

**ENVIRONMENTAL WEED STRATEGY
FOR WESTERN AUSTRALIA**

3 May 1999

Environmental Weed Strategy for Western Australia

Table of Contents

EXECUTIVE SUMMARY.....	iii
ACKNOWLEDGEMENTS.....	v
SUMMARY OF RECOMMENDATIONS	1
1. INTRODUCTION	4
2. WEED INTRODUCTION, SPREAD AND EFFECTS ON BIODIVERSITY.....	8
2.1. SUCCESSFUL PLANT INVASION	
2.1.1. <i>Species Introduction</i>	
2.1.2. <i>Establishment</i>	
2.1.3. <i>Survival</i>	
2.1.4. <i>Reproduction</i>	
2.1.5. <i>Dispersal</i>	
2.2. EFFECTS ON BIODIVERSITY.....	
2.2.1. <i>Genetic Diversity</i>	
2.2.2. <i>Species Diversity</i>	
2.2.3. <i>Ecosystems Diversity</i>	
3. INTEGRATED ENVIRONMENTAL WEED MANAGEMENT.....	12
3.1. STRATEGIC WEED MANAGEMENT	
3.2. PRIORITIES AND PLANNING	
3.3. WEED LED CONTROL.....	
3.3.1. <i>Preventing Weed Introductions</i>	
3.3.2. <i>Early Detection and Early Eradication</i>	
3.4. SITE CONTROL	
3.5. THREATENED SPECIES AND THREATENED COMMUNITIES LED CONTROL	
3.6. HUMAN RESOURCES LED CONTROL	
3.7. CAUSE LED CONTROL	
4. CONTROL METHODS.....	26
4.1. CONTROLLING DEGRADATION PROCESSES.....	
4.2. HERBICIDES.....	
4.3. BIOLOGICAL CONTROL	
4.4. MANUAL CONTROL.....	
4.5. FIRE MANAGEMENT.....	
5. MONITORING AND EVALUATION	31
5.1. PATCH LEVEL	
5.2. LOCAL LEVEL.....	
5.3. REGIONAL LEVEL.....	
5.4. STATE LEVEL	
6. COORDINATION AND INTEGRATION.....	33
6.1. COORDINATION.....	
6.2. INTEGRATION.....	

7. ROLES AND RESPONSIBILITIES.....	42
8. RESOURCES.....	47
8.1. HUMAN RESOURCES.....	
8.2. INFORMATION RESOURCES.....	
8.3. FUNDING RESOURCES.....	
9. PUBLIC AWARENESS AND COMMUNITY INVOLVEMENT.....	50
9.1. INTRODUCTION.....	
9.2. SUPPORT.....	
9.3. BENEFITS.....	
9.4. CONSTRAINTS.....	
9.5. FUTURE DIRECTIONS.....	
9.5.1. <i>Public Awareness and Promotion</i>	
9.5.2. <i>Education and Training</i>	
9.5.3. <i>Research and Environmental Weeds Database</i>	
BIBLIOGRAPHY.....	56
APPENDIX 1: ENVIRONMENTAL WEEDS RATING	
APPENDIX 2: DATABASE OF ENVIRONMENTAL WEEDS OF WA - WEEDBASE	
APPENDIX 3: LIST OF ENVIRONMENTAL WEED SPECIES OF ACTUAL AND POTENTIAL SIGNIFICANCE IN WA.....	

LIST OF FIGURES

FIGURE 1.	THE INTERIM BIOGEOGRAPHICAL REGIONS (IBRA) OF WESTERN AUSTRALIA
FIGURE 2.	ENVIRONMENTAL WEED MANAGEMENT APPROACHES.....
FIGURE 3.	FLOW CHART FOR INTEGRATED ENVIRONMENTAL WEED MANAGEMENT.....
FIGURE 4.	WEED LED CONTROL – STRATEGIES FOR THE REMOVAL OF INDIVIDUAL WEED SPECIES OR SMALL NUMBER OF WEED SPECIES.....
FIGURE 5.	SITE LED CONTROL – STRATEGIES FOR PROTECTION OF HABITATS CURRENTLY LARGELY FREE OF WEEDS.....
FIGURE 6.	THREATENED SPECIES AND THREATENED COMMUNITIES LED CONTROL FOR PROTECTION OF THREATENED SPECIES AND COMMUNITIES AS THE HIGHEST PRIORITY.....
FIGURE 7.	HUMAN RESOURCES LED CONTROL – RECOGNISING DIFFERENT WEED CONTROL STRATEGIES FOR VOLUNTEERS AND PROFESSIONALS.....
FIGURE 8.	.CAUSE LED CONTROL – RECOGNISING THAT THE REASONS FOR A WEEDS PRESENCE MAY BE DUE TO ALTERED CONDITIONS WHICH NEED TO BE ADDRESSED FOR THE WEED TO BE CONTROLLED.
FIGURE 9.	RELATIONSHIPS TO STATE ENVIRONMENTAL WEED GROUP.....
FIGURE 10.	CONCEPTUAL ILLUSTRATION OF THE CO-ORDINATION AND INTEGRATION OF THE ENVIRONMENTAL WEED STRATEGY FOR WA.....
FIGURE 11.	HIERARCHY OF RESPONSE TO ENVIRONMENTAL WEED MANAGEMENT CONTROL.....

LIST OF TABLES

Table 1:	WEED CONTROL PRIORITIES FROM NATIONAL AND LOCAL LEVELS
Table 2:	MODEL OF ROLES AND RESPONSIBILITIES FOR ENVIRONMENTAL WEED MANAGEMENT

EXECUTIVE SUMMARY

Management of environmental weeds in Western Australia is one of the major management issues requiring action if we are to protect our natural environments for future generations. Competition from weeds is a major process affecting threatened flora and threatened ecological communities. Many critically endangered plants have populations restricted to small, disturbed areas (e.g. remnant vegetation on private property and road verges). These are particularly vulnerable to invasion by environmental weeds and will receive priority for weed control, particularly through the implementation of recovery plans developed by the Department of Conservation and Land Management.

Environmental weeds are plants that establish themselves in natural ecosystems and proceed to modify natural processes, usually adversely, resulting in the decline of the communities they invade. Many environmental weeds are successfully invading Western Australian ecosystems. Some of these weed species are having a significant impact on biological diversity at genetic, species and community levels. More work is needed to understand the reasons for recent explosion of many weeds and the impacts weeds have at the ecosystem level. Research is vital to increase understanding in these areas to enable strategic management approaches.

CALM received funding through a Natural Heritage Trust (NHT) grant to prepare the Environmental Weed Strategy for Western Australia (EWSWA). The Strategy has been prepared by consultants and a Steering Committee comprised of various government agencies (CALM, Agriculture WA and the Water and Rivers Commission) and community groups concerned with environmental weed management.

The Environmental Weed Strategy for Western Australia and the associated environmental weed database provide both the direction and an approach to tackling this large problem. The Environmental Weed Strategy will ultimately contribute to the State Weed Strategy which will address both agricultural and environmental weeds.

In developing the Environmental Weed Strategy for Western Australia, criteria for the assessment and ranking of weeds in terms of their environmental impact on biodiversity were formulated. Three criteria were selected to rate weeds. These were:

- invasiveness,
- distribution, and
- environmental impacts.

A list of 1350 weeds were rated as either high, moderate, mild or low against these criteria. Thirty four (34) weed species were rated as high.

An integrated approach to environmental weed management has been developed by this Strategy. It involves the planned use of the following control options:

- weed led control
- site led control
- resource led control
- threatened species and communities led control, and
- cause led control.

The Strategy addresses adverse environmental impacts of weed management and advocates revegetation strategies to be undertaken alongside weed removal.

Control options for environmental weeds include:

- controlling ecosystem degradation processes
- herbicides
- biological control
- manual control, and
- fire management.

For many ecosystem/weed combinations in WA the best control options are not known and further research is required.

Monitoring programs covering the physical locations of weeds, rates of spread, success of control containment operations and the success of community effort are proposed. The Strategy recommends that monitoring efforts should be undertaken at patch, local, regional and State levels.

To successfully coordinate and integrate environmental weed management, the EWSWA advocates the establishment of the State Environmental Weed Group supported by CALM to bring together expertise for particular purposes.

The lack of specific legislation for environmental weed management is a major concern which can be corrected through revision of existing legislation to ensure clarity in defining roles and responsibilities

Environmental weed management in Western Australia will require significant resources to be successful. Resources include people resources, information resources and funding. Weed management requires long term action. Resources need to be applied in the long term if the Environmental Weed Strategy is to be successful.

The Strategy recognises that the community is now playing a significant beneficial role in environmental weed management and awareness raising in Western Australia. Constraints have been identified to greater involvement by the community in achieving best practice and in maximising outcomes. The Strategy suggests means to overcome these constraints so as to mobilise the community not only in actual weed control but also in awareness raising, training, research and monitoring of environmental weeds in WA.

ACKNOWLEDGEMENTS

Funding assistance provided by Environment Australia through the National Weeds Program of the Natural Heritage Trust is gratefully acknowledged.

The Environmental Weed Strategy for Western Australia has been prepared with the input of a number of people drawn from the field of weed sciences and management and community groups.

A Steering Committee consisting of the following people oversaw the preparation of the Strategy:

Mr Frank Batini	Chairperson CALM
Mr John Asher	Project Manager CALM
Mr Roger Armstrong	CALM
Mr Greg Keighery	CALMScience
Mr Patrick Pigott	CALMScience (Herbarium)
Mr Bevan Uren	Agriculture WA
Mr Rod Randall	Agriculture WA
Ms Verity Klemm	Water and Rivers Commission
Ms Marion Blackwell	National Parks and Nature Conservation Authority
Mr Tom Alford	Wildflower Society
Ms Joanna Seabrook	Environmental Weeds Action Network
Ms Judy Fisher	Environmental Weed Action Network

A workshop was undertaken as part of the preparation of the Strategy. Those who participated were:

Mr Rod Randall	Agriculture WA
Dr John Dodd	CSIRO
Dr John Scott	CSIRO
Mr Bob Dixon	Kings Park and Botanic Garden
Ms Penny Hussey	CALM
Ms Sandy Lloyd	Agriculture WA
and Steering Committee Members	

Mr John Thorp, Project Manager, National Weed Strategy Executive Committee provided valuable advice on ranking weeds.

Mr Greg Keighery, CALMScience contributed a large personal effort to rating the environmental weeds.

Messrs Neville Marchant, Paul Gioia, Alex Chapman and Nicholas Lander from the WA Herbarium provided technical information, support and guidance.

The Plant Protection Society allowed use of information from their recently published *Western Weeds, A guide to the weeds of Western Australia*, (Hussey et al., 1997).

The consultant team acknowledges and is deeply appreciative of the support and enthusiasm given by the above people in the formulation of the Strategy.

SUMMARY OF RECOMMENDATIONS

Chapter 3

RECOMMENDATIONS		
Number	Action	Responsibility
R3.1	Produce guidelines for integrated weed management and case studies to illustrate the guidelines. Adjacent landowners should receive encouragement to control weeds on their land, where integrated programmes are planned.	Agencies, with assistance in coordination from SEWG where required.
R3.2	The sale of plant species with high weed potential for either domestic use, revegetation or commercial use should be discouraged, by voluntary adoption of best practice by the relevant industries.	SEWG to promote via member organisations.
R3.3	Review current regulatory mechanisms and best practice concerning the sale and distribution of potential weed species or materials potentially containing weed species and recommend changes.	CALM, AgWA.
R3.4	Establish a mechanism to monitor the presence of new weed populations and the proliferation of existing “sleeper” weeds to ensure rapid action is undertaken if a weed is inadvertently or deliberately introduced or begins to spread rapidly.	Agencies, with assistance of SEWG as required.

Chapter 4

RECOMMENDATIONS		
Number	Action	Responsibility
R4.1	Facilitate research by the Federal Government into the biological control of weeds impacting on biodiversity in Western Australia.	Agencies with assistance of SEWG as required.
R4.2	Facilitate research into appropriate fire regimes for Western Australian ecosystems in terms of fire intervals, intensities and patchiness, and their relationship to environmental weeds.	Agencies managing natural areas, assisted by SEWG.
R4.3	Certify additional herbicides for environmental weed control to increase the range of treatments available.	Pesticide companies encouraged by SEWG.

Chapter 5

RECOMMENDATION		
Number	Action	Responsibility
R5.1	Monitor and evaluate weed control programs at patch, local, regional and State levels. Develop adequate training and pro formas for those undertaking these tasks.	Agencies, with assistance from SEWG as required.

Chapter 6

RECOMMENDATIONS		
Number	Action	Responsibility
R6.1	The coordinating group to consist of members from local government organisations, State government agencies, private landowners, industry, research institutions and community organisations. It is proposed that this group be called the State Environmental Weed Group	State Government

	and that members be appointed by the Minister for the Environment.	
R6.2	Provide the State Environmental Weed Group with executive and secretarial support.	CALM

Chapter 7

RECOMMENDATION		
Number	Action	Responsibility
R7.1	The lack of a specific legislative base for environmental weed control should be corrected through revision of existing legislation.	CALM

Chapter 8

RECOMMENDATIONS		
Number	Action	Responsibility
R8.1	Identify Government, industry and community resources and skills available for weed control. Identify deficiencies and recommend options for resolution.	Agencies, industry and community groups with assistance from SEWG.
R8.2	Identify sources of and promote funding for control of environmental weeds.	Agencies and community groups with assistance from SEWG.

Chapter 9

RECOMMENDATIONS		
Number	Action	Responsibility
R9.1	Increase public awareness of the importance of and threats posed by environmental weeds.	Agencies and community groups with assistance from SEWG.
R9.2	Encourage and support community participation in all aspects of weed management and control.	Agencies supported by SEWG where required.
R9.3	Support existing training programs for weed control and bush regeneration. Encourage establishment of new training programs.	Agencies, educational institutes, community groups supported by SEWG where required.

1. INTRODUCTION

In recent centuries the world's flora has undergone a vast, human-mediated dispersal. The process accelerated in the nineteenth and twentieth centuries as the volume and speed of intercontinental traffic increased. In some countries human-mediated changes to the indigenous flora have occurred over such a long time period that the concept of conserving and protecting the original ecosystems has little practical meaning. However, in Western Australia, the relatively recent introduction of new plants into the landscape means that we are currently occupying a region whose flora and vegetation are in a state of flux. Representative examples of most ecosystems exist that are free or relatively free of introduced plants. As a community we have enough scientific knowledge to identify and value our vegetation communities and structures, as well as their biota. We are faced with the dilemma of a flora in flux, knowledge of our role in the introduction and spread of exotic species and the understanding that we must do something to conserve and manage what we have.

The natural process of plant dispersal, particularly over intercontinental barriers, is slow and selective. Human-mediated plant dispersal can occur as rapidly as human transport systems operate. The volume and range of materials now transported globally, and the growth of the horticultural industry, increase the opportunity both for purposeful and accidental introductions. The role of illegal inshore discharge of ship's ballast water in introducing both macroalgae and microalgae has resulted in the introduction of Japanese Kelp, *Undaria pinnatifida*, to the waters off southern Australia where it has the potential to alter the structure and composition of continental shelf ecosystems (Anon, 1997).

Environmental weeds are plants that establish themselves in natural ecosystems (marine, aquatic and terrestrial) and proceed to modify natural processes, usually adversely, resulting in the decline of the communities they invade. Impacts of environmental weeds on ecosystem function include:

- resource competition
- prevention of seedling recruitment
- alteration to geomorphological processes
- alteration of hydrological cycle
- changes to soil nutrient status
- alteration of fire regime
- changes to the abundance of indigenous fauna, and
- genetic changes

(Carr et al., 1992; Humphries et al., 1993, Csurhes and Edwards, 1998).

Environmental weeds require management to ensure the long term survival of our natural ecosystems. Management solutions for environmental weeds are complex and require technical commitment, research, long term monitoring programs, training in ecosystem restoration and a commitment to maintaining our natural environments. The management of the vast natural resources of the state needs the support of government, landowners and managers, private enterprise and community groups.

The management and control of environmental weeds should be seen in the context of the restoration of the environments they invade. The removal of a Blackberry (*Rubus spp*) infestation from a creekline without restoration of the disturbed area will usually result in re-infestations of Blackberry or other weeds. Revegetating and restoring weeded areas with naturally occurring species is a critical component of the weed removal process. It is essential to increase the resilience of ecosystems through adaptive and best management practice to minimise the impacts from environmental weeds (McDonald, 1996).

Western Australia spans a wide range of climatic and geographic zones and contains 26 bioregions defined by the Interim Biogeographical Regionalisation for Australia or IBRA (Thackway and Cresswell, 1995), which represent approximately one third of the total number of bioregions in Australia (see Figure 1). Environmental weeds have impacts on a number of these bioregions, e.g.:

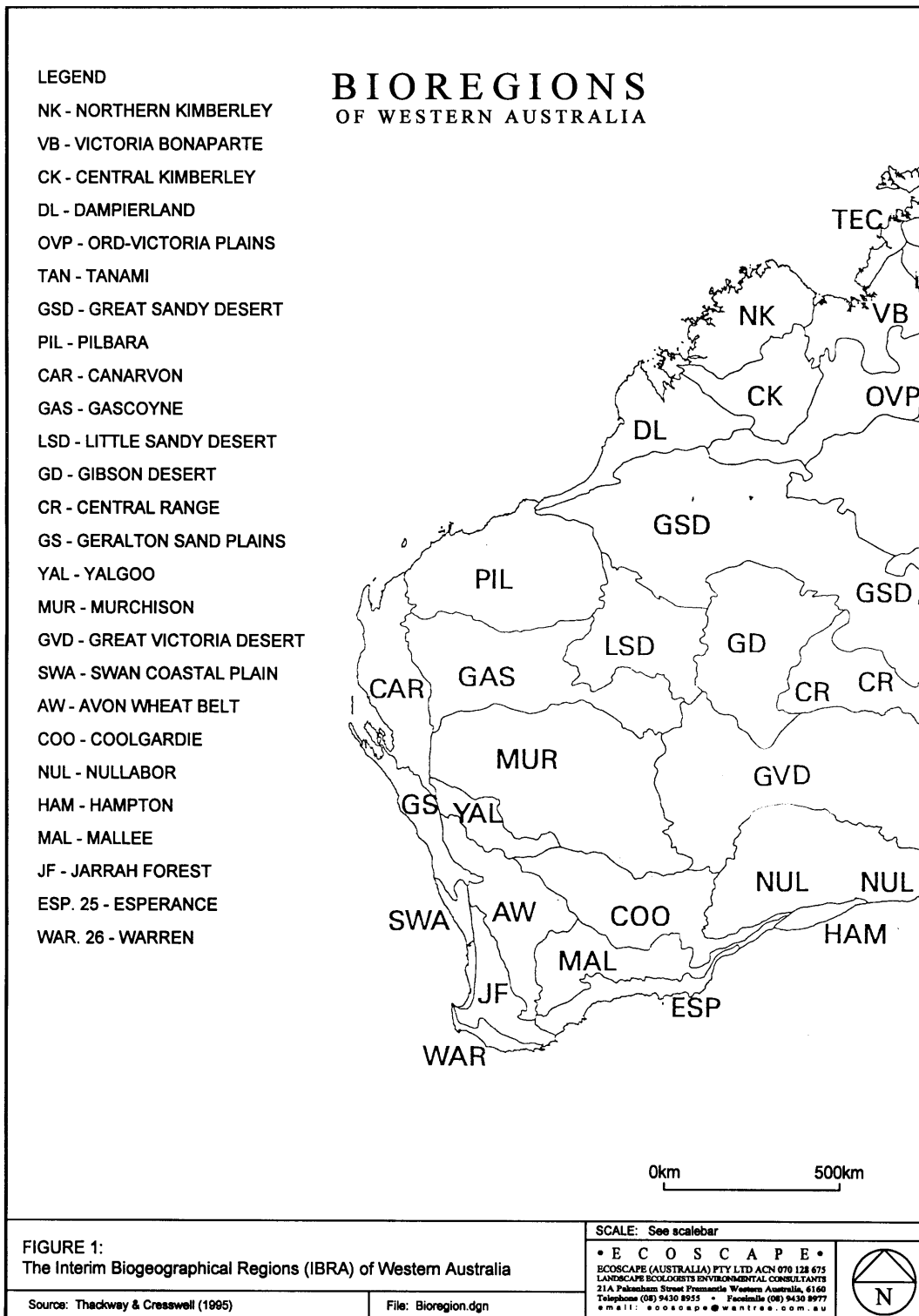
- Buffel Grass (*Cenchrus ciliaris*) is widely distributed and occurs in the Geraldton Sandplains, Carnarvon, Pilbara, Dampierland, Great Sandy Desert, Little Sandy Desert, Gascoyne, Murchison, Northern Kimberley, Central Kimberley, Ord-Victoria Plains IBRA regions.
- Bridal Creeper (*Asparagus asparagoides*) has widespread distribution and occurs in the Warren, Jarrah Forest, Swan Coastal Plain, Esperance, Avon Wheatbelt, Geraldton Sandplains and Mallee IBRA regions.
- Victorian Tea Tree (*Leptospermum laevigatum*) occurs in the Carnarvon, Yalgoo, Warren, Jarrah Forest, Swan Coastal Plain, Esperance, Avon Wheatbelt, Geraldton Sandplains and Mallee IBRA regions.
- Salvinia (*Salvinia molesta*) is a potential major threat to waterways and occurs in the Jarrah Forest, Pilbara and Swan Coastal Plain IBRA regions.

CALM received funds through a Natural Heritage Trust (NHT) grant to prepare an Environmental Weed Strategy for Western Australia. The development of the strategy has been carried out through a Steering Committee comprised of various government agencies (CALM, Agriculture WA and the Water and Rivers Commission) and community groups concerned with environmental weed management.

The Environmental Weed Strategy will contribute to a future State Weed Strategy which will address both agricultural and environmental weeds.

STRATEGY OBJECTIVES

- *To provide strategic direction for the management of environmental weeds in Western Australia involving an integrated and co-ordinated response.*
- *To develop a list of environmental weeds of actual and potential significance in Western Australia, including terrestrial, aquatic and marine weeds.*
- *To rate these species for their impacts on biodiversity according to predetermined criteria*
- *To develop a relational database of environmental weeds along with their biological characteristics such as life form, origin, means of reproduction, habit etc as well as methods of control. The database to be designed as a data catchment tool as well as an information base and analytical tool and be available for broadscale distribution.*



2. WEED INTRODUCTION, SPREAD AND EFFECTS ON BIODIVERSITY

2.1. Successful Plant Invasion

The key stages in successful plant invasions have been identified by Humphries (1995). These are:

- species introduction
- establishment, noting the role of both ecosystem vulnerability and species attributes
- survival
- production of numerous propagules, and
- widespread dispersal, requiring effective dispersal mechanisms and the ability (or opportunity) to cross regional barriers.

Disruption and failure of one or more of the first four stages effectively prevents widespread dispersal.

2.1.1. Species Introduction

Time is an important factor to consider. The time scale between establishment and widespread dispersal is variable. For many species, there has been a lag of years or decades between initial establishment and the awareness of the species as an environmental weed. *Mimosa pigra* was introduced to the Northern Territory in the late 19th Century. It was not until the 1970's that it suddenly began to spread in riverine systems and has the potential to replace riparian and wetland fringing vegetation through much of northern Australia. The time scale in which the effects of a weed or a suite of weed species may be observed may also vary between weed species. For example Rubber Vine (*Thunbergia grandiflora*) can smother tropical lowland rainforest canopies within months of initial establishment, whereas grassy weeds which compete with indigenous shrubs for recruitment opportunities may take decades for their effect to be visible.

Mechanisms for the spread of species from one location to another may include:

- transport corridors
- fragmentation (stem or root)
- dumping of garden rubbish
- faeces of grazers and seed-eating birds
- wind-borne spores or light weight seed
- grazing or pasture development
- clearing of native vegetation
- flowing water
- landscaping/gardening

2.1.2. Establishment

Establishment of an invading species in a new location is dependent on two groups of characteristics, the intrinsic characteristics of the weed species and the vulnerability or resilience of the community being invaded. Species with broad habitat requirements, rapid growth and the ability to reproduce vegetatively as well as sexually, are generally well adapted to establishment in new locations and communities. Hobbs and Humphries (1995) postulated that the characteristics, dynamics and history of a particular site are important factors in determining the resilience or vulnerability of an ecosystem.

Watercourses are an example of habitats that are vulnerable based on site characteristics. These areas have high moisture and nutrient availability, have a natural transport mechanism and are subject to a high degree of both natural and man-made disturbance factors (Humphries, 1995). Islands, due to their small area, are vulnerable to weed invasion. This is observable in the high proportion of introduced plants in island vegetation (e.g. Norfolk Island – 60%, Lord Howe Island – 48%, Tasmania – 31%) compared with mainland Australia – 15% (Humphries, 1995). Ecosystems in the main agricultural belts tend to have high levels of disturbance and clearing. Indigenous vegetation is often only present in small isolated remnants that are highly vulnerable to weed invasion (Panetta and Hopkins, 1991).

Most West Australian ecosystems are vulnerable to some extent to invasive plant species. Several authors have noted the relationship between degree of invasion and disturbance to the ecosystem, and see weed invasion as a symptom of disturbance and disruption, rather than as the primary cause of disruption (Adair and Groves, 1998; Hobbs and Saunders, 1995; Humphries et al., 1993). Humphries (1995) lists some resilient ecosystems. These include mangrove flats, alpine areas, red sandy deserts, intact upland rainforest and intact temperate forest. The key characteristics appears to be ‘intactness’ and, perhaps for some, the presence of climatic or nutrient extremes.

2.1.3. Survival

The third characteristic of successful invasion is ‘survival’. In red sandy desert areas and mangrove flats, for example, extreme conditions may limit the survival of invading species (Humphries et al., 1993). Weed species with a high tolerance for environmental stressors such as flooding, drought, low nutrient levels and fire, and the ability to produce stress resistant propagules have a greater chance of maintaining themselves in the post-establishment phase.

2.1.4. Reproduction

Effective reproductive strategies are a distinguishing characteristic of highly aggressive invasive weed species. Either the capacity to produce large numbers of viable seed, such as Veldt Grass (*Erharta calycina*), or the ability to reproduce vegetatively, such as Bridal Creeper, are a major contributing factor in their success in Australia.

2.1.5. Dispersal

Dispersal strategies include the establishment of small populations at a distance from the original establishment site. These populations then may also develop outlying populations. While initial populations of an environmental weed, referred to by Hobbs and Saunders (1995) as ‘nascent foci’, may be small in area and low in density, once conditions are right, they are able to rapidly increase their population size and density. The result is a sudden eruption of a widescale problem. Hobbs and Saunders (1995) note that at this stage, it is difficult to predict:

- which species will become problem species
- when they will become problems, and
- what role stochastic events, such as floods or fire, play in the sudden explosion of these species.

These observations are particularly troubling when it is recognised that on a national scale, most invasive species’ populations are still expanding (Humphries et al., 1991), and that the rate of plant invasion, which was linear, now is probably exponential (Carr, 1993).

2.2. Effects on Biodiversity

Environmental weed species that are of the greatest concern are those which affect or have the potential to affect biodiversity (Adair, 1995). The National Weeds Strategy identifies three levels of biological diversity that may be affected by weed invasions (Adair and Groves, 1998). These are:

- genetic diversity
- species diversity, and
- ecosystem diversity

2.2.1. Genetic Diversity

At the genetic level, environmental weeds are one factor, amongst many often inter-related factors such as clearing and changing fire regimes, that can reduce genetic diversity by reducing the viability and robustness of populations of native species. The potential for reducing genetic diversity by environmental weed species has not been quantified (except for some species already verging on extinction). The National Weeds Strategy (Anon, 1997) though, notes that quantification is now technically possible, with the advent of DNA marker technology.

2.2.2. Species Diversity

Weeds have the potential to affect the species diversity of both the flora and fauna of a community (Adair, 1995). Highly invasive weeds may change the composition of a community through competitive recruitment or through changing fire regimes. The most common outcome is a simplification of the species assemblage. The fire-weed cycle in many woodland areas in Western Australia has led to the progressive replacement of the original shrub layer with a perennial and annual grass understorey (Bridgewater and Backshall, 1981).

Incidental outcomes include the loss of fallen logs and standing dead timber. Shrub dependent species of birds, mammals and invertebrates may be lost from the location, notably those that rely on shrub species for nectar, seed and shelter, as well as those that require hollows for shelter and nesting. The National Weeds Strategy lists four plant species where environmental weeds have been a major factor in their extinction (Adair and Groves, 1998). The National Strategy also lists 20 other studies in Australia that have documented or quantified the impacts of environmental weeds on species richness and biodiversity.

Environmental weeds may affect ecosystem diversity by changing:

- the structure of a community by addition or removal of strata
- the fire regime which then results in the loss of species and structural components that are not directly subject to competition with environmental weeds, and
- geomorphological processes.

2.2.3. Ecosystem Diversity

The impacts of environmental weeds at the ecosystem level can be major and long lasting. Humphries (1995) notes that the Athel pine, *Tamarix aphylla*, has the potential to displace native flora, lower the water table, increase soil salinity and change river flow and sedimentation regimes.

Environmental weeds that impact on ecosystem diversity, and species diversity, have the greatest range of effects directly and indirectly on the Australian environment. Species that impact upon ecosystems with a limited distribution, or which are highly vulnerable due to fragmentation or inherent vulnerability are of particular concern. The National Weeds Strategy (Anon, 1997) notes that there is a lack of research that directly documents the impacts of invasive weeds at the ecosystem level, concluding that the effects are often so visible and dramatic that funding resources have generally been focussed on control and management research and implementation. There is a need to identify threshold levels for precipitating declines in biodiversity at all levels, as well as to identify and address land management practices that affect ecosystem vulnerability and resilience to environmental weeds.

SUMMARY

Many environmental weeds are successfully invading Western Australian ecosystems. Some of these weed species are having a significant impact on diversity at genetic, species and community levels. More work is needed to understand the reasons for recent explosion of many weeds and of the impacts weeds have at the ecosystem level. Research is vital to increase understanding in these areas to enable strategic management approaches.

3. INTEGRATED ENVIRONMENTAL WEED MANAGEMENT

3.1. Strategic Weed Management

Integrated weed management is the combination of social, economic and technical approaches that leads to successful weed management at all scales. It is the consideration and activation of the full range of weed control approaches in developing a weed control strategy that can be adopted and resourced by the Federal, State and Local Governments, private landowners and by the community.

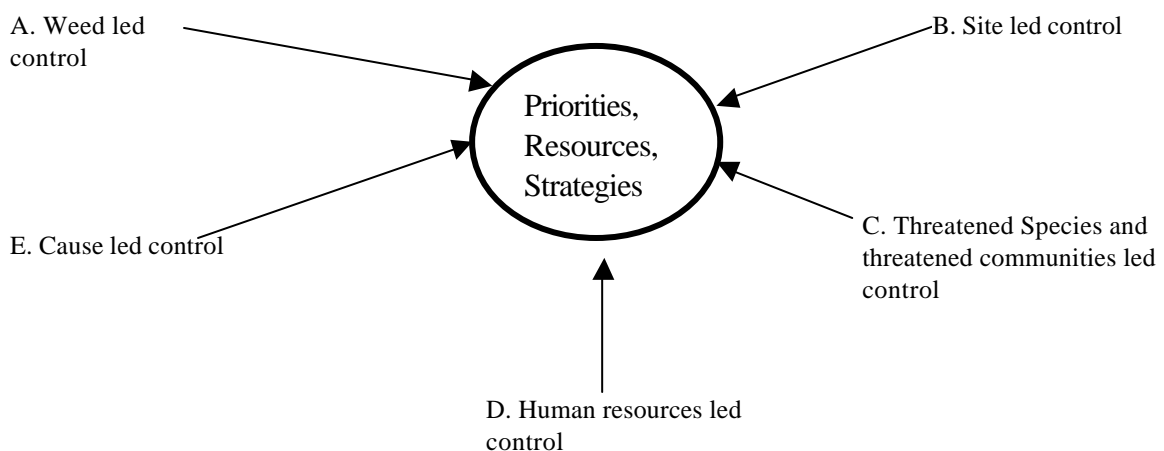
There are limited resources for environmental weed control in Western Australia and it is important that these resources are applied most effectively to achieve strategic weed management. Strategic weed management will only be achieved if there is integration of purpose and action between all the players at national, State, regional, local and patch scales. The purpose of this section is to provide a pathway towards a successful integrated weed management program for Western Australia.

Integrated weed management involves the planned use of all control options to achieve effective environmental weed management. The approaches to environmental weed management (Figure 2) include:

- weed led control
- site led control
- resources led control
- threatened species and communities led control, and
- cause led control

Figure 3 provides a flow diagram of how each approach is considered to create a strategic approach to environmental weed control.

FIGURE 2. ENVIRONMENTAL WEED MANAGEMENT APPROACHES



The challenge for environmental weed management is to look at weed control from a number of angles, to fully consider the range of possible approaches and then to decide the combination of approaches which will maximise nature conservation outcomes.

A strategic approach and agreement regarding priorities across all government agencies, private landowners and the community is required. The strategy must be agreed at all levels and resources channelled towards implementing that strategy. For example if a regional goal is to eradicate Arum Lily (*Zantedeschia aethiopica*), with the first priority being its eradication in selected nature reserves, then all government departments and local communities need to be working towards that goal. CALM could concentrate on nature reserves, possibly with the assistance of community. Local government could concentrate on sources of infestation into the reserves from roadsides and local government vested reserves, and private adjacent landowners should receive encouragement and incentives to control the weed on their land.

3.2. Priorities and Planning

Integrated weed management will provide a mechanism to maximise conservation outcomes while minimising adverse environmental impacts. The mechanism will provide the framework to allow decisions for weed control priorities to be transparent and thus able to be adopted by and resourced by all State and Local Governments, private landowners and the community. Planning for weed control at a State scale should consider the following priorities:

1. Recognise weed potential.

Early detection and eradication of new weeds is the highest priority. Weeds must be assessed for their potential to become serious environmental weeds and targeted according to this priority. This study has developed a database of environmental weeds which incorporates a rating for each weed. The methodology for rating the weeds is explained in Appendix 1 and the design of the database in Appendix 2.

2. Maintain significant areas of all ecosystems that have vegetation in good condition (see Kaesehagen, 1995 and Keighery, 1993 for vegetation condition scales).

Management of all ecosystems largely free of weeds, should be the next priority. While areas reserved for conservation purposes (e.g. national parks, nature reserves and conservation parks) are important, private and other lands often contain plant communities not represented in conservation reserves and maintenance of these areas in good condition is a high priority. Off-reserve conservation has been recognised as being vital to nature conservation needs (Hale and Lamb, 1997).

3. Control weeds impacting on threatened species and communities.

Management of weeds impacting on threatened native species and communities is very important to ensure the survival of nationally significant species.

At regional, local and patch scales it is rare that a single one of the approaches described above would be used alone and normally a combination of approaches is employed. What is important is that each approach is fully explored so that a strategy, which utilises the best elements of each pathway, is developed. The decision as to the best combination of approaches will be a judgement-based consideration of effectiveness of methods, urgency for control, the anticipated conservation outcomes and the resources available.

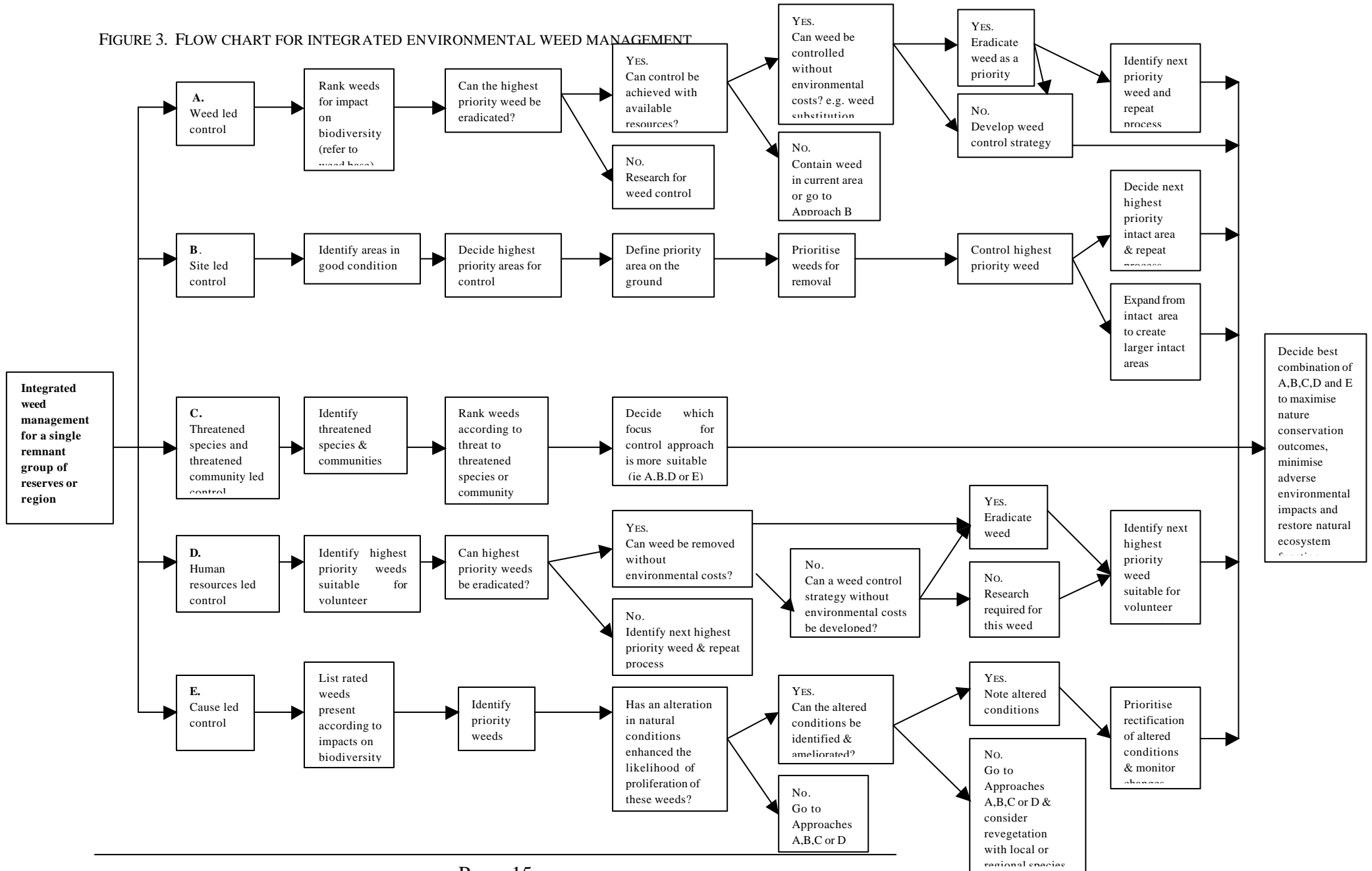
A key consideration is possible adverse impacts of weed management. Examples of adverse environmental impacts include:

- loss of faunal habitat, e.g. Blackberry (*Rubus sp.*) may provide habitat for wrens or protection for small mammals from predation by foxes and cats.
- weed substitution – a weed is removed only to be replaced by a weed which is more difficult to remove, e.g. Lupins (*Lupinus sp.*) substituted by Rose Pelargonium (*Pelargonium capitatum*) on the Swan Coastal Plain when Lupins are removed.
- chemical effects of fauna, e.g. impact on frogs by chemical sprays used for weed control.

Many potential adverse impacts of weed management can be prevented by revegetation with appropriate local species at the same time as weeds are removed. This approach maintains habitat values and reduces the risk of weed substitution.

Guidelines to determine which approach or which combination of approaches is most effective in particular circumstances would assist weed managers. It is important that such guidelines be produced. A case study approach will be most effective in communicating the complexities of weed control.

FIGURE 3. FLOW CHART FOR INTEGRATED ENVIRONMENTAL WEED MANAGEMENT



3.3. Weed Led Control

Controlling potentially significant new environmental weed species is essential if control is to be effective in the long term. Weed led control is a proactive strategy to prevent introduction, establishment, survival, reproduction and dispersal of an emerging environmental weed before it becomes a major problem either at a patch, local, regional, State or national level. Prevention and eradication is a powerful tool for weed managers in their efforts to control the expanding number of weeds. A species that is widespread can only be controlled as part of a site led program not a weed led one.

3.3.1. Preventing Weed Introductions

Prevention of weed introductions is significant at all scales:

- On a national and state level quarantine and assessment processes need to be at a sufficient level to prevent the introduction of new weeds to the nation or State. Education is vital to help the community understand the risks from weed introductions; and
- At regional and local scales prevention of new weed introductions is important.

Weeds are transported by both natural and human sourced mechanisms. We have the ability to control human vectors. The essence is good hygiene, whether it be education to prevent garden waste disposal into sensitive areas at a local scale, regulations to require the covering of transported hay at regional and State scales or regulations to ensure that new farm crops such as Tagasaste (*Chamaecytisus palmensis*) have a wide buffer between remnant vegetation and roadsides.

Sales of plant species with high weed potential for domestic use, for revegetation or commercial use, also requires attention, with such plants not being offered for sale either through voluntary adoption of best practice by the relevant industries or by regulation.

An investigation and development of best practice guidelines, and where appropriate regulations to ensure hygiene, for the sale and distribution of potential weed species or materials potentially containing weed species is required.

Monitoring for the presence of new weed populations and for the proliferation of existing “sleeper” weeds is essential to ensure rapid action if a weed is inadvertently or deliberately introduced or begins to spread rapidly. Community education towards notification and an action plan for eradication of new weeds is required at all scales.

3.3.2. Early Detection and Early Eradication

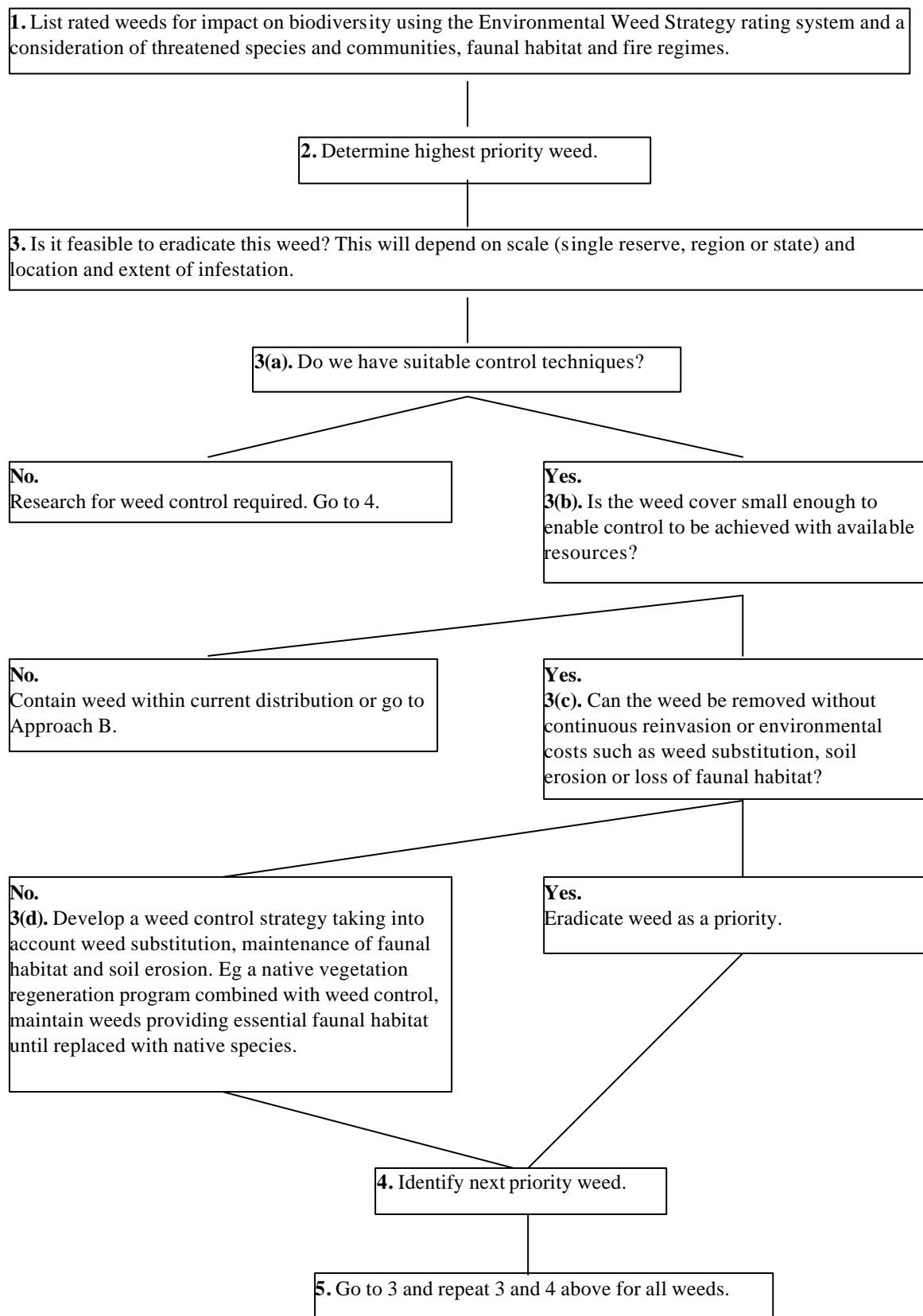
It may be possible to eradicate localised populations of weeds at all scales in some circumstances. A small effort early in the invasion process can save considerable effort or loss of ability to control in the long run. For example early control of a small population of *Briza maxima* in an isolated

wheatbelt reserve could prevent the weed invading the whole reserve. The key is identification of the effort required, both in amount and duration, to ensure that control is possible, that the resources are sourced and the effort sustained for sufficient time to achieve the goal. Eradication campaigns generally fail if one or more of the following criteria are not met:

- the population of the target species must be highly localised and the boundaries of the population assessed beforehand
- an effective control method needs to be available, and
- the infested area must not be continuously infested from soil seed reserves from surrounding areas or from nearby cultivated specimens (Csurhes and Edwards, 1998).

A strategic approach to the removal of new localised populations of individual weed species or small numbers of weed species is outlined in Figure 4.

FIGURE 4. WEED LED CONTROL – STRATEGIES FOR THE REMOVAL OF INDIVIDUAL WEED SPECIES OR SMALL NUMBER OF WEED SPECIES

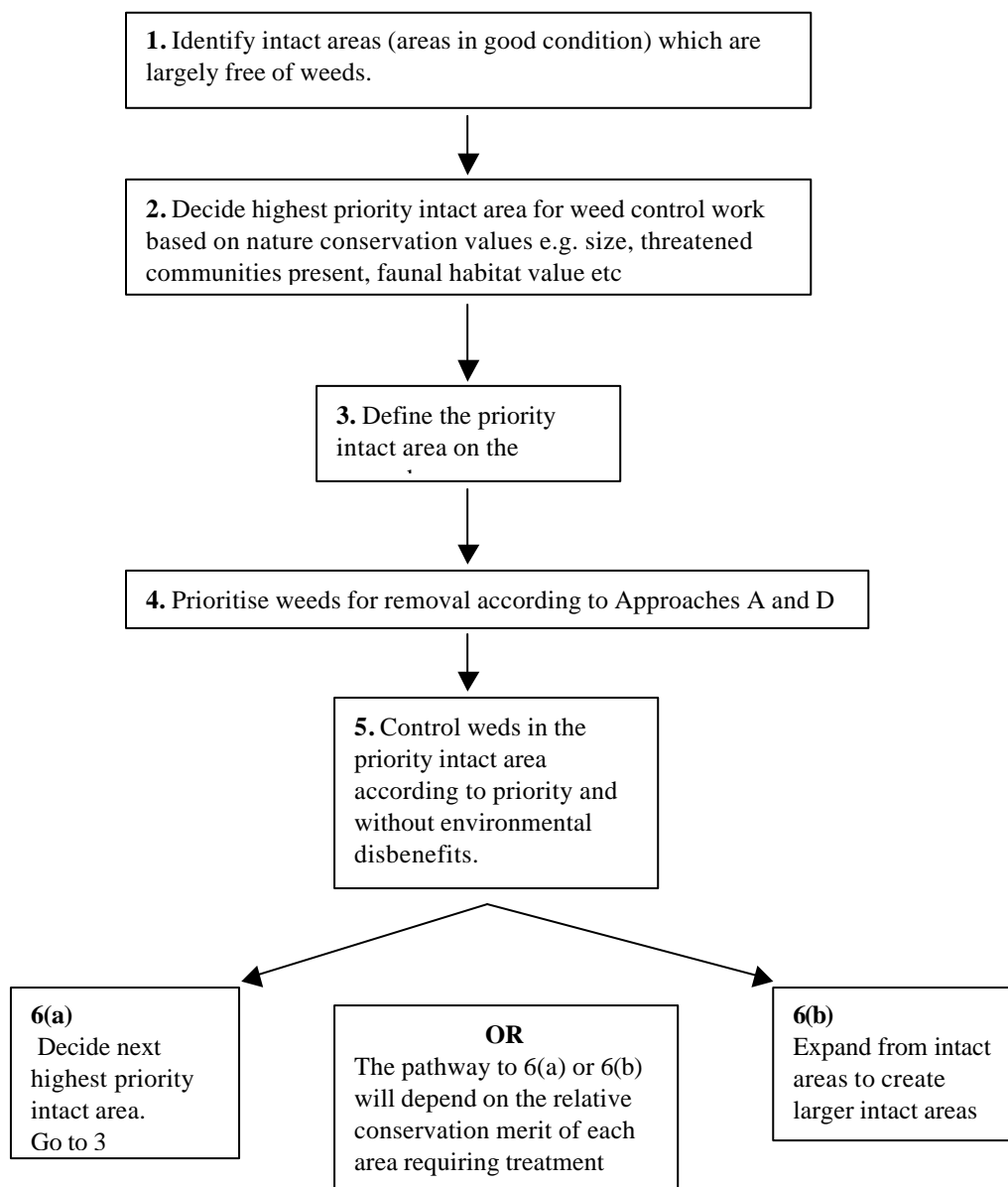


3.4. Site Control

Site led control focuses on identifying areas that require weed control to maintain their ecological values and sites which are currently in good condition and can maintain or improve that condition with planned effort. In some cases it is possible to expand control from areas in good condition to gain larger intact areas. The priority ranking of a proposed site led program is based on the biodiversity value of the core management unit and the urgency of control.

A strategic approach to identifying priorities for site led control is provided in Figure 5.

FIGURE 5. SITE LED CONTROL – STRATEGIES FOR PROTECTION OF HABITATS CURRENTLY LARGELY FREE OF WEEDS



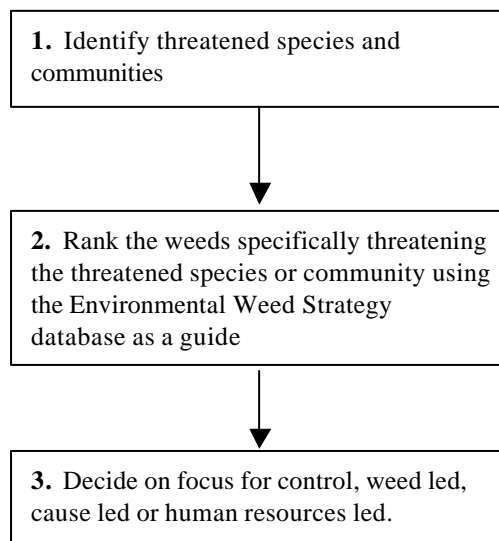
3.5. Threatened Species and Threatened Communities Led Control

This approach places the protection of threatened species and threatened communities on public and private land as the highest priority for weed control and is incorporated into species and ecological community recovery plans developed by CALM. This is a subset of site led control where the site is identified by the presence of a threatened species or community.

While the protection of threatened species and communities is a very high priority to prevent extinctions, it only focuses on points in the landscape and so needs to consider also the broader environment which may provide a continuing source of weeds.

A strategic approach for threatened species and threatened communities led control is provided in Figure 6.

FIGURE 6. THREATENED SPECIES AND THREATENED COMMUNITIES LED CONTROL FOR PROTECTION OF THREATENED SPECIES AND COMMUNITIES AS THE HIGHEST PRIORITY



3.6. Human Resources Led Control

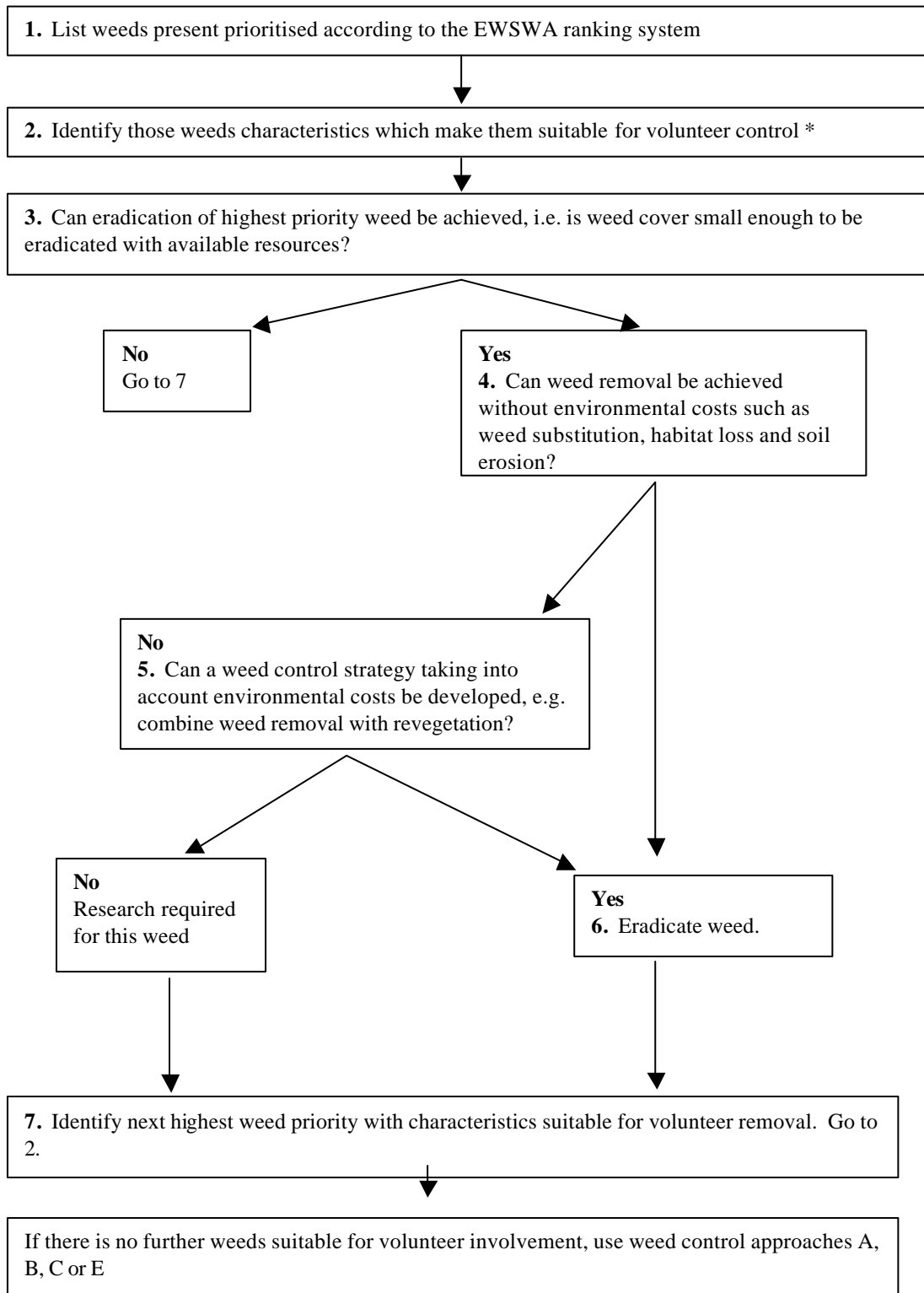
People and communities are becoming motivated to manage natural areas as evidenced by the steady growth of “friends groups”, the landcare movement and considerable effort by volunteers. Many of these groups are concentrating on bush regeneration and making significant contribution to weed control in natural areas. There is also an increase in professional weed control contractors and some municipalities are employing staff with expertise in environmental weed control.

Establishing priorities for weed management can be difficult and in some cases lack of understanding of ecological processes leads to weed replacement and continuous reinvasion. In these circumstances volunteers and professionals can lose motivation.

A human resources approach will identify weeds and particular circumstances best suited to volunteer control and those which are better managed by professionals. It may be best for volunteers to target small populations of highly visible weeds which are readily removed by simple manual or chemical methods and are ideal for essential follow up and monitoring. Professionals may be best used where spraying or machinery is required or where a concentrated effort is required. Making the best use of the capabilities of both volunteers and professionals will often lead to best long term outcomes.

A strategy for human resources led control - recognising control strategies for volunteers and professionals is provided in Figure 7.

FIGURE 7. HUMAN RESOURCES LED CONTROL – RECOGNISING DIFFERENT WEED CONTROL STRATEGIES FOR VOLUNTEERS AND PROFESSIONALS



❖ Weeds suitable for volunteer control, eg highly visible weeds which can be readily removed by simple manual or chemical methods.

3.7. Cause Led Control

Many environmental weeds are proliferating because they are able to take advantage of disturbances such as:

- a change in soil conditions either by altered water regimes or increased nutrients;
- unnatural soil disturbances such as earthworks;
- by changed fire regimes which alter ecosystem processes; and
- by constant reinfestation from external sources.

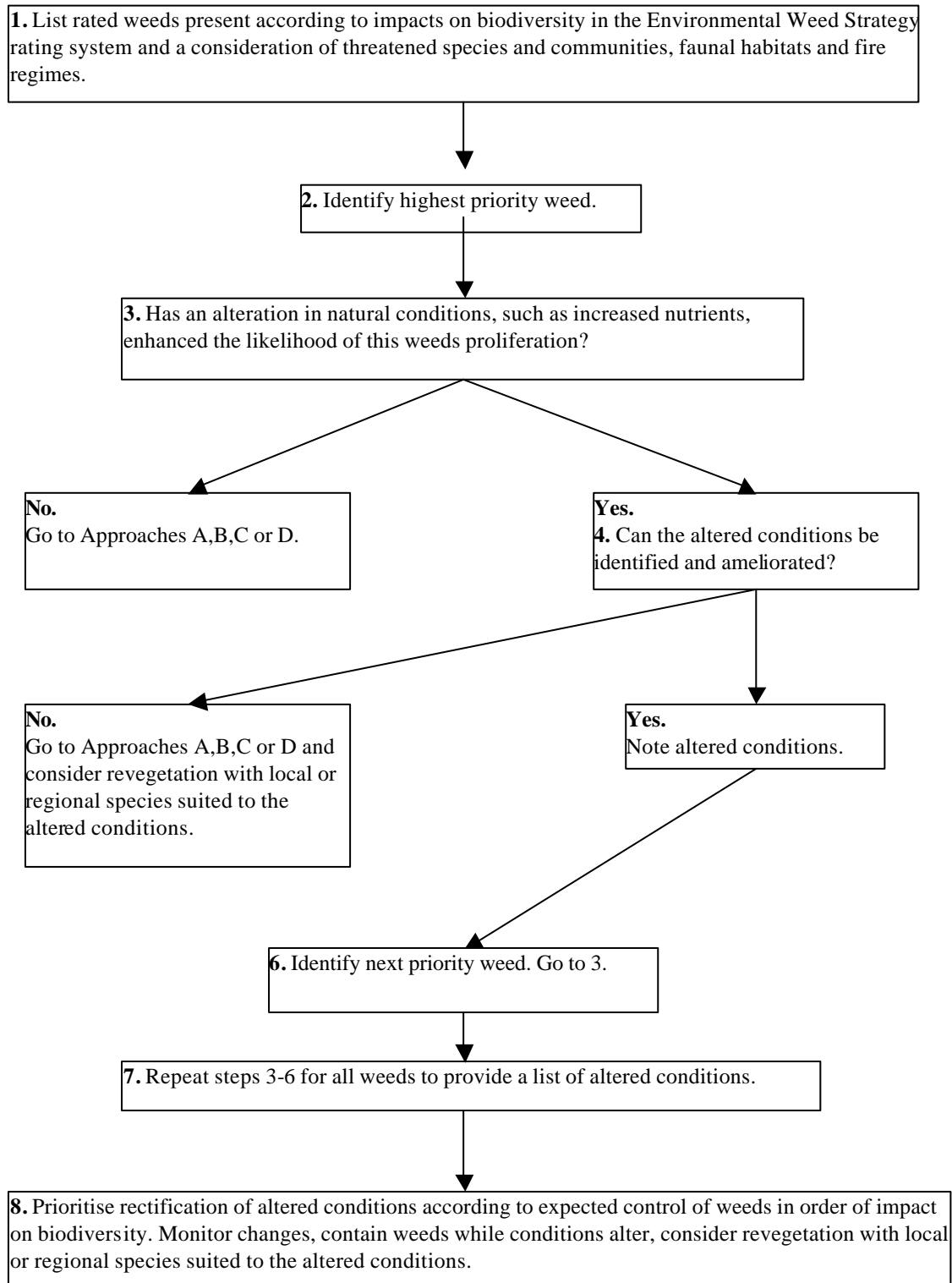
This approach to weed control focuses on controlling, reducing or eliminating disturbance factors that increase ecosystem vulnerability. Examples of this approach may include:

- control of access through bushland areas and rehabilitation of superfluous tracks;
- control of grazing in bushland areas and riparian vegetation through fencing of remnants;
- control and management of sources of nutrients entering waterways through planning controls and improved land management practices; and
- control of ballast water exchange e.g. Japanese Kelp (*Undaria pinnatifida*).

Cause led control can be seen as preventative in terms of ensuring that vegetation in good condition is protected from disturbances through planning controls and effective management strategies. Once environmental weeds are established, then control of disturbance factors is an important adjunct to other control methods in order to ensure effective control of environmental weeds and protection of environmental values.

A strategy for a cause led approach is provided in Figure 8.

FIGURE 8. CAUSE LED CONTROL – RECOGNISING THAT THE REASONS FOR A WEEDS PRESENCE MAY BE DUE TO ALTERED CONDITIONS WHICH NEED TO BE ADDRESSED FOR THE WEED TO BE CONTROLLED



SUMMARY

An integrated approach to environmental weed management is developed in this chapter. An integrated approach involves the planned use of the following control options:

- *weed led control*
- *site led control*
- *resource led control*
- *threatened species and communities led control, and*
- *cause led control*

Strategic planning will consider:

- *weed potential according to the criteria developed in this study*
- *maintaining significant areas of all natural ecosystems in good condition, and*
- *control of weeds impacting on threatened species and communities*

Adverse environmental impacts of weed management must be addressed and revegetation strategies need to be alongside weed removal.

RECOMMENDATIONS

Number	Action	Responsibility
R3.1	Produce guidelines for integrated weed management and case studies to illustrate the guidelines. Adjacent landowners should receive encouragement to control weeds on their land, where integrated programmes are planned.	Agencies, with assistance in coordination from SEWG where required.
R3.2	The sale of plant species with high weed potential for either domestic use, revegetation or commercial use should be discouraged, by voluntary adoption of best practice by the relevant industries.	SEWG to promote via member organisations.
R3.3	Review current regulatory mechanisms and best practice concerning the sale and distribution of potential weed species or materials potentially containing weed species and recommend changes.	CALM, AgWA.
R3.4	Establish a mechanism to monitor the presence of new weed populations and the proliferation of existing “sleeper” weeds to ensure rapid action is undertaken if a weed is inadvertently or deliberately introduced or begins to spread rapidly.	Agencies, with assistance of SEWG as required.

4. CONTROL METHODS¹

Weeds can be controlled by direct methods such as biological control agents, by manual methods, by using herbicides or indirectly by effective land and water management. The selection and implementation of the most appropriate method or combination of methods is a vital part of any weed control program. Correct selection will ensure that weeds are dealt with in a timely manner with minimal environmental costs both on and offsite.

Significant contributions are required at all levels of society (see Table 1). Activity cannot be effective on the ground without biological control and appropriate certifications for chemical control. Similarly control of introduction of weeds and quarantine are required at national and State scales.

4.1. Controlling Degradation Processes

Controlling degradation processes that increase ecosystem vulnerability to weeds is often the most effective way to control weeds.

In bushland areas procedures such as fire management, maintenance of buffer zones, prevention of nutrient inflows, fostering regeneration of indigenous species and restricting human access to managed walkways and roads all contribute to weed management. Reduction in weeds after the degradation processes are controlled may be slow and monitoring will be required to determine effectiveness and whether complementary measures such as revegetation or minor weed control are also required.

4.2. Herbicides

Herbicide application is often the most cost effective method for the control of weeds. While herbicide applications are efficient this approach requires careful consideration of:

- human health implications
- increasing herbicide resistance
- possible mitigation against the development of alternative approaches to weed management such as mechanical, ecological and system management due to current efficiency of the method
- impact on non-target flora and fauna, and
- the need for post treatment rehabilitation.

Careful consideration of the most appropriate use of herbicide control is required and over reliance on herbicides for weed control should be discouraged.

¹ *WeedPlan A Tasmanian Weed Management Strategy* is acknowledged as a major source for the development of this section.

4.3. Biological control

Biological control can be a very efficient form of weed management.

Biological control reduces weed populations and vigour through the introduction and release of natural parasites and predators. Biological control has many advantages over other weed control methods as it can be cost effective in the long term, is generally environmentally friendly and can reduce the need for less desirable weed control practices such as herbicide application. Biological control does not eliminate weeds but can reduce target weed populations to a level at which they have a low impact or are more readily controlled by other means. Biological control requires considerable investment and is long term. Increased research for biological control of the major weeds impacting on biodiversity in Western Australia is required. Managers must recognise the limitations of biological control and apply additional controls where required to protect conservation values.

4.4. Manual Control

Manual control is physical removal of the weed by mechanical or human effort.

Manual control is often the most expensive form of weed removal but it is the most appropriate method in many circumstances, e.g. for threatened flora populations where disturbance to individual native plants has to be avoided. It is particularly valuable for small infestations, where chemical control is inappropriate and where resources are available. Manual control needs to be carefully managed as enthusiastic efforts resulting in gross soil disturbance can lead to weed replacement, and the approach recommended by Bradley (1988) where revegetation is carried out in conjunction with weed removal needs to be considered.

Demonstrations of the most appropriate use of mechanical weed removal are required as examples to the community of best practice. These need to be documented as case studies and made available to weed control groups and for weed management education.

4.5. Fire Management

Fire is an acknowledged perturbation factor which occurs naturally in all terrestrial ecosystems but currently is often human mediated as a planned management tool or as an accidental or criminal action. Fire regimes in many parts of Western Australia have altered since European settlement, particularly in areas of high population density. The presence of environmental weeds may then contribute to a fire-weed cycle that is the primary cause of bushland degradation in some areas (Wycherley, 1984).

The causes of the cycle are many and diverse, but some of the key points are:

- Weed species are often advantaged by the burst of nutrients available immediately after a fire.
- Weed species, particularly grass weed species, accumulate biomass rapidly thus rapidly increasing fuel loads to levels that will sustain fires more frequently.
- Grass fuels have a different structure to shrub fuels. The grasses have a fine, evenly spread structure, compared with the more heterogenous, discreet structure of native understorey shrubs. This affects fire behaviour and rate of spread, particularly in the initial stages of a fire.
- Weed seeders are usually annuals whilst native seeder species require time between fires not only to set seed but also to replenish their seed stocks. This may take several years. Frequent fires deplete native seed stocks and encourage weed seed stocks, thus rapidly eliminating the native species from the species assemblage.
- Resprouters can also succumb if the fire interval is so frequent that the root stock resources become depleted.

Thus grassy weeds have characteristics which enable them to respond quickly to fires, and which support more frequent fire events, than many of the native perennial understorey shrubs. Some weed species (e.g. Acacias) are well adapted to fire and in the absence of their natural limiting agents are able to proliferate at the expense of endemic species.

However, arson or planned fire events may provide opportunities for weed control through the reduction in weed biomass and the provision of opportunities to treat resprouting plants. For example, a fire event in a thick infestation of Pampas Grass (*Cortaderia selloana*) will allow access to the area after burning to selectively chemically treat regrowth as well as allowing revegetation of bare areas.

To date, little research has been carried out on the definition of appropriate fire regimes for Western Australian ecosystems in terms of fire intervals, intensities and patchiness, and their relationship to environmental weeds. Without this information, the specific role of fire in ecosystem vulnerability to environmental weeds within different vegetation communities is unknown.

Table 1: WEED CONTROL PRIORITIES FROM NATIONAL AND LOCAL LEVELS

Methods	National	State	Regional	Local	Patch
Introduction and Spread	Quarantine, transportation measures, education	Quarantine, transportation measures, education	Sensitive commercial revegetation strategies, education	Fire control strategies, education, hygiene	Amelioration of causal agents
Biological Control	Establish National research priorities	Promote special State research requirements	Distribution and monitor effectiveness	Monitor effectiveness	Monitor effectiveness
Herbicide Control	Health and safety standards, research	Health and safety standards, training, research	Training	Training	Implementation and monitoring
Fire Management		Fire management policies, research	Fire management policies	Fire permits and training	Implementation and monitoring
Manual Control		Training and volunteer group support	Recognition of roles, training, volunteer group support	Volunteer group support and training	Implementation and monitoring

SUMMARY

Control options for environmental weeds include:

- *controlling ecosystem degradation processes*
- *herbicides*
- *biological control*
- *manual control, and*
- *fire management.*

For many ecosystem/weed combinations in WA the best control options are not known and further research is required.

RECOMMENDATIONS		
Number	Action	Responsibility
R4.1	Facilitate research by the Federal Government into the biological control of weeds impacting on biodiversity in Western Australia.	Agencies, with assistance of SEWG as required.
R4.2	Facilitate research into appropriate fire regimes for Western Australian ecosystems in terms of fire intervals, intensities and patchiness, and their relationship to environmental weeds.	Agencies managing natural areas, assisted by SEWG.
R4.3	Certify additional herbicides for environmental weed control to increase the range of treatments available.	Pesticide companies encouraged by SEWG.

5. MONITORING AND EVALUATION

Monitoring and evaluation of environmental weed occurrences, their impacts, weed spread, condition of intact areas, condition of threatened species and communities threatened by weeds and weed eradication/control operations is essential for making sound decisions for weed control. Currently there is no coordinating mechanism in Western Australia for this to occur.

Mechanisms and procedures by which the success of the Environmental Weed Strategy and other weed management programs may be monitored and evaluated are required. Mechanisms for monitoring at local scales are currently poorly developed and understood with little implementation. Key areas for monitoring include:

5.1. Patch Level

- Map bushland condition and distribution of high and moderately rated weed population at regular intervals (e.g. every 5 years).
- Establish monitoring quadrants and survey and record annually – particularly for different weed control treatments.
- Photograph trial areas from set points – use digital technology if available (ie digital camera or video).
- Monitor effectiveness of community weed removal and restoration work.

5.2. Local Level

- Monitor effectiveness of discrete and broadscale weed control programs in reserves vested with Local and State Government authorities.
- Map distribution of high and moderate rated weeds in reserves.
- Liaise with private landowners with bushland who are undertaking weed control programs and monitor and evaluate their successes and failures.
- Identify priority areas for weed control.

5.3. Regional Level

- Monitor the effectiveness of weed control programs within the region.
- Monitor the impacts of environmental weed species on different ecosystems and evaluate the resilience of different vegetation assemblages.
- Monitor the introduction of new weed species in terms of their impacts on biodiversity.
- Monitor for the emergence of "sleeper" weeds.
- Monitor awareness and education programs and attitudes of the public towards environmental weeds.

- Monitor the sale and distribution of potential and existing environmental weeds from wholesale and retail outlets.

5.4. State Level

- Continue the work of AQIS (Australian Quarantine and Inspection Service) to monitor the imports of new plants to Australia.
- Evaluate the success of environmental weed control programs.
- Develop proforma monitoring schedules for patch, local and regional levels and evaluate incoming data.
- Monitor impacts of weed control methods on biodiversity.
- Monitor the success of weed control and threatened species and ecological communities recovery plans.

SUMMARY

Western Australia needs weed monitoring programs covering the physical locations of weeds, rates of spread, success of control containment operations and the success of community effort. These monitoring efforts should be undertaken at patch, local, regional and State levels.

RECOMMENDATION

Number	Action	Responsibility
R5.1	Monitor and evaluate weed control programs at patch, local, regional and State levels. Develop adequate training and pro formas for those undertaking these tasks.	Agencies, with assistance from SEWG as required.

6. COORDINATION AND INTEGRATION

6.1. Coordination

The challenge of adequately dealing with the environmental weed problem in Western Australia requires the adoption of a new and innovative response to weed management and control. To be effective this response needs to be of sufficient focus and capacity to match the capacity of environmental weeds to invade and alter natural ecosystems.

The response will need to be strategic and pro-active rather than piecemeal and reactive. Characteristics of the strategic approach include identification of key goals and objectives, recognition of the available resources and adoption of a range of responses followed up by evaluation and critical appraisal of success. A key element of the strategic approach to environmental weed control is a high degree of coordination and integration between the different players.

The response that is required involves a whole of government and community (including private landowners) approach which effectively forges links, relationships and networks between the groups and individuals involved. There is a need for strong inter-agency cooperation and efficient coordination between the various agencies that have a role in environmental weed management and control in WA. Coordination is also needed at all levels. It is essential at the policy level as well as the program and control strategy level and all the way through the process right down to on-ground weed control efforts.

Part of the process of building and improving the coordination between agencies and groups will involve recognition of the wide range of inputs needed to address the problem and recognition of the diversity of resources, skills and experience that is currently available both within the community and government agencies. The critical link is to match the resources and skills available to the problem that exists through effective coordination and integration.

The role of CALM in achieving the necessary degree of intra and inter-agency coordination will be pivotal. CALM will be the main coordinating agency in the response to the environmental weed problem due to its statutory responsibility for protection of flora and fauna in WA.

However, many other government agencies have responsibilities for weed management, e.g. Water and Rivers Commission, Department of Land Administration, Main Roads Western Australia, etc. The skills and resources of these agencies need to be coordinated across the State.

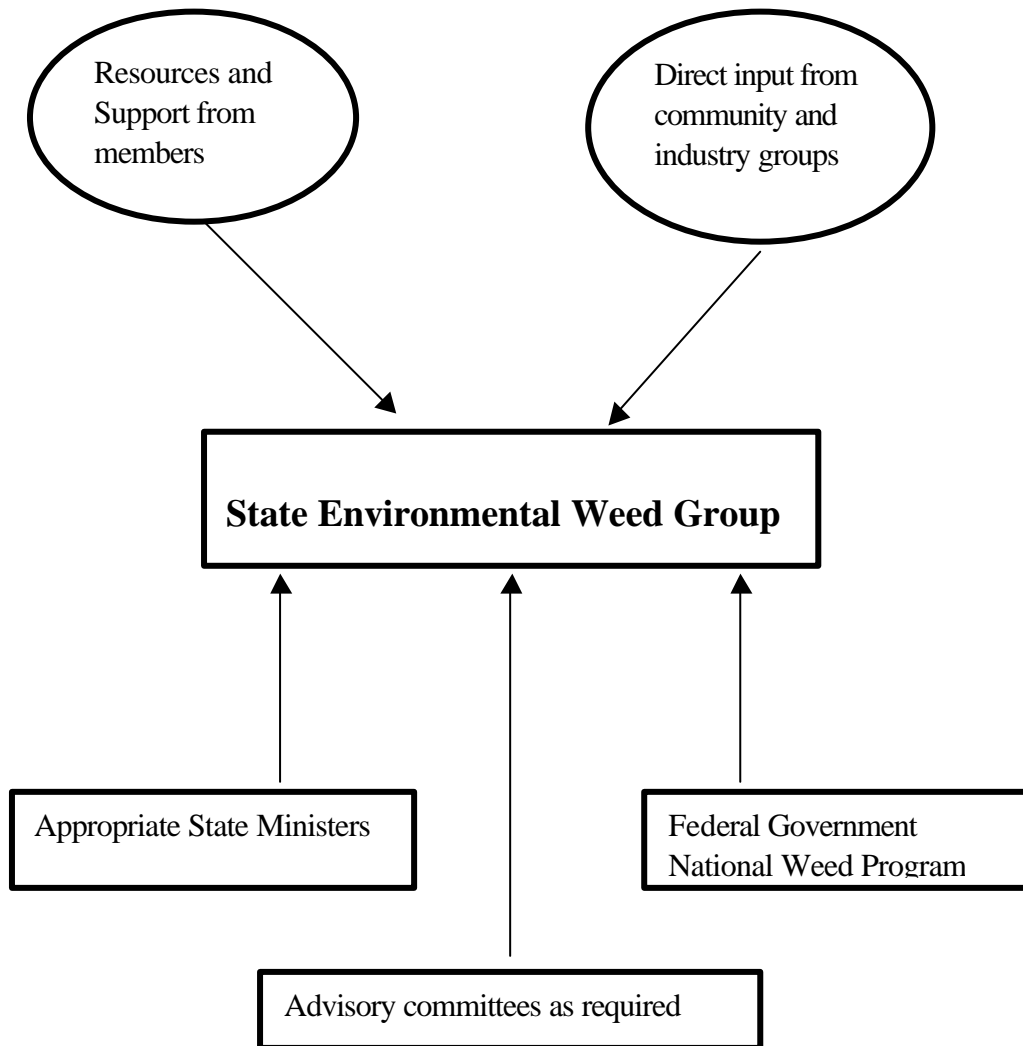
Coordination at the community level is also essential and should be carried out through local governments and existing community based non-government organisations.

There is clearly the need to build cooperative relationships between the active environment community and the weed control agencies and concentrate on skills, information and technology transfer.

The proposed method of achieving the required degree of coordination is through the formation of a senior level advisory group. This group will aim specifically to advise on and coordinate the implementation of the Environmental Weed Strategy for WA. The group will consist of members from local government organisations, State government agencies, private landowners, research institutions and community organisations. It is proposed that this advisory group be called the **State Environmental Weed Group**. This Group should be formed as a matter of priority following adoption of the Strategy.

The Mission Statement for the State Environmental Weed Group is to facilitate, advise and coordinate the successful implementation of the Environmental Weed Strategy for WA.

FIGURE 9. RELATIONSHIPS TO STATE ENVIRONMENTAL WEED GROUP



The proposed terms of reference of the State Environmental Weed Group are:

- Advise Government on environmental weed management in Western Australia.
- Provide leadership for environmental weed management.
- Recommend priorities for environmental weed management in Western Australia.
- Coordinate the implementation of the Environmental Weed Strategy for Western Australia.
- Coordinate between the government and non-government interests in environmental weeds.
- Coordinate between all relevant State Government agencies.
- Coordinate from a State perspective between the various levels of government.
- Advise on priorities for implementation of the Environmental Weed Strategy.
- Pursue funding for environmental weed management and control.
- Consult with industry including the farming, pastoral, forestry and nursery industries and the community in relation to environmental weed management and control.
- Promote research into environmental weeds by research organisations, educational organisations and community groups.
- Increase the awareness in WA of the insidious impacts of environmental weeds on natural ecosystems and bushland areas.
- Promote monitoring of environmental weeds and the success of control efforts.
- Assist to educate the community as a whole on the detrimental impacts of environmental weeds.

The appointment of the State Environmental Weed Group should be by the Minister for the Environment following the adoption of the Environmental Weed Strategy and negotiations with the proposed member bodies. The roles and responsibilities of member groups of the Environmental Weed Group will include adequately resourcing their involvement and commitment to the objectives of the State Environmental Weed Strategy. The groups and agencies that comprise the State Environmental Weed Group will need to commit to a whole of government and community approach to the environmental weed problem.

The State Environmental Weed Group should be supported by CALM through the provision of executive and secretarial resources.

If a State Weed Strategy is produced aimed at all weed issues in WA, then the roles and responsibilities of the State Environmental Weed Group would be reviewed and the most appropriate structures and arrangements adopted.

There are a number of other plans and strategies whose development is directly relevant to the Environmental Weed Strategy. These additional strategies should be taken into account by the State Environmental Weed Group in the implementation of the Environmental Weed Strategy in WA. These other strategies include:

- The National Weeds Strategy
- The National Strategy for the Conservation of Australia's Biological Diversity
- The proposed Biological Diversity Conservation Strategy for WA
- CALM's Bushland Weeds Policy, and
- The WA State of the Environment Report.

6.2. Integration

Integration of the Environmental Weed Strategy for WA involves the execution of policies and programs with maximum efficiency and cooperation and with a minimum of repetition and waste of time and resources. Integration will have to cover all facets of the Environmental Weed Strategy for WA, i.e. research, resourcing, priorities, control, education, monitoring and communication.

The primary method of integration of the various levels of weed control and management will be through the advisory and coordination roles of the State Environmental Weed Group. Integration of the various activities of the member groups of the State Environmental Weed Group will be an essential task if the aims and objectives of the Environmental Weed Strategy for WA are to be met. Within the confines of statutory obligations and available resources under which Group members must function, integration and coordination of activities will need to be a necessary part of each agency's commitment to the Environmental Weed Strategy for WA. It is proposed that integration be approached firstly through achieving a good understanding of agency responsibilities, constraints, current activities and proposed initiatives under the umbrella of an Environmental Weed Strategy for WA.

The process of integration of activities will be based on a structure (Figure 10) that recognises that as the geographical area of interest gets smaller and more localised, and the number of weed species under consideration decreases, the focus increases on the most effective control option rather than on environmental weed policy or strategy. Similarly there can be increasing local community input and involvement in weed control at the local level. Priorities can be set for local environmental weed problems based on local knowledge and the framework that the environmental weeds database and the integrated environmental weed management methodology provides.

Integration should be based on a common recognition and acceptance of a structure that has an increasing focus on progressively smaller geographic areas. The scales of operation with some examples of determining factors and integration strategies are outlined below (see Figure 11).

These scales are based on a combination of natural determinants and cultural units. Where possible the focus should be based on an appropriate scale determined by an ecological boundary (e.g. soil type, vegetation units) rather than a cultural boundary which often ignores the natural features and thus further complicates weed management and control.

FIGURE 10. CONCEPTUAL ILLUSTRATION OF THE CO-ORDINATION AND INTEGRATION OF THE ENVIRONMENTAL WEED STRATEGY FOR WA

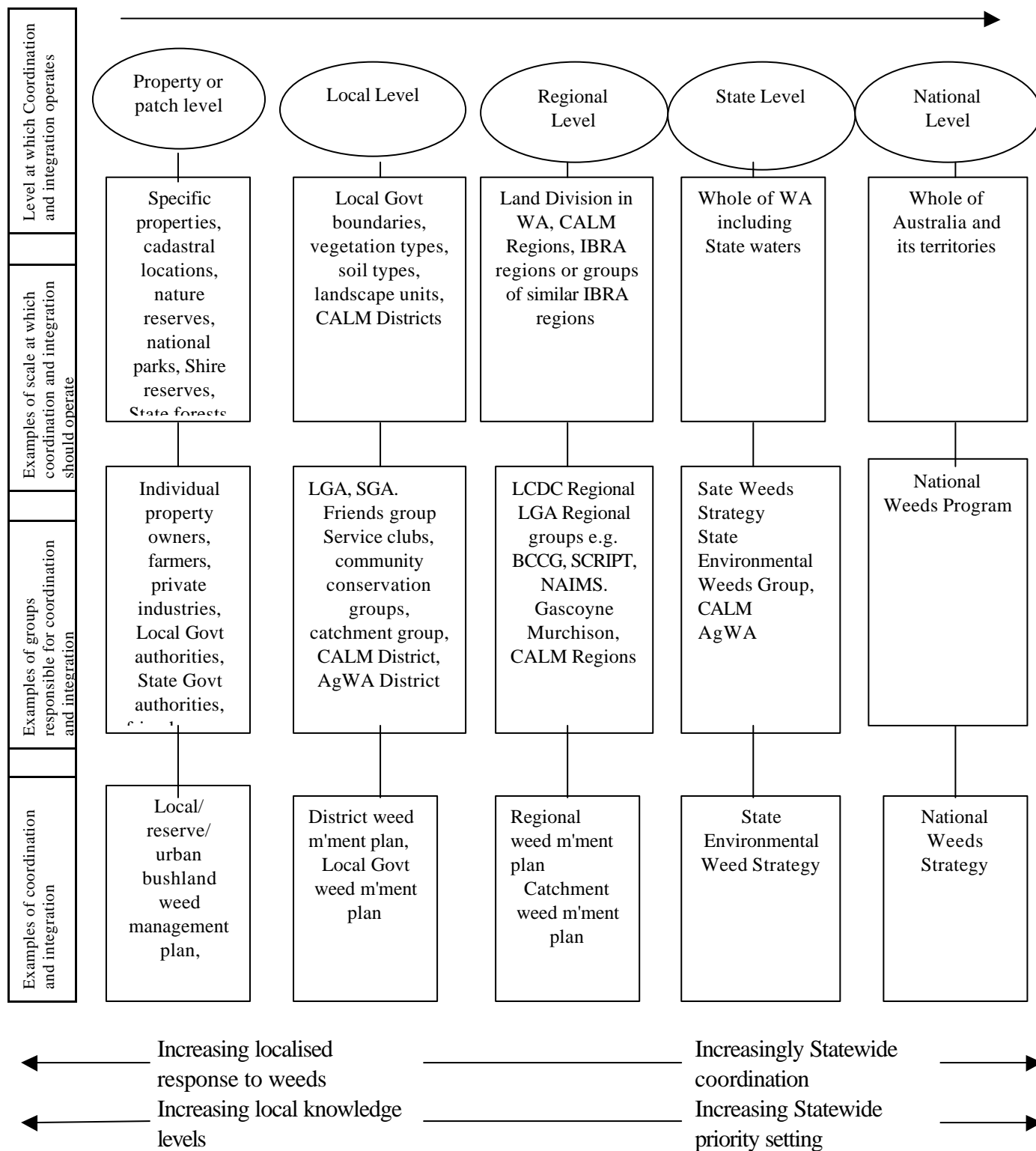
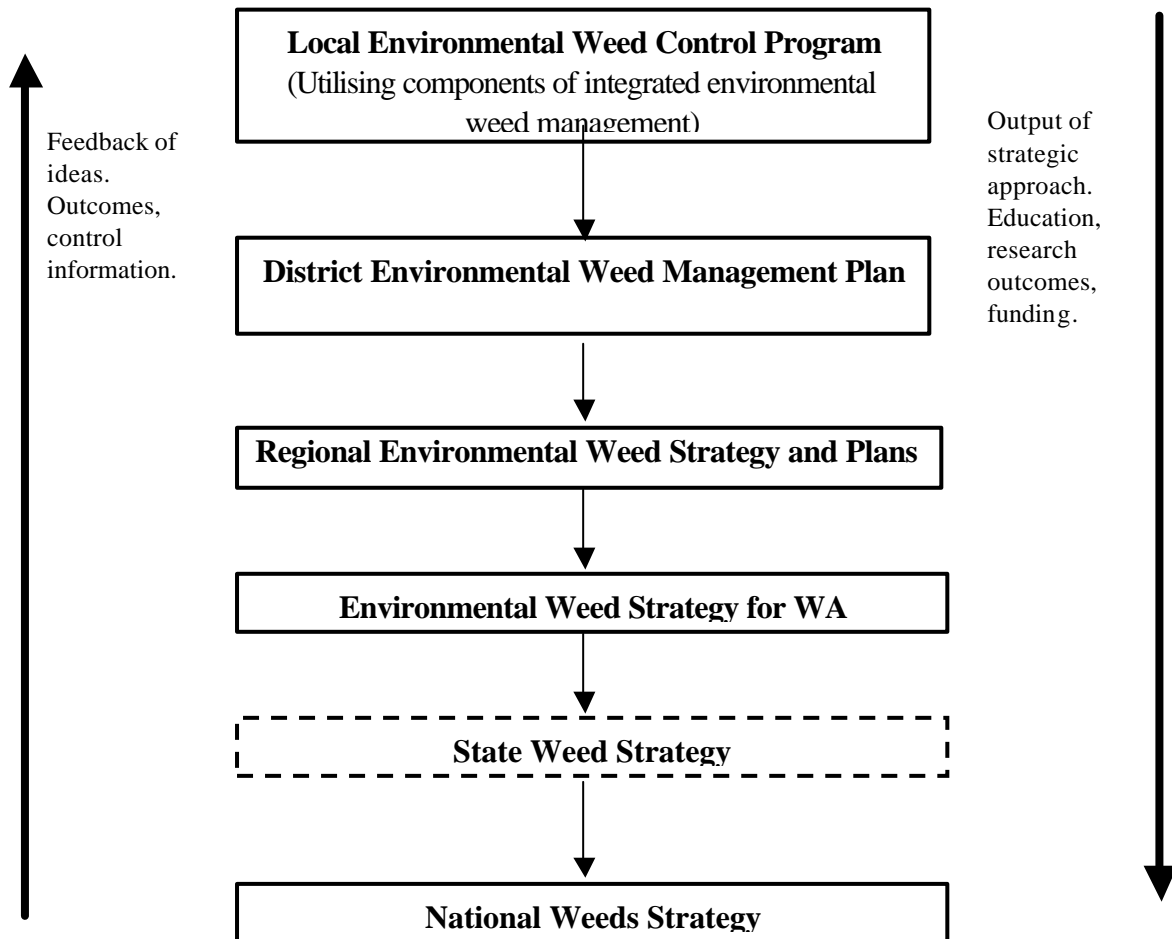


FIGURE 11. HIERARCHY OF RESPONSE TO ENVIRONMENTAL WEED MANAGEMENT CONTROL



SUMMARY

Successful coordination and integration of environmental weed management in Western Australia will require the appointment of an advisory/coordinating body. The Environmental Weed Strategy for Western Australia advocates the establishment of the State Environmental Weed Group.

Integration of activities can be achieved through a State Environmental Weed Group provided it has the acceptance and support of government agencies, local government, industry and the community.

RECOMMENDATIONS		
Number	Action	Responsibility
R6.1	The coordinating group to consist of members from local government organisations, State government agencies, private landowners, industry, research institutions and community organisations. It is proposed that this group be called the State Environmental Weed Group and that members be appointed by the Minister for the Environment.	State Government
R6.2	Provide the State Environmental Weed Group with executive and secretarial support.	CALM

7. ROLES AND RESPONSIBILITIES

Environmental weed problems characteristically cross cultural boundaries including land tenure boundaries, jurisdiction boundaries and boundaries of legal and legislative responsibilities. The coordination and involvement of all of the landholders in a defined geographic area towards collective action will be necessary to instigate effective long term control of any target species within any target area.

It is important to recognise all of the contributions to the Environmental Weed Strategy. A large range of groups have a role or responsibility in environmental weed control in WA. Virtually any agency or group, both government and non-government, involved in natural resource research, regulation and management has a role and or a responsibility in the Environmental Weed Strategy.

An appreciation of the roles and responsibilities of the various groups involved in the Environmental Weed Strategy will assist in further defining and separating the roles of the agencies that comprise the State Environmental Weed Group.

The roles and responsibilities of the myriad of players in environmental weed management and control should be clearly understood in order to provide a better recognition of the current legislative framework and to identify any gaps in responsibility that are not covered by existing structures.

At present there is no legislation that specifically addresses environmental weeds. Current legislation relating to weed control is focused on weeds that impact on agricultural values. There are three pieces of State legislation relating to weed management; Agricultural and Related Resources Protection Act 1976 (ARRP Act), Local Government Act 1996; and the Seeds Act 1981.

The ARRP Act focuses on weeds that impact on agricultural values. Many environmental weeds do not impact on these values and are not declared. The Agriculture Protection Board administers this Act. The Act enables the "declaration" of weeds in various areas of the State. Landholders are required to control all declared plants on their properties. Declaration allocates the target weed to one of five categories of control:

- P1 - Prevention: Plants, which cannot be introduced or spread. Most declared plants are under this category;
- P2 - Eradication: Includes potentially serious weeds which are not yet widely established;
- P3 - Control: Plant infestations should be reduced over time if eradication is not realistic;
- P4 - Containment: Plants should be prevented from further spread;
- P5 - Special action on public land: Provides for control on native reserves, saleyards and roadsides

The Local Government Act allows a local authority to declare plants as "pest plants". Declaration requires the control of that weed species on all lands within the local authority boundary. This legislation has the ability to address environmental weeds but is seldom used. When it is applied

there is no requirement for consistency between adjacent local authorities resulting in uncoordinated and ineffective control.

The Seeds Act controls the movement of plant material into the State. A list of prohibited species restricts the importation of plants that are considered to be potentially damaging weeds. Species of environmental weed may not be included on this list as its focus is on weeds that may be damaging to industry.

Existing legislation such as the CALM Act, Wildlife Conservation Act, Soil and Land Conservation Act and the Environmental Protection Act that deals with environmental values, do not specifically address weeds. The Wildlife Conservation Act is currently under review and is intended to address the impact of environmental weeds on biodiversity in its new form.

A major deficiency of the current legislative framework is that it is fragmented and not directly aimed at environmental weed management. It is recommended that the proposed review of the Wildlife Conservation Act specifically aim at ensuring that there is a legislative framework to support the general thrust of the Environmental Weeds Strategy for Western Australia. The impact of environmental weeds should be taken into account as part of conserving biodiversity.

A model of the roles and responsibilities, showing a hierarchy of response to the implementation of environmental weed management is shown in Table 2.

SUMMARY

Everyone has a role to play in environmental weed management. These roles need to be clearly stated and understood. The lack of a specific legislative base for environmental weed management is a major concern which can be corrected through revision of existing legislation to ensure clarity in defining roles and responsibilities.

RECOMMENDATIONS

R7.1	The lack of a specific legislative base for environmental weed control should be corrected through revision of existing legislation.	CALM
------	--	------

Table 2: MODEL OF ROLES AND RESPONSIBILITIES FOR ENVIRONMENTAL WEED MANAGEMENT

Group or Agency									
	Co-Ordination	Policy	Legislation	Funding	Research	Monitoring	Education	Advocacy	Environmental Weed Control
Federal Government Agencies									
CSIRO									
Australian Quarantine and Inspection Service									
Environment Australia									
Dept of Primary Industry									
Defence Department									
State Government Agencies									
Department of Conservation and Land Management									
Agriculture Western Australia									
Water and Rivers Commission									
Department of Environment Protection									
Main Roads WA									
Department of Land Administration									
Westrail									
Western Power									
Alinta Gas									
Water Corporation									
Swan River Trust									
Other State Level Boards, Authorities and Committees									
Lands and Forest Commission									
National Parks and Nature Conservation Authority									
Environmental Protection Authority									
Kings Park Board									
Roadside Conservation Committee									
Gordon Reid Foundation									
Pastoral Lands Board									
Rottnest Island Authority									
Local Government Interests									

Individual Local Government Authorities									
	Co-Ordination	Policy	Legislation	Funding	Research	Monitoring	Education	Advocacy	Environmental Weed Control
Local Government Regional Groups									
WA Municipal Association									
Country Shire Councils Association									
Local Volunteer Bush Fire Brigades									
Non Government Organisations									
Greening Western Australia									
Environmental Weeds Action Network									
Australian Association of Bush Regeneration (WA)									
Plant Protection Society									
Wildflower Society									
WA Naturalists Club									
Birds Australia									
Conservation Council of WA									
Australian Association Environmental Education									
Friends Groups									
Land Conservation Districts									
Catchment Groups									
Regional Partnership Groups									
Progress Associations									
Nursery Industry Association									
Farming Groups									
Australian Bush Heritage Fund									
National Trust of WA									
Private conservation land managers									
Urban Bushland Council									
Private Enterprise									
Farmers									
Mining Companies									
Bush Regenerators									
Nurseries									
Seed Companies									

Rehabilitation/Revegetation Companies									
Environmental Consultants									
Landscape Architects									
Private Landowners									

8. RESOURCES

In order to adequately deal with the challenges that effective environmental weed control in WA presents it is essential to have an understanding of the many and varied resources that will be needed to implement the Environmental Weed Strategy for WA. This section outlines some of these resources and how they can be utilised in a coordinated manner by the many players in the Strategy.

Currently available resources needed to be identified as well as potential resources and resource deficiencies. The basic resources needed to implement the Strategy have been divided into the broad categories of people resources, information resources and funding resources. These are briefly described below

8.1. Human Resources

Well-trained human resources are scarce. People's expertise, skills, knowledge and experience need to be fully appreciated and utilised to best effect to meet the needs of the Environmental Weed Strategy. Training is required to broaden the human resource base in numbers of individuals involved and increase the skill level of new recruits and volunteers generally.

There is also a need to educate the public as a whole about environmental weeds and the Environmental Weed Strategy. Volunteers should be encouraged to work on environmental weed control where appropriate though they should be adequately coordinated, trained, managed and resourced and their efforts fully appreciated and recognised.

8.2. Information Resources

Information on environmental weeds needs to be generated, disseminated and applied to meet the needs of the Environmental Weed Strategy.

Existing applicable information within Australia and overseas needs to be utilised as much as possible through improved mechanisms of sharing, exchanging and disseminating information. This can be achieved in a variety of ways including seminars, workshops, field days, newsletters, and environmental weed web sites. All current and useful sources of information on environmental weeds needs to be made accessible and specifically promoted.

The availability of information on environmental weeds is generally limited and the Environmental Weeds Database (WeedBase) is aimed at filling some of these gaps. The database needs to be progressively completed as research and monitoring results improve our knowledge-base on the existing and potential environmental weeds of WA. It also needs to be regularly updated and

promoted to the relevant level in the environmental weed response hierarchy. Information on species specific control needs to be promoted at the most appropriate level.

Where a specific lack of information has been identified the required new information should be gathered through targeted research projects. The need for research and its funding should be coordinated through the State Environmental Weed Group in order to maximise the return on the available research funding and avoid unnecessary duplication. Priorities for detailed longterm research such as biological control of environmental weeds will need to be coordinated nationally.

8.3. Funding Resources

Money is an essential resource that is primary to the success of the Environmental Weed Strategy, as the task is both large and complex.

A detailed understanding of the opportunities available to gain funding for the implementation of the strategy will be essential to its success. As many of the integrated environmental weed management programs are long term, securing long term funding commitments will be necessary. Short term and one-off annual funding will not meet all of the requirement of the Environmental Weed Strategy. The costs of environmental weed control will need to be shared equitably within the community as the benefits of environmental weed control are often not immediately identifiable or attributable to any one group in society.

Funding is available from both recurrent sources (e.g. annual grant schemes, departmental budgets) and also from one off special grants (e.g. the Natural Heritage Trust, industry sponsorships or the Gordon Reid Foundation).

SUMMARY

Environmental weed management in Western Australia will require significant resources to be successful. Resources include people resources, information resources and funding. Weed management is long term and resources need to be applied in the long term if the Environmental Weed Strategy is to be successful.

RECOMMENDATIONS		
Number	Action	Responsibility
R8.1	Identify Government, industry and community resources and skills available for weed control. Identify deficiencies and recommend options for resolution.	Agencies, industry and community groups with assistance from SEWG.
R8.2	Identify sources of and promote funding for control of environmental weeds.	Agencies and community groups with assistance from SEWG.

9. PUBLIC AWARENESS AND COMMUNITY INVOLVEMENT

9.1. Introduction

The community plays a substantial role in extending the knowledge, enthusiasm and human resources for environmental weed management across the vast areas of Western Australia. A growing number of community members are contributing to the awareness and control of environmental weeds. In many cases the community has resources which are not readily available to government, such as grants and labour.

Since the 1970's there has been a growing awareness of the role of environmental weeds and their impacts on the natural environment. Joan Bradley wrote her first book on the value of weed control and developed the concept of 'bush regeneration' in Australia (Bradley 1971). Since that time there has been a rapid increase in the concern and practical involvement in weed management.

Some of the community groups involved and concerned about the management of environmental weeds include:

Group	Description
Environmental Weeds Action Network (EWAN)	A group concerned with environmental weeds – lobbying for recognition of their importance and management needs
Australian Association of Bush Regenerators (WA) AABR(WA)	Fosters and encourages sound ecological practices of bushland management including weed removal and restoration
ECOPLAN	A Department of Environmental Protection initiative to encourage and train community involvement in bushland care and management
Friends Groups	There are probably over 150 Friends groups in the State involved in bushland management
Catchment Groups	A large number of community catchment groups exist which undertake river and catchment restoration work
Land Conservation Districts (LCD's)	Landcare groups are a well established community organisation involved in fostering sustainable land management practices
Wildflower Society	The Wildflower Society undertakes flora and vegetation surveys and is active in environmental weed publications
National Trust of WA	Concerned with the preservation of bush and

	natural environment. Manages some bushland areas
Urban Bushland Council	Lobby group for bushland protection and management
Conservation Council of WA	Umbrella group for various conservation organisations
Botanical Societies e.g. Broome Botanical Society	Undertakes botanical surveys of flora and weeds
Plant Protection Society	Has a very specific interest in weeds and has published widely including <i>Western Weeds</i>
Coastal Marine Alliance	A group interested in marine ecosystem conservation including introduced marine flora
Greening WA	A community based group organisation with a focus on revegetation and protecting remnant vegetation
Australian Trust for Conservation Volunteers	ATCV provides a voluntary workforce which assists in conservation works including weed control programs
APACE Aid Inc.	Apace runs Introduction to Bush Regeneration courses

9.2. Support

Support for community groups comes from a wide range of sources. For those groups directly involved in weed management and control, support is in the form of government assistance such as training and awareness (e.g. ECOPLAN). Training is also carried out by community organisations such as Apace Aid (Inc). Community groups also produce newsletters that contain information items on weed control and management. A number of large and small seminars and workshops have been organised by various community groups to help establish best practice management techniques for weed management

The WA Herbarium has developed the Regional Herbaria Project, which supports and trains community groups to collect and curate their own plant specimens. The program is being broadened to embrace naturalised species.

Local authorities provide assistance to community groups in the form of tools, machinery and funding. Grants such as the Gordon Reid Foundation (Lotteries Commission) grants, the Natural Heritage Trust grants and others support efforts to coordinate and facilitate community action on environmental weed management.

9.3. Benefits

Community groups contribute to the management of environmental weeds in a number of ways, these include:

- Raising awareness of the significance of environment weeds
- Lobbying government and the private sector for more resources to be put into weed management
- Direct control of weeds through the control or removal of environmental weed populations in bushland areas
- Bushland restoration
- Informing government agencies on occurrence and distribution of weed population (e.g. flora surveys)
- Experimentation with weed control methods
- Contributing to a positive community attitude to the importance of native vegetation
- Establishment of local and regional herbariums so that weeds can be easily identified
- Preparing publications on the identification and control of weeds species
- Holding seminars and workshops on weed management

The community has a long standing commitment to the conservation and management of our native environment and properly resourced, it can provide a major role in managing environmental weeds. Integration of community led programs into the broader Environmental Weed Strategy for WA, and the strengthening and support of partnerships and networking between community groups and other agencies will ensure that all efforts contribute to achievement of broader goals.

9.4. Constraints

There are important constraints to community involvement in practical weed control work particularly volunteer work. For example, people who lack training in weed recognition and removal may unwittingly contribute to the weed problem through the removal of non target species and unnecessary disturbance of the soil. Volunteer weed removal programs often lack follow-up work in successive years because of lack of energy or time and hence primary weed removal weed work can have minimal, if not negative, effects on the native ecosystem. Some of the other constraints on community involvement in weed management include:

- Lack of partnership and recognition – there is no explicit code of practice between landowners (such as Councils) and community groups such as friends groups which identify roles and recognises and rewards effort and achievement (although this is starting to emerge more strongly now).
- Lack of promotion – there is a general lack of broad scale promotion of the impacts of environmental weeds and the contribution the community can make to managing them.
- Lack of training and education – only one course currently exists (Introduction to Bush Regeneration) which teaches an integrated way of managing bushland including weed

identification and removal. TAFE or other education institution as yet have not developed courses which have specific training on environmental weed management.

- Standards of training and experience need to be developed so that weed management work is carried out with a proper understanding of the restorative processes of the environment. Developing standards for environmental weed management and control work is critical for successful implementation of management programs.
- There is generally poor coordination between government and non-government agencies who manage land areas which contain remnant ecosystems.
- Monitoring and support for monitoring programs is generally lacking or poorly resourced and executed.
- Weed management, particularly weed removal work, is difficult and sometimes dangerous. The scale of weed control required is large and can not be done by community volunteers alone. Support in the form of qualified professional bush regenerators, either employed by government or private practice, is required to provide the main front of attack with support from local volunteers. Management programs need to be long term to ensure that weed control is properly augmented.
- A general lack of expertise is available to community groups to help them tackle the weed problem they are addressing. This reflects both the lack of work being undertaken in this area and also the lack of training and research programs available.

9.5. Future Directions

Community involvement in recent years in environmental weed management has been strategically important. Community groups have played an advocacy role and set the direction and pace for tackling this major environmental problem. Future support for community involvement in weed management needs to be considered in the light of the integrated processes recommended in this strategy.

9.5.1. Public Awareness and Promotion

Important considerations for the future of community involvement include public awareness and promotion to make people aware of:

- Their personal impact on native vegetation
 - carrying weed seeds on vehicles, produce, footwear and clothing
 - pets such as dogs, cats and horses carrying weed seeds in their coats and droppings, and increasing the soil nutrients through their droppings
 - horses through the above and also soil disturbance
 - dumping of garden refuse which contains potential weeds
 - trampling and destruction of vegetation leading to weed invasion, and
 - the role of fire in promoting weed invasion of bushland.
- Liaison and lobbying both print and television media for a focus on environmental weeds in

- gardening and environmental programs
- posters and pamphlets to help people identify weeds and learn how to control them
- promotion of Weed Buster Week
- publishing the work that is being carried out by community groups
- providing an award system for groups which demonstrate outstanding commitment and success to environmental weed management, and
- development of internet web sites.

9.5.2. Education and Training

Training programs in bush regeneration and restoration ecology techniques need to be developed so that community volunteers can be trained in preparing weed management plans, restoration plans and specific weed control techniques. These training programs should be based on the best practices elsewhere in Australia and made available to community groups.

- Community volunteers need to be educated. Planning and training is critical before any weed control programs are undertaken in bushland areas.
- Local government should take a lead role in developing bush regeneration trained field staff so that they can work with and direct community volunteer efforts. Local governments could also facilitate workshops with community groups on the weed problem within its boundaries and the means by which it is going to manage it.
- Promotion of community involvement such as through ECOPLAN should be expanded to rural areas to increase awareness and training in these communities. It would also help promote greater integration and co-operation between city and rural communities.
- Standards – adequate standards of training and experience need to be developed for people undertaking weed management work (e.g. the Australian Association of Bush Regenerators (WA) have standards for bush regeneration professionals).

9.5.3. Research and Environmental Weeds Database

Community groups should be encouraged to participate in research programs such as identifying and reporting the occurrences of weeds in Western Australia so that the knowledge of environmental weed distribution is increased. Community groups should be encouraged to experiment with different weed control methodologies and monitor and report their success. These can be entered onto the environmental weeds database as suggested methods of control.

Community groups should be encouraged to participate in the development of the environmental weeds database through inputting data such as weed distributions, photographs of weeds, weed control methods etc thus making it a community resource.

SUMMARY

The community is now playing a significant beneficial role in environmental weed management and awareness raising in Western Australia and have some support from government and through community led training. Significant constraints have been identified to greater involvement by the community in achieving best practice and in maximising outcomes. These constraints need to be overcome to maximise outcomes in mobilising the community not only in actual weed control but also in awareness raising, training, research and monitoring of environmental weeds in WA.

RECOMMENDATIONS		
Number	Action	Responsibility
R9.1	Increase public awareness of the importance of and threats posed by environmental weeds.	Agencies and community groups with assistance from SEWG.
R9.2	Encourage and support community participation in all aspects of weed management and control.	Agencies supported by SEWG where required.
R9.3	Support existing training programs for weed control and bush regeneration. Encourage establishment of new training programs.	Agencies, educational institutes, community groups supported by SEWG where required.

BIBLIOGRAPHY

- Adair, R.J. (1995) The threat of environmental weeds to biodiversity in Australia: a search for solutions, in *Conserving Biodiversity: Threats and Solutions*. (eds) R.A. Bradstock, T.D. Auld, D.A. Keith, R.T. Kingsford, D. Lunny & D.P. Sivertsen, pp. 184-201. S Beatty & Sons. Sydney.
- Adair, R.J. and Groves, R.H. (1998) *Impact of Environmental Weeds on Biodiversity: A Review and Development of Methodology*. National Weeds Program. Environment Australia. Canberra.
- Anon (1996) *WeedPlan: A Tasmanian Weed Management Strategy*. Ministerial Working Group for the Development of Tasmanian Weed Management Strategy.
- Anon (1997) *The National Weed Strategy: A Strategic Approach to Weed Problems of National Significance*. Agricultural and Resource Management Council of Australia and New Zealand, Australian and New Zealand Environmental and Conservation Council, Forestry Ministers.
- Bradley, J. (1971) *Bush Regeneration*. Mosman Parklands and Ashton Park Association, Sydney.
- Bradley, J. (1988) *Bringing Back the Bush: the Bradley method of bush regeneration*. Landsdowne Press. Sydney.
- Bridgewater, P.B. & Backshall, D.J. (1981) *Dynamics of some Western Australian ligneous formations with special reference to the invasion of exotic species*. *Vegetation* **46**, 141-148.
- Carr, G.W., Yugovic, J.V. and Robinson, K.E. (1992) *Environmental Weed Invasions in Victoria: Conservation and Management Implications*. Department of Conservation & Environment and Ecological Horticulture Pty Ltd: Melbourne.
- Carr, G.W. (1993) Exotic flora of Victoria and its impact on indigenous biota, in *Flora of Victoria* Vol. 1 (eds) D.B. Foreman & N.G. Walsh, pp. 256-298. Inkata Press. Melbourne.
- Csurhes, S. and Edwards, R. (1998) *Potential Environmental Weeds in Australia*. Candidate Species for Preventative Control. National Weeds Program. Environment Australia.
- Ecoscape (1994) *Environmental Weeds in Perth's Urban Bushland*. Report to Department of Environmental Protection.
- Hale, P. and Lamb, D. (1997) *Conservation Outside Nature Reserves*. Centre for Conservation Biology, University of Queensland.
- Hobbs, R.J. and Humphries, S.E., (1995). An integrated approach to the ecology and management of plant invasions. *Conserve. Biol.* **9**: 761-70.
- Hobbs, R.J. and Saunders, D.A. (1995) Invasive Weeds: Prevention is the Key, in *Invasive Weeds and Regenerating Ecosystems in Western Australia*. Conference Proceedings. G. Burke (ed), Murdoch University, WA.
- Humphries, S.E., Groves, R.H. & Mitchell, D.S. (1991) *Plant Invasions of Australian Ecosystems*. Status Review and Management Directions. *Kowari* **1**, 1-127.

- Humphries, S.E., Groves, R.H. and Mitchell, D.S. (1993) Plant invasions: homogenizing Australian ecosystems. pp. 149-170 in *Conservation Biology in Australia and Oceania* ed. by C. Moritz and J. Kikkawa. Surrey Beatty & Sons. Chipping Norton.
- Humphries, S.E. (1995) Weeds – Insidious Threats to Biological Diversity pp 4-7 in *Invasive Weeds and Regenerating Ecosystems in Western Australia*. Conference Proceedings. G. Burke (ed), Murdoch University, WA.
- Hussey, B.M.J., Keighery, G.J, Cousens, R.D., Dodd, J. and Lloyd, S.G. (1997). *Western Weeds: a guide to the weeds of Western Australia*. Plant Protection Society of Western Australia (Inc.).
- Kaesehagen, D.B. (1995) Bushland Condition Mapping pp 33-39 in *Invasive Weeds and Regenerating Ecosystems in Western Australia Conference Proceedings*, G. Burke (ed), Murdoch University, WA.
- Keighery, B.J., (1993) Draft Disturbance and Vegetation Condition, from *draft Plant Community Survey for the Community* by Bronwyn Keighery for the Wildflower Society of Western Australia.
- Keighery, G.J. (1995). An Annotated List of the Naturalised Vascular Plants of Western Australia in *Invasive Weeds and Regenerating Ecosystems in Western Australia*. Conference Proceedings. G. Burke (ed), Murdoch University, WA.
- McDonald, M.C., (1996) *Ecosystem Resilience and the Restoration of Damaged Plant Communities: A Discussion Focusing on Australian Case Studies*, PhD. Dissertation, University of Western Sydney-Hawkesbury.
- Panetta, F.D. and Hopkins, A.J.M. (1991) Weeds in corridors: invasion and management. pp. 341-351 in *Nature Conservations 2: the Role of Corridors*. ed by D.A. Saunders and R.J. Hobbs, Surrey Beatty & Sons. Chipping Norton.
- Pigott, J.P. and Sage, L.W. (1997). Remnant vegetation, priority flora and weed invasions at Yilliminning Rock, Narrogin, Western Australia. 'Proceedings of the Granite Outcrops Symposium', Journal of the Royal Society of Western Australia, 80, 201-208.
- Scheltema, M. and Harris, J. (eds) (1995) *Managing Perth's Bushlands*. Greening Western Australia, Perth.
- Thackway, R. and Cresswell, I.D., (1995). *An Interim Biogeographic Regionalisation for Australia: a framework for establishing the national system of reserves*. Version 4.0 Canberra: Australian Nature Conservation Agency.
- Thorp, J.R. (1998) *Weeds of National Significance*. Standing Committee on Conservation. Out of Session Paper.
- Virtue, J. and Cooke, D. (1997) *National Weeds Strategy: "National Significance" Criteria Survey*. Animal and Plant Control Commission, South Australia.
- Wycherley, P., (1984). *People, Fire and Weeds: can the vicious spiral be broken?* pp 11-17 in *Management of Small Bush Areas in the Perth Metropolitan Area* ed by S.A. Moore. Department of Fisheries and Wildlife, Perth.