The impacts of invasive plant species on the biodiversity of Australian rangelands

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Abstract. Most parts of the Australian rangelands are at risk of invasion by one or more species of non-native plants. The severity of current problems varies greatly across the rangelands with more non-native plant species in more intensively settled regions, in climatic zones that have higher and more reliable rainfall, and in wetter and more fertile parts of rangeland landscapes. Although there is quantitative evidence of impacts on either particular taxonomic groups or specific ecological processes in Australian rangelands, a comprehensive picture of responses of rangeland ecosystems to plant invasions is not available. Research has been focused on invasive species that are perceived to have important effects. This is likely to down play the significance of species that have visually less dramatic influences and ignore the possibility that some species could invade and yet have negligible consequences. It is conceivable that most of the overall impact will come from a relatively small proportion of invasive species. Impacts have most commonly been assessed in terms of plant species richness or the abundance of certain groups of vertebrates to the almost complete exclusion of other faunal groups. All scientific studies of the impacts of invasive species in Australian rangelands have focused on the effects of individual invasive species although in many situations native communities are under threat from a complex of interacting weed species. Invasion by non-native species is generally associated with declines in native plant species richness, but faunal responses are more complex and individual invasions may be associated with increase, decrease and no-change scenarios for different faunal groups. Some invasive species may remain minor components of the vegetation that they invade while others completely dominate one stratum or the vegetation overall.

Additional keywords: plant invasion, plant species richness, weeds.

Introduction
Plant invasion presents a serious threat to biodiversity management and conservation in many parts of the world. This is certainly the case in Australia where plant invasion is ranked with habitat clearance, livestock grazing, forestry and soil degradation as a major source of pressure on native species and communities (SoEAC 1996). Around 2700 non-native plant species have become naturalised in Australia (Groves et al. 2003) out of the 27 000 non-native plant species that have been introduced (Virtue et al. 2004). There are frequent statements to the effect that these naturalized species are a threat to biodiversity, often in reference to particular rare and threatened species (Vidler 2004), but also in relation to plant and animal communities or ecosystem processes. Australian rangelands occupy around 6 million km² which equates to about 70% of the continent (Foran et al. 1990). This means that their management is very important for the overall conservation of Australia’s biodiversity. For example, 50% of Australia’s bioregions and 75% of its plant ecosystems are represented in the rangelands (Smyth and James 2004). For many faunal groups, including amphibians, birds and mammals, species richness in the rangelands is generally lower than in some more coastal parts of the continent though there are some notable exceptions (SoEAC 1996). In contrast, species richness of reptiles in the rangelands is relatively high (SoEAC 1996). The Australian rangelands support significant numbers of endemic species. Of the 15 biodiversity ‘hotspots’ announced by the Australian Government in 2003, five are located in the rangelands, though all are relatively close to the coast. These five ‘hotspots’ are the Einasleigh and Desert Uplands region in north-east Queensland, the Brigalow region in south-east Queensland, and the Carnarvon Basin, Hamersley/Pilbara and North Kimberley regions in the northern half of Western Australia (Department of Environment and Heritage 2003; Martin et al. 2006).

Many non-native plant species occur in the Australian rangelands with over 620 non-native plant species reported
as naturalised (Martin et al. 2006). However, the number of non-native plant species per one-degree grid cell is generally lower in the rangelands than in non-rangeland areas in the south-east and south-west of the continent (SoEAC 1996). Different regions of the rangelands have different proportions of their modern floras made up of non-native species as illustrated by a comparison of the ‘Flora of Central Australia’ (Jessop 1981) and ‘Plants of Western New South Wales’ (Cunningham et al. 1981). Whereas Central Australia, covering about 2.3 million ha has 1872 flowering plant species, of which 6% are non-native, Western NSW, which covers 383 000 ha, has 1917 flowering plant species, of which almost 21% are non-native (Grice 2000).

This paper focuses on the impacts of invasive, non-native plant species on the biodiversity of Australian rangelands. Clearly, those impacts are not a simple function of the number of non-native species present. The relative abundance of non-native species is extremely variable from place to place. Some invasive species dominate the vegetation that they invade while others contribute relatively little to total plant biomass even though they are abundant. It is possible for a species to be relatively uncommon, or contribute only a small amount to total biomass and yet have a disproportional influence on biodiversity or ecosystem function relative to its abundance. The non-native species that are of greatest concern are those that contribute a large amount to total plant biomass or disproportionately influence ecosystem function.

Here I review the impact of invasive species on Australian rangeland biodiversity by addressing the following questions.

(i) How important is the threat by invasive plant species to the biodiversity of Australian rangelands?
(ii) What components of biodiversity are under threat?
(iii) What are the impacts of different kinds of invasive plant species?
(iv) What are the mechanisms whereby invasive plant species affect biodiversity?
(v) What are the main gaps in knowledge of the relationship between invasive plant species and biodiversity?

How important is the threat from invasive plant species?

There are many published statements about the effects of invasive plant species on the structure and function of Australian ecosystems, on the integrity of their native plant and animal communities and on the distribution and abundance of species. For example, Vidler (2004) listed 41 cases in which a native Australian species is reported to be threatened by either a single or multiple weed species. The list was derived by searching species recovery plans and by consulting ecologists and other people familiar with particular species. In most cases, there were few if any quantitative data presented in evidence of the claims that the native species was detrimentally affected by the weed in question. However, Vidler’s synopsis indicates that expert opinion recognises invasive plant species as a threat to individual threatened species in Australia. At least nine of the 41 cases listed involve species from rangelands. In six cases, these relate to invasions by specific, non-native species and in three cases, to annual, non-native grasses collectively. The individual weeds mentioned in the nine cases are Mimosa pigra L., Opuntia spp. Mill., Acacia nilotica (L.) Delile, Brachytria mutica (Forsk.) Stapf (= Urochola mutica (Forsk.) TQ Nguyen) and Cenchrus ciliaris L. (Vidler 2004).

The perceived impacts of weeds at an ecosystem level are illustrated by the analysis of the conservation status of Queensland’s 13 bioregions (Sattler and Williams 1999). Ten of these bioregions are entirely or partially covered by rangelands and non-native plants are listed among the threats to the biodiversity of nine of them. Fifteen species are individually identified as threats (Table 1).

The current and potential distributions of 33 of the 71 non-native plant species that were investigated as potential weeds of national significance extend into Australian rangelands to some degree (Thorp and Lynch 2000). Fewer species currently extend into the more arid rangelands compared with the semi-arid or more northerly tropical rangelands.

Although expert opinion and general perception is that non-native plant species present a major threat to Australian biodiversity at species, community and ecosystem levels, there are relatively few quantitative data to back these views. This is illustrated by the nature of references to ‘environmental’ and ‘biodiversity’ impacts of individual weeds discussed in ‘The Biology of Australian Weeds’ (Groves et al. 1995; Panetta et al. 1998). For 18 species whose current Australian ranges extend into the rangelands, there is a reference to detrimental environmental impacts, though there are quantitative data for only a few of them (Table 2). In most cases, statements about the environmental or biodiversity impacts of particular weeds are based on more or less casual observations of the weed’s abundance.

Grice et al. (2004) reviewed publications providing quantitative data relating to the effects of weeds on the biodiversity of Australia. They identified 24 journal papers that provide quantitative data on the impacts of invasive plant species in Australian ecosystems. Nine of these described work undertaken in rangelands. Although the sample is small, they generally demonstrate that at least some invasive plant species do have significant impacts on biodiversity in the rangelands.

What is threatened by invasive species?

From the few quantitative studies of the effects of invasive plant species on Australian rangeland biodiversity it is apparent that the impacts are currently or potentially great. The extensive current or potential ranges of many rangeland weeds means that most bioregions are prone to...
Invasive plant species and biodiversity

Table 1. The principle non-native species that are listed among the threats to the biodiversity of the ten rangeland bioregions of Queensland

<table>
<thead>
<tr>
<th>Species</th>
<th>MII</th>
<th>GUP</th>
<th>CYP</th>
<th>MGD</th>
<th>CHC</th>
<th>ML</th>
<th>EU</th>
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<th>BSN, BSS</th>
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<tbody>
<tr>
<td>Acacia nilotica</td>
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<td>Acacia secafruticosa</td>
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<td>Bryophyllum tubiflorum Harv.</td>
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<td>Calotropis procera (Aiton) W.T.Aiton</td>
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<td>Cenchrus ciliaris</td>
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<td>Cryptostegia grandiflora</td>
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<td>Eichhornia crassipes (Mart.) Solms</td>
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<td>Lantana camara</td>
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<td>Non-native pasture spp.</td>
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<td>Parkinsonia aculeata L.</td>
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<td>Parthenium hysterophorus L.</td>
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<td>Rubus fruticosus L.</td>
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<td>Salvia molesta D.S. Mitch</td>
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<tr>
<td>Senna obtusifolia (L.) H.S. Irwin &amp; Barnby</td>
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<td>Themeda quadrivialis (L.) Kuntze</td>
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<td>Xanthium pungens Wall.</td>
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Table 2. Non-native plant species found in Australian rangelands and for which environmental/biodiversity impacts are reported (Groves et al. 1995; Adair and Groves 1998; Panetta et al. 1998)

<table>
<thead>
<tr>
<th>Species</th>
<th>Evidence of environmental impacts</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acacia nilotica</td>
<td>Perceived as significant</td>
<td>Mackey (1998)</td>
</tr>
<tr>
<td>Alternanthera philorhizaoides</td>
<td>Quantified range expansion and increasing abundance; reported to crowd out other plant species and disrupt ecological processes</td>
<td>Julian and Bourne (1988), Julien (1995)</td>
</tr>
<tr>
<td>Cabomba caroliniana</td>
<td>Reduces plant species richness</td>
<td>Mackay and Swarbrick (1998)</td>
</tr>
<tr>
<td>Centaurium ciliare</td>
<td>Increases fire intensity and frequency</td>
<td>Lutz (1993)</td>
</tr>
<tr>
<td>Chrysanthemoides monilifera</td>
<td>Reduces plant species richness</td>
<td>Weiss (1984), Weiss and Noble (1984a, 1984b)</td>
</tr>
<tr>
<td>Cryptostegia grandiflora</td>
<td>Perceived to seriously damage native communities</td>
<td>Humphries et al. (1991)</td>
</tr>
<tr>
<td>Cytisus scoparius</td>
<td>Quantified effects on native vegetation</td>
<td>Smith (1994, Waterhouse (1988)</td>
</tr>
<tr>
<td>Echium plantagineum</td>
<td>No reference to environmental impacts</td>
<td>Piggin and Sheppard (1995)</td>
</tr>
<tr>
<td>Eichhornia crassipes</td>
<td>Measured effects on aquatic microenvironment, plants and animals (not Australian)</td>
<td>References cited in Wright and Purcell (1995)</td>
</tr>
<tr>
<td>Emex australis</td>
<td>Noted to be present and abundant in areas of conservation significance</td>
<td>Keighery (1996)</td>
</tr>
<tr>
<td>Hydrochaeris chiragra</td>
<td>Reported effects on water flow</td>
<td>Swarbrick et al. (1995)</td>
</tr>
<tr>
<td>Hypoxis rhabarbarica</td>
<td>Noted as spreading into native forests; affects rare native species</td>
<td>Amor and Stevens (1976), Gifford and Kirkpatrick (1993)</td>
</tr>
<tr>
<td>Lantana camara</td>
<td>Reported to reduce native plant densities</td>
<td>Swarbrick et al. (1998)</td>
</tr>
<tr>
<td>Mimosa pigra</td>
<td>Quantified effects on biodiversity; converts aquatic grassland/sedgelands to shrublands</td>
<td>Braithwaite and Lonsdale (1987), Braithwaite et al. (1989)</td>
</tr>
<tr>
<td>Parthenium hysterophorus</td>
<td>Reported to dominate pastures</td>
<td>Chippendale and Panetta (1994)</td>
</tr>
<tr>
<td>Rubus fruticosus</td>
<td>Reported to suppress growth of other plants</td>
<td>Amor et al. (1998)</td>
</tr>
<tr>
<td>Salvia molesta</td>
<td>Perceived to cause water quality problems and so affect other plants and animals</td>
<td>Room and julien (1995)</td>
</tr>
<tr>
<td>Tamarix ramosissima</td>
<td>Altered trophic structure of avifauna and reduced habitat availability for reptiles</td>
<td>Griffin et al. (1989)</td>
</tr>
<tr>
<td>Ulex europaeus</td>
<td>Reported to invade pastures, creek banks, etc.</td>
<td>Richardson and Hill (1998)</td>
</tr>
<tr>
<td>Xanthium pungens</td>
<td>No reference to environmental impacts</td>
<td>Hocking and Liddle (1995)</td>
</tr>
</tbody>
</table>
some degree of invasion by one or more plant species (Table 1). Whether determined by casual observation or quantitative study, the impacts most frequently identified are on macrophytes and or vertebrates (Table 2). There are, for instance, few studies of the effects of invasive plants on soil flora and fauna or invertebrates in general. Few studies have quantified how an invasive species influences specific ecological processes.

Australia wide, and in the rangelands in particular, some invasive species have a demonstrated capacity to drastically alter plant species composition and the structure of native vegetation. Many of the more prominent rangeland weeds reach very high densities and biomass. For example, Tomley (1998) refers to densities of the shrubby vine Cryptostegia grandiflora R.Br. of 5000 plants/ha, the tree Acacia nilotica reaches densities of >150 plants/ha (Mackey 1998), and ‘typical’ densities of Mimosa pigra are around 10 000 plants/ha (Lonsdale 1992). In these situations other plant species are often largely excluded (Grice and Campbell 2000). Changes to the composition and structure of native vegetation doubtlessly has ramifications for the animal communities that depend on them though the available evidence suggests that faunal responses to invasive plant species are more complex than the floristic responses. This is illustrated by the information available for responses by northern coastal wetlands to invasion by Mimosa pigra (Braithwaite et al. 1989). This species is associated with reduced biomass and species richness of herbaceous vegetation and reduced densities of woody species. However, amphibians showed little response, lizards and many bird species declined and at least some small mammals increased.

It is not clear how susceptibility to invasion by non-native plant species varies across Australian rangelands. Water and nutrient availabilities, which vary widely at geographical and landscape scales, will influence the species that can establish. Environments that are in some way more extreme may be susceptible to fewer weed species. The lower proportion of non-native species in arid central Australia (Jessop 1981) compared with semi-arid western New South Wales (Cunningham et al. 1981) may reflect this. However, communities can be drastically altered by a single non-native species so that the biodiversity of the communities found in more extreme environments may be threatened if it is invaded by a species well-adapted to that environment. The invasion of the riparian zones of some central Australian river systems by Tamarix aphylla (L.) Karst. is an example of this (Griffin et al. 1989). Disturbance is also often seen as a prerequisite to plant invasions (Fox 1991) but species will differ in how they are affected by particular disturbance regimes and some may inhibit invasions by certain species. Sociological and historical factors can also be important determinants of the likelihood of plant invasion as they influence which species are introduced and where (Mack 1999). Current information is insufficient to determine the relative importance of all these factors in determining susceptibility of different rangeland types to plant invasions.

A large proportion of Australia’s rangelands are arid or semi-arid but they incorporate more mesic land units in the form of riparian zones and various kinds of wetlands. These parts of rangeland landscapes appear especially prone to plant invasions. Prominent riparian invaders include Acacia nilotica, Cryptostegia grandiflora, Jatropha gossypifolia L., Tamarix aphylla and Asparagus indicus A.Juss. Even species that are not riparian or wetland specialists can be more abundant in riparian or wetland habitats. For example, in north-east Queensland, Conarchus ciliaris occurs broadly across savannas and woodland landscapes but is especially prolific in the riparian zone. More mesic and more fertile parts of rangelands are also likely to support distinctive species and communities and to provide important refuges in times of drought. This coincidence of important habitat and susceptibility to weed invasion points to a need for weed management resources to be directed at more mesic and/or more fertile environments and landscape positions (see Martin and van Klinken 2006).

What are the impacts of invasive species?

Grice et al. (2004) proposed that four generalisations emerge from studies of the effects of invasive species on biodiversity Australia wide. Firstly, the abundances of individual native, threatened plant species are negatively correlated with the abundance of the weed species that has invaded their habitat (Gilfedder and Kirkpatrick 1993; Sorensen and Jusaitis 1995; Gentle and Duggin 1998). The second generalisation, based on a very small number of studies, is that the abundance of common components of invaded communities is reduced (Weiss and Noble 1984a, 1984b; Waterhouse 1988), though Smith (1994) reported that shade tolerant native species were more abundant at sites invaded by Cytisus scoparius (L.) Link.

Thirdly, the abundance/presence of invasive exotic species is consistently negatively correlated with that of native plant species (Waterhouse 1988; Braithwaite et al. 1989; Griffin et al. 1989; Smith 1994; Fensham et al. 1994; Franks 2002; Houston and Duivenvoorden 2002; McArdle et al. 2004). Two native species [Pittosporum undulatum Vent. and Acacia sophorae (Lahill.) R.Br.] that have been studied where they are invading Australian habitats outside their native ranges yielded similar results (Gleadow and Ashton 1981; Mull et and Simmons 1995; Rose and Fairweather 1997; Costello et al. 2000).

Finally, there is great variation among faunal groups in their responses to invasive plants. For example, bird communities are affected by invasive plant species (Braithwaite et al. 1989; Griffin et al. 1989; French and Zabovic 1997) but different guilds seem to respond in different ways, total abundance may not change and
there is little evidence of consistent changes in numbers of species present. These generalisations are based on relatively few studies and are not rangeland specific though a good proportion of the studies deal with various types of rangelands. The biology of the invasive species and the characteristics of the community being invaded is no doubt, important in governing the strength and direction of effects on the various faunal groups.

The many non-native plants found in Australia’s rangelands include species of a wide variety of growth forms (Grice 2000). Around 50% of species are annual forbs, 15% are perennial forbs, 17% are annual grasses, and the rest are perennial grasses, shrubs or trees (Grice 2000). Of the species identified as having the greatest impacts on biodiversity, however, 27% are shrubs and 26% are perennial grasses (Martin et al 2006). Whether native or alien, different growth forms play different structural and functional roles in the ecosystems that they occupy. The impact of a particular weed species will be influenced by its growth form. The effects of low-growing species, grasses, forbs and low shrubs, will be most apparent in the understorey. However, they could also influence the overstorey of woodland communities, for example via recruitment processes.

It is perhaps easier for non-native trees and shrubs to give an impression of having major impacts on the communities they are invading by dominating the overstorey. The perception of impact is especially strong when a woody species such as Acacia nilotica invades naturally treeless communities, in this case Mitchell grasslands (Mackey 1998). The situation is similar where Mimosa pigra invades floodplain communities (Lonsdale et al. 1995). Although trees and shrubs constitute only around 7% of the non-native species of Australian rangelands, they represent almost 40% of the rangeland species nominated as Weeds of National Significance (Thorpe and Lynch 2000).

Another prominent growth form group among the weeds of Australian rangelands is the perennial grasses. Two wetland species, Hymenachne amplexicaulis Nees and Urochloa mutica, are serious threats to the biodiversity of floodplain and riparian communities in the higher rainfall parts of the northern rangelands. However, quite a number of species are capable of occupying the drier parts of various rangeland landscapes. These species include Nassella trichotoma (Nees) Hack. ex Arechav. (Campbell and Vere 1998) and N. neesiana (Tininius & Ruprecht) Barkworth (Iaconis 2004), various exotic Sporobolus spp. R.Br. (Bray et al. 1999), Andropogon gayanus Kunth (Ronseck et al. 2003, 2004) and Pennisetum polyastachion (L.) Schult. (Setterfield et al. 2004). Perhaps the most important invasive grass of Australian rangelands is Cenchrus ciliaris (Franks 2002; Butler and Fairfax 2003; Jackson 2005), which has a capacity to thrive in arid and semi-arid areas. It should be acknowledged that some introduced grass species may play a role in maintaining or restoring some aspects of landscape functionality in areas subject to the effects of livestock grazing, and that landscape functionality is an important correlate of biodiversity (Noble et al. 1997; Ludwig et al. 2004). Currently, there are few options for controlling invasive perennial grasses of rangelands and development and implementation of such options should be given high priority.

In rangelands, some growth forms, for example perennial grasses, are more likely than others to dominate the vegetation, or at least the stratum that they invade, and so have serious consequences for the flora and fauna of those communities. These can be regarded as ‘transformer species’. Rangeland transformer species include the perennial grasses Cenchrus ciliaris and Andropogon gayanus, the riparian vine Cryptostegia grandiflora, and the trees Acacia nilotica, Tamarix aphylla and Prosopis spp. In contrast, the 70–80% of non-native rangeland plants that are annuals probably have more subtle impacts that are nevertheless important. Little or no effort has been directed at documenting the effects of invasive annuals on Australian rangeland ecosystems.

The mechanisms of impact
The abundance of a weed, as with any plant, is dependent in the first instance on its capacity to sequester basic resources: light, water, carbon dioxide, oxygen and nutrients. The more resources obtained by members of one plant species, the fewer are available for competing species. Weed species that sequester a large proportion of the available resources will dominate the vegetation that they invade and the severity of a weed infestation is often subjectively judged in terms of the degree to which the species dominates. This is probably a reasonable measure of the impact that a species is likely to have. However, most attempts to document the effects of weeds on natural ecosystems depend upon presence-absence comparisons (Grice 2004).

There are three main ways in which sequestration of resources by weeds influences the ecosystems that they invade. These are through (i) direct competition; (ii) effects on availability of resources for consumers; (iii) modification of ecological processes.

Inter-species competition in plants is potentially significant in relation to invasive species from two perspectives. One of these revolves around the possibility that intact, native communities are more resistant to plant invasion. This is consistent with the idea that disturbance is a prerequisite to invasion because it reduces native competitors (Fox 1991; Noble and Brown 1997). The other is that plants are invasive because they have a competitive advantage (Sheppard 2000). The general conceptual debate
were recorded on floodplain areas infested with *M. pigra* high densities of the rare marsupial *Sminthopsis virginiae* or their different resource requirements. For example, relatively species or higher taxa but degrade it for others because of responses by different faunal taxa to invasion by alien plant species or higher taxa. For example, aquatic weeds in waterways (e.g. *Braithwaite* et al. 2004) have been researched for how certain ecological processes are influenced by plant invasions. Fire is an important ecological phenomenon in most Australian ecosystems; management of fire regimes is important for the conservation of biodiversity (*Keith* et al. 2002). In Australian rangelands, fire has received attention in relation to invasion by alien perennial grasses. One example is the way in which *Cenchrus ciliaris* affects the biotic communities that it invades in central Australia is by increasing fire frequency and intensity (Griffin 1993). Quantitative data on these effects are available for *Andropogon gayanus* in northern Australia. It has been demonstrated that the presence of this species decreases fire regime complexity and fire regime consequences of the demonstrated shifts in fire regime due to invasion have not been elucidated.

There has been some research on how certain ecological processes are influenced by plant invasions. Fire is an important ecological phenomenon in most of Australia's ecosystems; management of fire regimes is important for the conservation of biodiversity (*Keith* et al. 2002). Although it is accepted that there is a general link between fire regimes and biodiversity (*Keith* et al. 2002), the specific biodiversity consequences of the demonstrated shifts in fire regime due to invasion have not been elucidated.

There has been speculation about other impacts of invasive plants on ecological processes including hydrological effects as a result of infestations of aquatic weeds in waterways (e.g. *Bunn* et al. 1998) and links between invasive plants and soil erosion.

**Conclusions**

It is widely accepted that invasive plant species have generally detrimental effects on the biodiversity of Australian ecosystems including those of the rangelands. Most parts of the Australian rangelands are at risk of invasion by one or more species though the severity of current problems varies greatly across the rangelands. In general, there are more non-native plant species in more intensively settled regions, in climatic zones that have higher and more reliable rainfall, and in those parts of rangeland landscapes that receive run-on or are relatively fertile.

For a number of invasive plant species of Australian rangelands there is quantitative evidence of impacts on either particular taxonomic groups or specific ecological processes. However, the paucity of research means that a comprehensive picture of responses of rangeland ecosystems to plant invasions is not available. Although invasion by non-native species is generally associated with declines in native plant species richness, faunal responses are more

about the relative importance of competition in unproductive environments (*Goldberg* and *Novoplansky* 1997) remains unresolved in relation to the vulnerability of different Australian rangeland types to plant invasions. There are many examples from the Australian rangelands where a non-native species dominates the vegetation over extensive areas. These include *Mimosa pigra* on floodplains in the Top End of the Northern Territory, *Acacia molotica* in Mitchell grasslands of western Queensland, *Cenchrus ciliaris* in central Australian woodlands and *Cryptopogon grandiflorus* in riparian vegetation of north Queensland. In these cases, competition is most likely a key factor in the interaction between the invading species and the native plant species of the invaded community, and probably accounts for the general decline of native plant species in the face of invasion. The exact nature of any competition that occurs, whether for light, water or nutrients, has not been researched for Australian rangeland species, though *Braithwaite* et al. (2004) showed that *Andropogon gayanus* does reduce nutrient and water resources available in the soil. The speculation is that these reductions lead to resource shortages for native species. Competition for water and nutrients, rather than light, for example, is likely to be most important in Australian rangelands where water is often limited and the soils are often poor in nutrients such as nitrogen and phosphorus (*Johans* et al. 1984).

Changes to the structure and species composition of vegetation affect the availability of resources. The nature of the resources that are available and the spatial and temporal patterning of resource availability can all be altered when an alien plant species invades. The changes in faunal communities that have been correlated with invasions of central Australian riparian zones by *Tamarix aphylla* (*Griffin* et al. 1989), of savanna woodlands by *Cenchrus ciliaris* (*Franks* 2002; *Butler* and *Fairfax* 2003), and of northern floodplains by *Mimosa pigra* (*Braithwaite* and *Lonsdale* 1987; *Braithwaite* et al. 1989), provide what are probably the most comprehensively studied examples of these resource availability effects in Australia. The great variation in the responses by different faunal taxa to invasion by alien plant species is no doubt due in part to the fact that a particular alien species may enhance habitat suitability for some species or higher taxa but degrade it for others because of their different resource requirements. For example, relatively high densities of the rare marsupial *Smithypus virginiae* were recorded on floodplain areas infested with *M. pigra* although wetland birds such as magpie geese (*Anseranas semipalmata*), brolga (*Grus rubicundus*) and green pygmy geese (*Neptunus palchellus*) are likely to decline as a result of this invasion (*Braithwaite* et al. 1989). The resources in question may be food, shelter or nest sites, though again there has been little research quantifying the details of changes to availability of resources in Australian rangelands as a result of plant invasions.

Changes in resource availability for one species or higher taxon will have repercussions through the food web though there are no Australian examples where these flow-on effects have been examined in detail. Some non-native plants probably provide food or other resources for particular animal species. Obvious examples include fleshy-fruited plants such as *Lantana camara* L. (*Stansbury* and *Vivian-Smith* 2003) and *Ziziphus mauritiana* Lam. (*Grice* 2002).
complex and individual invasions may be associated with increase, decrease and no-change scenarios for different faunal groups.

Species vary enormously in the impacts they have on the systems that they invade. Some may remain minor components of the vegetation while others can completely dominate one stratum or the vegetation overall. In addition, species can have effects out of proportion to their contribution to overall biomass. For example, understorey species may interfere with recruitment of community dominants.

Two areas of emphasis in research are apparent from the literature. One is the tendency to focus research on species that are perceived to have important effects. This emphasis will yield information about some of the effects of weeds perceived to be important, down play the significance of species that have visually less dramatic influences and ignore the possibility that some species could invade and yet have negligible consequences. It is conceivable that most of the overall impact will come from a relatively small proportion of invasive species.

The other area of emphasis concerns the taxa and ecosystem processes that are measured as indicators. Plant species richness has been a popular measure and vertebrate groups have received attention to the almost complete exclusion of other faunal groups.

All scientific studies of the impacts of invasive species in Australian rangelands have focused on the effects of individual invasive species. In many situations native communities are under threat from a complex of interacting weed species (Grieve et al. 2004). The importance for ecosystems of these inter-weed interactions can only be guessed.

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