Assessing weed spread in Australia using pathway risk analysis

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Summary While considerable effort has been made to establish how weeds and potential weeds enter Australia, no comprehensive studies had previously ascertained the ways that weeds spread once present within Australia, or assessed 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. Using a pathway risk analysis approach, this research sought to identify: which weed sources and pathways account for the majority of weed ingress; which pathways pose the greatest risk; ways in which these risks are changing (e.g. due to changing climate, economic or demographic patterns); and how pathway management strategies might be improved. These questions were addressed through a review of literature and a survey of Australian experts working in weed science, extension, and with relevant government agencies. Twenty-four 'sources' and seventeen natural and human-assisted 'pathways' were identified and assessed. The survey found the most significant weed sources were transport sites, land in transition, pastures and rangelands, ornamental horticulture, private gardens and arable/cropping land. When prevalence, risk and related weed sources were taken into account, the most significant spread pathways in Australia were trade in ornamental plants and machinery and vehicles – a finding that is supported in the literature. Nearly all pathways will be equally or more important in the future due to variable climate and changing economic and demographic patterns. Experts thought all pathways were inadequately managed and, while improvements will need to be pathway-specific, a general strategy of 'negative' regulation, 'positive' management, and more Australian-focussed research was suggested.

Keywords Pathway risk analysis, weed spread, source, risk assessment, policy.

INTRODUCTION

There has been considerable effort to determine 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). Weeds cause enormous damage to the Australian natural environment, and impose a significant cost on the Australian economy through control costs and lost agricultural production (estimated at $4 billion annually by Sinden *et al.* 2004). However, despite this impact no comprehensive studies had previously been undertaken to ascertain the way that weeds spread once present within Australia, or to assess the relative threats or risks of different 'sources' and 'pathways' of spread. This study sought to assess the means by which weeds spread in Australia using a pathway risk analysis approach.

METHODS

Pathway risk analysis The pathway risk analysis technique commonly involves identifying a set of relevant or potentially relevant pathways, assessing the risks associated with each pathway, and evaluating the ease with which each pathway might be managed. With respect to weed spread, the outcome is a smaller set of high-risk pathways that account for a large proportion of weed spread, and for which effective management programmes may be put in place. Pathway risk analysis has previously been used in the United States (Andow 2003), New Zealand (Williams *et al.* 2000) and the Australian state of Victoria (King *et al.* 2008) to identify commodities, industries and organisations that have the greatest potential to spread weeds.

Project method Using this technique, we sought to: assess the relative risks of the different sources and pathways of weed ingress within Australia; and identify ways to reduce these risks. The project progressed in two stages. The first was a review of Australian and international literature on weed spread to identify relevant weed sources and pathways, and evaluate the effectiveness of management approaches to restrict weed movement. Second, a survey of Australian experts working in weed science, government agencies and extension was conducted to collate the experience of these individuals with respect to each of the pathways and sources identified in the literature. The survey asked experts to consider the importance of each source, and their awareness of instances where each of the 17 pathways was a factor in weed spread in Australia. Pathway awareness was used as a proxy

measure of the relative prevalence of each pathway.

Pathway risk was evaluated in the survey according to eight pathway capabilities, with experts being asked to score each of these capabilities for a particular pathway. The higher the capability score, the higher the risk posed by a pathway. The same eight capabilities were used for each pathway. These capabilities included: speed (transport of weeds quickly over distances greater than 1 km); diversity (transporting a high diversity of weed species); quantity (transporting large numbers of propagules of one or more species in a single event); frequently (transport of weeds frequently, making it a regular/ongoing instead of occasional event); hospitability (delivery of live plants or viable propagules); environments (ability to introduce plants into suitable environments); tolerance (ability to overcome or avoid prevention and management strategies); and impact (transport of weeds into sensitive areas where the weed might have a high impact). An unweighted mean overall pathway capability (risk) rating was produced from these capabilities for each pathway.

For each pathway, the survey also asked experts to consider whether the pathway would become more or less important in the future (and to indicate their reasons for their choice). Current pathway management was also evaluated in a series of questions in which experts were asked to consider whether management strategies and regulations were adequate, and to offer suggestions for improvement.

RESULTS

Important sources and pathways The review of literature identified 24 sources of weeds (sites or areas of land where weeds are actively growing and from which new invasions may emerge), and 17 natural and human-assisted weed spread pathways (the means by which weed propagules are moved) relevant to the Australian context, for inclusion in the survey. Over 100 survey responses were received.

The 24 weed sources included in the survey were: nature conservation sites; minimal use land; land in transition; forestry; arable/cropping land; edible horticulture; ornamental horticulture; pasture/rangelands; intensive animal use; private gardens; public gardens; utility sites; mining; transport sites; waste treatment and disposal; commercial/industrial centres; research sites; defence force land; lakes; reservoirs and dams; rivers; channels and aqueducts; marshes and wetlands; and estuary/coastal waters. Of these, transport sites (roads, railways, ports and airports) was considered the most important source of weeds in Australia. Other important sources included land in transition (degraded, abandoned or unused land), pastures and rangelands (grazing land for dairy and beef cattle, sheep and goats), ornamental horticulture (fresh flowers, garden plants, aquarium plants, bulbs and seeds), private gardens (including water gardens and aquaria) and arable/cropping land (dryland and irrigated). Moving water (rivers, channels and aqueducts) was considered a more important source of weeds than still water bodies (lakes, dams and reservoirs). Sources considered relatively less important included nature conservation areas, intensive animal production sites, research sites and commercial/industrial centres, perhaps reflecting the effectiveness of existing management strategies or the inhospitable conditions for weed growth at these sites.

The 17 pathways of weed spread identified in the literature review were categorised as: those resulting from deliberate human activity that results in the spread of weeds (ornamental plant trade, aquarium plant trade, medicinal plant trade, food plant trade, fodder trade, revegetation and forestry); those that are an accidental side-effect of human activity (human apparel and equipment, machinery and vehicles, construction and landscaping materials, agricultural produce, research activity, livestock movement, waste disposal); and natural pathways of weed spread (birds, other animals, wind, water).

The proxy measure of the relative prevalence of the 17 pathways included in the survey suggested that the two most common weed spread pathways in Australia are the trade in ornamental plants, and machinery and vehicles. Other relatively common pathways according to experts include trade in fodder plants, contaminated agricultural produce, livestock movement, wind and birds. Those pathways that appear to be less important include food plant trade, research activity and medicinal plant trade.

High-risk pathways Overall, each of the pathways was considered by experts to pose a relatively high risk, but the highest risk pathways (based on the mean overall capability rating) included fodder trade, ornamental and aquarium plant trade, agricultural produce, machinery and vehicles, and water. Those pathways deemed a relatively low risk included revegetation and forestry, and research sites.

When both prevalence and risk is taken into account, the most important pathways appear to be the trade in ornamental plants, and movement of machinery and vehicles, while the related weed sources of ornamental horticulture and transport sites were also amongst the most significant. Other important weed sources, such as pastures and rangelands, arable/cropping land and utility sites (telecommunications and electricity), also contribute to the importance of the

machinery and vehicles pathway, particularly given the range of transport and equipment used at these sites.

When disaggregating the eight capabilities associated with a particular pathway, it became clear why that pathway poses a risk. For example, the high risk attributed to the ornamental plant trade pathway is derived largely from its *speed* (ability to transport weeds quickly over distances greater than 1 km), *hospitability* to live plants or propagules, ability to introduce weeds into suitable *environments*, and transport of a *diversity* of species (Table 1).

Table 1. Mean pathway capability ratings for the ornamental plant trade pathway (where 1 = 'low/non-existent capability' and 5 = 'high capability').

Capability	Rating	Std. dev.
Speed	4.61	0.91
Hospitability	4.43	0.92
Environments	4.37	0.85
Diversity	4.30	1.07
Impact	4.08	1.12
Frequently	3.95	1.24
Quantity	3.88	1.31
Tolerance	3.27	1.04

Future pathway risks With the exception of the research sites pathway, it was considered by the majority of experts surveyed that all pathways would be equally or more important in the future. Those pathways considered most likely to grow in importance were influenced by a range of factors. For example, experts who believed that the ornamental plant trade pathway would become more important in the future cited as influencing factors the increasing popularity of gardening, greater uptake of drought-tolerant species by gardeners, and peri-urban population growth and rural land sub-division, which are contributing to the spread of ornamental and garden species into rural areas.

Improving pathway risk management The majority of experts participating in the survey considered that there was currently insufficient management for all weed spread pathways. In particular, those pathways that were already governed by formal regulation, legislation or codes of practice in some way (such the ornamental, aquarium, medicinal and food plant trades) were most likely to be considered inadequately managed. This often reflects gaps in formal regulation and inadequate implementation. For example, in the case of ornamental plant trade, experts noted that some aspects were overlooked in regulatory frameworks (such as unregulated community markets at which ornamental species are readily available), while others noted that recent attempts at regulation within the nursery industry were voluntary, not binding.

While the mix of management or formal regulation required is pathway-specific, a general strategy for improving pathway risk management, as suggested by experts, includes 'negative' regulation (enforcement and fines), 'positive' management (education, labelling, codes of practice), and more research to assess the management options available for a particular pathway.

The recent Australian Weeds Strategy (NRMMC 2007) represents a positive step in that it establishes a national framework for managing weed spread, though at this stage its primary focus is on human-induced pathways.

DISCUSSION

Pathway risk analysis makes it possible to identify the most important (and highest risk) pathways and related sources associated with weed spread in Australia. Using this information, there is potential to focus scarce weed control funds and resources, policy options and research on those pathways and sources.

The 17 weed spread pathways identified in this project are all significant vectors for weed spread in Australia. Nonetheless, the importance attributed to ornamental plant trade and machinery and vehicles in our survey of experts (in terms of prevalence and risk) is strongly supported by the literature. Between 1971 and 1995, it was estimated that approximately 65% of species considered to have naturalised in Australia were originally introduced and spread as ornamental plants (Groves 1997). Furthermore, trade in ornamental plants remains a high risk weed spread pathway, with actual or potentially weedy species commonly available for sale in nurseries, community markets and so on, for some time after their weed potential has been identified (Barker *et al*. 2006).

Passenger vehicles, trucks and agricultural machinery have been identified as highly capable of spreading weeds over long distances into previously uninfested areas, with the spread of particular weed species having been linked closely to road and rail transport networks (Sindel 2001, Moerkerk 2006).

Despite the importance of these two pathways, improvements in management and regulation might go a long way towards diminishing their future risk. Experts suggest improving management of the ornamental plant trade pathway through: educating the public and the nursery/landscaping industry about the risk of particular species and the availability of non-weedy alternatives (e.g. NGIA 2009); the recently developed

national labelling guidelines that seek to identify invasive and potentially harmful plants; improving the weed risk assessment process for ornamental species; and improving codes of practice for the nursery and landscaping industries.

Improving management of the machinery and vehicles pathway is more problematic, given relative lack of understanding of its importance by researchers and machinery operators alike, growing use of machinery contractors in agriculture, and increasing traffic movement in rural areas associated with landscape fragmentation (rural population growth). Nonetheless, experts consider that improvements in managing the pathway may include: educating rural residents and machinery operators on the ability of the vehicles and machinery to transport propagules; improving machinery and washdown facility design, and developing enforceable codes of practice that require machinery operators to minimise weed spread via this pathway.

In a related project that surveyed regional weed inspectors, the ornamental plant trade pathway was considered a relatively less likely means of weed spread, being ranked 11th out of 17. Those pathways considered most likely to spread weeds by weed inspectors included birds, machinery and vehicles, wind, water and fodder trade. This discrepancy may be due to the vocational circumstances of inspectors: regional as opposed to national scale of interest, with a particular focus on agricultural rather than environmental weeds in rural Australia.

ACKNOWLEDGMENTS

Our thanks to Land and Water Australia for funding this research through the Defeating the Weed Menace R&D program, to all organisations and individuals who participated in the survey, and to those who provided valuable comments on the project, including Helen Anderson (on behalf of the weed spread risk assessment team of the Victorian Department of Primary Industries), Bruce Auld, Paul Kristiansen, Stephen Johnson, Rachel McFadyen, Peter Michael and John Virtue.

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