and Desert Uplands: Brigalow North and South: Hamersley/ Pilbara
64	*Paspalum notatum*	bahia grass	perennial grass	2, 10	Brigalow North and South: North Kimberley
65	*Peganum harmala*	African rue	perennial forb	9	none
66	*Pennisetum polystachion*	mission grass	perennial grass	1, 2, 4, 10	Hamersley/ Pilbara;
67	*Pennisetum setaceum*	African fountain grass	perennial grass	2, 4, 5, 6, 7, 8, 9, 10	Brigalow North and South: Hamersley / Pilbara
68	*Pereskia aculeata*	leaf cactus	shrub	0	none
69	*Phyla* spp.	lippia	aquatic/ perennial forb	10	Einasleigh and Desert Uplands; Brigalow North and South: Hamersley/ Pilbara
70	*Praxelis clematidea*	praxelis	perennial forb	2, 4	Einasleigh and Desert Uplands
71	Proboscidea louisianica	purple-flowered devil's claw	annual forb	8, 9, 10	Carnarvon basin
72	*Prosopis* spp.	mesquites	shrub/ tree	2, 3, 4, 6, 7, 8, 9, 10 (1)	Einasleigh and Desert Uplands: Brigalow North and South: Hamersley/ Pilbara
73	*Retama raetam*	white weeping broom	shrub	0	none
74	*Rubus fruticosus* sp. agg.	blackberry	shrub	8, 9, 10	none
75	*Salvinia molesta*	salvinia	aquatic	4, 10 (1, 2, 3, 5, 6, 7, 8, 9)	Einasleigh and Desert Uplands: Hamersley/ Pilbara
76	*Schinus molle*	Peruvian peppertree	tree	4, 6, 8, 9, 10	Brigalow North and South

Table 1: continued

Weeds posing the greatest threat to rangeland biodiversity

#	Scientific Name	Common Name	Growth Form	Current GLMZ (potential GLMZ)	Biodiversity Hotspot
77	*Senna obtusifolia*	Java bean	shrub	1, 2, 4, 10 (3)	none
78	*Senna occidentalis*	coffee senna	shrub	1, 2, 3, 4, 5, 6, 10	Einasleigh and Desert Uplands: Brigalow North and South: Hamersley/ Pilbara: North Kimberley
79	*Senna tora*	Java bean	shrub	1, 2, 4, 10 (3)	none
80	*Sida acuta*	spiny-head sida	perennial forb/ shrub	1, 2, 4, 5, 6, 10	Einasleigh and Desert Uplands: Hamersley / Pilbara: North Kimberley
81	*Sida cordifolia*	flannel weed	shrub	1, 2, 3, 4, 5, 6, 10 (7, 8, 9)	Einasleigh and Desert Uplands: Brigalow North and South: North Kimberley
82	*Sida rhombifolia*	Paddy's lucerne	shrub	1, 2, 3, 4, 5, 6, 10 (7, 8, 9)	Einasleigh and Desert Uplands: Brigalow North and South: Hamersley / Pilbara;
83	*Sporobolus fertilis*	giant Parramatta grass	perennial grass	2	Einasleigh and Desert Uplands: Brigalow North and South
84	*Sporobolus jacquemontii*	American rat's tail grass	perennial grass	2	Einasleigh and Desert Uplands: Brigalow North and South
85	*Sporobolus natalensis*	giant rat's tail grass	perennial grass	2, 4, 10	none
86	*Sporobolus pyramidalis*	giant rat's tail grass	perennial grass	4, 6, 10	Einasleigh and Desert Uplands: Brigalow North and South
87	*Sporobulus africanus*	Parramatta grass	perennial grass	8, 10	Einasleigh and Desert Uplands
88	*Stylosanthes scabra*	shrubby stylo	perennial forb	1, 2, 3, 4, 10	Einasleigh and Desert Uplands: Brigalow North and South: North Kimberley
89	*Tamarix aphylla*	athel pine, tamarisk	tree	5, 6, 8, 9 (3, 4, 10)	Einasleigh and Desert Uplands: Carnarvon basin
90	*Tamarix ramosissima*	salt cedar	shrub/ tree	6,9	none
91	*Themeda quadrivalvis*	grader grass	annual grass	1, 2, 4, 10	Einasleigh and Desert Uplands: Brigalow North and South: North Kimberley
92	*Ziziphus mauritiana*	Indian jujube, Chinee apple	shrub/ tree	3, 4, 6, 10 (5, 8, 9)	Einasleigh and Desert Uplands: Brigalow North and South: North Kimberley

Identifying weeds

The most cost-effective method of reducing the impact of weeds is to prevent them from establishing in new areas. First, we need to correctly identify them in the early stages of invasion so we can then determine the best course of action.

Information that helps land managers to identify non-native weeds, including those in the rangelands, is increasingly available in both hardcopy and electronic format on the internet, usually from the departments responsible for weed management in the respective states and territories (Table 2).

Table 2:
State and territory websites that help identify weeds

State/Territory	Department	Website
NSW	Department of Primary Industries	www.dpi.nsw.gov.au
NT	Department of Business, Industry and Resource Development	www.nt.gov.au
QLD	Department of Natural Resources, Mines and Water	www.nrm.qld.gov.au
SA	Department of Water, Land and Biodiversity Conservation	www.dwlbc.sa.gov.au
WA	Department of Agriculture	www.agric.wa.gov.au

The quantity of information provided by state and territory departments depends on the level of resources they allocate to weed-related issues. The most common extension tool is information brochures on individual weed species, such as Agfacts in New South Wales, Agnotes in the Northern Territory, and Pest Facts and Warning Brochures in Queensland. These are used by state and territory agencies to educate the community about what the plants look like, how and where they grow, and what control methods are available.

Recently, local government authorities and regional Natural Resource Management bodies have employed staff to identify and help manage weeds in their areas. As a result, these areas have seen a marked increase in the rate of detection of new outbreaks.

The Australian Quarantine and Inspection Service has also been proactive in undertaking surveillance activities for new introductions, with staff frequently finding the first recorded outbreaks of exotic species in Australia.

Since the implementation of the National Weeds Strategy in 1997, a number of national initiatives have commenced to minimise the impacts of weeds in Australia. Table 3 summarises these initiatives in terms of their impacts on improving weed identification.

Table 3:

National initiatives to minimise the impacts of weeds

National initiatives	Description and status
Weeds of National Significance (WONS) Program www.deh.gov.au/biodiversity/invasive/publications/#weeds	Establishing a grouping of Weeds of National Significance (WONS) has provided information to help people identify the 20 worst weeds in Australia. Coordinators have been appointed and management groups established. Extension products developed for individual species include: > weed management guides for all 20 WONS > Best Practice/Case Study Manuals for prickly acacia, parkinsonia, mesquite, lantana, parthenium and rubber vine > multi-species extension material for species with similar growth forms or species within the same genera > field trips for small groups
National Environmental Weed Alert List www.deh.gov.au/biodiversity/invasive/publications/#weeds	A compilation of 28 plant species that have the potential to become significant threats to biodiversity if they are not managed. Weed management guides, similar to those for the Weeds of National Significance, have also been produced.
National Weed Pocket Guide/ Identification Cards	A number of 'pocket guides'—small, durable booklets that can be easily transported and carried in vehicles—for identifying weeds in the field. With key identification traits customised for specific areas, the books have textbook quality pictures. Examples of guides produced include *Plants of the New South Wales Rangelands* (Brooke and McGarva 1998), the *Burdekin Dry Tropics* (Department of Natural Resources and Mines 2003), *Cape York Peninsula* (Department of Natural Resources and Mines 2001), and *Agricultural and Environmental Weeds of Far North Queensland* (Department of Natural Resources and Mines 2001). A National Pocket Guide for the Weed Identification Project has produced WEEDeck—identification cards for 170+ species in decks for temperate, sub-tropical and tropical weeds. For a fee, any organisation can request the production of a WEEDeck set of cards specific to the requirements of their region, catchment, or local government authority.
Weeds Australia website www.weeds.org.au/weedident.htm	This website aims to promote access to key weed policies, regulations, current issues, national initiatives, research, extension, training and personnel. It provides a weed identification tool based on the WEEDeck card series. Major weeds that are of current or potential importance are listed for any IBRA region. The weeds can be grouped into growth forms, such as, herbs, grasses, shrubs, trees, vines or water plants. For each weed listed, there are identification photos, details of current and potential distributions, descriptions of plant attributes and distinguishing features such as dispersal mechanisms.
Declared Plants of Australia: An Identification and Information System www.cbit.uq.edu.au	Declaration of pest plants under state legislation imposes legal responsibility for control on landholders and landholding agencies, and so it is important that tools are available for identifying relevant weeds. Declared plants of Australia is an interactive CD-ROM to help identify 300 declared species and an additional 500 species that occur in Australia. It includes illustrations of plants and key plant features, and information on aspects such as distribution, legislation and management.
Pilot National Weed Detection Project	The National Weed Detection Project is a pilot program run by the CRC for Australian Weed Management. If successful, the feasibility of implementation on a national scale will be investigated. The program objective is to increase capacity for detecting weed infestation in regional Australia by fostering community interest and skills in invasive plants, and assisting herbaria to play a supporting role. This will initially determine if regional networks can function effectively in two locations (Townsville and Rockhampton). The network will consist of people from varying backgrounds who can carry out weed surveillance, recognition and specimen collection for identification purposes. Training will be provided to those in the network.

The impact of weeds on biodiversity

Plant invasion presents a serious threat to biodiversity management and conservation in the Australian rangelands; it is ranked with habitat clearance, livestock grazing, forestry and soil degradation as a major source of pressure on native species and communities. Non-native plant species present a major threat to Australian biodiversity at species, community and ecosystem levels.

The impact of weeds is not a simple function of the number of non-native species present. Some invasive species dominate the vegetation that they invade while others, although abundant, are not important in terms of their contribution to total plant material. So, a species could be relatively uncommon and yet have a huge influence on biodiversity or ecosystem function.

How important is the threat from invasive plant species?

The scientific literature includes many accounts of native Australian species under threat, from either a single or multiple weed species.

The current and potential distributions of 33 of the 71 non-native plant species nominated as possible WONS cover some portion of Australia's rangelands.

At the ecosystem level, ten of Queensland's 13 bioregions are entirely or partially covered by rangelands. Nine of these have non-native plants listed as one of the threats to their biodiversity. Fifteen species are specifically identified as threats.

What is threatened by invasive species?

Although there have been few quantitative studies of the effects of weed species on Australian rangeland biodiversity, it is apparent that the impacts are currently or potentially great, with macrophytes and vertebrates the most affected. There are, however, few studies of the effects of invasive plants on soil flora and fauna or on invertebrates in general, or on how an invasive species influences specific ecological processes.

Some weed species can drastically change the structure and plant species composition of native vegetation. Many prominent rangeland weeds reach very high densities and out-compete native plant species. Changes to native vegetation subsequently affect the animal communities that depend on them.

Some types of rangeland environment are more prone to weed invasions. For example, riparian zones and wetlands appear to be especially prone to invasion. This is probably due to the weeds' own dispersal mechanisms, the availability of water, and the land being more fertile than other parts of the rangeland landscape. Prominent riparian invaders include prickly acacia (*Acacia nilotica*), rubber vine (*Cryptostegia grandiflora*), bellyache bush (*Jatropha gossypifolia*), athel pine or tamarisk (*Tamarix aphylla*) and neem (*Azadirachta indica*). In contrast, environments that are in some way more extreme—such as arid central Australia—seem to have fewer weed species. However, communities can be altered drastically by a single non-native species, and biodiversity can be threatened if the weed species is well adapted to that environment.



What are the impacts of invasive species?

Studies of the effects of invasive species on biodiversity show evidence of four general types of impacts:

- The abundances of individual native, threatened plant species are directly reduced by the abundance of the weed species that has invaded their habitat.
- The abundance of common components of the invaded communities is reduced (although shade-tolerant native species are reported to be more abundant at sites invaded by broom (*Cytisus scoparius*)).
- The abundance/presence of invasive exotic species reduces the abundance/presence of native plant species.
- Animal groups vary considerably in their response to weed invasions. For example, bird communities are affected by invasive plant species but different guilds seem to respond in different ways: in some cases, the total abundance of bird species may not change at all; in others, the numbers of species present may change inconsistently.

The growth form of a particular weed species influences its impact. For example, low-growing species, grasses, forbs and low shrubs will have most effect in the understorey, but they can also influence the overstorey of woodland communities, for example by affecting recruitment processes.

Although trees and shrubs constitute only around seven per cent of the non-native species of Australian rangelands, they represent almost 40 per cent of the rangeland species nominated as WONS. It may be that, due to their dominance of the overstorey, their impact is more obvious. This happens, for example, when a woody species such as prickly acacia (*Acacia nilotica*) invades naturally treeless communities such as Mitchell grasslands.

Another prominent growth form group among the weeds of Australian rangelands are the perennial grasses. Two wetland species, olive hymenachne (*Hymenachne amplexicaulis*) and para grass (*Urochloa mutica*), are serious threats to the biodiversity of floodplain and riparian communities in the wetter parts of the northern rangelands. The most important invasive grass in the Australian rangelands is buffel grass (*Cenchrus ciliaris*) which can thrive in arid and semi-arid areas. As there are few options for controlling invasive perennial grasses of the rangelands, developing control options should be a priority.

Some growth forms are very likely to dominate the vegetation, or at least the stratum that they invade. These ‘transformer species’ have serious consequences for biodiversity. They include the perennial grasses buffel grass (*Cenchrus ciliaris*) and gamba grass (*Andropogon gayanus*), the riparian rubber vine (*Cryptostegia grandiflora*), and the trees prickly acacia (*Acacia nilotica*), athel pine (*Tamarix aphylla*) and mesquite (*Prosopis* spp.). On the other hand, although there has been little research, the 70-80 per cent of non-native rangeland plants that are annual probably have more subtle impacts that are nevertheless important.

Vines can also be important invaders of rangelands. The most notable example is rubber vine (*Cryptostegia grandiflora*) which is highly invasive in northern Australian rangeland riparian zones.

The mechanisms of impact

Weeds influence the ecosystems that they invade:

- by direct competition; they out-compete native plants for light, carbon dioxide, oxygen and nutrients
- through their effects on availability of resources for animals
- by modifying ecological processes, such as fire regimes, which are important influencers of biodiversity in the rangelands

Reducing the impact of weeds on biodiversity

The four phases of invasion

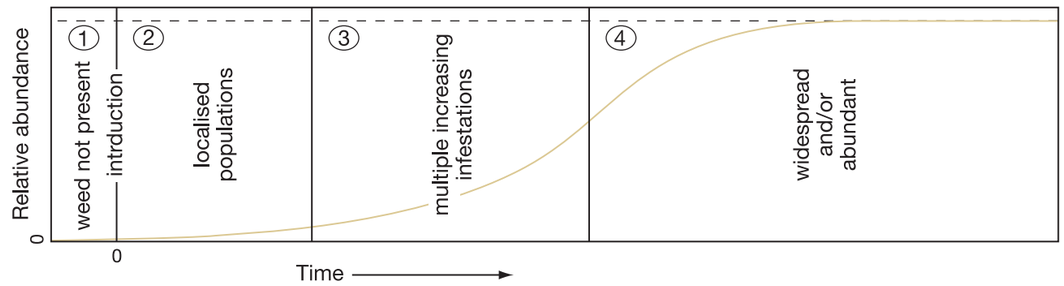
Strategies to manage problems caused by weeds can aim to prevent, eradicate, contain or control the weeds. Prevention is the most efficient means of dealing with any plant invasion; the aim is to prevent the particular plant species from being introduced in the first place.

Once a weed is introduced, the objective of management could be to eradicate, contain or control the species, or to ignore it. Eradicating the weed, i.e. completely eliminating the species from an area, is likely to be feasible only in the early phase of invasion when infestations are restricted to very few localised populations (Figure 3, phase 2).

Containing the weed, i.e. stopping the species from spreading, is an appropriate strategy when eradication is not feasible, the species has not reached the full extent of its potential range, and there are localised populations (Figure 3, phase 2).

When a weed is widespread and abundant (Figure 3, phases 3 and 4), the only strategic option is to control its impacts. This is the case with many weed problems in Australia's rangelands. As a general principle, weed management is more likely to be effective and efficient when undertaken early in the invasion process.

Figure 3: The four phases of plant invasion (Hobbs and Humphries, 1995)



Prevention

We use the term ‘prevention’ here to refer only to measures at the national scale i.e. measures that avoid new weeds being introduced to Australia. Plants are deliberately imported into Australia for a variety of reasons—pasture and crop plants for human consumption, and ornamental plants. Plants also make their way to Australia by accidental means such as birds, sea currents or as contaminants of grain or other shipments. These accidental introductions are quite common but only make up a small proportion of any new introductions. The Australian Quarantine and Inspection Service (AQIS) is the first line of defence against incursions of new, potentially invasive plants, whether deliberately or accidentally imported. The Australian Government and the state and territory governments recognise the importance of preventing new weed problems.

Recent legislative steps include:

- In 1997, a system of Weed Risk Assessment (WRA) was instituted to more carefully regulate the deliberate movement of plants into Australia. At around the same time, there was a major shift in policy from reliance on a Prohibited List to a focus on the use of a Permitted List. The permitted list was intended to be based on ‘scientific risk analysis’, and a prohibited list of assessed and rejected species maintained as a supplement to the permitted list.

- AQIS adopted this approach and Permitted and Prohibited Lists were included in the redrafted *Quarantine Proclamation 1998*. Propagable material of any plant not on the Permitted and Prohibited Lists is now subject to a WRA before permission to import is granted. Once a decision is made, the plant species is added to one of the lists. This approach is designed to result in fewer new weed incursions.

- The National Weed Strategy (ARMCANZ 1999) includes an objective (1.1) to prevent the introduction of new plant species with weed potential by strengthening import entry protocols for assessing all new plant imports.

Eradication

Eradication—eliminating every single individual of a species from an area in which recolonisation is unlikely to occur—is only possible during the very early stages of an invasion. Eradication programs are generally very expensive; however, they are particularly appealing because the alternatives, containment or control, require permanent, ongoing investment of time and money.

To implement an eradication strategy, a land manager must be confident that eradication is achievable. A recently-developed framework considers eradication feasibility as a function of the effort required. The effort required is a product of the total area of an infestation and the impedance to eradication due to the following factors:

- Detectability is determined by the weed’s visibility and the search effort, experience and method—usually a slow, labour intensive, costly procedure. The search rate (e.g. hours/ha) is a function of the vegetation in which the weed occurs, as well as the characteristics of the plant. Weeds may be detected more easily if they have a conspicuous stage. Weeds need to be detected before they reproduce.

- The biological characteristics of a weed include its reproductive traits and the persistence of seeds or other propagules. Features that make a plant invasive are a short pre-reproductive period, and long-lived propagules (some can survive for decades!) resulting in a persistent seed bank. Species such as *Tradescantia* spp. and *Opuntia* spp. that are capable of reproducing through vegetative fragmentation—simply breaking off a branch—pose a particular challenge as they can have this capacity at a young age.

- Effectiveness of control, or how effectively the weed can be killed, is influenced by the number of treatments, the size of the plant when treated (small plants may escape), and the suitability of the situation to treatment (e.g. riparian habitats may restrict the use of some herbicides). Some successful eradication programs have taken decades to complete—eradication of bitterweed (*Helenium amarum*) took 39 years. This highlights the need for long-term continuity of both funding and staffing.




– Logistic factors also play a part. As the number of infestations increases, the likelihood of spread, and therefore the area requiring further surveillance, also increases. This affects costs by increasing travel time, especially when infestations are widely dispersed. Accessibility is affected by travel time, ruggedness of the terrain, and operational difficulties posed by the type of vegetation in which the infestation occurs.

There have been few successful eradication programs in the Australian rangelands. It is not the biological characteristics of the weeds or their susceptibility to control measures that makes them difficult to eradicate. The two key reasons for the lack of success are due to the rangeland environment:

– Australia's rangelands are vast, with low human population densities. As a result, it is difficult to detect incursions at the stage when eradication would be feasible.

– Eradication requires not only control activities but also well-organised surveillance programs. Logistic considerations in the rangelands affect the amount of resources required, or available, to eradicate weeds.

There are also aspects of rangelands environments that can increase the feasibility of eradication.

– The generally open nature of plant communities means that target species may be readily detectable, as in the case of a shrub or tree invading a grassland or savanna community.

– With fewer landholders involved, issues of compliance may be less important provided that affected landholders support the eradication.

– Large areas can provide opportunities for eradication on a local scale; the risk of recolonisation can be low when there is substantial distance between the targeted infestations and the nearest source of propagules.

Containment

If it is not feasible to eradicate a particular weed, the best option is to contain it and prevent expansion or new infestations. This can be done by minimising dispersal outside existing infestations, and by treating new infestations as early as possible. Large areas of rangelands can easily be protected by taking care in moving animals, machinery, and produce (fodder, seed etc) from infested areas to clean areas. Machinery such as slashers should always be cleaned before being moved into weed-free areas. Feeding produce to stock in a confined area ensures that any weeds present are restricted to that area and not spread throughout the property. Stock brought onto a property for the first time should be placed in a confined area for a week or so; this ensures any viable weed seeds in their digestive tracts are expelled, minimising the spread of weed seeds.

In some states, for example Queensland, a Weed Hygiene Declaration provides information that helps people determine whether a product (e.g. machinery, stock, fodder, soil, water, gravel, grain, vehicles) could be contaminated by weeds. Informed decisions can then be made and any necessary precautionary steps taken.

A critical factor in any containment program is the location of containment lines or boundaries. Land managers must consider where the weed species is present or absent, abundant or uncommon, and exploit features of the landscape that form natural barriers.




Control

In recent years, the focus of weed control has increasingly been placed on using a combination of methods—a concept known as Integrated Weed Management (IWM) or Best Practice Management. IWM is a multi-disciplinary approach; it includes chemical, physical and biological methods of weed management together with an understanding of ecology and effective education and extension. Each weed control method has advantages and disadvantages and, even though individual techniques have become more sophisticated, none has emerged as the ultimate tool for effective weed management at a reasonable cost. Effective weed control can be achieved using various options at appropriate times.

Mechanical control

The physical control techniques include hand pulling (annuals and tree seedlings), cutting (vines, shrubs, tree saplings and trees), chaining (trees), mowing (annuals, tree saplings, shrubs and vines), tilling (annuals, shrubs and tree seedlings) and hoeing (plants regenerating underground).

Mechanical treatment can provide long-term control, especially if immediately followed by active rehabilitation of vegetation. It must conform to the tree clearing policies and gazetted Acts of the state or territory in which it is being carried out. For example, in Queensland, restrictions apply to the mechanical control of weeds in riparian habitats. Elsewhere, permits are required to use mechanical control in a riparian habitat. The control of riparian woody weeds becomes more difficult and costly if mechanical control is excluded from riparian areas, particularly when the weed has formed dense thickets and is the dominant species.

Control by fire

In many areas of the rangelands, it is thought that an increase in exotic woody weeds is due to reduced fire frequency and/or intensity. Major germination events occur during the relatively infrequent very wet years, and a lack of fire allows the resultant seedlings to survive. The number of woody weeds killed by burning depends on the species, the age of the plants and their density. The response of a particular species may vary a lot with the fire regime adopted. Fire intensity itself is dependent on environmental factors, fuel moisture content, fuel load, fuel height and slope of the land.

In rangelands used for pastoralism, the link between livestock grazing and fuel loads is important.

When undertaking a burning program to control woody weeds, the aim is to kill the target species but have minimal long-term impact on non-target components of the vegetation.

Control by grazing

In pastoral rangelands, weed management must be closely linked with grazing management. Compared with unstocked or well-managed pastoral rangelands, land degraded by grazing is more likely to be invaded by weed species. Sound pastoral practices can make rangelands less susceptible to weed invasion by encouraging desirable species and reducing seed production by weeds. What constitutes sound grazing management varies greatly from one rangeland type to another and with management history; it also depends upon the species of weeds present.

Grazing by livestock, including cattle, sheep, goats and camels, can be used to control weeds, although it may also exacerbate some problems. For example, heavy grazing for woody weed control can degrade pasture and soil, resulting in further weed invasion.

Chemical control

Herbicides are a primary method of weed control in most rangeland situations. Generally, herbicides are applied only to weed infestations of low to medium density. Before an herbicide can be sold, supplied, distributed or used in Australia, it must go through a rigorous assessment process operated by the Australian Pesticides and Veterinary Medicines Authority to ensure that it meets high standards of safety and effectiveness.

Herbicides are labelled to indicate which weeds are susceptible to the herbicide, the appropriate application method, and any withholding period, if applicable, after application to crops. Labels also describe the situations in which the herbicides may be applied. 'Rangeland' is not a situation that appears on any herbicide label, though a number of situations where herbicides can be used are located within the rangelands. There are no chemical recommendations for more than half of the 92 species listed as threats to rangeland biodiversity (Table 1).

For each weed species, an efficient herbicide and an economically optimum dose must be determined. In rangelands, herbicides are applied usually by ground or hand-held applicators for low to medium densities, and by helicopter or fixed-wing aircraft for large, dense infestations. Cost is usually the key factor in a land manager's decision as to which active ingredient to select for control of a weed species, particularly when a number of herbicides are registered for that weed. The cheapest herbicide mix in the long-term is not always the most cost-effective herbicide to apply. The choice of herbicide should also take account of environmental and ecological factors.

Herbicides seldom provide long-term control of weeds when used alone, and combining herbicides with other control methods often improves weed control. Weeds vary greatly in their susceptibility to different herbicides. Herbicide performance is affected by season, method of application, concentration and the addition of surfactants. Performance is reduced by inadequate spray coverage, moisture-stressed plants, fruiting plants, high ambient temperatures (>35 ºC), and plants infested with biological control agents (for example, leaf feeders or rust).

Though the use of herbicides is often criticised, chemicals often provide the most cost-effective means of managing a light to scattered weed infestation.

Within any population of weeds there are potentially a few individual plants able to resist the action of herbicides. Repeated use of the same herbicide, or similar acting herbicides, can lead to a resistant population of weeds and herbicide failure.

Biological control

Biological control has been undertaken in Australia for almost 100 years. An early and well-known program, because of its spectacular success, is the control of prickly pear (*Opuntia* spp.) in the 1920s by the moth *Cactoblastis cactorum*, and the cochineal bug, *Dactylopius opuntiae*.

Many other biological control projects in Australia have targeted rangeland weeds. Some have been completed successfully, others not. There is considerable potential to develop new projects targeting rangeland weeds. It is important that the technique is developed together with other weed management tools to provide the best possible outcomes.

The effect of the biological agent may be direct, (for example, it may reduce flowering or seeding of the target weed), or indirect (for example, it may reduce the weed's ability to compete with other plants or cope with environmental stress).

Biological control includes the following steps:

1. Approval of the weed as a target for biological control

   The Australian Weeds Committee manages the formal process of approving a weed as a target for biological control. Approval requires agreement by the heads of the appropriate state and territory departments and Australian Government departments. Conflicts are dealt with by negotiation and, if unresolved, can be submitted for consideration under the *Biological Control Act 1985*. Recently, governments have indicated that exploration for potential biological control agents will not be supported until approval of the weed as a target for biological control has been obtained.

2. Testing

   Potential biological control agents for weeds must be tested for host specificity against a range of plant species. This list of test species is compiled by biological control researchers and submitted to the Australian Government Department of Agriculture, Fisheries and Forests (DAFF) for approval. DAFF consults the 21 co-operators representing state and territory and Australian Government interests.

3. Importing and release of the biological control agent

   Before an organism can be imported into an Australian quarantine facility, a permit to import must be obtained; this requires approvals from DAFF and the Department of the Environment and Heritage (DEH). The application to release a biological control agent is managed by DAFF and DEH in consultation with the 21 co-operators.







Biological control agents released in Australia have targeted 22 weed species that occur in the rangelands, with good control of six achieved, though in some cases not throughout the whole invaded range. Surveys have been conducted of potential agents for a further eight rangeland weed species.

The results of two long-term projects targeting Paterson's curse and mimosa are beginning to show promise. Several projects have not controlled the target species; these include common heliotrope (*Heliotropium amplexicaule*) and parkinsonia (*Parkinsonia aculeata*).

Four projects are underway where insects have either been released or are under assessment prior to release. Targets include mesquite (*Prosopis* spp.), blackberry (*Rubus fruiticosus*), lantana (*Lantana camara*), mother-of-millions (*Bryophyllum delagoense*), athel pine (*Tamarix aphylla*), Bathurst burr (*Xanthium spinosum*), and saffron thistle (*Carthamus lanatus*).

There has been little progress in the control of grass weeds using biological control. Until recently this technique was deemed unsuitable for grass weeds as it was uncertain whether agents would be sufficiently host-specific.

Some fungi were thought to be specific enough but the deliberate importation and release of fungi was not seen as acceptable. Attitudes are changing as many fungi are demonstrated to be very specific and have the potential to safely control weeds.

The only biological control programs underway against grass weeds in Australia are for the non-native weedy *Sporobolus* spp., serrated tussock *(Nassella trichotoma*) and Chilean needle grass (*N. neesiana*). Conflicts of interest may prevent research on important pasture species that are also serious weeds, for example buffel grass (*Cenchrus ciliaris*), and may restrict research on others such as olive (*Olea*) and hymenachne (*Hymenachne amplexicaulis*). For grasses such as gamba grass, (*Andropogon gayanus*), African love grass (*Eragrostis curvula*) and mission grass (*Pennisetum polystachion*), there are fewer such conflicts and their importance and a lack of alternative strategies suggests consideration be given to biological control.

Measuring the success of biological control is difficult. When weeds decline or flourish dramatically, success or failure is obvious.

Even when successful, most biological agents take time to control the target. Evaluation should therefore take sufficient time, perhaps up to 10 years after release.

Biological control has many advantages as it can reduce the spread of weeds by reducing plant mass, density and reproductive potential. As biological control agents disperse to new target populations, it may also provide access to areas where other control methods are difficult to implement due to distance or terrain. It can control weeds that extend beyond the rangelands. Studies of the cost/benefit ratio of successful biological control projects generally show a high benefit. Overall, the benefits to Australia are considered so high that they far outweigh the total cost of all biological control projects.

Like all control methods, biological control does have limitations. These include:

- Finding safe, effective agents requires time, resources and particular expertise. However, this is still more cost-effective than developing a new herbicide.
- Techniques must be researched and applied on a weed-by-weed basis.
- Agents are unlikely to be suitable across the whole invaded area for widespread weed species because of the variability in soil, climate and topography across the rangelands.
- Low rainfall and humidity prevents some insects from completing their life-cycle.
- Many rangeland weeds are tree species and, although biological control agents may shorten longevity through added stress, it is unlikely that they will kill the trees.
- Many rangeland weeds are grasses and progress on identifying biological agents for these is relatively slow.

Until recently, Australia was a world leader in the field of biological control; however, its capacity in this field has dwindled. There has been a reduction in the number of newly-declared targets and in the number of agents released, from ten per year a decade ago to two per year since 2000. At the same time, there has been a decline in the level of scientific activity in the field and loss of experienced staff. This is despite increasing recognition of the threats posed by invasive weeds where biological control may be the only suitable long-term solution.




Weed management strategies

Weed management in the rangelands requires a strategic approach that integrates available techniques—prevention, eradication, containment and control—at times and places that make them most effective and efficient. The most effective and efficient combination depends on factors such as the biology of the particular weed(s) and the circumstances under which it is growing. It means tackling weed problems not simply at the level of the individual infestation but also at other scales, such as the management unit (grazing property, conservation reserve, Indigenous community etc), catchment, landscape and region.

The advantages of a strategic approach are reflected in the national strategies that have been developed for the 20 WONS and some other species.

Developing a strategy requires consideration of the following:

- integrated weed management options—mechanical, chemical, biological, and fire control
- the biology of targeted weed species, including factors such as the size of the soil seed-bank, seed longevity, requirements for germination and establishment, age at first reproduction, and plant life span
- the extent of the overall infestation and the densities of the populations that constitute it
- the economics and feasibility of control
- the nature of the invaded environment including that of non-target vegetation, as any control technique has potential side effects on the native flora and fauna

Clearly, the consequences for biodiversity of a weed management strategy must be more desirable than the effects of the weed itself. However, there has been no thorough investigation of the consequences of different weed management regimes for biodiversity. Approaches to weed management are judged by how well they meet weed management goals.

Expenditure on weed management in the rangelands between 1997 and 2004, most of which was sourced from the Natural Heritage Trust, is estimated at $80 million. Thirty per cent was allocated to Weeds of National Significance (WONS)—14 of the 20 WONS occur in the rangelands.

Different states have allocated different levels of funding to weed management. While some of this disparity is explained by the disproportional threat posed by weeds in various states (often the presence and extent of WONS), it may also reflect a lower priority for weed management in particular states. Management capacities in Western Australia and New South Wales are below the level required to identify and adequately respond to weed threats in the rangelands. In terms of weed eradication programs and weed research, the greatest investment comes from the Australian Government, and the Northern Territory and Queensland governments.

Weed management programs for weeds other than WONS include eradication programs for Siam weed (*Chromolaena odorata*); management, research and biological control targeting species such as bellyache bush (*Jatropha gossypifolia*); and containment or mitigation programs targeting non-native grasses such as gamba grass.

Several of the greatest threats to biodiversity in the rangelands receive relatively few resources because of:

- conflicts of interest confounding efforts (for example, buffel grass is an important pasture species in large parts of Australia, but is environmentally devastating)
- intractability of the problem (for example, it is impossible to prevent long-distance dispersal of olive hymenachne in parts of the ‘Top End’; the weed is spread both by birds and by fragmentation and both processes are difficult to manage)
- lack of effective broad-scale control methods (for example, for buffel grass)
- insufficient appreciation of threats (for example, neem (*Azadirachta indica*) in northern Australian riparian zones)

Most funds are spent on research and management of specific weeds, particularly their eradication or containment/mitigation. Relatively little is spent on prevention despite its feasibility in the rangelands, and on identification and cause of weed problems.

Pastoral, conservation and Indigenous Australian interests all share a concern regarding the impact of weeds on landscapes but have different perceptions of what is a weed and what is not. All parties invest significant funds and resources into weed management but weed management priorities can differ.

An important constraint in evaluating most rangeland weed programs is that outcomes take longer than any funding cycle and, so, cannot be included in standard project reporting processes.

The overall effectiveness of weed management in the rangelands, and of NHT investments in particular, is difficult to assess. Given current reporting procedures and without detailed baseline information and repeated surveys, there is no way to determine the success of projects in terms of weed management and, in the long-term, biodiversity conservation. Final reports tend to document funds spent and actions taken, but are too early to determine the ultimate success of most projects.

A checklist for weed management best practice

The following checklist helps people make decisions when planning and implementing projects that aim to reduce the impacts of weeds on the biodiversity and general conservation values of Australia's rangelands.

It is designed to be used to evaluate project proposals and existing projects that address rangeland weed problems relevant to environmental or biodiversity management. However, it can be modified to suit projects that relate to plants that are problematic to commercial land uses or to non-rangeland situations.

Table 4:

A checklist for best practice weed management

Question	Comments
1. The project's objectives	
1.1 Does the project have clear objectives?	
1.2 Does the project address a weed or weed management issue of national, regional and/or local significance?	Consider whether the target weed is (i) a Weed Of National Significance and/or identified in the National Weed Strategy, and hence, already identified as a national priority; (ii) declared under state legislation and so identified as a state priority; (iii) identified as a priority in one or more Regional Natural Resource Management Plans; (iv) listed in one or more local government Pest Management Plans.
1.3 Will the project contribute to key national or regional biodiversity targets?	To reduce the threat of weeds on biodiversity or natural ecosystems, identify the specific links between particular target weeds, or weeds in general. Few cases in Australia have good quantitative data to describe the impacts of invasive plants and of these only a subset deal with rangelands. In spite of the lack of data, assess projects using whatever evidence is available.
1.4 Are the species, communities and ecosystems targeted by the project at risk or threatened locally, regionally or nationally?	Projects should have biodiversity targets that are as specific and measurable as possible. Evaluate them in terms of (i) the species, communities or ecosystems threatened; and (ii) the geographical context of those threats.
1.5 Is the area that this project is protecting clearly defined?	A project proposal should clearly identify the area to be targeted. This holds even for projects that do not intend to carry out on-ground works, for example, an educational project.
1.6 If the project involves on-ground management, is the infestation strategically located?	A project may be strategically located from the point of view of the weed infestation relative to areas under threat or from the point of view of the entity that is threatened.
1.7 If the project is focussed on a single species, has it considered threats posed by other weeds?	Projects should address the broader issue of invasive species. Projects that focus on a single species should consider if the particular focus is justified, or if the target weed may subsequently be replaced by other species just as detrimental to biodiversity.
1.8 Has the broader management context been considered?	Give attention to the broader natural resource management context of the project (e.g. grazing management, fire, and other threatening processes).
1.9 Will the research project provide information to reduce impacts of weeds on biodiversity?	For research projects, evaluate the objectives of the research in terms of biodiversity outcomes.

Table 4:

A checklist for best practice weed management contd.

Question	Comments
2. The project's methodologies	
2.1 If the project involves on-ground management, is it proposing to use the most appropriate control methods?	Assess the project in terms of whether the proposed technique(s) is consistent with best available practice. For most weed species of Australian rangelands, there is more than one technique available for control. Different techniques are suited to different situations depending upon factors such as extent and density of infestation, accessibility, available resources, and risks of deleterious side effects. A project team should consult weed management experts in state agencies and National Management Committees for Weeds of National Significance.
2.2 Is the project being done at the appropriate spatial scale?	Consider both the temporal and spatial scales of weed control efforts in rangelands. The spatial scale relevant to a particular project must be relevant to the scales of the species, communities or ecosystems targeted by the project. Will the project have lasting consequences at a scale that is meaningful for the set biodiversity targets?.
2.3 Is the project being done at the appropriate temporal scale?	Consider how long the project benefits will last. How will weed re-infestation be avoided? Is there ongoing commitment beyond the funding cycle of this project (e.g. landholder/community involvement)?
2.4 Are there any potential deleterious effects of the project?	Weed management projects will often have unwanted side effects such as unwanted or at least unplanned effects on biodiversity or ecosystem function. It is important to identify what these effects might be and the period over which they may occur.
3. Project resources	
3.1 Has the project been resourced for long enough to enable it to achieve lasting outcomes?	Weed management plans will be more successful if developed in an adequate planning context. These could be property level plans, catchment level plans, local government pest management plans, regional pest management plans.
3.2 Does the project have broad community support?	Indicate community and local government and other (as appropriate) commitments to the objectives and methodologies of the project.
3.3 Does the project have, or have access to, appropriate skills to carry out the project?	Should these skills be located in the project team or can they be accessed elsewhere?
4. Monitoring and evaluating achievements	
4.1 Has the project considered how it will monitor and evaluate its achievements?	A monitoring protocol should identify (i) what will be monitored; (ii) the time frame (frequency and duration) of monitoring; (iii) those responsible for monitoring. To achieve biodiversity objectives, what are the most appropriate indicators of the components of biodiversity? Questions to consider are: (i) Is the indicator reliable? (ii) Can it be monitored with available resources? (iii) Can it be monitored at appropriate temporal and spatial scales? (iv) Does it relate well to project objectives?

Recommendations

The following recommendations, if implemented, will reduce the effect of current weeds on the biodiversity of Australian rangelands and minimise the risk of new weed problems arising.

Priority species, areas and projects

Give priority to weed management projects that focus on:

- weed species that specifically threaten biodiversity, are in riparian zones, or are in early stages of invasion
- the broad natural resource management context; this will help address underlying causes of weed invasion and dominance and also help policy development that encourages a holistic approach to weed management
- biodiversity hotspots on a national scale i.e. (1) Einasleigh and Desert Uplands, (2) Brigalow North and South, (3) Carnarvon Basin, (4) Hamersley/Pilbara and (5) North Kimberley
- the Grazing Land Management Zones of Tropical Savannas and Arnhem Land; weeds that threaten biodiversity heavily affect these areas
- addressing the biodiversity impacts of introduced, high-biomass rangeland pasture grasses, including the pasture grass that has the most significant impacts in rangelands—buffel grass (*Cenchrus ciliaris*); avoiding further introductions of rangeland forage species—the traits that make plants ideal as forage also make them highly invasive

On-ground works

Give priority to projects that address the likely consequences of interactions between weeds as well as addressing weeds in the broader context of natural resource management.

Assess the feasibility of eradication projects (i.e. detectability, biological characteristics of the target species, the likely effectiveness of available control methods, and logistics). In particular, determine the likely duration of an eradication campaign so that sufficient resources are allocated.

Tools and methods

- Encourage and expand tools and initiatives designed to improve weed identification skills, such as extending available weed identification guides so that they cover all areas, and promoting use of weed identification internet sites and CD-Rom tools.
- Support programs and projects that build capacity and networks for detecting and responding to weed infestations—eradication is more likely with each detection and action.
- Increase awareness of weeds among rangeland residents and visitors, highlighting weeds as a serious economic, social and environmental issue and encouraging investment in weed detection and management.
- Provide appropriately targeted information and training for Indigenous communities on integrated weed management, including the safe and effective use of herbicides.

Research needs

Support research that aims to understand the mechanisms of impact that will lead to better approaches to weed management, including:

- impacts of weeds on Australian ecosystems, and specifically rangelands
- invasion of rangeland ecosystems by multiple weed species as well as individual species
- complementary studies that encompass a broad array of weed types, environments and mechanisms
- interactions between invasive plant species and their synergistic effects on natural ecosystems

Knowledge gaps and priorities for future investment

- Develop methods to manage the biodiversity impacts of non-native high-biomass, perennial grasses while balancing conservation/biodiversity and pastoral objectives.
- Assess site-based methods of weed management, such as riparian fencing, to better understand factors that govern weed invasions. High priorities are managing riparian habitats, and improved integration between different NRM objectives (including management of fire, feral animals and livestock).
- Support projects that prevent new weed incursions; for example, during development of new infrastructure such as the Darwin-Alice Springs railway, or by improving regulation/risk assessments of forestry industry plantings (e.g. neem), pastoral (e.g. *Leucaena leucocephala*) and nursery stocks (e.g. athel pine still being planted by council in Karratha).
- Increase research capacity in biological control as this may be the best control option for many widespread and abundant rangeland weeds.

Funding and evaluation

- Evaluate the effectiveness of weed management efforts across the Australian rangelands to determine types of projects that are most worthwhile and that best address national priorities.
- Align funding for weed research and management projects with time-scales of the objectives, rather than stop-start funding that often results in failure of weed management programs, and can significantly add to the cost of success of both management and research programs.

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Further information

References

See the full report for a comprehensive list of references:

Grice, A. C. and Martin, T.G. 2005. The management of weeds and their impact on biodiversity in the rangelands. The CRC for Australian Weed Management. Townsville.

The report includes a complete list of Australian rangeland weeds. Printed copies are available from the Department of the Environment and Heritage Community Information Unit. Electronic copies are available from the website: http://www.deh.gov.au/land/management/rangelands/index.html

Useful web links

The Australian Rangeland Society www.austrangesoc.com.au

CRC for Australian Weed Management www.weeds.crc.org.au

Department of the Environment and Heritage – Managing rangelands www.deh.gov.au/land/management/rangelands/index.html

Environment ACT www.environment.act.gov.au

National Environmental Weed Alert List www.deh.gov.au/biodiversity/invasive/publications/#weeds

Natural Heritage Trust www.nht.gov.au

New South Wales Department of Primary Industries - Agriculture www.agric.nsw.gov.au

Northern Territory Department of Natural Resources, Environment and the Arts www.nt.gov.au/nreta

Queensland Department of Natural Resources, Mines and Water www.nrm.qld.gov.au

South Australia Department of Water, Land and Biodiversity Conservation www.dwlbc.sa.gov.au

UQ Centre for Biological Information Technology www.cbit.uq.edu.au

Weeds Australia www.weeds.org.au

Weeds of National Significance (WONS) www.weeds.org.au/natsig.htm

Weeds of National Significance (WONS) Program www.deh.gov.au/biodiversity/invasive/publications/#weeds

Western Australia Department of Agriculture www.agric.wa.gov.au