Prioritising sleeper weeds for eradication

Selection of species based on potential impacts on agriculture and feasibility of eradication

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Executive summary

Eradication is a desirable and feasible management strategy for some weeds.

We report a set of methods for identifying weeds where eradication is both desirable and feasible ... and identify ten candidate weeds.

17 potential sleeper weeds in Australia were short listed in consultation with the States and Territories, in this context a sleeper weed is ...

... a naturalised exotic plant species that is currently only present in a small area but that has the potential to spread widely and have a major negative impact on agriculture.

We verified that these 17 species would not be permitted for import into Australia by using the AQIS Weed Risk Assessment system.

Weeds are one of the major natural resource management problems in Australia and are considered by farmers to be the highest priority land degradation issue. The cost of weeds to Australian agriculture has been estimated at $3.3 billion per year compared to the $2.4 billion estimated for salinity, sodicity and soil acidity combined. A strategic approach to weed management should include eradication of emerging weed species before they become major problems where the only management options are ongoing control or containment.

In this study, we apply a suite of existing and new approaches to identify ‘sleeper weeds’ that could be eradicated before they become major agricultural weeds in Australia. Ten species are recommended for eradication based on their potential impacts and feasibility of eradication. All of the approaches reported here could also be applied to environmental or urban sleeper weeds with little or no modification.

A preliminary short list of 144 potential sleeper weeds was identified on the basis of previous work and circulated to all Australian jurisdictions through the Australian Weeds Committee (AWC). Consultation with the jurisdictions reduced this list to 17 species for analysis in more detail and defined an agricultural ‘sleeper weed’ as:

“A naturalised exotic plant species that is currently only present in a small area but that has the potential to spread widely and have a major negative impact on agriculture.” Freshwater aquatic weeds were included in our analysis but marine and estuarine species were excluded. Weeds already targeted for eradication under a national cost sharing approach were also excluded.

For each of the 17 species, we undertook a Weed Risk Assessment (WRA) using a system that has been operated by the Australian Quarantine and Inspection Service (AQIS) since 1996 to support decisions on whether to allow or prevent the import of new exotic plants. This system uses information about the plant’s current weed status overseas, climate preferences and biological attributes to calculate a numerical score related to weed risk. The WRA score for each weed was well within the range of scores where import would not be permitted.
We then quantified the value of agricultural production potentially at risk from ... and the relative feasibility of eradication of each of the 17 potential sleeper weeds.

We recommend 10 species for eradication efforts based on both potential impact and feasibility of eradication.

The first phase of eradication should be field surveys of the geographic distribution of the priority species to validate the model of eradication feasibility and support the development of detailed eradication plans where the results confirm that eradication is feasible.

For each of the 17 species, we assessed the area of Australia where there was potentially suitable climatic environments using the computer program ‘Climate’. The revenue and profit of agricultural production at risk for each weed was quantified based on land uses that each weed could impact on within its potential distribution.

To assess the feasibility of eradication of the 17 species, we developed a system to quantify the relative amount of effort required to eradicate a weed based on a limited number of variables describing its current distribution and biological attributes. We calibrated the system against an estimated cost for an eradication campaign and expressed the results as a relative measure of benefit-cost ratio for each weed. We recommend the ten species with the highest modelled benefit-cost ratios for further eradication efforts, these are:

- *Eleocharis parodii* (N.S.W)
- *Baccharis pingraea* (Vic.)
- *Piptochaetium montevidense* (Vic.)
- *Centaurea eriophora* (S.A.)
- *Crupina vulgaris* (S.A.)
- *Asystasia gangetica* ssp. *micrantha* (N.S.W.)
- *Onopordum tauricum* (Vic.)
- *Oenanthe pimpinelloides* (S.A.)
- *Rorippa sylvestris* (Tas., S.A.)
- *Nassella charruana* (Vic.)

For an eradication campaign to be successful, it requires a time-limited plan supported by detailed benefit-cost analysis and a commitment of resources for the term of the eradication. This period may exceed ten or twenty years where a persistent seed bank is present. In this study, we found that the most significant factors influencing the likelihood of successful eradication are area, number of infestations, ease of access and propagule longevity. Since fieldwork was beyond the scope of this study, the first three of these were based on estimates of experts in the jurisdictions where the weeds occur. We recommend that field surveys be undertaken for the ten priority weeds to collect firm data on their geographic distribution to validate the model of eradication feasibility and support the development of detailed eradication plans where the results confirm that eradication is feasible.
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Introduction

Background

Recent work on agricultural weeds has highlighted the fact that many of the exotic weed species already naturalised in Australia could have major impacts in the future if they are not eradicated. Groves et al. (2002) undertook preliminary screening of all known exotic plants that have become naturalised (around 3000 species) and identified nine potential weeds for eradication. Brinkley and Bomford (2002) then quantified the value of agricultural production potentially at risk from these species, confirming the benefit of eradication as a strategy.

These earlier reports raised some questions about the ability of existing methods to identify weeds where eradication is the most desirable and feasible management strategy. Among the recommendations were that more potential sleeper weeds be assessed and that criteria for assessing the feasibility of eradication be developed. In January 2003, the Australian Government Department of Agriculture, Fisheries and Forestry commissioned the Bureau of Rural Sciences (BRS) to undertake further work to develop a practical, repeatable methodology for use in the assessment of sleeper weeds that is transparent and scientifically objective without being too costly or complex. The terms of reference for the project called for the identification of a priority subset of up to ten sleeper weeds that threaten agriculture that was objectively defensible and accepted by the States and Territories as much as possible. This project was funded through the national component of the Natural Heritage Trust (NHT).

Weeds and the ‘sleeper weed’ concept

Weeds have a major impact on agricultural and natural environments throughout the world. In Australia, the cost of weeds to agricultural systems has been estimated at $3.3 billion per annum (Combellack 1987; Jones et al. 2000; Groves 2002) compared to the $2.4 billion estimated for salinity, sodicity and soil acidity combined (CRCAWM 2002). Australian farmers consider weed control to be the highest priority land degradation issue (Mues et al. 1998).

Sleeper weeds have been defined as ‘… invasive plants that have naturalised in a region but not yet increased their population size exponentially’ (Groves 1999). Examples of sleeper weeds in Australia include mimosa bush, a sleeper weed for 70 years before becoming a major weed (Miller and Lonsdale 1987; Lonsdale et al. 1989) and pampas grass, a sleeper for decades before becoming a weed in the 1970s (Rawling 1994).

Grice and Ainsworth (2003) discuss six classes or situations that characterise sleeper weeds. These occur when introduced plants are:

1. Restricted by a narrow genetic base poorly adapted to the local environment;
2. Restricted by limited suitable habitat;
3. Restricted by limited opportunities for recruitment;
4. Restricted by a low intrinsic population growth rate;
5. Restricted by the absence of mutualists; and
6. Species that are wrongly perceived to be not invasive.

This is not a comprehensive list of criteria and opinion is divided on what defines the sleeper weed phenomenon. Regardless of definitional issues, the National Weeds Strategy notes ‘… a need to recognise and eliminate sleepers during their benign phase or at least identify the events that could turn them into major weeds.’
Number of potential weeds

In Australia, 335 weeds are listed as noxious according to the National Weeds Strategy (www.weeds.org.au/noxious.htm). Groves et al. (in prep.) identified 429 species under active control or declared noxious in at least one State or Territory or part thereof. The Australian vascular flora is thought to consist of around 25,000 species (George et al. 1999). Of these, around 2000 to 3000 are exotic plants that have naturalised (Orchard 1999, Groves et al. 2002). This category includes all of the current major weeds.

Imported plants are a source of newly naturalised plants along with accidental introductions via contaminated products. The total number of alien plant species introduced into Australia is estimated to range from about 25,000 (Groves 2002) to 32,000 (Randall 2002, cited in WWF Australia 2003). Most introduced species have not yet naturalised and are unlikely to. Williamson and Fitter (1996) estimate the probability of introduced plants becoming weeds is in the range of 0.1 to 1%, consistent with the observed ratio in Australia (Figure 1). The aim of sleeper weed eradication is to prevent species moving from the naturalised flora category to the declared or noxious weed category. Other management strategies may focus on border control and post-border incursions that have not yet established naturalised populations.

Figure 1. Potential exotic weeds in Australia. The aim of sleeper weed eradication is the prevention of plants moving from the naturalised category to the weed category.
**Eradication concept**

Eradication can be defined as ‘the complete and permanent removal of all wild populations from a defined area by a time-limited campaign’ (Bomford and O’Brien 1995). Eradication of weeds is seen as an attractive management strategy because it involves a finite investment compared to the indefinite commitment of resources to an ongoing containment strategy or simply living with the costs of the weed.

Many incursions of weeds have been eradicated before becoming established as a naturalised or self-sustaining population although these are rarely reported in the literature. Eradication of naturalised weeds is more difficult although there have been a number of successful eradications from the Australian flora. Groves et al. (in prep.) identified 29 naturalised plant species thought to have been eradicated from Australia and 156 cases where eradication attempts have or are being made throughout or within a State/Territory and 16 species for which eradication is being attempted at a national scale. Examples of naturalised weeds eradicated from part or all of Australia include kochia (*Bassia scoparia*), salvinia (*Salvinia molesta*) bitterweed (*Helenium amarum*) and seroty weed (*Eupatorium seratinum*).

Kochia was eradicated from Western Australia over a period of around 10 years (Dodd and Randall 2002). It was introduced in 1990 as salt-tolerant forage on 52 properties and by 1992 had spread to 270 properties over an area of 3200 ha. An eradication campaign commenced in 1992 and by 2000 the area infested had been reduced to five ha. By 2003 it was considered eradicated and the campaign is considered one of the most successful weed eradications. Salvinia, an aquatic weed, was eradicated from the Adelaide River in the Northern Territory over a 10-year period from 1977 (Miller and Pickering 1988).

Other weeds have taken far longer to eradicate. Bitterweed was first detected near Brisbane in 1953; it eventually spread over an area of 50 ha in two infestations. By 1987 it was eradicated after 370 person-days of work over 39 years. Seroty weed was first detected near Brisbane in 1962 and by 1970 it had spread to two sites covering 0.5 ha. It was eradicated after 50 person-days over 18 years (Tomley and Panetta 2002).
Methods

Short-list of candidates

A staged assessment was conducted with identification of candidates for detailed analysis followed by assessments of weed risk, potential impacts and feasibility of eradication. The aim of the first stage was to screen the list of around 3000 exotic species for potential sleeper weeds and focus on a relatively small number for the more costly processes of the subsequent stages. A preliminary list of 144 taxa was produced on the basis of previous work (mainly Groves et al. 2002) and submitted to all jurisdictions via the Australian Weeds Committee (Nothrop and Cunningham 2003). AWC members were asked to nominate potential sleeper weed species for assessment and to comment on the definition of sleeper weed in the context of this project.

In consultation with stakeholders, the definition of ‘sleeper weed’ was refined to: A naturalised exotic plant species that is currently only present in a small area but that has the potential to spread widely and have a major negative impact on agriculture. Freshwater aquatic weeds were included in the analysis but marine and estuarine species were excluded. Weeds already targeted for eradication under a national cost sharing approach were also excluded. For this project, sleeper weeds also excluded native plants; garden plants not yet naturalised; and crop and pasture species.

The initial list of 144 potential candidate taxa was reduced to 17 with many species considered unfeasible or unworthy of eradication and a limited number of additional species suggested for further investigation. A detailed account of the short-listing methods including a list of excluded taxa plus reasons for their exclusion from the final shortlist are presented in Appendix A.

Weed Risk Assessment (WRA)

For each of the 17 short-listed species, we undertook a Weed Risk Assessment (WRA) using the system that has been operated by the Australian Quarantine and Inspection Service (AQIS) since 1996 to support decisions on whether to allow or prevent the import of new exotic plants (Pheloung et al. 1999). This system scores up to 49 attributes of a plant to calculate a weed risk score based on its domestication/cultivation; climate and distribution; weed history elsewhere; undesirable traits; plant type; reproduction; dispersal mechanisms; and persistence attributes. Information on these attributes was obtained by a desktop review based on sources listed in Appendix B and supplemented with expert opinion where available.

Potential impact assessment

The assessment of potential impact was based on the potential of the weed to extend its distribution and the consequences of this in terms of impacts and costs imposed on agricultural activities. The potential impacts on agriculture were quantified after the methods of Brinkley and Bomford (2002) with modifications. This approach measures both the potential distribution of a species (through climate matching) and the value of production of the affected land use(s) within that potential distribution. The key difference in our methodology was the application of the program ‘Climate’ (after Pheloung 1996; Thorp and Lynch 2000; Duncan et al. 2001; and Kriticos and Randall 2001) and different sets of data on value of production at risk (Hajkowicz and Young 2002). The Hajkowicz and Young data
allowed for a better measure of revenue and also provided a measure of profitability of agricultural production at risk. A detailed description of methods is provided at Appendix C.

**Eradication feasibility assessment**

While eradication may be desirable for many weeds, it is not always feasible. The aim of the final stage was to assess the 17 selected species for the feasibility of eradication, based on factors such as their current area of infestation and the relative merits of eradication and control. Since there are no published methods of quantifying the relative feasibility of eradication, we developed a system of quantifying the relative effort required to eradicate a weed based on limited knowledge of its current distribution and biological attributes. The system draws heavily on methods under development to assess feasibility of containment (Virtue 2002) and feasibility of eradication (Panetta and Timmins in prep.). The key difference in our approach was that we calibrated the attributes of each weed against an estimate of the cost involved in an eradication campaign to determine the weightings of each attribute. This was done by a survey of individuals with expertise in weed eradication. Survey respondents were asked to examine each of 15 hypothetical weed profiles and estimate the probability of eradicating the weed for each of 8 broad cost ranges, based only on the attributes described in the profile. The cost ranges represent the maximum total cost over the life of an eradication effort. A detailed costing was not required because the method was designed primarily to assess the relative probability of eradication, not the absolute cost.

The data from the surveys were analysed in a two-step process. First, the individual responses were used to estimate the cost of an eradication campaign that would have a 95% probability of success for each weed. Once the responses had been standardised in this way standard regression techniques were used to explore the relationship between the eradication cost and the weeds characteristics. The significant variables were found to be area; number of infestations; ease of access; and propagule longevity. A model based on these four variables was used to rank the 17 species in terms of relative feasibility of eradication.

The variables which were not significantly associated with likelihood of successful eradication were shoot growth; appearance; tolerance to control; time to seeding; number of propagules; vegetative regeneration, maximum propagule dispersion distance; and knowledge of current locations. Full details of this analysis can be found in Appendix D.
Results

Shortlist of species for detailed analysis

Table 1 lists the candidate agricultural sleeper weeds that were selected for detailed analysis of potential impacts and feasibility of eradication, and their distribution by State. There were 17 candidate weed taxa, most occurring in a single State each, but with three taxa found in two States each. No candidates were nominated for the Australian Capital Territory, Northern Territory, Western Australia although a number of candidates were excluded in preliminary assessments. Details on each of the 17 shortlisted weeds are in Appendix E and contact details for individuals with knowledge of the weeds are included at Appendix F.

<table>
<thead>
<tr>
<th>Species</th>
<th>Common name</th>
<th>State(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Aeschynomene paniculata</em></td>
<td>pannicle jointvetch</td>
<td>Queensland</td>
</tr>
<tr>
<td><em>Brillantaisia lamium</em></td>
<td></td>
<td>Queensland</td>
</tr>
<tr>
<td><em>Froelichia floridana</em></td>
<td>snakecotton</td>
<td>Queensland</td>
</tr>
<tr>
<td><em>Gmelina elliptica</em></td>
<td>badhara bush</td>
<td>Queensland</td>
</tr>
<tr>
<td><em>Asystasia gangetica ssp. micrantha</em></td>
<td>Chinese violet</td>
<td>New South Wales</td>
</tr>
<tr>
<td><em>Eleocharis parodii</em></td>
<td></td>
<td>New South Wales</td>
</tr>
<tr>
<td><em>Baccharis pingraea</em></td>
<td>chilquilla</td>
<td>Victoria</td>
</tr>
<tr>
<td><em>Hieracium aurantiacum</em></td>
<td>orange hawkweed</td>
<td>Victoria, Tasmania</td>
</tr>
<tr>
<td><em>Hypericum tetrapertum</em></td>
<td>square-stalked St Johns wort</td>
<td>Victoria, Tasmania</td>
</tr>
<tr>
<td><em>Nassella charruana</em></td>
<td>Uruguay needle grass</td>
<td>Victoria</td>
</tr>
<tr>
<td><em>Oenanthe pimpinelloides</em></td>
<td>meadow parsley</td>
<td>South Australia</td>
</tr>
<tr>
<td><em>Onopordum tauricum</em></td>
<td>Taurian thistle</td>
<td>Victoria</td>
</tr>
<tr>
<td><em>Piptochaetium montevidense</em></td>
<td>Uruguayan ricegrass</td>
<td>Victoria</td>
</tr>
<tr>
<td><em>Rorippa sylvestris</em></td>
<td>yellow creeping cress</td>
<td>Tasmania, South Australia</td>
</tr>
<tr>
<td><em>Centaurea eriophora</em></td>
<td>mallee cockspur</td>
<td>South Australia</td>
</tr>
<tr>
<td><em>Crupina vulgaris</em></td>
<td>common crupina</td>
<td>South Australia</td>
</tr>
<tr>
<td><em>Cuscuta suaveolens</em></td>
<td>Chilean dodder</td>
<td>South Australia</td>
</tr>
</tbody>
</table>

Potential impacts

Weed risk assessment (WRA)

Under the AQIS WRA, a score of less than zero means that a plant is acceptable for import, plants scoring from one to five require more information while scores of six and above result in import applications being rejected. The WRA score of each weed ranged from 16 to 30, well above the maximum of 5 where import would not be permitted (Figure 2). A complete list of attributes scored by the WRA is presented in Appendix G along with all of the input data and results.
Figure 2. Weed Risk Assessment score for 17 candidate agricultural sleeper weeds.

Climate matching, land use matching and value of production at risk
Maps of the current and potential distribution of each candidate species are shown in Appendix C along with the information used to predict the potential distributions. The potential impact is quantified in Table 2 in terms of revenue at risk and profit at risk in land uses threatened by the weeds.
<table>
<thead>
<tr>
<th>Species</th>
<th>Ranking</th>
<th>Specific land use(s) at risk</th>
<th>Gross area at risk (km²)</th>
<th>Area of specified land use(s) at risk (km²)</th>
<th>Revenue at risk for specified land uses (million $)</th>
<th>Positive profit at full equity at risk for specified land use(s) (million $)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rorippa sylvestris</td>
<td>1</td>
<td>All cropping, all grazing, all horticulture</td>
<td>942,805</td>
<td>671,465</td>
<td>9,201</td>
<td>2,769</td>
</tr>
<tr>
<td>Hypericum tetrapterum</td>
<td>2</td>
<td>All cropping, all grazing, all horticulture</td>
<td>713,506</td>
<td>476,717</td>
<td>8,764</td>
<td>2,504</td>
</tr>
<tr>
<td>Oenanthe pimpinelloides</td>
<td>3</td>
<td>All cropping, all grazing, all horticulture</td>
<td>597,557</td>
<td>367,950</td>
<td>8,400</td>
<td>2,481</td>
</tr>
<tr>
<td>Eleocharis parodii</td>
<td>4</td>
<td>Irrigated cropping, irrigated grazing, irrigated horticulture and irrigated other</td>
<td>3,087,532</td>
<td>18,523</td>
<td>6,989</td>
<td>2,981</td>
</tr>
<tr>
<td>Asystasia gangetica ssp. micrantha</td>
<td>5</td>
<td>All cropping, all grazing, all horticulture, all other</td>
<td>1,773,433</td>
<td>1,145,430</td>
<td>5,618</td>
<td>1,827</td>
</tr>
<tr>
<td>Piptochaetium montevidense</td>
<td>6</td>
<td>All cropping, all grazing</td>
<td>637,599</td>
<td>480,131</td>
<td>5,570</td>
<td>1,721</td>
</tr>
<tr>
<td>Cuscuta suaveolens</td>
<td>7</td>
<td>All cropping, all grazing</td>
<td>272,199</td>
<td>176,964</td>
<td>4,762</td>
<td>1,514</td>
</tr>
<tr>
<td>Nassella charruana</td>
<td>8</td>
<td>All grazing</td>
<td>651,457</td>
<td>440,952</td>
<td>4,000</td>
<td>789</td>
</tr>
<tr>
<td>Baccharis pingraea</td>
<td>9</td>
<td>All grazing</td>
<td>649,452</td>
<td>436,836</td>
<td>3,910</td>
<td>819</td>
</tr>
<tr>
<td>Centaurea eriophora</td>
<td>10</td>
<td>Dryland cropping, all grazing</td>
<td>326,542</td>
<td>208,291</td>
<td>3,639</td>
<td>1,129</td>
</tr>
<tr>
<td>Crupina vulgaris</td>
<td>11</td>
<td>All grazing</td>
<td>584,256</td>
<td>259,967</td>
<td>3,599</td>
<td>725</td>
</tr>
<tr>
<td>Onopordum tauricum</td>
<td>12</td>
<td>All grazing</td>
<td>318,770</td>
<td>172,033</td>
<td>2,940</td>
<td>597</td>
</tr>
<tr>
<td>Hieracium aurantiacum</td>
<td>13</td>
<td>All grazing</td>
<td>269,967</td>
<td>121,110</td>
<td>1,774</td>
<td>306</td>
</tr>
<tr>
<td>Froelichia floridana</td>
<td>14</td>
<td>All grazing</td>
<td>558,207</td>
<td>411,307</td>
<td>1,267</td>
<td>259</td>
</tr>
<tr>
<td>Gmelina elliptica</td>
<td>15</td>
<td>All grazing</td>
<td>357,432</td>
<td>188,731</td>
<td>935</td>
<td>280</td>
</tr>
<tr>
<td>Aeschynomene paniculata</td>
<td>16</td>
<td>All grazing</td>
<td>901,578</td>
<td>593,830</td>
<td>352</td>
<td>46</td>
</tr>
<tr>
<td>Brillantaisia lamium</td>
<td>17</td>
<td>All cropping, all grazing</td>
<td>152,872</td>
<td>138,251</td>
<td>88</td>
<td>10</td>
</tr>
</tbody>
</table>
Feasibility of eradication

The results of the feasibility of eradication assessments are presented in Table 3 as modelled eradication costs. Full results and methods are reported in Appendix D.

Table 3. Relative feasibility of eradication of 17 candidate sleeper weeds

<table>
<thead>
<tr>
<th>Species</th>
<th>Feasibility ranking</th>
<th>Modelled eradication cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baccharis pingraea</td>
<td>1</td>
<td>$23,500</td>
</tr>
<tr>
<td>Eleocharis parodii</td>
<td>2</td>
<td>$35,100</td>
</tr>
<tr>
<td>Piptochaetium montevidense *</td>
<td>3</td>
<td>$35,100</td>
</tr>
<tr>
<td>Centaurea eriophora</td>
<td>4</td>
<td>$38,600</td>
</tr>
<tr>
<td>Crupina vulgaris</td>
<td>5</td>
<td>$104,000</td>
</tr>
<tr>
<td>Gmelina elliptica</td>
<td>6</td>
<td>$146,000</td>
</tr>
<tr>
<td>Onopordum tauricum</td>
<td>7</td>
<td>$175,000</td>
</tr>
<tr>
<td>Asystasia gangetica ssp. micrantha *</td>
<td>8</td>
<td>$198,300</td>
</tr>
<tr>
<td>Nassella charruana</td>
<td>9</td>
<td>$325,300</td>
</tr>
<tr>
<td>Aeschynomene paniculata</td>
<td>10</td>
<td>$457,000</td>
</tr>
<tr>
<td>Brillantaisia lamium *</td>
<td>11</td>
<td>$457,000</td>
</tr>
<tr>
<td>Oenanthe pimpinelloides *</td>
<td>12</td>
<td>$502,000</td>
</tr>
<tr>
<td>Hieracium aurantiacum</td>
<td>13</td>
<td>$553,000</td>
</tr>
<tr>
<td>Rorippa sylvestris **</td>
<td>14</td>
<td>$553,000</td>
</tr>
<tr>
<td>Hypericum tetrapterum</td>
<td>15</td>
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</tr>
<tr>
<td>Cuscuta suaveolens</td>
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<td>$1,230,000</td>
</tr>
<tr>
<td>Froelichia floridana *</td>
<td>17</td>
<td>$1,230,000</td>
</tr>
</tbody>
</table>

* indicates species for which information on propagule longevity could not be obtained, in these case the longest longevity category was used in the model and the feasibility of eradication could be higher.

** indicates a species for which an estimate of area was unavailable and the largest area category was used, in this case the largest area category was used in the model and the feasibility of eradication could be higher or lower.
Priority species recommended for eradication

The final priority list was produced by combining the modelled potential impact and feasibility of eradication measures. A conservative estimate of 10% of production was used to quantify the potential impact for each weed on agricultural production (Table 4). Combining the results in this way preserves the relativities in each of the two sets and the relativities between the two sets. The result for each species is a modelled benefit-cost ratio, expressed here in dollars to demonstrate the relative benefit-cost ratio of each weed. These results should not be considered as actual benefit-cost ratios for reasons outlined in the methods and discussion sections of this report.

Table 4. Prioritisation of 17 candidate sleeper weeds for eradication based on potential impacts and feasibility of eradication

<table>
<thead>
<tr>
<th>Species</th>
<th>Revenue at risk for specified land uses (million $)</th>
<th>Ranking (in terms of revenue at risk)</th>
<th>Modelled eradication cost ($) (feasibility)</th>
<th>Ranking (in terms of feasibility of eradication)</th>
<th>Modelled Benefit/cost (10% of modelled potential impact/modelled eradication cost)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Eleocharis parodi</td>
<td>6,989</td>
<td>4</td>
<td>$35,100</td>
<td>2</td>
<td>$19,913</td>
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<tr>
<td>2 Baccharis pingraea</td>
<td>3,910</td>
<td>9</td>
<td>$23,500</td>
<td>1</td>
<td>$16,640</td>
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<tr>
<td>3 Piptochaetium montevidense</td>
<td>5,570</td>
<td>6</td>
<td>$35,100</td>
<td>3</td>
<td>$15,868</td>
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<tr>
<td>4 Centaurea eriophora</td>
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<td>10</td>
<td>$38,600</td>
<td>4</td>
<td>$9,427</td>
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<td>5 Crupina vulgaris</td>
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<td>$104,000</td>
<td>5</td>
<td>$3,461</td>
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<td>5</td>
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<td>8</td>
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<tr>
<td>7 Onopordum tauricum</td>
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<td>7</td>
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<tr>
<td>8 Oenanthe pimpinelloides</td>
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<td>3</td>
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<td>12</td>
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<tr>
<td>9 Rorippa sylvestris</td>
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<td>9</td>
<td>$553,000</td>
<td>14</td>
<td>$1,664</td>
</tr>
<tr>
<td>10 Nassella charruana</td>
<td>4,000</td>
<td>8</td>
<td>$325,300</td>
<td>9</td>
<td>$1,230</td>
</tr>
<tr>
<td>11 Hypericum tetrapterum</td>
<td>8,764</td>
<td>2</td>
<td>$750,000</td>
<td>15</td>
<td>$1,169</td>
</tr>
<tr>
<td>12 Gmelina elliptica</td>
<td>935</td>
<td>15</td>
<td>$146,000</td>
<td>6</td>
<td>$641</td>
</tr>
<tr>
<td>13 Cuscuta suaveolens</td>
<td>4,762</td>
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<td>$1,230,000</td>
<td>16</td>
<td>$387</td>
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<tr>
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<td>$553,000</td>
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<td>$321</td>
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<tr>
<td>15 Froelichia floridana</td>
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<td>$1,230,000</td>
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<td>$103</td>
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<tr>
<td>16 Aeschynomene paniculata</td>
<td>352</td>
<td>16</td>
<td>$457,000</td>
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<td>$77</td>
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<tr>
<td>17 Brillantaisia lamian</td>
<td>88</td>
<td>17</td>
<td>$457,000</td>
<td>11</td>
<td>$19</td>
</tr>
</tbody>
</table>

* indicates species for which information on propagule longevity could not be obtained, in these case the longest longevity category was used in the model and the feasibility of eradication could be higher.

** indicates a species for which an estimate of area was unavailable and the largest area category was used, in this case the largest area category was used in the model and the feasibility of eradication could be higher or lower.

Based on available data, the ten species with the highest modelled benefit-cost ratios are:

Eleocharis parodi (N.S.W)
Baccharis pingraea (Vic.)
Piptochaetium montevidense (Vic.)
Centaurea eriophora (S.A.)
Crupina vulgaris (S.A.)
Asystasia gangetica ssp. micrantha (N.S.W.)
Onopordum tauricum (Vic.)
Oenanthe pimpinelloides (S.A.)
Rorippa sylvestris (Tas., S.A.)
Nassella charruana (Vic.)

These species are recommended for further eradication efforts as discussed below, they are described briefly in Table 5 and in detail in Appendix E.
Table 5. Brief description of ten sleeper weeds recommended for further eradication efforts

**Baccharis pingraea** (Vic.)
- A weed in South Africa
- A threat to grazing
- Naturalised near Maryborough, Victoria some time before 1989. Also recorded in NSW in 1969.
- There is thought to be only one infestation covering an estimated total of around 0.2 ha.

**Piptochaetium montevidense** (Vic.)
- Is listed in ‘A Global Compendium of Weeds’ (Randall 2002)
- A threat to cropping and grazing
- Naturalised near Altona, Victoria since 1988 or earlier
- There is thought to be only one infestation covering an estimated total of around 1 ha.

**Eleocharis parodii** (N.S.W)
- Listed in ‘A Global Compendium of Weeds’ (Randall 2002)
- A threat to irrigated cropping, grazing and horticulture
- Naturalised near Griffith, New South Wales since 1977 or earlier
- There is thought to be only one infestation covering an estimated total of less than 1 ha.

**Centaurea eriophora** (S.A)
- A weed in Colorado and California, and possibly Israel.
- A threat to cropping and grazing (rotational pastures)
- Naturalised near Cambrai, South Australia since 1984 or earlier
- There is thought to be only one infestation covering an estimated total of less than 2 ha.

**Crupina vulgaris** (S.A)
- A weed in North America and southern Russia
- A threat to grazing
- Naturalised near Adelaide, South Australia since 1936 or earlier
- There is thought to be only one infestation covering an estimated total of <100 ha.

**Oenanthe pimpinelloides** (S.A.)
- A weed in Ireland and New Zealand
- A threat to cropping and grazing
- Naturalised near Meadows, South Australia since 1971 or earlier
- There is thought to be only one infestation covering an estimated total of over 200 ha.

**Onopordum tauricum** (Vic.)
- A weed in south western Europe and the USA
- A threat to grazing
- Naturalised near Goroke, Natimuk and Euroa, Victoria since 1913 or earlier
- There are thought to be three infestations covering an estimated total of less than 20 ha.

**Rorippa sylvestris** (Tas., S.A.)
- A weed in USA, Japan and New Zealand
- A threat to cropping, grazing and horticulture
- There are thought to be two infestations in Tasmania covering an estimated total of less than 1 ha, and three infestations in South Australia with a total area still to be determined.

**Asystasia gangetica** ssp. micrantha (N.S.W.)
- A weed of tropical Americas, Malaysia, the Pacific Islands, Christmas Island and La Reunion
- A threat to cropping, grazing and horticulture
- Naturalised near Nelson Bay, New South Wales since 1999
- There are thought to be five main infestations covering an estimated total of around 10 ha.

**Nassella charruana** (Vic.)
- A weed in Uruguay, Argentina and Paraguay
- A threat to grazing
- Naturalised near Thomastown and Epping, Victoria since 1948 or earlier
- There are thought to be three infestations covering an estimated total of around 15 ha.
Discussion and conclusions

Principles and methods for prioritising sleeper weeds for eradication

When formulating cost-sharing approaches for the management of exotic plant incursions involving resources from the Federal government and a State or Territory, a number of guiding principles have been established and endorsed by the AWC (Panetta et al. 2002). Although we do not necessarily recommend that cost-sharing arrangements be made for eradication of the priority weeds, these principles are useful in providing a decision making framework for weed management regardless of funding sources. Principles one to four are decision principles based on potential impact and feasibility of eradication. The extent to which each of these principles is addressed in our methodology is as follows.

**P1  The identification of the suspected weed must be authoritatively confirmed**

This principle is covered in part by earlier work (Groves et al. 2002), which limited the list of naturalised plants to species for which a Herbarium voucher specimen was confirmed. The species analysed in this study are a subset of this list.

**P2  The weed must be potentially a serious weed of Australia**

This principle is addressed by the application of the Weed Risk Assessment and matching of potential distribution based on climate and land use. There is scope to consider soil type in modelling the potential distribution of weeds for which there is more knowledge of how this affects distribution. The ‘Digital atlas of Australia soils’ (BRS 1999) could be used as an additional layer in the GIS for this purpose. For environmental weeds, vegetation/plant community maps and maps of threatened species could be used as well as the land use maps used in this study to assess agricultural impacts. The timing of impacts is not explicitly addressed in our potential distribution models, i.e. the time it would take for a weed to impact on its entire potential distribution. This could be partially addressed with population and dispersion models, although there would be little data to support these for most potential sleeper weeds. Another area where further research would be useful is the application of modelling to predict which weeds or potential weeds are likely to become more problematic under predicted climate change scenarios.

There is also a need to quantify the marginal costs of specific weeds to agricultural production (e.g. additional costs on top of current weed management regimes for each land use and impact on trade of commodities produced). Again, this information is difficult to obtain for sleeper weeds unless they occur in countries with production systems similar to Australia or there are trade issues associated with the weed. Other costs not explicitly measured in our assessments are costs associated with a weed being a disease host, food or habitat for pest animals and altering land value.

**P3  Eradication must be feasible, the infestation confined to a small area and without there being major biological/ecological impediments to eradication**

This principle is addressed by assessment of infestation area and biological/ecological impediments to eradication. There is a need to confirm the infestation areas through delimiting surveys (see recommendations below).
P4  Cost-benefit of eradication must be favourable – there should be a clear and significant net benefit to Australia

This principle is addressed in part through potential impact measured in terms of value of production and profit at risk and modelled eradication effort. Note that the modelled eradication costs should be interpreted carefully. First, they are based on estimated eradication probabilities and not actual eradication data. Second, they are based on broad categorization of the weeds attributes. In any actual eradication campaign more detailed estimates would clearly be more reliable and useful in planning. The estimates that are produced are useful for assessing the relative feasibility of the candidate weeds, which was the aim of this project. Note also that the estimated costs are for the life of an eradication campaign while the estimated benefits are based on only one year’s production.

There is scope to include trade considerations and marginal costs of weeds (i.e. costs which are in addition to existing weed management costs). For a detailed eradication plane, the level of resources would need to be documented in greater detail than the modelled eradication cost which is used here as a relative measure. A discounted benefit-cost analysis would also be required.

Bomford and O’Brien (1995) and Simberloff (2003) have reviewed the factors that influence the likelihood of success of eradication campaigns and identified eight criteria that must be met for an eradication to be successful:

1. The rate of removal must exceed the rate of increase at all population densities (Bomford and O’Brien 1995)

2. Immigration must be zero (Bomford and O’Brien 1995) or the probability of reinvasion should be considered (Simberloff 2003)

3. Target species must be detectable at low densities (Bomford and O’Brien 1995; Simberloff 2003)

4. All reproductive individuals must be at risk (Bomford and O’Brien 1995)

5. Discounted cost-benefit analysis must favour eradication over control (Bomford and O’Brien 1995); economics should favour eradication (Simberloff 2003)

6. There must be a suitable socio-political environment (Bomford and O’Brien 1995); adequate resources must be committed to see the eradication project through to completion; and clear lines of authority must be established (Simberloff 2003)

7. The target species must have appropriate biological attributes (Simberloff 2003)

8. After eradication, subsequent restoration must be able to prevent reinvasion or other ecological problems (Simberloff 2003).

These factors align closely with the principles outlined by Panetta et al. (2002) and should be considered before implementing any eradication campaign. Some key points to be considered for the priority species identified in this study are that immigration must be zero (i.e. it should be confirmed that target species are not commercially traded or permitted for import) and that restoration after eradication should be considered.
Conclusions and future directions

The methods for this project were required to be transparent, scientifically objective and efficient. The intention was to apply widely accepted principles and methods that have already been the subject of peer review in the scientific community. Original approaches were limited to the integration of these existing methods. The methods are an effective tool for screening a large number of potential candidates with minimum input data.

We recommend that eradication be considered for the ten species identified above. For the purposes of analysing weeds for this project, the extent of infestations was estimated by consultation with the States and Territories. The project excluded fieldwork, Herbarium analyses and public awareness campaigns. A delimiting survey should be undertaken prior to any eradication effort for priority species. Rorippa sylvestris may have been confused with R. palustris in other parts of Australia; this should be investigated to determine how widespread this species actually is before undertaking fieldwork.

For an eradication campaign to be successful, it requires a time-limited plan supported by detailed benefit-cost analysis and a commitment of resources for the term of the eradication. This period may exceed ten or twenty years where a persistent seed bank is present. In this study, we found that the most significant factors influencing the likelihood of successful eradication are area, number of infestations, ease of access and propagule longevity.

Since fieldwork was beyond the scope of this study, the first three of these were based on estimates of experts in the jurisdictions where the weeds occur. We recommend that field surveys be undertaken for the ten priority weeds to collect firm data on their geographic distribution to validate the model of eradication feasibility and support the development of detailed eradication plans where the results confirm that eradication is feasible.
Acknowledgements

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David Cooke, Christian Goninon, David Maclaren, Kate Blood, Bruce Wilson, Geoff King and Brent Williams; and

References


