WEEDS AND THE MONITORING OF BIODIVERSITY IN AUSTRALIAN RANGELANDS

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Abstract

Invasion by alien plants is widely recognised as a major threatening process for a great variety of ecosystems worldwide. Australian rangelands already support a large number of alien plant species of a wide variety of growth forms but, in general, quantitative documentation of the effects that they have on biodiversity is poor. Impacts of weeds on biodiversity can be expected because they have the potential to alter virtually any aspect of ecosystem structure and function. There will be value in monitoring how biodiversity responds to weed invasions because it will provide a basis for decision-making about weed management in natural ecosystems. The presence, abundance, growth forms and diversity of weed species may also be useful indicators of the health of ecosystems and the biodiversity they contain.

INTRODUCTION

Invasion\(^1\) by alien plants\(^2\) is widely recognised as a major threatening process for a great variety of ecosystems worldwide. This is certainly true in Australia (State of the Environment Advisory Council 1996) where an estimated 1500-2000 species have become naturalized\(^3\) (Humphries et al. 1991). Many of these species are recognised as “environmental weeds\(^4\)”, that is, they invade ‘natural’ ecosystems, as opposed to being restricted to, for example, areas used for agriculture. Like other natural or semi-natural systems, rangelands are subject to

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1 Invasive plant: naturalized plant that produces reproductive offspring at considerable distances from parent plants and so has the potential to spread over considerable areas (Richardson et al. 2000).

2 Alien plant: present due to intentional or accidental introduction by humans (Richardson et al. 2000).

3 Naturalized plant: alien plants that reproduce consistently and sustain populations over many life cycles without human intervention (Richardson et al. 2000).

4 Weeds: plants that grow at sites where they are not wanted (Richardson et al. 2000).
plant invasions (Lonsdale and Milton 2002). This has consequences for the structure, function and composition of rangeland ecosystems and so for the biodiversity that they support.

This paper: (i) outlines the nature of the threat that invasive plant species pose to Australian rangelands; (ii) describes the mechanism whereby invasive species affect rangelands systems and, in particular, the biodiversity that they support; (iii) discusses the significance of invasive species for the monitoring of rangeland biodiversity.

**RANGELAND WEEDS**

There is no comprehensive, quantitative picture of the scale of invasion of Australian rangelands by alien plant species. The number of alien plant species in Australian rangelands is lower than in non-rangeland parts of the continent (State of the Environment Advisory Council 1996), but floras of rangeland regions list significant numbers of alien plant species. For example, the *Flora of Central Australia* (Jessop 1981), which covers 30% of the Australian continent and 43% of its rangelands, documents 114 species of alien plants making up 6% of the total species listed for the region. *Plants of Western New South Wales* (Cunningham *et al.* 1981), which covers 5% of the continent and 7% of its rangelands, documents 400 species of alien plants making up 21% of the total species listed for the region.

However, statistics of this kind do not indicate the scale of the impacts that alien plant species have in rangelands. Impacts are more likely to be a function of total weed abundance, expressed in terms of densities or biomass of individuals rather than simply of species richness.

The growth form of a weed is also likely to be important with the possibility that some growth forms (e.g. smothering vines) may have impacts out of proportion to their abundance. 50-60% of the exotic species listed in Australian rangeland floras are annual forbs. Other growth forms contribute smaller proportions of exotic species: annual grasses (17%), perennial forbs (12-19%), perennial grasses (5-8%), shrubs (ca. 5%) and trees (1-2%) (Grice 2000). Noxious weed declarations are rather subjective and relate strongly to particular land uses, especially agricultural and pastoral industries. However, they can give some indication of perceived impacts of weeds. Using the information from central Australia (Jessop 1981) and western New South Wales (Cunningham *et al.* 1981), annual forbs, annual grasses and perennial forbs are under-represented in noxious weed lists (Parsons and Cuthbertson 1992) relative to their contributions to the exotic floras. By contrast, perennial forbs, shrubs and trees are over-represented (Figure 1). These ratios may reflect pastoral interests more strongly than they reflect environmental interests. For example, the perennial grass *Cenchrus ciliaris* (buffel grass) remains the most widely sown perennial pasture grass in northern Australian despite widespread concerns about its
invasive characteristics and environmental impacts in central Australia, northern Western Australia and parts of Queensland. The nominations of Weeds of National Significance also indicate predominance of woody species among exotic species that have been highlighted as most relevant to the rangelands (Table 1; Thorp and Lynch 2000).

Figure 1. Percentage contribution of different growth forms to exotic plant and declared weed lists species for Australian rangelands based on data from Jessop (1981), Cunningham et al. (1981) and Parsons and Cuthbertson (1992).

Table 1. A large proportion of species that were nominated as Weeds of National Significance, and that are relevant to rangelands, are shrubs or trees (from Thorp and Lynch 2000).

<table>
<thead>
<tr>
<th>Scientific name</th>
<th>Common name</th>
<th>Growth form</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Xanthium spinosum</em></td>
<td>Bathurst burr</td>
<td>annual forb</td>
</tr>
<tr>
<td><em>Hyptis suaveolens</em></td>
<td>Hyptis</td>
<td>annual forb</td>
</tr>
<tr>
<td><em>Argemone ochroleuca</em></td>
<td>Mexican poppy</td>
<td>annual forb</td>
</tr>
<tr>
<td><em>Xanthium occidentale</em></td>
<td>Noogoora burr</td>
<td>annual forb</td>
</tr>
<tr>
<td><em>Parthenium hysterophorus</em></td>
<td>parthenium</td>
<td>annual forb</td>
</tr>
<tr>
<td><em>Themeda quadrivalvis</em></td>
<td>Grader grass</td>
<td>annual grass</td>
</tr>
<tr>
<td><em>Bryophyllum tubiflorum</em></td>
<td>Mother-of-millions</td>
<td>perennial forb</td>
</tr>
<tr>
<td><em>Sida</em> spp.</td>
<td>Sida species</td>
<td>perennial forb</td>
</tr>
</tbody>
</table>
As well as being subject to invasion by alien plant species, Australian rangelands have experienced major shifts in the composition of the native flora. Some of these shifts involve increases in the abundance of native shrubs and small trees (Noble 1997) that are often referred to as “invasions” but that, strictly speaking, do not conform to the definition of Richardson et al. (2000) but rather are generally proliferations within their native ranges. Nevertheless, these shifts no doubt have significant consequences for biodiversity.

**MECHANISMS OF IMPACT ON ECOSYSTEMS**

Weeds affect the ecosystems that they invade in a variety of ways and often, dramatic changes are obvious. Weeds sequester resources (water, nutrients and light) that would otherwise be available to native plant species. The pathways and rates of water and nutrient cycling are then likely to be altered relative to the situation in the uninvaded state, as is the light regime. The resources that are acquired by a plant may be (i) retained by the individual, (ii) passed on to the succeeding generation by being used to produce seeds, or (iii) captured by consumers. The availability to consumers of the resources that are acquired by plants varies depending on the plant species. For some alien weed species, there may be few, if any, herbivores capable of accessing the resources that have been sequestered by the weed. Specialist herbivores, most notably insects, from the weed’s native range may not have been introduced. This forms part of the argument in favour of biological control as a weed management technique. The ramifications for the food web may also extend to decomposers because litter derived from weed species may differ from that produced by native species.

Weeds also alter the structure of the vegetation that they invade. The growth form of the weed(s) is important in this regard and the effects are likely to be most extreme in cases where a weed is of a growth form that does not exist, or is
only a minor component in the uninvaded community. Examples include the invasion of Top End floodplains by the shrub *Mimosa pigra* (Lonsdale 1992), of Queensland Mitchell grass plains by the tree *Acacia nilotica* (Mackey 1998), and of northern Australian riparian zones by the shrubby vine *Cryptostegia grandiflora* (Tomley 1998).

Weeds also affect ecosystems by altering fire regimes. These effects occur when weeds influence fuel loads or the timing of curing, with repercussions for the intensity, timing and frequency of fires. Effects on fire regimes are cited among the impacts of the bulky perennial grasses *Andropogon gayanus* (gamba grass) and *Pennisetum polystachion* (mission grass) in the Top End, and *C. ciliaris* in central and Western Australia.

**EFFECTS OF WEEDS ON BIODIVERSITY**

The mechanisms whereby weeds affect the ecosystems that they invade, as outlined above, are largely hypothetical. Some effort has gone into documenting how weeds change ecosystems in general and affect biodiversity in particular, but overall the impacts have not been widely quantified.

A typical approach is that used by Mullett and Simmons (1991). This example relates not to an invasive exotic species but to the indigenous Australian shrub *Pittosporum undulatum* (sweet pittosporum) that is spreading into communities or parts of the landscape that it did not occupy in pre-European times as well as apparently expanding its range in Victoria. Mullett and Simmons (1991) quantified its environmental impacts by estimating cover of all vascular plant species in 3x3m quadrats located along transects running through small clumps of *P. undulatum*. Multivariate pattern analysis showed that fewer plant species occurred in quadrats where the abundance of *P. undulatum* was high and the abundance and cover of the indigenous species was inversely correlated with that of *P. undulatum*.

Working in central Queensland woodlands, Fairfax and Fensham (2000) compared floristic diversity across boundaries between uncleared land and cleared land with either native (exotic species <10% of total ground cover) or exotic (exotic species >10% of total ground cover) pastures. The total number of native species was greater in uncleared land than in either native or exotic pastures on cleared land. In cleared land, native species richness was greater in native pastures than in exotic pastures. One of the difficulties with such studies is in separating the effects of invasion by exotic pasture species from the effects of livestock gazing. McIvor (1998) examined effects of various pasture management treatments, including over-sowing with legume/grass mixtures, on species diversity of experimental pastures in north-east Queensland. The presence of sown species, which included the grasses *C. ciliaris* and *Urochloa mosambicensis* and the legumes *Stylosanthes hamata* and *S. scabra*, was associated with reduced numbers of native species at plot and quadrat scales.
This is also a case in which the exotic species were deliberately sown and the effects of their presence cannot be separated from the effects of the actual sowing treatments.

Even less research has examined the effects of weeds on animal groups where the focus has been more on the ecological responses of individual vertebrate species. Again, quantification of effects has not been a strong point of much of the work. Perhaps in contrast to the situation with vascular plants, weeds can affect individual vertebrate species either positively or negatively. This is evident from a list of exotic plant species that are eaten by a variety of Australian bird species (Loyn and French 1991). It is not apparent from this kind of evidence how important the weeds are in the diets of the species listed, nor does the information indicate what the net effects are on bird species or communities. Through their role as weed dispersal agents, birds also facilitate changes in plant communities that may continue for many decades or even hundreds of years, with repercussions for other components of biodiversity and ecosystem processes (Williams and Karl 1996).

The literature contains several examples of native Australian mammal species possibly benefiting from the presence of exotic plant species. These include the use of *Ulex europaeus* (gorse) by the eastern barred bandicoot (*Perameles gunnii*), of *Rubus procerus* (blackberry) by the broad-toothed rat (*Mastacomys fuscus*) (Brown *et al.* 1991) and of *Mimosa pigra* (giant sensitive plant) by the red-cheeked dunnart (*Sminthopsis virginiae*) (Braithwaite and Lonsdale 1987). In the first two of these examples, the apparent associations between weed and mammal are not quantified or evaluated experimentally.

These examples are sufficient to indicate that native plant species richness is generally lower in places where one or more weed species are abundant and that individual native animal species can respond positively or negatively to invasion by a weed species. Causal relationships are generally implied but not demonstrated. These conclusions fall well short of providing a comprehensive picture of how biodiversity responds to exotic plant invasions though it is generally agreed that the net effect of weed invasions is negative. In particular, a more specific understanding of the relationships between weed and biodiversity in rangelands is not available.

Obviously, alien plant invasions are only one of the threats to biodiversity and both the relative importance of various threatening processes and interactions between them must be considered. Leigh and Briggs (1992) (cited in Groves and Willis1999) evaluated numbers of extinct and endangered Australian plant species threatened by various factors. They considered that 57 species (13% of total extinct and threatened species) were threatened by “weed competition”, making this factor third most important after “grazing and agriculture” and “low population numbers”.
WEEDS AND BIODIVERSITY MONITORING

There are two important aspects to the relationship between weed invasions and biodiversity monitoring. The first concerns the need to monitor how biodiversity responds to weed invasions and the second how the occurrence, distribution and abundance of weeds could be used as an indicator of biodiversity.

Given that weed invasion is a major threatening process for biodiversity, it will be valuable to document the occurrence, distribution and abundance of alien plant species as part of a biodiversity monitoring program. Effort in this area should not simply be aimed at showing that weeds are having impacts on biodiversity in general, or at individual sites. An important reason for collecting such data should be to help make decisions about directing resources at weed management in order to slow, halt or reverse biodiversity decline. The following points should be considered:

1. Weed species richness (weed species per unit area) of a site is unlikely, on its own, to indicate how severely weeds may be affecting biodiversity at that site. Some weed species have a far greater impact than others. On the other hand, the presence of a large number of alien species may be correlated with other forms of disruption to the invaded ecosystem and so with overall effects on biodiversity.

2. Current evidence indicates that the shapes of the relationships between weed abundance and biodiversity measures are variable (Panetta and James 1999). It seems unlikely that biodiversity decline is a linear function of weed abundance. Rather, the impacts of weeds are likely to be greater when weeds are in an advanced stage of invasion. There may be thresholds such that the rate of decline or loss of species or communities will be much greater at high levels of weed abundance. Such thresholds should be quantified.

3. Weed management is most effective and efficient when weeds are in the early stages of invasion. In this regard, the early stages of an invasion will be defined differently for different species. The “early” stage of an invasion will pass more quickly for species whose populations increase and whose ranges expand rapidly than for species that increase and spread more slowly. This is illustrated by the few examples of successful eradication programs for alien weeds (Groves and Panetta 2002)

4. The temporal and spatial patterns of change in biodiversity with changing weed abundance will vary from one taxonomic group to another. There is a need to seek generalizations about how different taxonomic groups respond to different types of weed invasion. This raises the parallel question of whether and how weed invasions might be classified.

5. It is inadequate that documentation of the effects of weeds on biodiversity be limited to examining the effects of individual weed species. This is because it is common for natural ecosystems to be invaded by more than
one species. There are many examples of what are in effect ‘new’ plant communities within Australian ecosystems as ‘weed complexes’ combine with native species than can co-exist with them.

6. There may be scope for using a growth form or functional group approach for predicting or evaluating the effects of weeds on biodiversity. Weed growth forms that are novel to the invaded system are likely to be more significant for biodiversity than growth forms for which there is a native ecological analogue.

7. Effort to gather data on relative weed abundance should be most heavily concentrated on those species and growth forms that make the greatest contribution to the biomass of the ‘weed community’ or have the potential to do so. Such species are the ones most likely to have significant impacts on ecosystem structure and function.

8. Information on the relative abundance of weeds should be gathered as part of a biodiversity monitoring program. Typically, the severity of infestations of weedy trees and shrubs are described in terms of plant density (e.g. Campbell and Setter 1999). This is a practical means of making inter-site or temporal comparisons of abundance of weed species whose individuals are of approximately equal size. However, where there is a need to make comparisons that include species whose individuals differ in size, particularly in multi-species systems, measurement of biomass will be far more informative. In a biodiversity monitoring program, site-specific data on the biomass of weeds and how that biomass is distributed between species and growth forms would be preferable to simple lists of species present. It may also be the case, however, that a weed can have an influence out of proportion to its biomass contribution because of its impacts on ecosystem processes.

9. In rangelands, riparian zones are likely to support a greater variety of weed species than upland areas. Many weed species tend to be more abundant in riparian zones than in adjacent upland areas. Riparian zones, and comparable parts of the landscape, also support species and communities that do not occur elsewhere in rangelands landscapes. Their importance for biodiversity is disproportionate to the area of land that they occupy. Monitoring weeds as part of a biodiversity monitoring program is especially important for riparian zones.

10. It is important to evaluate and respond to the threats posed by invasive species in the context of the overall threats to biodiversity and also to consider how the various threatening processes interact.

REFERENCES


Braithwaite, R. W. and Lonsdale, W. M. (1987) The rarity of Sminthopsis virginiae...


