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Does invasive plant management aid the restoration of natural ecosystems?

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ABSTRACT

Invasive alien plants of natural ecosystems, commonly referred to as weeds, can reduce the abundance and diversity of native flora and fauna, and alter ecosystem processes. Using Australia's 20 'Weeds of National Significance' (WoNS), we investigated how natural ecosystems responded following their management. We reviewed the literature and surveyed land managers involved in WoNS management programs by distributing a questionnaire through various e-mail networks. While most of the 95 papers reviewed measured the effect of management on the target WoNS, only 18 assessed the response of other plant species. In these studies, native plant species did not necessarily recover following management and in many instances the managed WoNS was replaced by other weed species. Three other studies investigated the response of invertebrate communities and an ecosystem process following WoNS management but none examined the response of vertebrates or microbial communities. A total of 168 replies were received to the land manager survey. Of the 142 land managers who evaluated their WoNS management program, 86 monitored the response of native plant species and/or other weeds, mostly using qualitative assessments. These managers reported no vegetation response after management of the WoNS (7%) or re-colonisation by a combination of native and weed species (52%) or only by native plants (33%) or the targeted WoNS (2%). Our results emphasise the need to select sites for weed management that are less degraded and thus have a higher likelihood of natural recovery and/or to incorporate activities that facilitate recovery of native plant communities in conjunction with weed removal.

1. Introduction

Invasive alien plants of natural ecosystems, commonly referred to as weeds, have the potential to reduce the abundance and diversity of native plants; in some situations even threatening the survival of species (Levine et al., 2003; Burgman et al., 2007; Downey, 2008a; Mason et al., 2009). Weeds may also adversely affect vertebrates (Horncastle et al., 2005; Nordby et al., 2009), invertebrates (Lindsay and French, 2006; Moron et al., 2009), soil microbes (Yu et al., 2005; Li et al., 2006), ecological communities (Coutts-Smith and Downey, 2006), fire (Brooks et al., 2004a) and other disturbance regimes (Mack and D'Antonio, 1998), trophic structure and food webs (Strayer et al., 2006; Gerber et al., 2008), ecosystem processes such as nutrient cycling (Ehrenfeld, 2003; Standish et al., 2004), soil sedimentation (Gordon, 1998) and hydrological cycles (Richardson et al., 2007). Collectively, these impacts can lead to severe losses in ecosystem integrity (Richardson and van Wilgen, 2004).

As a result of the serious negative impacts caused by weeds in natural ecosystems, land managers invest large quantities of resources for weed management (Mason et al., 2005). A recent study estimated that at least 20 million AUD is spent each year in Australia on programs to manage weeds invading natural ecosystems (Sinden et al., 2005). This estimate does not reflect true costs of management as it does not include time spent by volunteers controlling weeds in these environments. It also does not include annual investment in biological control programs targeting these weeds. Substantial investments are also made elsewhere to control weeds within natural environments. For example, in Florida 3–6 million USD is spent annually to control the melaleuca tree (*Melaleuca quinquenervia*) in forest and grassland ecosystems of the Everglades and about 14.5 million USD to control hydrilla (*Hydrilla verticillata*) invading lakes (Pimentel et al., 2005). On Cruz Island, Galapagos the annual cost to manage the invasive quinine tree (*Cinchona pubescens*) is up to 2225 USD per hectare (Buddenhagen and Yánez, 2005). In South Africa, about 825 million ZAR (≈80 million USD) was spent from 1995 to 2000 to control weeds as part of the ongoing 'Working for Water' program, which aims to clear

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weeds from riparian areas to increase water supply (Binns et al., 2001). Furthermore, once a dominant weed species has been controlled, additional investments, which can be substantial, may be required to restore sites (Dehnen-Schmutz et al., 2004).

It is often assumed that the control of weeds invading natural ecosystems will bring about the recovery of native assemblages and ecosystem functions (Zavaleta et al., 2001). However, weed management is only one of the tools available to restore ecosystems. The extent and rate of recovery of native plant species following weed control is highly dependent on the level of disturbance and degradation at sites, the presence of propagules in the soil and the composition of the surrounding vegetation (Prach and Hobbs, 2008; Reinecke et al., 2008). Where native species recovery has been compromised due to depleted seed banks or poor connectivity to surrounding native vegetation, a reduction in the infestation of a dominant weed may provide an opportunity for other weed species to establish (D'Antonio and Meyerson, 2002; Buckley et al., 2007; Turner et al., 2008b). Weed management actions can vary in their capacity to foster recovery of ecosystems and may have adverse impacts, including promoting secondary weed invasion (Galatowitsch and Richardson, 2005; Mason and French, 2007). In situations where an ecosystem has been fundamentally changed due to weeds (e.g. transformer species – Richardson et al., 2000), or when the presence of weeds is a symptom rather than the cause of degradation, weed removal, alone, is highly unlikely to restore the ecosystem (MacDougall and Turkington, 2005; Hastings et al., 2007).

While the capacity of weed management programs to aid restoration has been assessed in a number of ecosystems (e.g. Erskine Ogden and Rejmánek, 2005; Harms and Hiebert, 2006; Barton et al., 2007; Blanchard and Holmes, 2008), a more comprehensive assessment is warranted given that most management programs fall outside scientific research. We have therefore taken a two-pronged approach to evaluate whether weed management programs contribute to the restoration of natural ecosystems using a review of the literature and a survey of current land managers undertaking weed control. We focused our study on the 20 Australian 'Weeds of National Significance' (Thorp and Lynch, 2000) (hereafter referred to as WoNS), as they have attracted significant investments for management and research efforts, both before and after they became known as WoNS (see Table 1 for list). The 20 WoNS were judged the most threatening to Australia's agriculture, forests and natural ecosystems based on a comparative multi-criteria assessment of 71 weed species that had been nominated by state and territory agencies in Australia (Thorp and Lynch, 2000). A strategy for each WoNS was then developed, listing a series of actions required to achieve sustainable, long-term management of the weed on a national basis. Based on the outcomes of this desk-top study, we outline implications for the restoration of natural ecosystems and make a plea for land managers and researchers to work together more regularly and systematically to undertake more comprehensive evaluation of weed management programs.

2. Materials and methods

2.1. Literature review

A literature search targeted published papers on WoNS management programs in Australian natural ecosystems, which contained a description of the control methods used and some detail on the outcomes of each program. Natural ecosystems were defined as those that (1) had not been cleared for agriculture or other purposes, such as forestry (excluding native forests where selective logging occurs), (2) contain representatives of local native plant species, (3) were rarely utilised for agricultural production, and (4) did not include man-made water bodies or those used for aquaculture.

The database *Web of Science* (1992–present) was searched using the common and scientific names of each WoNS as primary search terms. These were paired with the secondary search terms: chemical, mechanical, biological, control, fire and management. A search of the Australian Weeds Conference Proceedings (1993–2008) was also undertaken as these papers are peer-reviewed, but do not appear in the *Web of Science* database. Additional papers published in journals not included in the *Web of Science* database were

Table 1
Number of papers found in the literature and number of replies received to the land manager survey on management programs for each of Australia's 20 Weeds of National Significance invading a natural ecosystem in Australia.

Weeds of National Significance[a]	Total number of papers	Number of papers that measured the response of associated plants, animals or ecosystem processes to management	Total number of survey replies	Number of survey replies that formally evaluated the response of associated plants to management
Alligator weed (*Alternanthera philoxeroides*)	8	–	2	–
Athel pine (*Tamarix aphylla*)	1	1	3	1
Bitou bush/boneseed (*Chrysanthemoides monilifera*)	14	7	23	16
Blackberry (*Rubus fruticosus* agg.)	3	–	30	18
Bridal creeper (*Asparagus asparagoides*)	4	3	18	8
Cabomba (*Cabomba caroliniana*)	–	–	–	–
Chilean needle grass (*Nassella neesiana*)	1	–	5	2
Gorse (*Ulex europaeus*)	6	–	14	8
Hymenachne (*Hymenachne amplexicaulis*)	–	–	1	–
Lantana (*Lantana camara*)	8	1	15	12
Mesquite (*Prosopis* spp.)	3	–	9	2
Mimosa (*Mimosa pigra*)	15	4	2	–
Parkinsonia (*Parkinsonia aculeate*)	5	–	3	1
Parthenium weed (*Parthenium hysterophorus*)	1	1	1	1
Pond apple (*Annona glabra*)	–	–	2	2
Prickly acacia (*Acacia nilotica* spp. indica)	3	–	4	1
Rubber vine (*Cryptostegia grandiflora*)	9	3	6	4
Salvinia (*Salvinia molesta*)	11	1	2	–
Serrated tussock (*Nassella trichotoma*)	–	–	12	4
Willows (*Salix* spp. except *S. babylonica*, *S. X calodendron*, *S. X reichardtii*)	1	–	16	6
Total	95	21	168	86

[a] Thorp and Lynch (2000).

identified by examining the reference lists of the papers already gathered and included in the review. Some relevant papers may have been missed using this approach, but we are confident that the range of papers included in the review cover the majority of management programs for WoNS undertaken in Australian natural ecosystems. The selected papers were assessed to determine if they reported on the response of plant, animal and microbial communities and ecosystem processes to management of the WoNS.

2.2. Land manager survey

Land managers, including private landholders, community groups and local and state government officers responsible for weed management on public land, were surveyed by distributing a questionnaire through various e-mail networks. Information was gathered on (1) the aims and details of each management program, (2) the extent and types of evaluation undertaken, and (3) the outcomes of the management programs in terms of the WoNS population and the response of plant communities.

The questionnaire was e-mailed to government-employed natural resource management coordinators (including 7 regional Landcare coordinators, 56 regional Natural Resource Management (NRM) or Catchment Management Authority (CMA) facilitators and 13 national WoNS coordinators), requesting that they distribute it throughout their network of land managers. The questionnaire was sent on 7 September 2007 and participants were asked to reply by 31 October 2007. The total number of questionnaires sent out could not be determined due to cross-posting and redistribution. Survey participants were asked to fill in a separate questionnaire for each site and WoNS. Sample sizes varied between questions because not all questions were answered by respondents and several questions enabled the respondents to provide multiple answers.

3. Results

3.1. Literature review

We found 95 papers that investigated the management of WoNS in natural ecosystems in Australia (Table 1). Of the 20 WoNS, 16 had one or more papers investigating their management. We found no papers on management in natural ecosystems for four species, while only three species were each the subject of more than 10 papers.

Of the 95 papers considered, only 21 investigated the response of plant and invertebrate communities and ecosystems processes to weed management (Table 1). The duration of the evaluation period after management ranged from less than 1–8 years (median 2 years, mode 3 years).

Eighteen papers specifically examined the response of plant communities following WoNS control. Three papers on mimosa (*Mimosa pigra*) and rubbervine (*Cryptostegia grandiflora*) did not provide detail on the types of vegetation replacing the WoNS (Cook, 1993; Paynter, 2005; Collins et al., 2008). For example, Paynter (2005) noted an increase in other vegetation at mimosa-invaded sites where the biological control insect agent *Carmenta mimosa* was present but did not list any plant species. Similarly, Collins et al. (2008) reported an increase in herbs and grasses following rubbervine control with fire and herbicide but did not state whether or not they were native and did not list the species.

Even though a number of papers reported that some native plant species recovered after WoNS control, most indicated that active and sustained management was required to manage other weed species present in the recovering communities. Six papers reported an increase in species richness, abundance or cover of native plant species after WoNS control (Melland et al., 1999; Macleay, 2004; Tomley and Evans, 2004; Brown and Grace, 2006; Thomas et al., 2006; Radford et al., 2008). This claim however, was only based on a few observations in some of these papers, lacking detailed data on replacement species.

Four other papers reported that the number or cover of both native and weed species increased following management of a WoNS (Miller and Schultz, 1993; Paynter and Flanagan, 2004; Turner and Virtue, 2006; Mason and French, 2007). For example, Mason and French (2007) found that intensive management of bitou bush (*Chrysanthemoides monilifera* spp *rotundata*), using hand pulling and application of herbicide, resulted in the recovery of some native plant species and an increase in other weeds. While Turner and Virtue (2006) observed no significant difference in native plant diversity between plots infested with bridal creeper (*Asparagus asparagoides*) and plots where the weed was killed with herbicide, they recorded a net increase in abundance and cover of the native chenopod shrub *Enchylaena tormentosa* and cover of native perennial grasses, but also of the weed soursob (*Oxalis pes-caprae*) after removal of bridal creeper. Similarly, native grasses and sedges as well as the weed, para grass (*Brachiaria mutica*), increased after successful management of mimosa (Miller and Schultz, 1993).

The remaining five papers that investigated the response of plant communities reported a variety of results. By comparing non-invaded sites with sites where bridal creeper cover had been reduced by more than 75% in the 15 months following the introduction of the biological control agent *Puccinia myrsiphylli*, Turner et al. (2008a) did not detect a change in native plant and weed species cover at two of the three managed sites. At the third site where bridal creeper was reduced, the cover of native vines, as well as other weed species, was approximately 6 times higher than in the reference non-invaded site. This study however, may have been too short to measure the recovery of native species at all sites. Mason et al. (2007) found no difference in the richness and composition of native seed banks between sites with low and high bitou bush infestations as well as those where the weed had been managed. This suggests either that there were no evident impacts or that seed banks were spatially variable making any effects of management difficult to detect. High variability is a feature of soil seed banks and is a poor predictor of mature vegetation composition (Holmes and Cowling, 1997; Bekker et al., 1999). In the other three papers, an increase in weeds but not native plants was recorded after control of the target WoNS. The aquatic weed salvinia (*Salvinia molesta*) was replaced with dense waterweed (*Egeria densa*) at some sites where the biological control insect agent *Cytrobagous salviniae* was effective (Hennecke and French, 2008). An increase in bare ground and invasive herbs and grasses were mainly observed after herbicide was used to control bridal creeper (Pritchard, 1996). Similarly, bare ground and predominantly invasive grasses were recorded following control of parthenium weed (*Parthenium hysterophorus*) with herbicides in a disturbed roadside site (Brooks et al., 2004b).

The literature review found only two papers that documented the response of invertebrate communities and only one that investigated an ecosystem process following WoNS management. We did not find any paper that examined the response of vertebrates and below or above-ground microbial communities during or after a management program. Lindsay and French (2004) did not detect any change in abundance and composition of leaf litter invertebrates following control of bitou bush with glyphosate at invaded coastal dune sites in New South Wales. Similarly, no difference in the abundance, taxonomic richness and composition of litter invertebrates was found within 4 months of bitou bush control with the herbicide metsulfuron-methyl (French and Buckley, 2008). The only paper we found that investigated the response of an ecosystem process after removal of a WoNS was that of Gosper et al. (2006). The authors reported no difference in rates of native fruit removal by birds between sites infested with bitou bush and sites where the weed had been killed using herbicide. In contrast, the rate of bitou bush fruit removal from experimental stations (spikes with fruits attached to dead plants) within managed sites was lower than in infested sites, suggesting that the control of bitou bush may have affected the activity of frugivores.

3.2. Land manager survey

3.2.1. Respondent statistics

We received 168 replies to the survey, covering 19 of the 20 WoNS (Table 1). Most of the replies received were from the states of Victoria (37%; $n = 62$) and New South Wales (28%; $n = 47$), followed by Queensland (15%; $n = 25$), Western Australia (9%; $n = 15$) and South Australia (8%; $n = 13$). Only four and two replies were received from Tasmania (2%; $n = 4$) and the Australian Capital Territory (1%; $n = 2$), respectively. None were received from the Northern Territory.

State government agencies, primarily those responsible for managing protected areas or national parks, provided the greatest number of replies (38%; $n = 64$). Other replies were received from community groups (25%; $n = 43$), local government organisations (22%; $n = 37$), private landholders (7%; $n = 11$), NRM/CMA Boards (6%; $n = 10$) and other organisations such as universities and non-government organisations (2%; $n = 3$).

3.2.2. Aims and detail of management programs

An aim of 76% of respondents ($n = 126$; total of 166 respondents) was to manage the WoNS for biodiversity conservation. Eradication of the WoNS at the infested site was also a goal of many management programs (66%; $n = 109$), followed by containment (39%; $n = 65$), complying with the legislation (33%; $n = 54$), maintaining neighbour/public relations (22%; $n = 37$) and protecting assets (20%; $n = 34$) and cultural heritage (6%; $n = 10$). Fifty-seven per cent of total respondents ($n = 96$) considered that one or more native plant species were at risk from the targeted WoNS at their site, but only half listed the actual species.

The size of areas targeted by management programs ranged from less than 1 to more than 5000 ha, with 47% of programs ($n = 68$; total of 144 respondents) covering areas less than or equal to 50 ha and 20% ($n = 29$) targeting areas larger than 1000 ha. Forty-nine per cent of respondents ($n = 77$; 156 respondents answered this question) indicated that their management programs had been running for 3 years or less and many of these were ongoing. The duration of other management programs included 4–9 years (33%; $n = 52$), 10–15 years (10%; $n = 16$) and more than 15 years (7%; $n = 11$). The longest running program had been carried out for 37 years, targeting blackberry (*Rubus fruticosus* agg.). The use of herbicide was by far the principal control method (65%; $n = 109$) employed by the total respondents, followed by hand weeding (20%; $n = 33$), biological control (7%; $n = 12$), mechanical methods (4%; $n = 7$) and other measures such as grazing and fire (4%; $n = 6$).

3.2.3. Evaluation of management programs

Eighty-five per cent ($n = 142$) of respondents indicated that they evaluated the outcomes of their management programs on the target WoNS either during and/or after the program ended. Of the respondents that did not undertake any or limited evaluation ($n = 74$), most stated that it was due to lack of time (72%; $n = 53$), funds (50%; $n = 37$) and/or guidance or expertise (43%; $n = 32$). Some respondents indicated that evaluation was not undertaken because the site was difficult to access (8% of replies; $n = 6$) or they had just started the program (12%; $n = 9$).

The response of the target WoNS to management was assessed by 96% ($n = 137$) of the 142 respondents who performed some level of evaluation. In contrast, the response of other weeds to WoNS control was evaluated by 27% ($n = 39$) of respondents, and the response of native plant species by 58% ($n = 83$) of respondents.

Evaluation was mainly done through qualitative observations (82%; $n = 116$; total of 142 respondents), or by photos taken at reference points over time (58%; $n = 82$) or by mapping (51%; $n = 72$). Changes in plant species composition were sometimes assessed by estimating per cent cover (20%; $n = 28$) or counting numbers of plants along transects (13%; $n = 19$) or within quadrats (10%; $n = 14$). Our survey did not request respondents to provide this quantitative data.

3.2.4. Outcomes from management programs

Most management programs reported substantial reductions in the target WoNS after control. Six-three per cent ($n = 90$) of the 142 respondents who evaluated the outcomes of their management program estimated that the area infested by the WoNS was reduced by more than 50%. In contrast, 22% ($n = 31$) of the respondents indicated that the infested area was reduced by only 1–50%, while about 2% ($n = 2$) reported no change or an increase of the infested area. Thirteen per cent ($n = 19$) of respondents could not estimate by how much the WoNS infestation had changed.

Of the 86 respondents who specified that they formally evaluated the response of other plant species to the management of the dominant WoNS (Table 1), 52% ($n = 45$) indicated that the WoNS was replaced by a combination of both native and other weed species. Thirty-three per cent ($n = 28$) reported that the WoNS was replaced by native plants only, while 2% ($n = 2$) recorded that the WoNS recolonised the site following control. No vegetation response (i.e. bare ground) after management was reported by 7% ($n = 6$) of respondents, while 1% ($n = 1$) did not specify what had replaced the target WoNS. None of the respondents reported that the controlled WoNS was replaced by other weeds species alone. Four respondents (5%) selected more than one category of vegetation change when answering this question. These respondents indicated that the target WoNS was replaced by a combination of both native and weed species, but also that the WoNS had reinvaded part of the site after management. In addition to these changes, one respondent indicated that bare ground had also increased following management. Only 62% ($n = 48$) of the 77 respondents who reported that other weeds and/or native plants had replaced the controlled WoNS listed the species.

Duration of the management program slightly influenced the type of vegetation that replaced the controlled WoNS (Fig. 1). In short programs (<3 years) the amount of bare ground frequently increased (specific to terrestrial habitats) after initial control of the target WoNS. A mixture of weeds and native plants was most frequently recorded following management programs that lasted more than 1 year. The abundance of native plants was highest after WoNS management programs of 7–9 years duration.

Thirty-three per cent ($n = 55$) of respondents specified that they attempted to revegetate the area following their management program, either using seeds (9%; $n = 5$) or tube stocks of native plants (76%; $n = 42$), or a combination of both (15%; $n = 8$).

4. Discussion

The primary drivers for managing a dominant weed that has invaded a natural ecosystem are to reduce its impacts on native species and communities (D'Antonio and Meyerson, 2002; Hulme, 2006; Downey, 2008a; Foxcroft and Downey, 2008) and to constrain its spread (Foxcroft et al., 2007). Results from our literature review and land manager survey indicated that limited quantitative data are collected in Australia to document changes in plant communities following reduction or removal of any of the 20

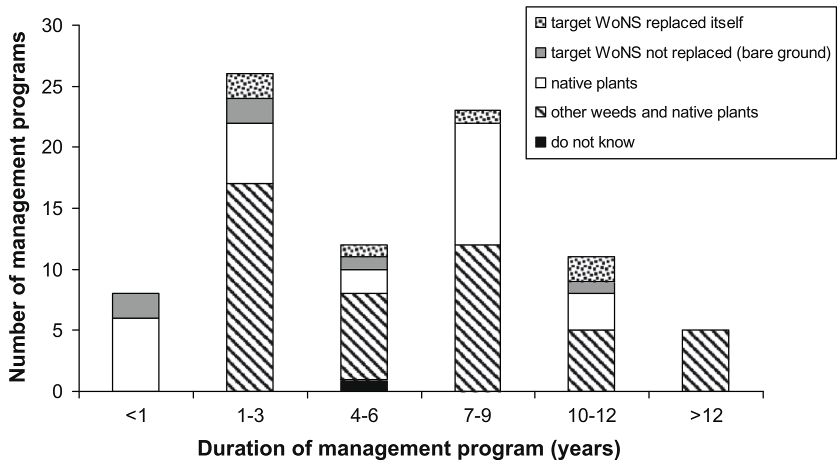

Fig. 1. Vegetation replacing Weeds of National Significance (WoNS) after management programs of different duration. Data presented is from 80 land managers who specified in the survey that they formally evaluated the response of other plant species to management as well as the program duration. More than one category of vegetation replacement was selected by four of these managers and none of them reported that the controlled WoNS was replaced by other weeds species alone.

WoNS species. In addition, evidence that weed management programs lead to the stable recovery of ecosystems is also not readily available. A similar lack of data for management programs targeting a range of other weed species of natural ecosystems in both Australia (Thomas and Reid, 2007) and elsewhere (Denslow and D'Antonio, 2005) is likely. For example, in a worldwide review of successful biological control projects, where noticeable reductions in cover and distribution of the target weeds had been reported, Denslow and D'Antonio (2005) found limited quantitative information on the responses of invaded communities to weed reduction. Some land managers may have collected high quality, quantitative data, but did not have the impetus to publish in scientific journals or conference proceedings and preferred to communicate their results through unpublished reports, regional meetings or informal channels, such as electronic list servers. Consequently, their data are not easily accessible to the wider community. Extensive mining of the 'grey' literature, including reports to funding bodies, is necessary to locate additional data on the response of plant communities following WoNS management, although it is unlikely that these would significantly change the overall trends identified in this study.

Only 18 of the 95 papers on WoNS management programs in natural ecosystems reported on changes in associated plant communities following control of the target species. Some of these papers only reported a few observations without detailed data on species. Similarly, despite biodiversity conservation being a goal of 76% of management programs undertaken by land managers, only half of survey respondents assessed how native plant communities responded to the control of the WoNS. Qualitative assessments based on simple observations and photo points were most frequently used by land managers for evaluation. These approaches are attractive because they are not expensive and time consuming, but they are not appropriate to measure the detailed response of plant communities following a reduction in abundance of the target weed (King and Downey, 2008). For instance, the return of vegetation cover does not imply that native species richness or particular valuable species has been restored. Thus native species may still be missing from the ecosystem, reducing the biodiversity value arising from the management program.

Lack of long-term funding, expertise or guidance on how to assess plant communities may explain why limited evaluation of the response of native plant communities following WoNS management was undertaken by land managers. Some information is available on how to collect data to assess plant community recovery following a weed management program (e.g. Atkinson, 1994; Greening Australia, 2005; Hill et al., 2005; Croft et al., 2007; Ainsworth et al., 2008), but more training for land managers may be necessary to encourage uptake. Many land managers may not know how to interpret their data once collected and how to use it to inform adaptive management decisions (Shea et al., 2002) or to demonstrate the outcomes of their management program (Field et al., 2007). In addition, while funding bodies request reports on the effectiveness of the management program in controlling the target weed, they do not generally require managers to report on biological responses of native species following weed management. Land managers would benefit from closer partnership with researchers to design and implement protocols to assess whether weed management programs have achieved their ultimate goal of maintaining or restoring native species, communities and ecosystems processes.

Evaluation during and after weed management programs is essential to gather the necessary information for land managers to decide if additional actions are required to achieve lasting outcomes for conservation (Hulme, 2006; Field et al., 2007). To be most effective, evaluation protocols should be planned well before any weed management program is implemented (Blossey, 1999) and specify which native plant species the manager aims to protect and/or restore. This enables baseline data to be gathered and used to assess progress made in achieving program goals. Evaluation is then carried out at regular intervals, applicable to the development times of plant communities (e.g. every 1–2 years for a woodland).

In weed management programs surveyed in our study, where some form of plant community evaluation was carried out, native plants did not necessarily recover or re-colonise the site extensively; at least in the immediate years after the WoNS population was reduced or eliminated. A mixture of native plants and other weeds was reported to replace the controlled WoNS in more than 50% of programs. While these results indicate some level of net improvement arising from these weed management programs, they highlight that more activities to assist the recovery of the ecosystem are required to restore many of the sites. There is a wide range of variables that could have influenced such results, including site history and condition, residence time and nature of the invasion (e.g. whether disturbance regimes or soil nutrients have been altered), native species diversity and composition and the availability of propagules at the site and in the surrounding landscape (e.g. up-stream) (Bakker and Berendse, 1999; King and Buckney, 2002; Lake and Leishman, 2004; Kinloch and Friedel, 2005;

Turner et al., 2008b). The management method itself may also have adversely affected native plant species at the invaded site, for example through off-target damage from herbicide application. An integral part of reducing the deleterious effect of weeds in natural ecosystems is to ensure that plant communities are resistant to re-invasion after management; most likely through facilitating native plant community recovery, thus decreasing resource availability for invaders (Davis et al., 2000).

While greater emphasis could be given to selecting sites for weed management that are less degraded as there would be a higher likelihood of natural recovery, such selection is not always possible (e.g. when protection of threatened species is the primary reason for weed management) (Hobbs, 2007; Downey, 2008b). Nonetheless, where native plant species are not regenerating following removal of a dominant weed, sustained follow-up management of new weed recruits and actions to assist recovery of native plant communities are required to reduce the risk of further invasion by weeds (Hobbs, 2003; Blanchard and Holmes, 2008). In such instances, controlling all weed species at a site is not necessarily the goal; in fact the presence of some minor weeds at the start of a restoration program can be tolerated or even beneficial to the outcomes (e.g. by shielding recovering native plants from intense heat and radiation, protecting against large herbivores, restoring nutrient levels following nutrient-enrichment (Ewel and Putz, 2004)). Recovery actions may include stimulating seed bank germination (e.g. through judicious use of fire), adding local native seeds or seedlings in terrestrial habitats or altering hydrology and nutrient dynamics in aquatic systems. Reference to nearby uninvaded sites dominated by native species may help define the objectives of the restoration program. While identifying and addressing possible underlying causes of the initial invasion, such as change in fire frequency (Lunt and Morgan, 2002) or nutrient-enrichment (Lake and Leishman, 2004) would assist in restoring an ecosystem over the long-term (MacDougall and Turkington, 2005; Hobbs, 2007), it is unfortunately often outside the immediate control of most land managers.

The implementation of a weed management program should be seen as only one component in the restoration of invaded natural ecosystems. Reversal of the impacts of a dominant weed requires more than just the removal of the target species, as the invasion may have changed fauna and flora species richness as well as ecosystem processes (e.g. Mack and D'Antonio, 1998; Gerber et al., 2008; Mason et al., 2009). The structure and function of ecosystems may be permanently affected unless other actions are implemented. Three key, interdependent activities focusing on evaluation, weed management and ecosystem recovery actions are necessary to restore native communities and ecosystem functioning at invaded sites (Fig. 2). Evaluation is crucial to assess whether the overall goal of a weed management program is met and if additional actions to assist recovery of the ecosystem are required. Setting a realistic and achievable restoration goal is essential (Hobbs, 2007). Greater collaboration between weed managers and restoration specialists, to draw on the strengths of each other, is required to implement such a framework and develop sustainable management strategies for invaded natural ecosystems within specific landscapes. The development of evaluation methods and ecosystem recovery strategies, in conjunction with best practice weed management guidelines, would help integrate these currently disjunct activities, resulting in a more sustained reduction in the impact of weeds on biodiversity and ecosystem processes.

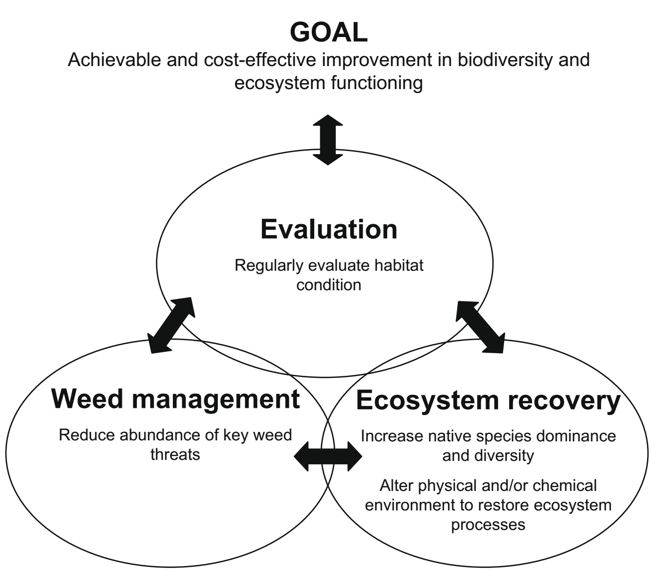

Fig. 2. Conceptual framework integrating evaluation, weed management and ecosystem recovery actions to more effectively restore invaded natural ecosystems.

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References

Ainsworth, N., Adair, R., Cheal, D., 2008. A Method of Monitoring Biodiversity for Changes Associated with Invasive Plants. Victorian Government Department of Sustainability and Environment, Melbourne, Australia. <http://www.dse.vic.gov.au/CA256F310024B628/0/5D892C32F98E7C4DCA257449001F5269/$File/06056_DSE+Monitoring+Biodiversity_lr.pdf> (accessed 10.02.09).

Atkinson, I.A.E., 1994. Guidelines to the Development and Monitoring of Ecological Restoration Programmes. Department of Conservation, Wellington, New Zealand. <http://www.doc.govt.nz/upload/documents/science-and-technical/docts07.pdf> (accessed 10.02.09).

Bakker, J.P., Berendse, F., 1999. Constraints in the restoration of ecological diversity in grassland and heathland communities. Trends in Ecology and Evolution 14, 63–64.

Barton, J., Fowler, S.V., Gianotti, A.F., Winks, C.J., de Beurs, M., Arnold, G.C., Forrester, G., 2007. Successful biological control of mist flower (*Ageratina riparia*) in New Zealand: agent establishment, impact and benefits to the native flora. Biological Control 40, 370–385.

Bekker, R.M., Lammerts, E.J., Schutter, A., Grootjans, A.P., 1999. Vegetation development in dune slacks: the role of persistent seed banks. Journal of Vegetation Science 10, 745–754.

Binns, J.A., Illgner, P.M., Nel, E.L., 2001. Water shortage, deforestation and development: South Africa's Working for Water programme. Land Degradation and Development 12, 341–355.

Blanchard, R., Holmes, P.M., 2008. Riparian vegetation recovery after invasive alien tree clearance in the fynbos biome. South African Journal of Botany 74, 421–431.

Blossey, B., 1999. Before, during and after: the need for long-term monitoring in invasive plant species management. Biological Invasions 1, 301–311.

Brooks, M.L., D'Antonio, C.M., Richardson, D.M., Grace, J.B., Keeley, J.E., DiTomaso, J.M., Hobbs, R.J., Pellant, M., Pyke, D., 2004a. Effects of invasive alien plants on fire regimes. Bioscience 54, 677–688.

Brooks, S.J., Vitelli, J.S., Rainbow, A.G., 2004b. Developing best practice roadside *Parthenium hysterophorus* L. control. In: Sindel, B.M., Johnson, S.B. (Eds.), Proceedings of the 14th Australian Weeds Conference. Weed Society of New South Wales, Wagga Wagga, Australia, pp. 195–198.
Brown, C., Grace, B., 2006. Athel pine in the Northern Territory: a strategic approach to eradication. In: Preston, C., Watts, J.H., Crossman, N.D. (Eds.), Proceedings of the 15th Australian Weeds Conference. Weed Management Society of South Australia, Adelaide, Australia, pp. 649–652.
Buckley, Y.M., Bolker, B.M., Rees, M., 2007. Disturbance, invasion and re-invasion: managing the weed-shaped hole in disturbed ecosystems. Ecology Letters 10, 809–817.
Buddenhagen, C., Yánez, P., 2005. The cost of quinine *Cinchona pubescens* control on Santa Cruz Island, Galapagos. Galapagos Research 63, 32–36.
Burgman, M.A., Keith, D., Hopper, S.D., Widyatmoko, D., Drill, C., 2007. Threat syndromes and conservation of the Australian flora. Biological Conservation 134, 74–82.
Collins, E.M., Contarino, A.J., Hasted, J., Williams, P.R., 2008. The effect of fire and herbicide on rubber vine (*Cryptostegia grandiflora*) in Bowling Green Bay National Park, Queensland. In: van Klinken, R.D., Osten, V.A., Panetta, F.D., Scanlan, J.C. (Eds.), Proceedings of the 16th Australian Weeds Conference. Queensland Weed Society, Brisbane, Australia, pp. 488–490.
Cook, G.D., 1993. Environmental monitoring of weed control on Aboriginal land: a case study. In: Swarbrick, J.T., Henderson, C.W.L., Jettner, R.J., Streit, L., Walker, S.R. (Eds.), Proceedings of the 10th Australian and 14th Asian-Pacific Weed Conference. Weed Society of Queenland, Brisbane, Australia, pp. 176–180.
Coutts-Smith, A.J., Downey, P.O., 2006. The Impact of Weeds on Threatened Biodiversity in New South Wales. Technical Series 11. CRC for Australian Weed Management, Adelaide, Australia. <http://www.weedscrc.org.au/documents/tech_series_11.pdf> (accessed 10.02.09).
Croft, S.J., Pedler, J.A., Milne, T.I., 2007. Bushland Condition Monitoring Manual. Nature Conservation Society of South Australia Inc., Adelaide, Australia (3 Vols.).
D'Antonio, C.M., Meyerson, L.A., 2002. Exotic plant species as problems and solutions in ecological restoration: a synthesis. Restoration Ecology 10, 703–713.
Davis, M.A., Grime, J.P., Thompson, K., 2000. Fluctuating resources in plant communities: a general theory of invasibility. Journal of Ecology 88, 528–534.
Dehnen-Schmutz, K., Perrings, C., Williamson, M., 2004. Controlling *Rhododendron ponticum* in the British Isles: an economic analysis. Journal of Environmental Management 70, 323–332.
Denslow, J.S., D'Antonio, C.M., 2005. After biocontrol: assessing indirect effects of insect releases. Biological Control 35, 307–318.
Downey, P.O., 2008a. Determination and management of alien plant impacts on biodiversity: examples from New South Wales, Australia. In: Tokarska-Guzik, B., Brock, J., Brundu, G., Child, L., Daehler, C., Pyšek, P. (Eds.), Plant Invasion: Human Perceptions, Ecological Impacts and Management. Backhuys Publishers, Leiden, The Netherlands, pp. 369–385.
Downey, P.O., 2008b. Determining sites for weed control and biodiversity conservation. In: van Klinken, R.D., Osten, V.A., Panetta, F.D., Scanlan, J.C. (Eds.), Proceedings of the 16th Australian Weeds Conference. Queensland Weed Society, Brisbane, Australia, pp. 387–388.
Ehrenfeld, J.G., 2003. Effects of exotic plant invasions on soil cycling processes. Ecosystems 6, 503–523.
Erskine Ogden, J.A., Rejmánek, M., 2005. Recovery of native plant communities after the control of a dominant invasive plant species, *Foeniculum vulgare*: implications for management. Biological Conservation 125, 427–439.
Ewel, J.J., Putz, F.E., 2004. A place for alien species in ecosystem restoration. Frontiers in Ecology and the Environment 2, 354–360.
Field, S.A., O'Connor, P.J., Tyre, A.J., Possingham, H.P., 2007. Making monitoring meaningful. Austral Ecology 32, 485–491.
Foxcroft, L.C., Downey, P.O., 2008. Protecting biodiversity by managing alien plants in National Parks: perspectives from South Africa and Australia. In: Tokarska-Guzik, B., Brock, J., Brundu, G., Child, L., Daehler, C., Pyšek, P. (Eds.), Plant Invasion: Human Perceptions, Ecological Impacts and Management. Backhuys Publishers, Leiden, The Netherlands, pp. 387–403.
Foxcroft, L.C., Rouget, M., Richardson, D.M., 2007. Risk assessment of riparian plant invasions into protected areas. Conservation Biology 21, 412–421.
French, K., Buckley, S., 2008. The effects of the herbicide metsulfuron-methyl on litter invertebrate communities in a coastal dune invaded by *Chrysanthemoides monilifera* ssp. *Rotundata*. Weed Research 48, 266–272.
Galatowitsch, S.M., Richardson, D.M., 2005. Riparian scrub recovery after clearing of invasive alien trees in headwater streams of the Western Cape, South Africa. Biological Conservation 122, 509–521.
Gerber, E., Krebs, C., Murrell, C., Moretti, M., Rocklin, R., Schaffner, U., 2008. Exotic invasive knotweeds (*Fallopia* spp.) negatively affect native plant and invertebrate assemblages in European riparian habitats. Biological Conservation 141, 646–654.
Gordon, D.R., 1998. Effects of invasive, non-indigenous plant species on ecosystem processes: lessons from Florida. Ecological Applications 8, 975–989.
Gosper, C.R., Whelan, R.J., French, K., 2006. The effect of invasive plant management on the rate of removal of vertebrate-dispersed fruits. Plant Ecology 184, 351–363.
Greening Australia, 2005. Native Vegetation and Property Management: A Guide to Research and Resources. <http://live.greeningaustralia.org.au/nativevegetation/pages/index1.html> (accessed 10.02.09).
Harms, R.S., Hiebert, R.D., 2006. Vegetation response following invasive Tamarisk (*Tamarix* spp.) removal and implications for riparian restoration. Restoration Ecology 14, 461–472.
Hastings, A., Byers, J.E., Crooks, J.A., Cuddington, K., Jones, C.G., Lambrinos, J.G., Talley, T.S., Wilson, W.G., 2007. Ecosystem engineering in space and time. Ecology Letters 10, 153–164.
Hennecke, B.R., French, K., 2008. Impact of biological control of *Salvinia molesta* on native plant species biodiversity in temperate climates. In: van Klinken, R.D., Osten, V.A., Panetta, F.D., Scanlan, J.C. (Eds.), Proceedings of the 16th Australian Weeds Conference. Queensland Weed Society, Brisbane, Australia, pp. 195–197.
Hill, D.A., Fasham, M., Tucker, G., Shewry, M., Shaw, P., 2005. Handbook of Biodiversity Methods: Survey, Evaluation and Monitoring. Cambridge University Press, Cambridge, United Kingdom.
Hobbs, R.J., 2003. Ecological management and restoration: Assessment, setting goals and measuring success. Ecological Management and Restoration 4 (Supplement), S2–S3.
Hobbs, R.J., 2007. Setting effective and realistic restoration goals: key directions for research. Restoration Ecology 15, 354–357.
Holmes, P.M., Cowling, R.M., 1997. Diversity, composition and guild structure relationships between soil-stored seed banks and mature vegetation in alien plant-invaded South African fynbos shrublands. Plant Ecology 133, 107–122.
Horncastle, V.J., Hellgren, E.C., Mayer, P.M., Ganguli, A.C., Engle, D.M., Leslie Jr., D.M., 2005. Implications of invasion by *Juniperus virginiana* on small mammals in the southern Great Plains. Journal of Mammalogy 86, 1144–1155.
Hulme, P.E., 2006. Beyond control: wider implications for the management of biological invasions. Journal of Applied Ecology 43, 835–847.
King, S.A., Buckney, R.T., 2002. Invasion of exotic plants in nutrient-enriched urban bushland. Austral Ecology 27, 573–583.
King, S.A., Downey, P.O., 2008. Assessing the recovery of native plant species following bitou bush control: the need for monitoring. Plant Protection Quarterly 23, 40–41.
Kinloch, J.E., Friedel, M.H., 2005. Soil seed reserves in arid grazing lands of central Australia. Part 1: seed bank and vegetation dynamics. Journal of Arid Environments 60, 133–161.
Lake, J.C., Leishman, M.R., 2004. Invasion success of exotic plants in natural ecosystems: the role of disturbance, plant attributes and freedom from herbivores. Biological Conservation 117, 215–226.
Levine, J.M., Vila, M., D'Antonio, C.M., Dukes, J.S., Grigulis, K., Lavorel, S., 2003. Mechanisms underlying the impacts of exotic plant invasions. Proceedings of the Royal Society of London, Series B – Biological Sciences 270, 775–781.
Li, W., Zhang, C., Jiang, H., Xin, G., Yang, Z., 2006. Changes in soil microbial community associated with invasion of the exotic weed, *Mikania micrantha* H.B.K.. Plant and Soil 281, 309–324.
Lindsay, E.A., French, K., 2004. The impact of the herbicide glyphosate on leaf litter invertebrates within Bitou bush, *Chrysanthemoides monilifera* ssp *rotundata*, infestations. Pest Management Science 60, 1205–1212.
Lindsay, E.A., French, K., 2006. The impact of the weed *Chrysanthemoides monilifera* ssp. *rotundata* on coastal leaf litter invertebrates. Biological Invasions 8, 177–192.
Lunt, I.D., Morgan, J.W., 2002. The role of fire regimes in temperate lowland grasslands of south eastern Australia. In: Bradstock, R.A., Williams, J.E., Gill, A.M. (Eds.), Flammable Australia: The Fire Regimes and Biodiversity of a Continent. Cambridge University Press. Cambridge, United Kingdom, pp. 177–196.
MacDougall, A.S., Turkington, R., 2005. Are invasive species the drivers or passengers of change in degraded ecosystems? Ecology 86, 42–55.
Mack, M.C., D'Antonio, C.M., 1998. Impacts of biological invasions on disturbance regimes. Trends in Ecology and Evolution 13, 195–198.
Macleay, R., 2004. Regeneration response after removal of *Lantana camara* L. from mixed forest in the lower Bellinger valley, northern New South Wales. Ecological Management and Restoration 7, 70–71.
Mason, T.J., French, K., 2007. Management regimes for a plant invader differentially impact resident communities. Biological Conservation 136, 246–259.
Mason, T.J., French, K., Russell, K.G., 2007. Moderate impacts of plant invasion and management regimes in coastal hind dune seed banks. Biological Conservation 134, 428–439.
Mason, T.J., French, K., Lonsdale, W.M., 2009. Do graminoid and woody invaders have different effects on native plant functional groups? Journal of Applied Ecology 46, 426–433.
Mason, T.J., Lonsdale, W.M., French, K., 2005. Environmental weed control policy in Australia: current approaches, policy limitations and future directions. Pacific Conservation Biology 11, 233–245.
Melland, R., Ainsworth, N., Roush, R.T., 1999. Reducing the fitness of the fittest: how to control a *Chrysanthemoides monilifera* ssp. *monilifera* (Norl) invasion. In: Bishop, A.C., Boersma, M., Barnes, C.D. (Eds.), Proceedings of the 12th Australian Weeds Conference. Tasmanian Weed Society, Hobart, Australia, pp. 294–297.
Miller, I.L., Schultz, G.C., 1993. The management of weeds on aboriginal land with special reference to *Mimosa pigra*. In: Swarbrick, J.T., Henderson, C.W.L., Jettner, R.J., Streit, L., Walker, S.R. (Eds.), Proceedings of the 10th Australian and 14th Asian-Pacific Weed Conference. Weed Society of Queenland, Brisbane, Australia, pp. 439–444.
Moron, D., Lenda, M., Skórka, P., Szentgyörgyi, H., Settele, J., Woyciechowski, M., 2009. Wild pollinator communities are negatively affected by invasion of alien goldenrods in grassland landscapes. Biological Conservation 142, 1322–1332.
Nordby, J.C., Cohen, A.N., Beissinger, S.R., 2009. Effects of a habitat-altering invader on nesting sparrows: An ecological trap? Biological Invasions 11, 565–575.
Paynter, Q., 2005. Evaluating the impact of a biological control agent *Carmenta mimosa* on the woody wetland weed *Mimosa pigra* in Australia. Journal of Applied Ecology 42, 1054–1062.

Paynter, Q., Flanagan, G.J., 2004. Integrating herbicide and mechanical control treatments with fire and biological control to manage an invasive wetland shrub, *Mimosa pigra*. Journal of Applied Ecology 41, 615–629.
Pimentel, D., Zuniga, R., Morrison, D., 2005. Update on the environmental and economic costs associated with alien-invasive species in the United States. Ecological Economics 52, 273–288.
Prach, K., Hobbs, R.J., 2008. Spontaneous succession versus technical reclamation in the restoration of disturbed sites. Restoration Ecology 16, 363–366.
Pritchard, G.H., 1996. Bridal creeper control with herbicide. In: Shepherd, R.C.H. (Ed.), Proceedings of the 11th Australian Weeds Conference. Weeds Society of Victoria, Melbourne, Australia, pp. 424–427.
Radford, I.J., Grice, A.C., Abbott, B.N., Nicholas, D.M., Whiteman, L., 2008. Impacts of changed fire regimes on tropical riparian vegetation invaded by an exotic vine. Austral Ecology 33, 151–167.
Reinecke, M.K., Pigot, A., King, J.M., 2008. Spontaneous succession of riparian fynbos: is unassisted recovery a viable restoration strategy? South African Journal of Botany 74, 412–420.
Richardson, D.M., Holmes, P.M., Elser, K.J., Galatowitsch, S.M., Stronberg, J.C., Kikrman, S.P., Pyšek, P., Hobbs, R.J., 2007. Riparian vegetation: degradation, alien plant invasions, and restoration prospects. Diversity and Distributions 13, 126–139.
Richardson, D.M., Pyšek, P., Rejmánek, M., Barbour, M.G., Panetta, F.D., West, C.J., 2000. Naturalization and invasion of alien plants: concepts and definitions. Diversity and Distributions 6, 93–107.
Richardson, D.M., van Wilgen, B.W., 2004. Invasive alien plants in South Africa: how well do we understand the ecological impacts? South African Journal of Science 100, 45–52.
Shea, K., Possingham, H.P., Murdoch, W.W., Roush, R., 2002. Active adaptive management in insect pest and weed control: intervention with a plan for learning. Ecological Applications 12, 927–936.
Sinden, J., Jones, R., Hester, S., Odom, D., Kalisch, D., James, R., Cacho, O., Griffith, G., 2005. The economic impact of weeds in Australia. Plant Protection Quarterly 20, 25–32.
Standish, R.J., Williams, P.A., Robertson, A.W., Scott, N.A., Hedderley, D.I., 2004. Invasion by a perennial herb increases decomposition rate and alters nutrient availability in warm temperate lowland forest remnants. Biological Invasions 6, 71–81.
Strayer, D.L., Eviner, V.T., Jeschke, J.M., Pace, M.L., 2006. Understanding the long-term effects of species invasions. Trends in Ecology and Evolution 21, 645–651.
Thomas, M.B., Reid, A.M., 2007. Are exotic natural enemies an effective way of controlling invasive plants? Trends in Ecology and Evolution 22, 447–453.
Thomas, J., Hofmeyer, D., Benwell, A.S., 2006. Bitou Bush control (after fire) in Bundjalung National Park on the New South Wales North Coast. Ecological Management and Restoration 7, 79–92.
Thorp, J.R., Lynch, R., 2000. The Determination of Weeds of National Significance. National Weeds Strategy Executive Committee, Launceston, Australia. <http://www.weeds.org.au/docs/WONS/> (accessed 10.02.09).
Tomley, A.J., Evans, H.C., 2004. Establishment of, and preliminary impact studies on, the rust, *Maravalia cryptostegiae*, of the invasive alien weed, *Cryptostegia grandiflora* in Queensland, Australia. Plant Pathology 53, 475–484.
Turner, P.J., Virtue, J.G., 2006. An eight-year removal experiment measuring the impact of bridal creeper (*Asparagus asparagoides* (L.) Druce) and the potential benefit from its control. Plant Protection Quarterly 21, 79–84.
Turner, P.J., Scott, J.K., Spafford, H., 2008a. Implications of successful biological control of bridal creeper *Asparagus asparagoides* (L.) Druce in south-west Australia. In: van Klinken, R.D., Osten, V.A., Panetta, F.D., Scanlan, J.C. (Eds.), Proceedings of the 16th Australian Weeds Conference. Queensland Weed Society, Brisbane, Australia, pp. 390–392.
Turner, P.J., Scott, J.K., Spafford, H., 2008b. The ecological barriers to the recovery of bridal creeper (*Asparagus asparagoides* (L.) Druce) infested sites: impacts on vegetation and the potential increase in other exotic species. Austral Ecology 33, 713–722.
Yu, X.J., Yu, D., Lu, Z.J., Ma, K.P., 2005. A new mechanism of invader success: exotic plant inhibits natural vegetation restoration by changing soil microbe community. Chinese Science Bulletin 50, 1105–1112.
Zavaleta, E.S., Hobbs, R.J., Mooney, H.A., 2001. Viewing invasive species removal in a whole-ecosystem context. Trends in Ecology and Evolution 16, 454–457.