MANAGING WEEDS IN AUSTRALIA'S PUBLIC LANDS AND FORESTS

F.D. Panetta[A] and D.W. Lane[B]
[A] Alan Fletcher Research Station, PO Box 36, Sherwood, Queensland 4075, Australia
[B] Department of Natural Resources and Environment, 71 Hotham Street, Traralgon, Victoria 3844, Australia

INTRODUCTION

Australian public lands and forests embody natural, social and economic values. Weeds impact upon these values in a variety of ways. The formal recognition of weeds as threats to the conservation and amenity values of public lands and forests began to develop in the early 1970s. Impetus for the management of environmental weeds was provided by extensive and severe infestations of weeds such as boneseed (*Chrysanthemoides monilifera* ssp. *monilifera* (L.) Norl.) and blackberry (*Rubus* spp.), and more recently giant sensitive plant (*Mimosa pigra* L.) and rubber vine (*Cryptostegia grandiflora* R.Br.).

As with agricultural weeds, which have a history of management going back thousands of years, two activities quickly developed. In the field, trialling of control methods and the implementation of control programs were directed towards established problems. On the theoretical side, the evaluation of current and potential problems was directed towards creating awareness and action at the broader level of the protection of public land values. The aim of this overview is to look at how the proposals for weed management on public lands and in forests match up with what is being done on the ground, particularly with regard to:

- management objectives,
- assigning priorities to weed problems,
- integrated control as an alternative to single, specific methods,
- preventing weed invasions – the roles of prediction, management and education, and
- noxious plants legislation.

We draw upon contributions to the last four Australian Weeds Conferences where appropriate and indicate how key issues are addressed by the National Weeds Strategy.

MANAGEMENT OBJECTIVES

Weed management has a central role to play in maintaining all of the values mentioned above, but the objectives of management may differ according to the ways in which public lands are utilized. It is generally accepted that invasive plant species pose a major threat to natural values through their negative effects on biodiversity (Humphries *et al.* 1991). Where conservation values are pre-eminent, e.g. in many national parks and reserves, plant invasions must be managed to minimize the depletion of biodiversity. However, the balance of conservation and other values may differ under other uses of public lands. Where some recreational values are foremost, for example, less emphasis on management for the maintenance of biodiversity may be warranted. Synthetic communities (Bridgewater 1990) perform a range of ecosystem functions, including regulation of the hydrological cycle, wildlife support and soil binding (Westman 1990). The economic values associated with utilizing forests for production are important but will not be considered further here.

Since the justification for weed control is to prevent or remove an adverse impact, the objectives of a program of management should include the rehabilitation of the ecosystem where necessary. The questions then are whether rehabilitation is possible and whether it will occur naturally, or require active intervention. The ability of an ecosystem to recover following weed control will depend on whether the factors leading to invasion can be reversed, as well as reversibility of the changes caused by the invader itself (Hobbs and Humphries 1995). The latter authors have argued that the degree of management intervention warranted at a given site may be determined by classifying the site in terms of its conservation value and its relative degree of disturbance. Both factors should be taken into account in decisions whether to rehabilitate degraded communities that are parts of larger parcels of reserved land. Recent additions to the National Park Estate have included lands that are heavily infested with weeds, as a legacy of earlier patterns of land use (Good 1987, Thompson 1993). While the idea of restoring these may appeal, the expense of doing so should be seen within the context of competing demands for resources for pro-active management of invasive weeds elsewhere (see below). The subject of revegetation is considered further under 'integrated control'.

ASSIGNING PRIORITIES TO WEED PROBLEMS

The National Weeds Strategy highlights a need to establish procedures to assist in identifying and ranking weed problems of potential national significance. The fundamental basis for the determination of priorities is a clear definition of impact in relation to which species and situations can be evaluated and compared. Established priorities assist in gaining political support (Humphries 1993) and for directing the allocation of limited resources (Harley 1984, Smith *et al.* 1993). Definitions proposed

relate to the impact of weeds on natural ecosystems, measurable in terms of structural/compositional modification (with associated changes in biotic abundance and diversity), and changes in key ecosystem functions such as nutrient cycling and the provision of 'ecosystem services' (Van Wilgen *et al.* (1996) for an excellent discussion of the effects of alien species upon water resources). It is important to remember, however, that other factors may have a bearing upon the determination of priorities, such as the feasibility of obtaining a positive management result, and the extent to which a delay in action may influence the amount of effort required in the long run (Hiebert and Stubbendieck 1993).

Direct changes to ecosystem structure following weed invasion can be striking. Swarbrick (1991) lists 'canopy dominant' weeds as the most serious environmental weeds. Invasions by these have led to significant structural changes in Australian ecosystems (Table 1). The study of Braithwaite *et al.* (1989) on the impact of *Mimosa pigra* in tropical Australia illustrated the broad consequences of the invasion of wetland communities and formation of closed stands. The generic impacts of a similar structural change induced in the wetlands of tropical eastern Australia by another tall woody invader, *Annona glabra* L. (Swarbrick 1993), are likely to be qualitatively similar. We question how much would be gained by elucidating the details of the ecological impacts of the latter invasive: from the studies that have been done, both in Australia and overseas, it seems wholly reasonable to conclude that substantial reductions in biodiversity will follow wherever there are major structural changes as the result of invasion and dominance by one or more non-indigenous plants. These are the invaders that should receive the highest priorities for management from the viewpoint of conserving biodiversity.

Perhaps research effort could be more strategically directed towards a better understanding of the structural changes that develop slowly as indirect results of weed invasion. For example, alterations to fire regimes consequent to invasion by grass weeds may have a major effect upon ecosystem structure as the structurally dominant woody species fail to regenerate over periods spanning decades, or longer (Humphries 1993). Another type of indirect structural change has been predicted to arise from the failure of shrub and tree recruitment in southern Australian forest remnants, owing to the competitive effects of invasive herbs and grasses. Given that there is a considerable amount of time for ameliorative intervention in these scenarios, an opportunity exists to extend the understanding of such degradative processes in order to decide where, when and how best to intervene.

Quantification of the effects of changes in ecosystem structure or composition upon ecosystem functioning remains a major challenge for ecologists, one requiring a more rigorous approach than has generally been the case (Lamont 1995). In practical terms, however, while changes in communities and key functions can be quantified, causes and consequences can often be assessed only subjectively. In these cases priorities may have to be based upon the value assigned to natural ecosystems by their degree of uniqueness, or classification as national parks, World Heritage Areas, or similar. Notwithstanding the increasingly perceived importance of off-reserve conservation, the fact remains that national parks etc. contain some of the largest tracts of unmodified native vegetation associations. Protecting these from invasion by major weeds should be of the highest priority.

INTEGRATED CONTROL

The desirability of integrated approaches to weed control has achieved sporadic attention in the proceedings of recent Weeds Conferences. What has been intended by 'integrated' has varied. Miller *et al.* (1987) wrote of an integration of short-term chemically-based control of isolated infestations of *M. pigra* with a search for effective biological control agents. Compatibilities of herbicides with biocontrol organisms were investigated by Wright and

Table 1. Direct structural modifications of Australian native plant communities resulting from weed invasions.

Initial community type	Modified type	Invading species
Sedgeland	Tall shrubland	*Mimosa pigra* L.
Wet grassland	Closed forest	*Annona glabra* L.
Dry grassland	Tall shrubland	*Acacia nilotica* (L.) Willd. ex Del.
Lowland rainforest	Vine thicket	*Thunbergia grandiflora* Roxb.
Subtropical rainforest	Vine thicket	*Macfadyena unguis-cati* (L.) A. Gentry *Anredera cordifolia* (Ten.) Steenis
Aquatic (shallow water)	Wet grassland	*Glyceria maxima* (Hartman) Holmb. *Brachiaria mutica* (Forsskal) Stapf

Shilling (1987) and Pritchard (1990). The objectives of these studies were to determine whether the degree of control achieved by biocontrol agents could be either elevated or hastened by the use of chemicals in some situations, without compromising the effectiveness of either method.

A number of authors have proposed that improved management of particular weeds would be achieved through the integrated use of fire and herbicides (Groves 1990, Swarbrick 1993) or fire with biological control (Briese 1993, Scott 1993). A major advance in the thinking about weed management came with the realization that better understanding was required of the compensatory potential of the indigenous vegetation following reductions in the vigour and abundance of targeted invasive species. Groves (1990) argued that better knowledge of the biology of potentially competing indigenous species should provide the basis for the selection and promotion of plants that could usurp resources freed by weed control, so preventing either a reinvasion by the targeted weed or invasion by another. He wrote, 'The success of control programs for weeds in areas of natural vegetation, whether conservation reserves or not, will depend on the extent to which different control methods can be combined, especially those involving prescription burning, biological and chemical control and active programs of revegetation'. The failure of natural processes to effect revegetation three years after *M. pigra* had been controlled with herbicides is a case in point (Cook 1993), and an outcome that had been predicted earlier (Groves 1990). Attributes such as the mechanism for recovery from disturbance and tolerance of competition are important considerations in the selection of species chosen for revegetation (Panetta and Groves 1990).

Papers from previous Weeds Conferences on the control of environmental weeds provide little reference to proposals for, or processes of, rehabilitation. A recent review by Adair (1995) gives some examples of control methods that include rehabilitation using native species, but it would appear that this approach is far from being generally adopted (Choate 1995). The need to undertake rehabilitation in order to prevent replacement of a weed species by others will be paramount where multiple species invasions have occurred. Papers on control tend to relate to single species, but lists of environmental weeds (Carr *et al.* 1992, Swarbrick and Skarrat 1994) indicate the wide range of existing and potential problems. Humphries *et al.* (1991) note that multiple species invasions are the predominant pattern in southern Australia. Both policy and practice must take the range of weed problems within a community into account.

A major constraint in weed management on public land is that fewer management options are available in comparison with agricultural land. Rehabilitation is further hindered by a general lack of information on the means to restore ecological balances. This is an area where both theory and practice need to be developed. The National Weeds Strategy does not give this much consideration.

Integrated control programs often take a number of years to implement, a problem when project funding is considered on a short-term basis, or programs are driven by particular individuals (who may not remain in place) rather than by more widely defined strategies (Choate 1995).

PREVENTING WEED INVASIONS

Preventative management approaches A recurring theme in recent writings on the management of invasive species is that ecosystems should be managed in such a way as to minimize their invasibility rather than focusing upon individual invaders. Hobbs and Humphries (1995) state 'The changes in ecosystem structure or processes which allow the initiation or intensification of weed invasion have to be addressed before effective weed control can be achieved'. Since disturbance is a major factor affecting the invasibility of natural ecosytems, it is argued that the control of human-induced disturbances such as grazing and fire regimes, fragmentation, eutrophication and road construction is crucial to reducing the overall susceptibility to invasion.

There are few technical or operational impediments to the achievement of reductions in the action of some of these disturbance factors, e.g. habitat fragmentation and construction of new roads. Some difficulties lie in the socio-economic realm, but provided these are overcome, there are predictable benefits. In the long run, however, it may prove increasingly difficult to manage other disturbance factors, such as fire regimes. Fire has played a key role in the maintenance of biodiversity over much of Australia, allowing the co-existence over landscapes of indigenous species with different requirements for fire frequency and intensity. The problem is that invading species are often in a position to capitalize on the very type of disturbance that is required for the persistence of native species (Hobbs and Huenneke 1992). Furthermore, as the number of potential invaders increases with time, it is to be expected that land managers will be faced with an expanding suite of invasive species, containing plants that are adapted to any of a variety of fire regimes. In evaluating the feasibility of obtaining effective weed control, Hiebert and Stubbendieck (1993) consider situations where practices utilized in attempts at community management may be ineffective.

We do not believe that it is appropriate to force a choice between an 'ecosystem focus' and an 'invader

focus', for several reasons. The first is that there are a limited number of ways in which we can manage effectively at the ecosystem level. Secondly, a preventative approach to weed management places a premium upon eradication or containment of weeds wherever possible. This depends upon actions that are focused upon specific invaders. It seems most likely that more effective management of invasive plants will arise from a combination of activities that aim to reduce community invasibility, coupled with control actions targeting priority invasives. The appropriate management actions for such invasives depend upon the stage of invasion (Table 2). It is important to get the balance right; focus on priority species in control programs may overshadow any consideration of differences in the value of different situations affected. This is a potential area of divergence between theory and practice, if the first focuses on conservation values as the priority, and the latter becomes species focused.

Predicting weed potential The adoption of effective screening procedures is essential if the introduction to Australia of invasive species is to be minimized. Intentional introductions of plants that subsequently became major environmental weeds have been made primarily for purposes of ornamental/amenity use and for agricultural production. While the detection of weediness is central to a capability for excluding invasive plants, it is important not to confuse the issue of weed potential with that of sectoral conflict (Panetta 1994). The National Weeds Strategy identifies the need for a mechanism, involving consultation and arbitration, to resolve conflicts between stakeholder groups regarding plant introductions.

Assessment of the weed potential of a plant that is not invasive in its native range and has had no previous history of introduction seems destined to remain problematic. The weed risk assessment protocol developed by Pheloung (1995) leads to decisions to accept for importation, to reject or to further evaluate. It demonstrates a limited ability to identify potential environmental weeds at the pre-entry screening level, but requires that some form of post-entry field assessment be available. There are few leads on how to conduct such assessments, however, pointing to a need for strategic research in this area. Since invasiveness is as much a function of the receiving environment as of the biological features of the invader, it is unlikely that a realistic appraisal of invasive potential in a range of ecosystems could be made as part of an assessment under quarantine conditions. To date the most successful attempt to identify invasive risk (Tucker and Richardson 1995) combined the biological attributes of potential invaders (trees and shrubs) with a detailed understanding of the barriers to invasion in a particular ecosystem (the South African fynbos). This would appear an unattainable standard for the evaluation of risk in relation to most Australian ecosystems.

Many future weeds of conservation reserves are at present confined to suburban or homestead gardens. This is just as relevant to the use of non-indigenous native species as it is to exotic ornamentals (Groves 1990). Given the small percentage of naturalized species that become major weeds, Panetta (1987) suggested that newly naturalized plants be examined *in situ* for their weed potential. More recently Hobbs (1993) has argued that since the formation of many small foci of infestation often precedes a transition to a phase of rapid spread (following the so-called 'lag' phase of invasion), the existence of multiple foci could be used to identify future problem weeds. However, since new ornamental species

Table 2. Stages of weed invasion, appropriate actions and management constraints.

Invasion milestone	Management actions	Constraints[A]
Colonization	Reduction of invasibility	Effectiveness of 'community management'
	Management of dispersal vectors	Nature of vector
	Maintenance of buffer zones	Cooperation of neighbours
	Eradication	Detection
Reproductive maturity	Eradication	Detection
		Duration of juvenile period
Seed bank development[B]	Eradication (?)	Rate of seed bank decline
Structural change	Targeted weed control	Off-target damage
(direct or indirect)	Assisted recruitment/revegetation	Attributes of indigenous spp.
	Controlled disturbance regimes	Regeneration requirements of indigenous spp.

[A] Limited availability of resources is considered to be a major constraint for nearly all management actions and is not listed for this reason.

[B] Relevant only to species with overlapping seed generations.

are actively introduced over many sites, any plant that becomes naturalized is likely to exhibit an initial pattern of many small populations. Yet most naturalized species will not become major weeds! This points to a need for strategic research focused on developing methods for the early identification of plants with potential impacts upon public lands and forests.

Where the potential for significant impact is clearly identified, weeds should be subjected to control programs while their numbers and distributions are relatively limited (Carter *et al.* 1990, Groves 1990). 'Weed elsewhere' knowledge that is gained through observations made on a plant's behaviour in Australia is every bit as crucial in designing pro-active management schemes as it is in quarantine decision-making processes (see above). The use of climate matching computer programs (e.g. BIOCLIM), in conjunction with the distribution of ecological community types known or suspected to be invasible, should provide a reliable estimate of the total extent of areas at risk of invasion.

The National Weeds Strategy places great emphasis on the prediction of weed potential, quarantine procedures and early identification and control of infestations of new weeds. From the drafting of the Strategy has arisen a concerted effort to develop a protocol that would reduce the numbers of invasive species intentionally introduced to Australia (see Pheloung 1995). The Strategy points to decisions being based on subjective judgement, using the precautionary principle, in the absence of other information. Because of this, progress may well depend more on changing attitudes, developed through education, than arguments based on data.

Education and community issues Education of the community should assist in reducing the numbers of plantings of invasive plants that have been, or are currently, legally sold. Gaining community support on this issue is absolutely essential. The growing awareness in major cities throughout Australia of the problems caused by invasive ornamental species is a very encouraging sign.

For weed management projects that require a large labour force, the most cost effective, and sometimes the only, approach is to use community groups. In New Zealand, the Department of Conservation has utilized volunteer labour to considerable effect on a variety of weeds in a number of areas, including National Parks (S. Timmins personal communication). Careful attention must be paid to the planning of activities and to the training and supervision of volunteers. Valuable spin-offs from this sort of undertaking include increased general awareness of weeds as threats to natural areas, as well as wider conservation issues.

Management, the use of predictions, and education are not alternatives, but essential components in an overall strategy to prevent weed invasions. The place of each of these is well defined and generally recognised in most programs.

NOXIOUS PLANTS LEGISLATION

Smith (1987) stated that one of the criteria for declaration of a species should be evidence that the plant causes, or has the potential to cause 'harm to the environment through invasion and dominance of natural vegetation'. Declaration of plants whose sole or major impact is outside the realm of agricultural production remains a vexed issue, owing to the difficulties in gaining compliance with obligations to control such plants on private land (Panetta and Scanlan 1995). However, species that impact upon conservation as well as production values should have a higher priority for declaration than those that impact upon production alone. One negative effect of weed declaration is that efforts to manage declared plants have been ineligible for funding under the National Landcare Program (NLP). Control programs targeting other environmental weeds, such as camphor laurel (*Cinnamomum camphora* (L.) Nees & Eberm.) in New South Wales, are eligible for funding under NLP because these plants have not been proclaimed (Carter 1995).

Most weeds legislation has been developed to provide a mechanism for regulating the control of weeds by land owners. Since most conservation areas are on public land, proclamation serves little useful purpose. While many declared plants are often of lesser significance in public lands than in surrounding rural areas (Good 1987, Smith 1987), due regard must be taken of the likely effects of declared plants in public lands on neighbours when formulating weed management plans. Buffer zones work both ways (Table 2)!

It has been suggested that where environmental weeds are concerned, legislation should relate solely to the prohibition of sale and distribution of invasive or potentially invasive plants (Panetta and Scanlan 1995). In this regard, the lack of co-ordination between States and Territories in legislated lists of prohibited species remains a major deficiency, one that is recognised by the National Weeds Strategy. Ultimately, the scope for prohibiting the sale and distribution of invasive plants is limited by our ability to predict invasiveness.

CONCLUDING OBSERVATIONS

The National Weeds Strategy refers to most of the issues we have raised in relation to weed management. It does, however, give greater emphasis to issues dealing with individual weed species, rather than to the inherent or

induced susceptibility of natural environments to the impact of weeds. This approach is probably consistent with the Strategy's emphasis on management of species that have been identified as major weeds on the basis of broad, objective criteria.

Perhaps two factors have served to link proposals for weed management with on-ground programs. Most programs have been established in response to issues that were identified to meet conservation objectives, with close links between the people involved. In general, public land management is undertaken by agencies that undertake policy development and implement on-ground works, which maintains links between the two. Overall, it appears that limitations in knowledge and resources, rather than differences in approach and awareness, have led to any differences between proposals and practices.

Management of weeds on public lands and forests requires support and development in three areas:

1. Important values and objectives need clear and specific documentation, and weed risks to these values assessed. This will provide a basis for preventative programs and a focus for education programs and policies to reduce the introduction and distribution of potentially harmful species.
2. Limited availability of resources remains a barrier to the effective implementation of proposals for weed management. In the context of management for conservation values, this problem has been exacerbated by the tendency of governments to give a higher priority to the acquisition of land than to its management. Weed management programs should align with identified risks to values.
3. Options for the control of species in particular situations need to be developed. Managing disturbances which increase susceptibility to invasion and the development of processes for the rehabilitation of natural ecosystems are important components of control programs.

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