Review

Human involvement in the spread of noxious weeds: what plants should be declared and when should control be enforced?

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Summary

A major objective of noxious plant legislation is to reduce the spread of serious weeds. While weed seeds are dispersed by a variety of agents, analysis of the dispersal syndromes of non-native Australian noxious weeds (*n*=233) revealed that humans contributed to the dispersal of nearly 90%, including 21% that were dispersed by humans alone. For the majority of Australian noxious weeds, there is thus an underlying mechanism that could be regulated by obliging landholders to take measures to reduce seed dispersal. However, the movement of weed seeds seems to have been controlled only where well organized and funded programs have been mounted to eradicate or contain particular species. For the most serious weeds, it is suggested that tighter controls be placed on human-mediated dispersal of seed, including some level of inspection of machinery and transported domestic animals, crop seed and fodder. The use of quarantine procedures should be considered for properties infested during the earliest stages of weed invasion.

A need for enforcement of control and/or a major extension campaign can be anticipated where certain plant features (e.g. inconspicuousness or lack of toxicity) suggest that few people would voluntarily comply with regulations. Declaration of a weed should not proceed without an evaluation of the likely success of a strategy designed to reduce its spread, given the amount of resources available for the establishment of a budget dedicated to the strategy.

The potential for effective use of noxious plant legislation is greatest during the early stages of invasion. Control should not be enforced where weed invasion has progressed to an advanced stage. Here the role of government should lie in supporting the development of integrated management systems and in extension.

Introduction

A principal aim of noxious plant legislation is to reduce the external costs that arise when weeds spread to uninfested land. Such externalities provide a justification for government intervention in weed control, since the optimal level of weed control for an individual landholder is less than the optimal level for society (Menz and Auld 1977). The examination of the ecological aspects of spread is a prerequisite to the formulation of sensible control strategies (Auld *et al.* 1987); in fact, Auld (1987) has stated that studies on the ecology of weed spread are necessary to determine whether there is any need at all for public policies in relation to weeds.

Objective criteria are often of secondary importance in determining which plant species are declared noxious. Declarations are made ostensibly on the basis of evidence for (or perceived) economic and environmental impact. However, social and political considerations commonly figure highly in the decision-making process (Amor and Twentyman 1974). Panetta (1987) maintained that the biological and ecological features of a weed's dispersal syndrome (defined as the combination of dispersal mechanisms involved) are central to the feasibility of regulating its spread. Weeds spread as advancing fronts, scattered isolated colonies, and perhaps most frequently, by a combination of these patterns. The pattern of spread is a major determinant of the potential effectiveness of noxious plant legislation; species that exhibit a saltatory ('jumping') form of spread extend their distributions more rapidly and are more difficult to contain than those spreading by advancing fronts (Auld *et al.* 1978/79, Menz *et al.* 1980/81).

In their model of a spreading plant population, Auld and Coote (1980) described rate of spread in terms of:

i. population growth rate at a primary locus of infestation,
ii. the proportion of annual increase that is dispersed beyond the boundaries of this locus,
iii. the area over which this proportion is dispersed and
iv. the favourability of areas for colonization and invasion.

Presumably, slowing of weed spread may be achieved through reductions in any of these parameters.

Management efforts that aim to reduce either weed propagule (hereafter 'seed') production (i) or the favourability of sites for colonization by weeds (iv) do not impinge upon (ii) or (iii), the dispersal factors. However, the potential for manipulation of (ii) and (iii) is central to our ability to regulate weed spread. Depending upon the particular species, land use and land management practices concerned, efforts to suppress either (i) or (iv) are often only partly successful; failures to gain significant reductions in reproduction or colonization are common to the management of all weed species. Since plants may differ considerably in relation to their dispersal behaviour, it is important to assess the scope for controlling the movement of weed seeds in order to determine, at least in theory, when implementation of noxious plant legislation could affect weed spread through reducing levels of seed dispersal.

The consideration of plants for noxious weed status is ongoing in Australia, owing to the increasing number of species that become naturalized and subsequently major problems (Panetta 1993). Given that the implementation of noxious plant legislation will consume increasingly scarce government resources, it is necessary to ensure that species are declared noxious only when declaration can be expected to have a manifestly beneficial outcome. We agree with Amor and Twentyman (1974) that such an outcome is as dependent upon community levels of compliance with regulations as it is upon weed biological and ecological features *per se.*

In this paper we examine firstly weed dispersal syndromes and secondly factors influencing compliance, in order to develop generalizations regarding the suitability of weeds for declaration under noxious plant legislation. In addition, we examine the roles of enforcement of regulations and extension in relation to changing distributions of noxious weeds.

Dispersal syndromes of noxious weeds

Dispersal vectors for each of 233 non-native noxious weeds were determined by reference to Parsons and Cuthbertson (1992). Three categories of dispersal were employed:

i. physical (seeds transported by wind and/or water),
ii. wild animals and
iii. human (including seeds transported on machinery, in plant products and by domestic animals).

Where weeds had been originally introduced and distributed by humans (e.g. *Baccharis halimifolia* and *Rubus fruticosus*), people were not considered as a dispersal agent if the plants are now spread only by other vectors.

Humans and their agencies play a very prominent role in the dispersal of noxious weeds, contributing to the spread of almost 90% of the species (Table 1). The most common weed dispersal syndrome combines physical vectors with dispersal by humans (52%), while a smaller group of weeds (21%) is dispersed by humans alone. Only 24 species (10%) demonstrated dispersal syndromes in which humans currently play no part, although a number of these were actively introduced and distributed by humans during their early history in Australia. Approximately 2% of the species had a poorly defined dispersal syndrome, for example slow lateral vegetative spread coupled with little or no production of viable seed (Table 1).

Implementation of noxious plant legislation, through regulating the movement of seeds, is thus a potentially effective means of reducing the spread of most noxious weeds, since their dispersal is to a large extent under the direct influence of humans.

Contribution of dispersal mode to weed spread

Very little information is available concerning the effects of dispersal mode upon weed spread. Data cannot be derived simply from patterns of seed deposition owing to the environmental 'filter' constituted by the colonization term (iv) in the model for plant spread. Studies that have examined weed spread in detail have generally been of short duration, on a small scale and have not examined dispersal mechanisms *per se* (Harradine 1985, Auld 1988).

In a recent investigation of spread by *Mimosa pigra* in the Northern Territory, Lonsdale (1993) obtained estimates of the relative contributions of dispersal by wind and water. This study illustrated how patterns of spread may originate from the action of more than one vector, and suggested that the contribution of a different vector type would be required to move *M. pigra* between disjunct flood plain habitats separated by extensive eucalypt savannas.

The effects of different vectors upon the pattern of spread may be qualitatively similar, e.g. the spread of sweet briar (*Rosa rubiginosa*) by pied currawongs and horses (Hatton 1989), or may combine different spread types, such as the spread of hawthorn (*Crataegus monogyna*) by birds and brush-tailed possums. In the latter case, birds spread *C. monogyna* at random distances from a source, after which local population expansion was facilitated by possums (Williams and Buxton 1986). Prickly acacia (*Acacia nilotica*) was planted along bore drains in Queensland, but was dispersed widely from these plantings by cattle (Parsons and Cuthbertson 1992).

The involvement of numerous dispersal vectors makes it very difficult to determine the relative effectiveness of individual vector types, apart from cases where a single vector dominates the dispersal syndrome, e.g. when plant dispersal is largely mediated by humans. In this situation, seeds are generally moved further and in larger numbers than by other dispersal vectors, creating secondary foci at greater distances from primary foci of infestation and leading to the jumping form of spread mentioned in the 'Introduction'.

The mode of dispersal interacts with colonization processes, since the potential for movement of seeds in groups varies, as does the quality of the microsites in which seeds are deposited. Where few seeds are dispersed, the invasion may fail owing to a number of factors (Panetta and Randall 1994), including random physical processes (e.g. extremes in moisture availability or temperature) and biological constraints (e.g. the inability of a single self-incompatible plant to reproduce). Seeds of human-dispersed species are often deposited in circumstances that favour establishment, the most outstanding example of which is the sowing of weed seeds with seeds of crop or pasture species. Deposition of weed seeds in the dung of domestic stock may significantly enhance the probability of establishment, especially for hard-seeded species (see Brown and Archer 1987).

Table 1. Contribution of vectors to dispersal syndromes for non-native weeds currently declared noxious in Australia (*n*=233). Calculated from descriptions in Parsons and Cuthbertson (1992).

Vector			
Physical[A]	Human[B]	Wild animals	% weed species
+	+	+	9.0
+	+	–	51.9
+	–	+	1.7
+	–	–	4.7
–	+	+	6.0
–	+	–	20.6
–	–	+	3.9
–	–	–	2.1[C]

[A] Includes dispersal by wind and water.
[B] Includes dispersal in contaminated produce, in and on domestic animals and on machinery.
[C] No clear contribution of any vector to dispersal.

Table 2. Dispersal of selected Australian noxious weeds by birds (from Loyn and French 1991).

Weed	No. bird species dispersing	No. bird species dispersing additional noxious weeds
Chrysanthemoides monilifera	15	9
Lantana camara	7	5
Lycium ferocissimum	23	18
Rubus fruticosus agg.	10	6
Myrsiphyllum asparagoides	6	5
Crataegus spp.	23	10

The potential to control dispersal of seeds

The highest degree of control over the formation of secondary infestation foci can be achieved when weeds are totally reliant upon humans for their dispersal. An extreme example is that of *Agrostemma githago*, a European crop weed that was rendered virtually extinct through developments in seed cleaning machinery (Harper 1977). Other modes of dispersal entirely mediated by humans include movement in (or on) domestic animals, contaminated soil, fodder or machinery.

At the opposite end of the spectrum are weeds that are primarily dispersed by wild animals. Some of Australia's most important noxious weeds are dispersed by a number of bird species and individual bird species may disperse a number of noxious weeds (Table 2). The use of noxious plant legislation could be expected to be less effective in reducing the spread of these species. While local control or management of some wild vectors of weed seeds, e.g. feral animals, could have an impact upon weed spread, it is unlikely that efforts to reduce dispersal by others, e.g. native bird species, would be effective (or even acceptable to the public at large).

Humans may exercise some degree of control over physical, as opposed to biotic, dispersal vectors. For example, levels and direction of water movement can be regulated and the reliance of some species upon dispersal by water provides a focus for control activities. However, the preferential control of weeds along watercourses is strictly a reduction in annual population increase (parameter (i) in the spread model), not a means of controlling the dispersal vector. There is some potential to interfere with the dispersal of weeds by wind, for example by slashing or felling seed-bearing plants so that the height of seed release is reduced or through planting 'guard rows' of other species to interfere with seed movement on air currents, by analogy with the use of such rows to reduce movement of pollen from field plots of genetically modified species (Crawley 1990).

Compliance with noxious plant regulations prohibiting movement of weed seeds

Noxious plant legislation provides a basis to enforce compliance with the relevant regulations. Perhaps compliance with any regulations would be relatively high if penalties for non-compliance were severe and the regulations were enforced strictly. However, in reality, the enforcement of noxious plant regulations as a whole is often non-existent or poor for a number of reasons, including hesitation to enforce control of weeds on properties belonging to individuals with political power, the reluctance of courts to impose substantial fines, and the economic difficulties associated with controlling weeds on extensive public lands.

There appears to be little evidence for voluntary compliance with regulations prohibiting the movement of seeds of noxious weeds. In fact, much evidence exists to the contrary. For example, Thomas *et al.* (1984) found a high incidence of 'restricted' or 'prohibited' species in samples of fodder and grain transported in southern Australia during the major drought of 1980–81 (Table 3). Trade records relating to the movement of drought fodder have been utilized by Erkelenz *et al.* (1990) to detect new satellite infestations of *Amsinckia lycopsoides* and *A. calycina* in South Australia.

Table 3. 'Prohibited' or 'restricted' species that were detected in grain and hay samples during a major drought in southern Australia (from Thomas *et al.* 1984).

Species	Frequency of contaminated samples (%)	
	Grain	Hay
Avena fatua	65	32
Echium plantagineum	15	8
Polygonum aviculare	0	63
Rumex acetosella	15	29
R. brownii	4	21
Sisymbrium sp.	8	3

Giant rat's tail grass (*Sporobolus pyramidalis* and *S. natalensis*), a recently declared serious noxious weed of native and improved pastures, has been spreading through coastal and subcoastal Queensland for the past 30 years and continues to be dispersed via vehicles, other machinery, contaminated pasture seed and fodder (Panetta *et al.* 1993).

In all probability, weeds are moved routinely as contaminants of pasture and crop seed, particularly where seed certification is not practised; a major recent outbreak of parthenium weed in northern New South Wales was attributed to the purchase of contaminated pasture seed from central Queensland (I. Kelly personal communication). Similarly, the continued rapid spread of parthenium weed in Queensland subsequent to its declaration as a noxious weed in 1975 (Auld *et al.* 1982/83) could have been due only partly to dispersal by non-human vectors. Recent research investigating seed excretion of cutleaf mignonette (*Reseda lutea*) and silverleaf nightshade (*Solanum elaeagnifolium*) by sheep has indicated that animals should be quarantined for periods of up to two weeks when they are moved from infested to uninfested areas, indicating that current on-farm quarantine periods of several days are grossly inadequate (Heap and Honan 1993).

Instances where weed seed movement appears to have been controlled effectively are ones in which intensive, government-organized and/or -funded programs were instituted. For example, there has been a high degree of compliance with a quarantine protocol that was designed to prevent dispersal of skeleton weed (*Chondrilla juncea*) via seeds in animal fleeces and harvested grain in Western Australia (J. Dodd personal communication). This compliance has been encouraged through the implementation of substantial awareness and control programs by the state government; compliance may have been low had the Government not established and run an eradication campaign over several decades.

Another Western Australian eradication effort has targeted kochia (*Kochia scoparia*), a forage plant introduced for reclamation of saline soils (Dodd 1993). Compliance by the public has been achieved to the extent that further trading of kochia seeds and additional plantings have not occurred. As with skeleton weed, the major part of the eradication effort has been made by government staff (Dodd 1993).

A recently detected invasion by siam weed (*Chromolaena odorata*) of several locations in tropical northern Queensland has been the subject of an intensive eradication campaign that has included the prohibition of movement of sand and soil from areas where the weed is known or suspected to occur. That such an apparently effective campaign was mobilized very quickly is due largely to previous efforts at publicizing the threat of invasion by this serious weed (McFadyen 1989).

Although the prevention of noxious weed seed dispersal is critical to slowing weed spread, it appears that voluntary compliance with regulations concerning the movement of weed seeds is not common. As a result, there may be grounds for increasing the level of inspection activities, rather than decreasing them, as is the current trend in Australia. For the most serious weeds, inspection of machinery and transported stock and plant products may be required in order to ensure compliance with regulations. It could be argued that, unless there is strong control over weed seed movement, it is pointless declaring any weed (cf. Auld's (1987) statement that studies on the ecology of weed spread have crucial bearing on the question of whether there is a need at all for public policies in relation to weeds).

Predicting the level of voluntary compliance

Since effective reduction in the rate of weed spread depends upon a high level of voluntary compliance within the community, we next examined the factors that influence compliance.

For the Australian noxious weeds that affect agricultural production (n=187), the potential for voluntary compliance by landholders with noxious weeds regulations was evaluated according to scores (+, 0 or -) for each of 17 parameters. Parameters were divided into three groups (Table 4) relating to the visual impact of a species (3 parameters) and its potential costs (9 parameters) and benefits (5 parameters).

By the use of non-independent parameters, weighting was given to visual impact (plants with conspicuous structures were also generally visible at low density). This procedure was considered appropriate, since conspicuous plants have on occasion been declared noxious for apparently no other reason (Amor and Twentyman 1974). Weighting was also given to potential effects upon the health of grazing stock: if fatal poisoning occurred, a positive compliance value was recorded for both animal illness and animal death. Most information on the 17 parameters was obtained from Parsons and Cuthbertson (1992).

Voluntary compliance ratings were broadly distributed, with a mode of 2 (Figure 1). Notable was the fact that over 30% of the species rated 0 or less, indicating a low likelihood of voluntary compliance. Extensive enforcement of noxious weeds regulations for these species would presumably be required. (This has been the case for eradication schemes targetting *Chondrilla juncea* in Western Australia, funded by a levy upon Western Australian grain producers, and *Eriocereus martinii* in Queensland, funded by consolidated revenue.) If a high level of government support could not be committed to control efforts, enforcement of the regulations, and / or a major education initiative, declaration of species with negative values (Table 5) might achieve little.

A further complication is that different groups within the community may have contrasting attitudes towards individual plant species (Wilson 1993). All of the above issues emphasize the importance of accurately assessing the potential for voluntary compliance (thus the requirement for future government support), plus ensuring that the required resources will be available, prior to declaring a species.

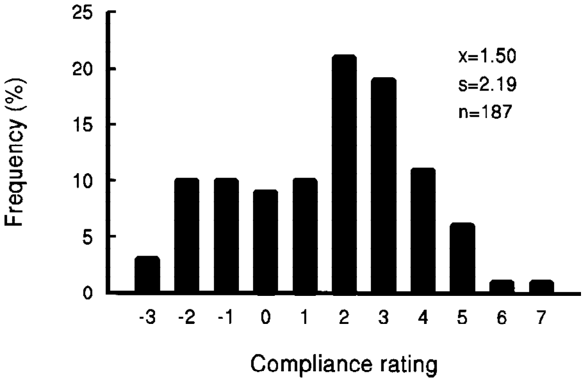

Figure 1. Distribution of potential voluntary compliance ratings for Australian noxious weeds of agricultural production.

Extension, compliance and the enforcement of regulations

The type of effort put into pest plant control should be dependent on the stage of invasion of a species. Stage of invasion can be classified and varies from early to advanced (Figure 2). As it is the objective of noxious plant legislation to slow, if not halt, the progression of invasion by a weed species, the effort made by government and the compliance expected from landholders in relation to weeds of production should be as follows.

Table 4. System for determining potential voluntary compliance with a requirement to control a noxious weed of production. Values[A] are estimates of producer perceptions.

	Species[B]						
Criterion	1	2	3	4	5	6	7
Visual impact							
Prominence at low density	-	+	-	-	+	+	+
Conspicuous flowers / fruit / foliage	-	-	-	-	+	+	+
Constancy of visibility	-	+	-	-	-	-	-
Potential costs							
Plant production							
Competitor in pasture	0	0	+	+	+	+	+
Reduces crop production	+	0	+	+	+	0	+
Interferes with cultivation / harvesting	+	0	0	0	0	0	0
Devalues product	0	0	+	+	0	0	+
Animal production							
Causes animal illness	0	0	0	0	+	0	+
Causes animal death	0	0	0	0	+	0	+
Devalues product	0	0	0	0	0	+	0
Human health	0	0	0	+	0	0	0
Harbours pests	0	+	0	0	0	+	0
Potential benefits							
Fodder / food	-	-	0	0	-	0	-
Soil stabilization / amelioration	0	0	0	0	-	0	0
Shade	0	-	0	0	0	0	0
Ornamental	0	-	0	0	-	0	0
Honey / pollen source	0	0	0	0	0	0	-
	-2	-1	0	+1	+2	+4	+4

[A] + promotes compliance, - disfavours compliance, 0 is compliance-neutral.
[B] 1=*Chondrilla juncea* (skeleton weed), 2=*Gleditsia triacanthos* (honey locust), 3=*Sporobolus pyramidalis* (giant rats tail grass), 4=*Parthenium hysterophorus* (parthenium weed), 5=*Kochia scoparia* (kochia), 6=*Carduus nutans* (nodding thistle), 7=*Echium plantagineum* (Paterson's curse).

Early invasion

During this phase, the majority of land units have either low densities of the weed or are uninfested (Figure 2). Government effort should be channelled into control programs aimed at achieving a very high level of control (eradication if possible). Control programs should largely be government-funded, either through government-employed control teams or through inspectors locating infestations and assisting landholders with control.

Voluntary landholder compliance at this stage may be limited, depending upon how the threat posed by the weed is perceived (Table 4), hence the requirement for strong enforcement. However, there is also a need to achieve wider public recognition of the problem.

Mid-stage invasion

At this stage, land units as a whole display a broad range of densities (Figure 2). There may be requests for government assistance (free or subsidised herbicide, provision of labour), especially from those landholders with dense infestations. Landholders with low density patches may be willing to control the weed on their properties, but difficulties could arise where adjoining landholders or others in the same region do not or cannot contain their infestations.

The potential roles of government here are many. Enforcement of control should be concentrated in those areas where weed densities are low and the potential for further invasion high. Strategic control areas should be established in order to contain the geographic spread of the weed. There is considerable scope for research into management practices that reduce weed impact, including biological control, where feasible. Community education will be a high priority, with the emphasis differing between areas of predominantly low, medium and high densities. Perceptions that low weed densities equate to minor threats to production or other values must be addressed.

Advanced invasion

At this stage, infestations of relatively high density occur on most land units (Figure 2). There is no role for enforcement of control. The level of control by landholders will be determined largely by economic considerations. In cases where the cost of control exceeds the value of the land, control measures are likely to be very limited. The role of the government should lie in the areas of education and developing integrated management systems.

Discussion

We have argued that noxious plant legislation should be most effective for

Table 5. Species with negative voluntary compliance ratings.

Voluntary compliance rating -3	-2	-1
Cucumis myriocarpus	*Ambrosia artemisiifolia*	*Acroptilon repens*
Ecballium elaterium	*Andropogon virginicus*	*Alhaga maurorum*
Euphorbia lathyrus	*Berkheya rigida*	*Allium vineale*
Froelichia floridana	*Carduus pycnocephalus*	*Ambrosia psilostachya*
Physalis viscosa	*C. tenuiflorus*	*Anthemis cotula*
	Centaurea nigra	*Conium maculatum*
	Chondrilla juncea	*Eremocarpus setigerus*
	Cyperus aromaticus	*Euphorbia heterophylla*
	C. eragrostis	*Foeniculum vulgare*
	C. rotundus	*Iva axillaris*
	Eragrostis curvula	*Marrubium vulgare*
	Eriocereus martinii	*Mimosa pudica*
	E. tortuosus	*Myagrum perfoliatum*
	Gorteria personata	*Onopordum acanthium*
	Juncus acutus	*O. acaulon*
	Sporobolus africanus	*Rubus fruticosus*
	Stevia eupatoria	*Salpichroa organifolia*
	Stipa brachychaeta	*Silene vulgaris*
	S. caudata	*Themeda quadrivalvis*

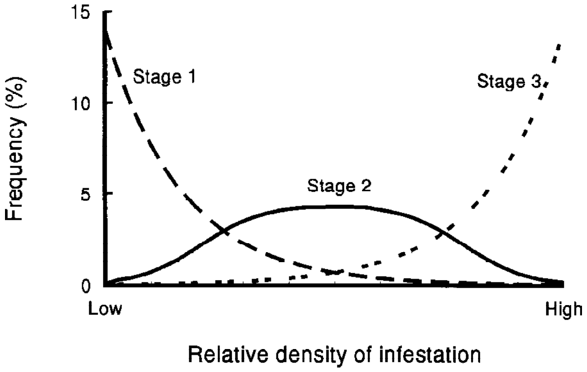

Figure 2. Hypothetical frequency distributions of infestation densities at different stages of weed invasion, from early (Stage 1) to advanced (Stage 3). These distributions refer to infestations when viewed over larger scales (e.g. States or major river catchments). The distribution for Stage 3 could be modified considerably by management practices that maintain weeds at low densities.

human-dispersed weeds, since humans have the capacity to control the relevant dispersal processes. In reality, however, it would be difficult to demonstrate that legislation has been most effective for this group of species. Apart from a lack of historical information on patterns of invasion, the available measures of compliance with regulations (e.g. the movement of prohibited or restricted weed seeds in grain and fodder, the sale of noxious weeds as ornamentals) suggest that compliance with noxious weeds regulations is generally poor. Ironically, weeds that are spread by humans offer the greatest opportunity for intervention through regulations, but will spread fastest where non-compliance occurs. This suggests that there must be a strong commitment to gaining control over weed seed dispersal if anything is to be gained by declaring a species noxious. While compliance with regulations relating to each of the parameters (i)–(iv) in the spread model is necessary, we believe that significant reduction of weed spread is unlikely to be achieved if seed dispersal is not controlled.

The effectiveness of Australian noxious plant legislation has been questioned for some time now (Moore 1971, Amor and Twentyman 1974, Moore 1975). Very few species have been eradicated following declaration (Dodd 1990) and the majority has undergone range extension over decades. Moore (1975) provided a cogent summary of the situation: "In my experience once a species has been in a region, State or country for several years—the time varying with the species and its characteristics—and is established even sparsely in a number of places, there is little possibility of eradication. The species will eventually occupy all of the sites to which it is adapted, and for most species the chances of containment are negligible." Such evaluations of the legislation dwell on the almost universal failure to achieve eradication or containment. However, little attempt has been made to assess the potential benefits of reducing the rate of spread of an invading species. The faster the rate of weed spread, the stronger is the rationale for government intervention to reduce spread (Auld *et al.* 1978/79), although the cost of reducing spread increases with increasing rate of spread (Menz *et al.* 1980/81).

Benefits that could accrue from reducing rates of weed spread include continued production in the absence of an invader plus the 'bought time' that could be used to devise effective weed management strategies. Studies are required to examine the costs and benefits of enforced weed control in relation to slowing of weed spread; analyses to date have incorporated either a constant spread rate for a weed in its early stages of invasion (Pannell 1984) or a range of spread rates for long-established species (e.g. Roberts and Crackel 1986).

Declaration of environmental weeds under noxious plant legislation will continue to be a contentious issue. Measures to prevent the introduction or sale of environmental weeds can be enforced fairly readily, given adequate resources to do so. However, depending upon their perceptions of environmental issues, landholders may be reluctant to carry out control activities necessary to prevent or reduce weed spread. Publicity may be used to advantage in order to increase public awareness of the threats posed by these weeds, but it is likely that a considerable amount of government resources would have to be devoted to the enforcement of their control (or government agencies would have to take direct responsibility for weed control). Much depends upon whether landholders and local governments act upon issues of immediate, primarily economic, interest or whether they assume a broader responsibility for the environment. Nevertheless, the division between environmental weeds and weeds of production is often arbitrary as a number of plants belong to both categories.

Management of one weed cannot be divorced from management of the total weed burden (plus other pests). Within the bounds of limited budgets, perhaps the decision to declare a species should be coupled with a decision to remove another from the list of declarations: for how many species are there sufficient resources to maintain effective control campaigns? An alternative approach might be to make new declarations contingent upon the establishment of budgets for implementation of the legislation for the species under consideration. This tactic has been employed in Victoria's new Catchment and Land Protection Act (D. Lane personal communication).

Since weeds generally obtain wide distributions regardless of the degree of human intervention, benefits that might arise from the implementation of noxious plant legislation are transient. As an invader spreads through a number of regions and ultimately approaches its natural limits, there is increasingly less public benefit to be gained through attempted reduction of further spread. Moore (1975) asserted that an amnesty should be proclaimed for 80–90% of the plants on Australian noxious weeds lists. Historically, a major error in the government approach to noxious weed control in Australia would appear to lie in the enforcement of regulations during the advanced stages of weed invasion (Figure 2). Such enforcement consumes resources that might be used more effectively either to reduce rates of spread of recent invaders or to exclude potential invaders. Accordingly, the continued implementation of noxious plant legislation should be contingent upon results from periodic assessments of weed distribution.

Conclusions

i. The potential for effective use of noxious plant legislation is greatest during the early stages of weed invasion. In most cases the greatest benefit that can be expected from the implementation of such legislation is a slowing of weed spread into uninfested areas.

ii. The mode of dispersal for a weed plays a significant role in determining how effective noxious plant legislation can be; this should be considered in decisions concerning declaration. Regulations pertaining to the movement of seeds of the most serious weeds must be enforced, and should involve some level of inspection of machinery and transported domestic animals and plant products. The use of property quarantine protocols should be considered in the earliest stages of weed invasion, particularly for weeds that have proven to be highly damaging elsewhere in Australia or overseas.

iii. Declaration of a plant should not proceed without a determination of the likely success of a strategy designed to reduce its spread, given the amount of resources available for the establishment of a budget specifically allocated to the strategy.

iv. There is a need for the continuing rationalization of noxious weeds lists, with particular regard to the relative stage of weed invasion. A weed that has invaded the major part of its potential range should not be declared.

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