

Pathway risk
analysis for
weed spread
within Australia
(UNE61)

Summary of Project Results

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Further Information

The final project report is available from Land & Water Australia, and may also be downloaded free of charge from:

www.ruralfutures.une.edu.au

(Institute for Rural Futures, University of New England).

The final report for the related project, *Best practice for on-ground property weed detection*, is also available at the same address.



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Introduction

There has been considerable effort to elucidate the means by which weeds and potential weeds enter Australia (e.g. Groves 1997) and to assess the risks associated with the importation of plants (Groves *et al.* 2001). However, no comprehensive studies have been undertaken to ascertain the ways that weeds spread once present within Australia, or to assess the relative threats or risks (likelihood and potential magnitude) of different weed ‘sources’ and ‘pathways’ due to species, quantity of propagules, distance, and sensitivity of the invaded environment.

The overall goals of this project were to:

- assess the relative risks of the different sources and pathways of weed ingress within Australia; and
- identify ways to reduce these risks.

The first stage of the project involved a review of Australian and International literature on weed spread. The review identified various weed sources and pathways, and sought to evaluate the effectiveness of management approaches to halt weed movement. ‘Source’ and ‘pathway’ are defined on the following page.

Many individuals and organisations, including research and extension agencies, have first-hand experience in the form (levels) and function (principles) of weed spread. The second stage of this project involved collating the experience of these individuals and organisations with respect to each of the weed sources and pathways identified in the review of literature, to build a major repository of information regarding the relative risks of weed sources and spread pathways in Australia.

Australian scientific weed experts were identified and surveyed by questionnaire to provide their experience of relative risks of weed ingress, the effects of changing trade patterns and environmental conditions, and effective management techniques. Over 100 responses to the survey were received.

The purpose of this booklet is to provide a summary of the key findings from this survey. The section on weed sources is followed by a short description of the various pathways of weed ingress. Trends found between pathways are described followed by a description of the findings of each pathway. This booklet concludes with the outlook of each pathway in the future.

Definitions

What is a weed?

A weed is a plant that requires some form of action to reduce its harmful effects on the economy, environment, human health and amenity (Australian Weeds Committee 2006). This definition includes plants not native to Australia and native plants growing outside their known natural range.

What is a pathway?

A pathway is described by Barker (2006) as any means or mechanism by which weed plants or propagules may be dispersed. In the case of human directed activities, spread may be through either intentional trade in invasive plants or their propagules for some perceived benefit, or as a result of contaminated products, clothing, machinery, equipment etc.

What is a source?

A source differs from a pathway in that it is not the means of moving weeds. It is a site or area of land where weeds are actively growing and from which new invasions may emerge.

What is a propagule?

A propagule is any structure with the capacity to give rise to a new plant, e.g. a seed, stem or a vegetative part of a plant, capable of independent growth if detached.

What are the sources of weed ingress in Australia?

Twenty-four sources of weeds were identified in the review of literature. Survey respondents were asked to rate the importance of each weed source as a contributor to weed spread within Australia, on a scale of 1 ('Not Important'), to 4 ('Very Important'). Each source and its mean rating are presented in Table 1. While there are clearly more important sources of weed ingress in the opinion of survey respondents, all sources listed in Table 1 were considered to be at least somewhat important.

Weed Source	Description	Mean Rating
Transport	Roads, railways, ports and water transport, airports etc.	3.62
Land in transition	Degraded, abandoned, unused land	3.38
Pasture/rangelands	Cattle, sheep, dairy, goats, etc.	3.37
Horticulture – ornamental	Fresh flowers, garden plants, aquarium plants, bulbs and seeds, etc.	3.36
River	Natural water courses, streams, creeks, etc.	3.33
Private gardens	Includes water gardens and aquariums	3.33
Channel/aqueduct	Artificial water courses for supply or drainage	2.90
Utilities	Sites used for energy or telecommunication i.e. for generation, storage, transmission	2.87
Waste treatment and disposal	Landfill, green waste, stormwater, sewage, etc.	2.76
Cropping	Dryland and irrigated	2.69
Public gardens	Botanic, civic, zoos, schools, water gardens etc.	2.60
Minimal use	Stock route, residual native cover, rehabilitation etc.	2.60
Forestry	Native and planted forests	2.56
Defence	Land owned or managed by the Australian Defence Forces	2.53
Horticulture – edible	Fruit, nuts, bulbs, roots, seeds, berries, herbs, vegetables, etc.	2.53
Marsh/wetland	Ephemeral and permanent	2.51
Mining	Mines, quarries, tailings, etc.	2.51
Estuary/coastal waters	Beach, dunes, mangroves, etc.	2.38
Nature conservation	Nature reserves, national parks, flora and fauna reserves, traditional / indigenous land, other protected landscapes	2.38
Research	Plant research and development facilities	2.33
Intensive animal use	Feedlots, pigs, poultry, saleyards, aquaculture, etc.	2.33
Reservoir/dam	Artificial body of standing water	2.32
Lake	Natural body of standing water	2.27
Manufacturing and services	Commercial centres and industrial estates	1.99

Table 1: The importance of weed sources, where 1 = 'Not important' and 4 = 'Very Important'.

What are the pathways of weed spread within Australia?

Seventeen different pathways for weed spread in Australia were identified in the review of literature. For the survey of weeds professionals, these pathways were grouped according to: deliberate spread by humans, accidental spread by humans, and natural spread. Survey participants were asked a range of questions in relation to each of the pathways, and were asked to address only those pathways with which they were most familiar. The pathway names and definitions are listed in Table 2.

Pathways for the spread of weed propagules within Australia	
Deliberate Spread by Humans	
1. Ornamental plant trade	Through nursery sales and escape of garden and landscaping plants.
2. Aquarium plant trade	Through sales at nurseries, pet shops and escape into waterways.
3. Medicinal plant trade	Plants propagated and sold in nurseries and among alternative medicine enthusiasts.
4. Food plant trade	Plants grown and promoted as food for humans.
5. Fodder trade	Sales and planting of fodder plants for livestock grazing.
6. Revegetation and forestry	Planting for soil conservation and to produce timber.
Accidental Spread by Humans	
7. Human apparel and equipment	Attachment of seeds to clothes and footwear.
8. Machinery and vehicles	Attachment of seeds to passenger vehicles, slashers, farm equipment, boats, and earth moving equipment.
9. Construction and landscaping materials	Contamination of gravel, soil, sand, mulch and turf.
10. Agricultural produce	Contamination of hay, grain and pasture seed.
11. Research sites	Escape from research sites.
12. Livestock movement	Through faeces or attached to livestock such as sheep, cattle, horses and goats.
13. Waste disposal	Unsafe dumping of garden refuse and aquarium plants.
Natural Spread	
14. Birds	Through consumption and excretion of seeds and fruits.
15. Other animals	Through consumption and excretion of seeds and fruits, and external attachment to native and introduced wildlife.
16. Wind	Distribution of wind blown seeds.
17. Water	Distribution of seeds or plant parts via waterways.

Table 2: Pathways of weed spread.

Pathway risk summary

The following two pages provides a brief overview of results from the survey. The next section of this booklet includes a more detailed discussion of survey results in relation to the specific risks posed by each of the pathways identified in this project.

Which pathways currently pose the greatest risks?

According to survey respondents, trade in fodder, ornamental and aquarium plants, contamination of agricultural produce, machinery and vehicles, and natural water movement features were considered to have the greatest overall capability to spread weeds, and therefore currently pose the highest risk. Nonetheless, all pathways were regarded as having relatively high capability to cause weed spread (see Figure 1). Specific weed spread pathway capabilities are discussed from page 8 onwards.

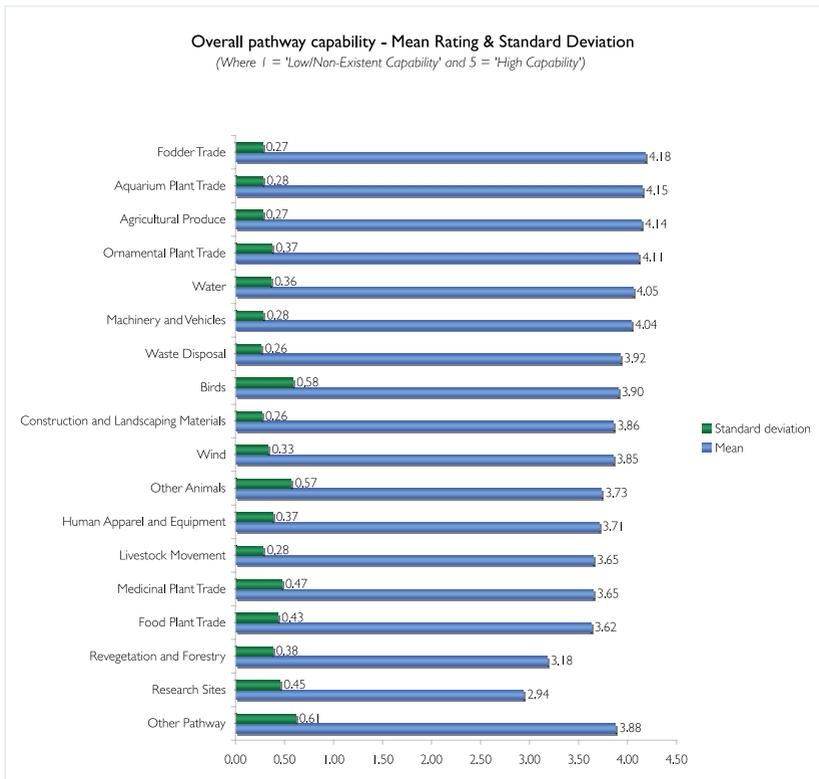


Figure 1: Overall capability of pathway to cause weed spread.

In what ways are the risks changing with changing environmental conditions, local trade and changes in other patterns of movement?

As a pathway for weed spread, water was considered to be increasing in importance due to the apparent increase in climatic variability, with droughts followed by floods, and because of lack of herbicides for use along waterways.

The risks involved with agricultural produce increase during periods of drought due to *'movement of stock fodder from interstate or even overseas.'*

Machinery and vehicles were considered to be of increasing importance for weed spread due to increasing traffic movement.

The ornamental plant trade was gauged as becoming more important as the industry continues to grow, and as the urban and peri-urban sprawl takes ornamental plants out into otherwise rural areas. However, some respondents believed that trade in ornamental plants may become less important over time as a contributor to weed spread, due to increasing awareness of this method of weed spread by the nursery sector and public in recent years.

How can current and emerging risks be managed?

For each weed spread pathway identified in the survey, at least 50 per cent of respondents believed that regulatory and management strategies currently in place were inadequate. Management strategies specific to each weed spread pathway, as suggested by survey respondents, are discussed on the following pages.

On what potential sources and pathways do we have insufficient information to identify their importance or to design management strategies?

The pathways about which respondents appeared to have the least knowledge included human apparel and equipment, food plant trade, revegetation and forestry, other animals, waste disposal, medicinal plant trade and construction and landscaping materials. This suggests that these pathways are in most need of further research to quantify their contribution to the spread of weeds within Australia.

Birds stood out as the pathway where the highest percentage of respondents (57.9 per cent) believed that there is insufficient information to design management strategies for the pathway. Other significant pathways in this regard included other animals, medicinal plant trade and human apparel and equipment. Generally, these pathways tend to avoid detection strategies currently in place.

What are the risks associated with each weed spread pathway?

In the survey we asked respondents to identify the pathway or pathways with which they were most familiar, and to answer a range of questions with respect to each pathway. These questions related to the characteristics of the pathway (leading to an overall measure of each pathway's capacity to spread weed propagules), adequacy of current regulatory and management arrangements, the importance of the pathway in the future, and Australian research into the pathway. Each pathway is discussed on the following pages on an individual basis, in the context of these questions.

Respondents were asked to rate the various capabilities of the pathways using a numeric scale, where 1 equalled a low or non-existent capability, and 5 equalled a high capability (Table 3). These capabilities included:

- ability to transport weeds quickly over long distances (>1km),
- ability to transport a high diversity of weed species,
- ability to transport large numbers of weed propagules in a single event,
- ability to transport weeds frequently,
- ability to introduce weeds into hospitable environments,
- ability to avoid/overcome prevention and management strategies,
- ability to transport weeds into sensitive areas, and
- hospitability to weeds (able to deliver live plants or viable propagules).

The overall mean rating of each pathway for all capabilities combined is discussed on the following pages.

Definition	Score
Low/Non-existent capability	1
	2
	3
	4
High capability	5

Table 3: Numeric scale adopted to determine the capability of each pathway

Ornamental plant trade

Weed spread via this pathway occurs through nursery sales, and garden and landscape ‘escapee’ plants.

The capability of weeds to spread by the ornamental plant trade was determined by respondents overall to be high (mean 4.11[†], standard deviation 0.37). Eighty-seven responses were received for this pathway.

This pathway was gauged by respondents as becoming more important in the future for a number of reasons, including:

- the continued growth of the industry;
- the peri-urban sprawl, which is taking ornamental plants out into rural areas; and
- due to climate change, demand by the public for drought adapted species for dry gardening.

It should be noted, however, that some respondents (12.8 per cent) believed that the importance of the ornamental plant trade as a pathway for weed spread may *decrease* in the future, due to increasing awareness of the pathway, and tightened regulation.

Approximately 29 per cent of respondents believed that there was insufficient information to identify the importance of the ornamental plant trade pathway. Furthermore, 32.6 per cent of respondents agreed that there was insufficient information to design management strategies.

The nursery and garden industries are actively working to reduce the number of invasive plants that are grown and sold in Australia. A set of national labelling guidelines has been developed, including a section on invasive and potentially harmful plants. The guidelines are recommended for adoption by all plant producers, suppliers of plant material, plant retailers and label manufacturers. See the full review of literature (*available from www.ruralfutures.une.edu.au*) for more information.

Educating nurseries, the landscaping industry and the public was considered critical in the management of current and future risks, according to 26.5 per cent of survey responses. Almost 9 per cent of responses indicated that improvements in the weed risk assessment process of ornamental



[†] Refers to the current capability of a pathway for weed ingress; see Table 3 on page 8.

plants were necessary for the management of current and future risks of this pathway.

Finally, it was noted that produce markets and private plant collectors are harder to regulate for the ornamental plant trade pathway, to a greater extent than nurseries.

Aquarium plant trade

This pathway involves sale of weedy aquatic plant species at nurseries, pet shops, and escape of these species into waterways (either accidentally or through dumping). Virtually all of Australia's major aquatic weed species were originally imported for use in garden ponds or as ornamental aquarium plants (Csurhes and Edwards 1998).



Forty-six participants answered the questions on the current capability of the aquarium plant trade pathway to spread weeds. The pathway was assessed as having a relatively high capability in terms of its current ability to spread weeds (mean 4.15[†], standard deviation 0.28).

Half of the respondents believed that, in the future, the aquarium trade would remain as important a pathway for weed spread as it is currently, while 37.5 per cent of respondents believed this pathway would increase in importance in the future. Only 4.2 per cent of respondents believed that the pathway would decrease in importance.

Nearly 29 per cent of respondents believed that there was insufficient information to identify the importance of the aquarium plant trade pathway as a means of weed spread. Approximately 36 per cent of respondents agreed that there was insufficient information to design management strategies for the pathway.

The National Aquatic Weeds Management Group, in partnership with State/Territory governments, aquatic plant trade representatives and New Zealand's National Institute of Water and Atmospheric Research, have initiated a Weed Risk Assessment (WRA) of aquatic plants within

[†] Refers to the current capability of a pathway for weed ingress; see Table 3 on page 8.

the ornamental plant trade (Petroeschevsky and Champion 2008). The process ensures declarations will be based on research conducted under Australian conditions and made in consultation with industry. To date, the process has used data on historic and current sales to identify 25 high-risk aquatic plant species for which a national ban is recommended.

Education, extension and publicity activities were considered important to the current and future management of this pathway according to 25 per cent of responses. A further 25 per cent indicated that more research into aquatic weed control was needed to manage future risks with regard to this pathway.

Medicinal plant trade

The spread of weeds via this pathway occurs through plants propagated and sold in nurseries or via mail and internet order, or amongst alternative medicine enthusiasts using potential weed plants for their medicinal or therapeutic properties.

The medicinal plant trade pathway was assessed as having a medium to high capability by respondents overall (mean 3.65[†], standard deviation 0.47) in terms of its current risk of weed spread. Fifteen respondents answered questions on this pathway.



Over one third of respondents (38.1 per cent) believed that the trade in medicinal plants would remain as important as a pathway of weed spread in the future, while 23.8 per cent believed that this pathway would increase in importance in the future.

The main reason for respondents expecting the pathway to grow in importance was related to the “...increasing demand for products from this source, brought about by dissatisfaction with conventional medicine”. However, approximately 29 per cent of respondents believed that this pathway would become less important in the future as a method of weed spread. Reasons given included that “more research (is) going into medicinal plant species for human consumption than ever” and “trade in these species is generally not that

[†] Refers to the current capability of a pathway for weed ingress; see Table 3 on page 8.

large...”. Nearly 10 per cent of respondents were unsure of the future outlook of the pathway.

There was no clear agreement amongst respondents on ways to improve regulation of the medicinal plant trade pathway.

Thirty-five per cent of respondents agreed that there was insufficient information to identify the importance of this pathway. Almost 43 per cent of respondents believed that there was insufficient information to design management strategies for the spread of weeds through medicinal plant trade.

Twenty-five per cent of responses suggested that the current and future risks regarding the pathway could be managed by increasing public awareness.

Food plant trade

This pathway includes plants grown and promoted as food for human consumption, which have the potential to become invasive species.

The current risk of this pathway for weed spread was assessed by survey respondents as medium (mean 3.62[†], standard deviation 0.43). Thirty experts answered questions relating to this pathway.



Almost half (44.8 per cent) of respondents believed that the food plant trade pathway would remain as important in the future. However, a relatively high proportion of respondents (20.7 per cent) believed that this pathway would decrease in importance.

Approximately 40 per cent of respondents believed that there was currently insufficient information to identify the importance of food plant trade as a pathway of weed spread. However, only 30 per cent of respondents believed that there was insufficient information available to design management strategies for this pathway.

Only a few responses were obtained on managing the risks associated with the pathway. Two pertinent comments included “*we need to identify what food plants pose a weed risk*”, and “[*a*] *compulsory weed management system for all weed potential plants [needs] to be written into management plans and implemented/regulated*”.

[†] Refers to the current capability of a pathway for weed ingress; see Table 3 on page 8.

Fodder trade

This pathway of spread occurs through sale and planting of fodder plants for livestock grazing. Of the 290 weed species thought to have naturalized in Australia between 1971 and 1995, 7 per cent were introduced to Australia for agricultural reasons (Groves *et al.* 2005).



Of all the pathways identified in the survey, trade in fodder was considered by respondents to pose the greatest risk of weed ingress (mean capability of 4.18[†] and standard deviation of 0.27). However, it should be noted that at times, respondents confused this pathway with accidental contamination of agricultural produce, including fodder, which was also considered to pose a high risk. Sixty-four respondents answered questions relating to this pathway.

This pathway was assessed as becoming more important in the future by 43.5 per cent of respondents, due to increasing frequency of drought associated with climate change, and an increased need to grow more hardy fodder crops. Furthermore, approximately 50 per cent of respondents believed that this pathway would remain as important in the future as it is currently.

Only 25.4 per cent of respondents believed that there was insufficient information to identify the importance of fodder trade as a method of weed spread. However, 36.5 per cent of respondents believed that there is currently insufficient information to design management strategies for this pathway.

Suggestions for managing future and current risks relating to the fodder trade pathway included greater industry and vendor responsibility, education and labelling, and more research.

The most common improvements identified by respondents with respect to pathway management included certification of weed status by fodder vendors, and extra resources and staff.

[†] Refers to the current capability of a pathway for weed ingress; see Table 3 on page 8.

Revegetation and forestry

Revegetation using exotic and native species occurs for a number of reasons, including stabilization of disturbed areas, rehabilitation of degraded soils, to provide shelter or shade for stock and humans, and to produce timber.

The current risk of this pathway regarding its capability for weed spread was assessed by survey respondents as medium (mean 3.18[†], standard deviation 0.38). Thirty-six experts provided information on the revegetation and forestry pathway.



Approximately 28 per cent of respondents believed that the revegetation and forestry pathway will become more important in the future, 44.4 per cent believed that it will remain as important in the future, and 22.2 per cent believed that its importance will decline in the future. Comments from those who believed the importance of this pathway will decline included that “...*Most revegetation (projects) use local indigenous spp.*”, that there was a “*move to native species*”, and that there was “*more awareness*”.

Just over 36 per cent of respondents believed that there is currently insufficient information available to identify the importance of revegetation and forestry as a pathway of weed spread. At the same time, 30.3 per cent of respondents believed that there is insufficient information to design pathway management strategies.

Respondents often suggested that management of the future and current risks of this pathway required improved management codes, such as “*a contractor code of conduct and practices that ensure a come clean/go clean policy*”, because “*anecdotal evidence received suggests that St. John’s wort has been spread ... from forests in other regions. Debarking of logs, and strict adherence to routes, would make it easier to manage this situation. There would need to be dialogue between foresters and control authorities so that situations could be monitored*”.

The main improvements required to regulate and manage the pathway, according to respondents, include extra resources and staff, and education or extension programs.

[†] Refers to the current capability of a pathway for weed ingress; see Table 3 on page 8.

Human apparel and equipment

Humans can inadvertently spread weed propagules that cling to their hair, clothing and equipment, and within mud on their footwear.

The current capability of this pathway was assessed by survey respondents as being a medium to high risk (mean 3.71[†], standard deviation 0.37). Information on the pathway was provided by 48 respondents.



Over 95 per cent of respondents believe that the spread of weeds via the human apparel and equipment pathway would either remain just as important, or increase in importance in the future due to the increasing human population and increasing visits to wilderness areas (forests, National Parks etc).

However, it was this pathway about which, overall, the experts surveyed for this project appeared to know the least:

- Nearly 43 per cent of respondents agreed that there was insufficient information to identify the importance of this pathway.
- Likewise, nearly 43 per cent of respondents believed that there was insufficient information to design management strategies for this pathway.

Education and publicity was suggested as important in the management of current and future risks of weed spread through this pathway (18.2 per cent of responses), for example amongst bushwalkers and as signage or other information made available in high conservation areas. Research into this pathway was also considered important (18.2 per cent of responses), such as *“on the weed seed adhesion properties and methods of prevention/containment”*.

[†] Refers to the current capability of a pathway for weed ingress; see Table 3 on page 8.

Machinery and vehicles

Spread of weeds by this pathway occurs through the attachment of propagules to passenger vehicles, slashers, farm equipment, boats and earth moving equipment.



Overall, the current capability of this pathway in terms of weed spread was assessed as being high risk (mean 4.04[†], standard deviation 0.28). Eighty-five respondents provided information on the machinery and vehicles pathway.

The risk of weed spread by machinery and vehicles was assessed as likely to increase in importance in the future, given increasing traffic movements, greater use of contractors, and increased development and ‘fragmentation’ of landscapes, such as peri-urban growth, ‘sea-change’ and ‘tree-change’.

Thirty-two per cent of respondents believed that there was insufficient information to identify the importance of machinery and vehicles as a pathway for weed spread. Furthermore, 34.5 per cent of respondents believed that there is insufficient information to design management strategies for this pathway.

Twenty-five per cent of respondents suggested that education was important in the management of current and future risks of this pathway. In addition, one respondent indicated that *“in regards to cars and trucks, it would be useful to have a better understanding of conditions and locations in which propagule loads are shed.”* This would aid with machinery design and the development of more effective wash-down facilities.

A *“paradigm shift in roadside vegetation management by councils”* was also needed according to more than one expert. *“Effective standard operating procedures and hygiene procedures need to be effectively implemented across council roadside vegetation management practices. This means re-educating individuals involved in roadside vegetation management, or imposing work conditions that force compliance. Apathetic, disinterested, attitudes from some workers are a real and serious impediment to change here”.*

A study by Lonsdale and Lane (1994) revealed that vehicle type is an important predictor of seed dispersal ability. Four-wheel drive (4WD) vehicles carried significantly more seeds than two-wheel drive (2WD)

[†] Refers to the current capability of a pathway for weed ingress; see Table 3 on page 8.

vehicles, presumably because of the increased likelihood that 4WD vehicles will be driven off-road. This finding was supported by Moekerk (2006) who also found that passenger vehicles were much more likely than machinery to carry weed seeds, noting that this is somewhat contrary to the popular belief that machinery is more likely to spread noxious weed species.

Construction and landscaping materials

This pathway of weed spread includes the contamination of gravel, soil, sand, mulch and turf used for construction or landscaping.

The current capability of this pathway to spread weeds was assessed by survey respondents to be medium to high (mean 3.86[†], standard deviation 0.26).

Information on the construction and landscaping materials pathway was provided by 39 respondents.



Sixty-two per cent of respondents believed that the construction and landscaping materials pathway would remain as important in the future as a means of weed spread. However, 32 per cent of respondents believed that this pathway would become more important in the future. Reasons given for its increasing importance included *“construction activities, especially in more and more remote areas, [which] will continue to escalate, increasing the chances of weed seeds being dispersed”* and *“increased development and fragmentation of landscapes [which] will mean that weeds are spread further and into more core bushland areas”*. No respondents indicated that this pathway would become less important in the future.

The main suggestions for managing the current and future risk of this pathway included:

- education and publicity;
- establishing specified dumping areas;
- using clean fill in sensitive areas;
- improving management codes and legal enforcement; and
- extra resources and staff.

[†] Refers to the current capability of a pathway for weed ingress; see Table 3 on page 8.

Agricultural produce

Many common agricultural weeds are spread as contaminants in fodder, pasture seed and seed crops.

The current capability of this pathway, with regard to weed spread, was assessed by survey respondents as high (mean 4.14[†], standard deviation 0.28). Sixty respondents answered questions relating to weed spread via the agricultural produce pathway.



As with the sale and planting of fodder plants, the transportation of agricultural produce into drought affected areas is expected to expand due to increasing droughts associated with climate change. Consequently, the weed spread risks associated with this pathway were assessed by respondents as becoming more important in the future.

Greater education and extension activities were suggested by 27.8 per cent of respondents as a way to manage the current and future risks associated with this pathway. As for the fodder plant trade pathway, respondents also emphasized certification of weed status and vendor declarations as important aspects of pathway management.

Research sites

Plants introduced for agricultural research purposes have been known to escape from trial sites and spread as weeds in surrounding areas.

Research sites were given a relatively low capability rating by respondents, in each of the characteristics addressed by the survey, suggesting that this pathway is adequately regulated. Information on research sites as a pathway for weed spread was provided by 24 respondents.



More than half of the respondents addressing this pathway (51.9 per cent) indicated that improved knowledge, regulation and greater responsibility on research sites would lead to this pathway becoming less important as a

[†] Refers to the current capability of a pathway for weed ingress; see Table 3 on page 8.

method of weed spread in the future.

Due to a small response, no trend emerged from the survey regarding improved management practices for this pathway. However, suggestions ranged from education to hygiene improvement and better management codes.

Useful suggestions regarding management of current and future weed risks from research sites included *“need more information on safe buffer distances and management requirements to limit spread of high value species. Plus standard hygiene to remove species (including propagules) from trial plots at their end.”* Furthermore, *“research institutes need to have budgetary capacity to manage their grounds, with sufficient expertise to prevent escape and naturalization of any species”*.

Livestock movement

Zoochory, or seed dispersal by animals, occurs in 50 per cent of all plant species (Tiffney and Mazer 1995). Animals can disperse weeds by exozoochory, where weed propagules are attached to their bodies, or by endozoochory, where seeds are ingested and passed through the gut (Stanton 2006).



The current capacity of livestock movement as a pathway for weed spread was assessed by survey respondents as being medium to high (mean 3.65[†], standard deviation 0.28). Fifty-six responses were received on this pathway.

Eighty-eight per cent of respondents indicated that the livestock movement weed spread pathway will either remain as important or increase in importance in the future, as stock movement may actually increase due to a greater probability of drought. However, 12 per cent of respondents indicated that this pathway would decrease in importance in the future due to, amongst other things, increased awareness and more stringent industry standards.

Education and quarantine processes were suggested as the two key areas for managing the current and future risks of weed spread associated with this pathway (42.9 per cent and 14.3 per cent of responses respectively). One respondent commented that *“on-property quarantine areas are an important way of isolating new stock, which allows them to empty out in a confined space that can be more easily monitored”*.

[†] Refers to the current capability of a pathway for weed ingress; see Table 3 on page 8.

Waste disposal

Disposal of garden and aquarium waste, either through council green waste collection, illegal dumping along roads, or emptying aquariums into drains and waterways, can spread weed propagules including seeds, bulbs and rhizomes.



The current risk capability of the waste disposal pathway was assessed by survey respondents as being medium to high (mean 3.92[†], standard deviation 0.26). Information on this pathway was provided by 42 respondents.

The majority of respondents (60.5 per cent) indicated that the spread of weeds via this pathway would remain as important in the future. A further 27.9 per cent of respondents believed that this pathway would increase in importance in the future, due to urban development and the increasing popularity of gardening.

Education was highlighted as an important strategy to manage the risks of weed spread through waste disposal (30.8 per cent of responses), as was making it easy for people to dump their green garden waste in specified safe dumping areas (30.8 per cent of responses). One respondent suggested providing “*alternative waste disposal methods, e.g. green waste collections*”, while another suggested that “*all local government bodies should provide areas for free dumping of garden waste (to discourage dumping in bush areas).*”

Birds

This pathway involves consumption and excretion of seeds and fruits by birds.

The current capacity of birds as a pathway for weed spread was rated by survey respondents as medium to high (mean 3.90[†], standard deviation 0.58). Fifty-five experts provided information on the spread of weeds via birds.



Over 90 per cent of respondents indicated that this pathway would either become more important or remain as important as a means of weed spread in the future.

The pathway was acknowledged by respondents as difficult to manage, and

[†] Refers to the current capability of a pathway for weed ingress; see Table 3 on page 8.

it was suggested that management needs to focus on containment at the source (23.8 per cent of responses), alternative planting (19.0 per cent of responses), and public education (14.3 per cent of the responses).

One respondent noted that since *“it’s hard to control the pathway itself (birds), it’s important to control the seed sources. We need to prioritise and manage the major sources of propagules, and/or the sources closest to sensitive areas. Sale and growth of exotic, fleshy, fruited, ornamental plants should be banned (or sterile varieties developed and tested), as species of this group are almost all a high risk”*.

One management issue raised in the literature was that, while the threat of weeds to biodiversity cannot be ignored, in some cases, such as heavily modified landscapes, fleshy-fruited exotic plants play an important ecological role in sustaining native frugivores. To manage this conservation conflict, Gosper and Vivian-Smith (2008) advocate a replacement approach in which native fleshy-fruited plants are planted to support native frugivore populations in instances of extensive invasive plant control.

Other animals

This pathway occurs through consumption and excretion of seeds and fruits, and external attachment to native and introduced wildlife.



The spread of weeds by other animals was determined by survey respondents to currently have a medium to high risk capability (mean 3.73[†], standard deviation 0.57). Information on this pathway was provided by 36 respondents.

Seventy-one per cent of respondents indicated that this pathway would remain just as important in the future, while a further 17 per cent stated that it would become more important in the future.

As with birds, this pathway appears to be difficult to manage. Approximately one third of responses regarding the management of current and future risks of weed spread by this pathway suggested containment and control of weeds at the source as a potential management strategy. One respondent noted a need to *“prioritise control of populations of weeds that might be spread by animals that are in close proximity to sensitive natural areas”*.

[†] Refers to the current capability of a pathway for weed ingress; see Table 3 on page 8.

Wind

Wind dispersal, termed anemochory, can transport seed over long distances.

The current risk of wind as a pathway for weed spread was assessed by survey respondents as having a medium to high risk capability (mean 3.85[†], standard deviation 0.33). Fifty-six respondents provided information on the spread of weeds via this pathway.



Just over 20 per cent of respondents indicated that there is insufficient information to identify the importance of wind as a pathway for weed spread. However, over 90 per cent of respondents believe that this pathway will be just as important or more important in the future.

Research into patterns of dispersal of wind-borne seeds over landscapes and the effectiveness of wind breaks were the most suggested methods of improving management of this pathway. Control of wind-dispersed seeds at their source was considered to be an effective management approach by some respondents.

Water

Dispersal of weed propagules via water, or hydrochory, can occur in floodwaters, stormwater and via natural waterways and oceans.

Water was considered by survey respondents as having a high risk capability (mean 4.05[†], standard deviation 0.36). Forty-two experts provided advice on the pathway.



Of all the weed spread pathways, water was considered to increase in significance in the future by the greatest proportion of respondents. The water pathway appears likely to increase in importance for a range of reasons:

[†] Refers to the current capability of a pathway for weed ingress; see Table 3 on page 8.

- an apparent increase in climatic variability (drought, or extended dry weather followed by floods);
- the conduciveness of this pathway for weed spread;
- an increased focus on the value of water resources and their management; and
- the declining number of herbicides available for use in waterways.

No respondent rated water as a potentially less important weed spread pathway in the future.

Approximately two-thirds of respondents suggested management of weed infestations at the source as the method most likely to address current and future risks associated with this pathway. As one respondent noted, *“the only effective management across a range of weed species is going to be maintaining healthy and uninvaded vegetation upstream, and as just about everywhere is upstream of somewhere else, we would need to maintain uninvaded vegetation just about everywhere”*.

Outlook of the different pathways in the future

As has been discussed above, survey respondents were asked to indicate the outlook of the pathway with regard to its future importance as a method of weed spread. Respondents were asked to indicate whether they thought the pathway would become more important, remain as important as it is currently, or become less important.

The response to this question for all pathways addressed by the survey is summarised in Figure 2 on the following page. As the figure shows, natural methods of weed spread (water, wind, birds and other animals) are considered by the highest proportion of respondents as likely to remain as important in the future.

According to the highest proportion of survey respondents, the ‘man-made’ pathways that may become more important methods of weed spread in the future include fodder trade, ornamental plant trade, agricultural produce, machinery and vehicles, and aquarium plant trade. This suggests that management of weed spread in the context of agricultural production and gardening or landscaping activities will become more important.

Relatively few survey respondents suggested that the weed pathways addressed in the survey would become less important in the future, with the exception of research sites and, to a lesser degree, medicinal plant trade, food plant trade, and revegetation and forestry. Management strategies already in place for these pathways may be sufficient to address future risks.

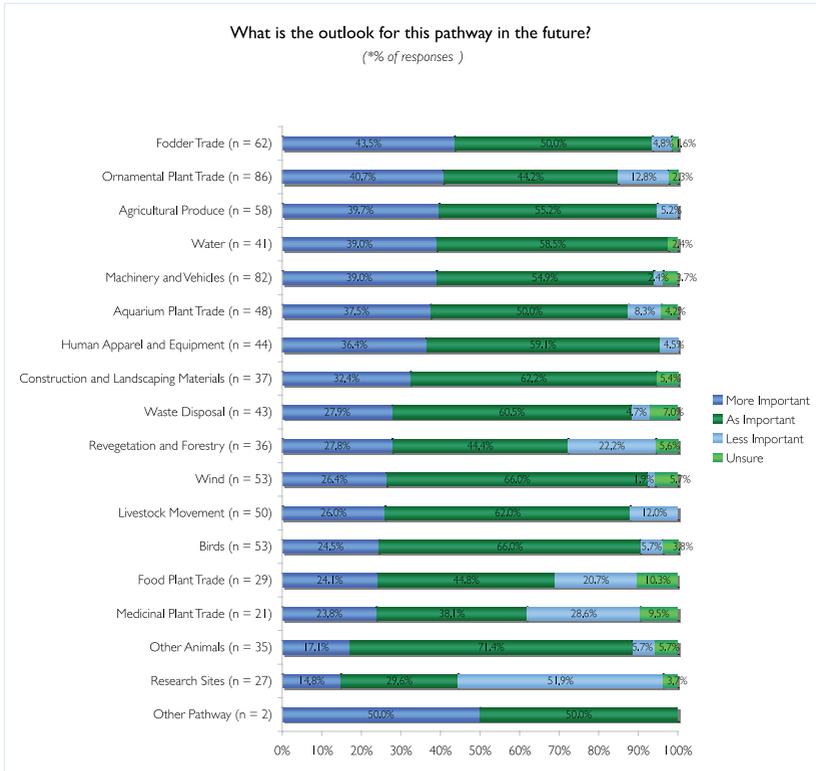


Figure 2: Outlook of each pathway in the future

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The full report for this project on which this summary is based,
'Pathway Risk Analysis for Weed Spread within Australia'
is available for free download from:
www.ruralfutures.une.edu.au



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