

Prioritizing weed species based on their threat and ability to impact on biodiversity: a case study from New South Wales

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Summary

Weeds pose a significant threat to biodiversity, but information on which species pose the greatest threat and the level of their impact is missing (i.e. only available for a few of the 3100+ naturalized plant species in Australia). Here we assessed the 1665 naturalized plant species in NSW to ascertain their level of threat as well as their ability to impact on native species. First we excluded those species which were (i) not known to be invasive, (ii) known from only a few locations, or (iii) not environmental weeds. The remaining 340 species were then modelled to establish a prioritized list. While we did not assess the actual impacts, the five attributes used in the model (i.e. spatial threat, species impact, invasive ability, number of species at risk and habitat type), when combined, provide a reasonable assessment given the lack of robust data available on impacts. The modelling process identified three extreme and 19 very high priority species with respect to their ability to have negative impacts on biodiversity. Of these many have been identified in other weed lists (e.g. the three extreme species, *Anredera cordifolia* (Madeira vine), *Lantana camara* (lantana) and *Chrysanthemoides monilifera* subsp. *rotundata* (bitou bush) were ranked as forty-first, fourth, and sixth, respectively, in the determination of the Weeds of National Significance). Our prioritized list of weed species based on their ability to impact on biodiversity will help to aid management decisions, especially for those weed species posing a landscape scale impact, in the absence of impact data.

Introduction

Weeds have been widely acknowledged as posing a threat to biodiversity (Humphries *et al.* 1991, Adair and Groves 1998, Byers *et al.* 2002, Richardson and van Wilgen 2004,

Coutts-Smith and Downey 2006). However, few studies exist that assess the biodiversity at risk or the weed species that pose the threat or how they impact upon native species (Downey 2008). Thus many discussions about impacts have been anecdotal in nature (Parker *et al.* 1999), in part because of the difficulties in collecting quantitative data (Adair and Groves 1998, Parker *et al.* 1999, Grice *et al.* 2004, Downey and Grice 2008). Therefore management decisions occur in the absence of robust data (Hiebert 1997, Grice *et al.* 2004). Several authors have endeavoured to quantify such impacts across weed species in an attempt to help conservation managers make prioritized decisions as not every weed species poses the same risk (e.g. Hiebert 1997, Adair and Groves 1998, Parker *et al.* 1999, Williamson 2001, Byers *et al.* 2002, D'Antonio and Kark 2002, Richardson and van Wilgen 2004, Randall *et al.* 2008). Despite these attempts, few lists of weed species ranked by their impacts on biodiversity have been produced upon which management decisions can be made (exceptions include Carr *et al.* 1992, Batianoff and Butler 2003, Nel *et al.* 2004, Randall *et al.* 2008). To rectify this situation other authors have attempted to compile information on the native species at risk from weeds, for example, as a pseudo measure (e.g. Coutts-Smith and Downey 2006) or as an inference based on the species at risk from a specific weed (DEC 2006, Turner and Downey 2010). However, this approach also has shortcomings and an alternative approach is needed, especially to assess multiple weed species.

Definitions

The terms *threat* and *impact* as used here have different meanings and are based on definitions in Downey *et al.* (2010). *Impact* describes the actual effects that an alien plant species has on native species and

is supported with quantifiable data (e.g. 'the invasion impacted the native species by reducing its density by 70% within 12 months'). Thus we use the term *impact* here in the context of whether a weed species has the ability to **cause** an impact, rather than by describing the **actual** impact. *Threat* is used to describe a possible danger (or exposure to harm), combined with the likelihood of that harm occurring to the native species present, without describing the nature of the threat. A further assessment is then needed to examine the actual impact.

Prioritizing weed species

Several systems have been developed to prioritize weeds (e.g. Hiebert 1997, Reid 1998, Parker *et al.* 1999, Thorp and Lynch 2000, Randall 2000, Pheloung 2001, Virtue *et al.* 2001, Nel *et al.* 2004, Anon. 2006, Randall *et al.* 2008, Downey *et al.* 2010). Most use a questionnaire system based around a similar set of questions to assess individual weed species, the values of which are then summed to provide a priority ranking. Questions asked are typically based around current and potential distribution, invasiveness, the level of threat or incorrectly impact, and feasibility of control. Given the lack of data, information on threats and to a greater degree impacts to biodiversity are typically encompassed under a broader ecological umbrella, and thus fail to account for the real nature or scale of the threat or impact (see Downey 2008).

In an attempt to better define the impacts of alien species Parker *et al.* (1999) established a measure of Impact (I) using three variables, being the invader's Range (R), Abundance (A) and Effect (E) (or $I = R \times A \times E$). Whilst on the surface this measure and the three variables might seem appropriate, its applicability to a non-theoretical situation is not; which the authors themselves discuss. Firstly the spatial interaction of range and abundance can be extremely variable (from monocultures to scattered individuals) thus these measures oversimplify the actual interaction (i.e. at any given location residence time, including lag phases, distributional limits or even biotic resistance can drive the interaction). Next, as Parker *et al.* (1999) point out, comparing the effect across any one of the five levels described: genetic, individual, population, community, and ecosystem or between them has difficulties. Thus the measure of effect is rarely achievable when examining alien species which pose broad impacts. Also the spatial interaction between range and effects is oversimplified in that the effect for many invaders is rarely correlated to their distribution pattern for the reasons outlined above. Lastly the effect measure does not account for other processes like the facilitation of subsequent invasions.

Thus the use of a single value measure for each is not appropriate, and a different process is needed.

The need for a prioritization process in Australia

There has been considerable discussions by land managers in Australia about the need to prioritize the weed species that fall between the 71 species considered during the Weeds of National Significance assessment (Thorp and Lynch 2000) and the 28 national alert species (see DEH 2000); being potentially the two extremes of the invasion spectrum. Approximately 97% of the 3100+ naturalized weed species in Australia are not encompassed by these assessments; a situation which is also evident at the state and territory level. The number of naturalized alien species in New South Wales (NSW) is around 1665 (based on vouchers at Australian herbaria). There are 183 state Noxious Weeds, but information on their impacts is confined to a few species, mostly following their nomination as Key Threatening Processes under the NSW threatened species legislation. For the rest of the naturalized alien species little is known about their impact on biodiversity. Many land managers are thus making decisions about large numbers of weed species with limited data, which greatly influences their ability to deliver outcomes. However, there is no comparative system to establish priorities for weed control for biodiversity conservation across NSW, let alone a list of weed species or biodiversity at risk (Williams *et al.* 2008). Whilst Downey *et al.* (2010) have developed a triage approach to prioritize control based on models to assess the species at risk (once known) and sites for control, their work has not involved a systematic assessment of all weed species that pose a threat to native species.

The aim of this project was to assess the 1665 naturalized plant species within NSW with respect to their threat and ability to pose an impact upon biodiversity and produce a prioritized list of significant environmental weeds for management.

Methods and results

Weeds in New South Wales

We used the 1665 naturalized plant species present in NSW, derived from herbarium records (RBG unpublished data) as the base list upon which to assess those weed species posing a threat to, or having an ability to impact upon, biodiversity. Weed nomenclature followed the Flora of NSW (Harden 1993-2002), with more recent taxonomic revisions as published on PlantNET (BGT 2007, the NSW Herbarium website). Where possible the species and/or subspecies/variety name was used, except where the taxonomy was uncertain (e.g. blackberry (*Rubus fruticosus* L. aggregate)).

Selecting weed species which have an ability to impact on biodiversity

By using information on the: (1) degree of naturalization, and (2) weed type (see further discussion below), as determined by either the published literature, and/or the authors' knowledge, we truncated the list of 1665 naturalized plant species to 340 weed species which we believe currently have the ability to pose a threat to, or impact upon, biodiversity in NSW (i.e. now or within then next five years).

(1) Degree of naturalization Each species was assessed to determine the degree of naturalization (along an invasion continuum from newly naturalized through to widespread species), using the respective naturalization codes in Groves *et al.* (2003) and the authors' knowledge and published literature. Those species with small distributions or not widely naturalized (codes 0 to 2 in Groves *et al.* 2003 – see Table 1) were removed from the list, along with any of the newly naturalized species and/or species for which there was insufficient information to make an accurate determination.

(2) Weed type Each weed was then classified as either environmental, agricultural, neither or a combination (see Table 2) using the codes in Groves *et al.* (2003) as well

as the authors' knowledge and the available literature. Through this process we identified 340 environmental weed species in NSW to prioritization for management.

Literature used

Numerous sources were examined to help determine the various attributes used here (see above and below) for each weed species. The main literature included: Csurhes and Edwards (1998), Blood (2001), Parsons and Cuthbertson (2001), Randall (2002), Groves *et al.* (2003), Coutts-Smith and Downey (2006), Richardson *et al.* (2006), Harden (1993-2002) and BGT (2007).

Development of a model for prioritizing weeds threatening biodiversity

The model we developed incorporated various aspects of other weed assessment systems as well as several new attributes, specifically relating to the spatial threat to biodiversity at a landscape scale. Assessments for each of the 340 weed species examined were made based on the authors' knowledge and the published literature.

The model

The model developed here uses five attributes, that when combined, enabled an assessment of the weed species likely threat and ability to impact upon biodiversity to be undertaken in the absence of

Table 1. Categories for assessing the degree of weed naturalization (from Groves *et al.* 2003).

Code	Category explanation
0	Reported as naturalized but only known naturalized population now removed or thought to be removed
0?	Uncertainty as to whether any plants exist
1	Naturalized and may be a minor problem but not considered important enough to warrant control at any location
1?	Uncertainty as to whether a small number of plants remain
2	Naturalized and known to be a minor problem warranting control at 3 or fewer locations within a State or Territory
3	Naturalized and known to be a minor problem warranting control at 4 or more locations within a State or Territory
4	Naturalized and known to be a major problem at 3 or fewer locations within a State or Territory
5	Naturalized and known to be a major problem at 4 or more locations within a State or Territory
?	Information not available at present

Table 2. Three weed type categories.

Weed type TM
Environmental (either entirely or partly)
Agricultural (e.g. entirely within pasture and cropping systems)
Neither agricultural nor environmental, or partly agricultural (being a species primarily of wastelands, roadsides and disturbed areas, but not currently within natural areas)

quantitative data on actual impacts. The five attributes used are: spatial threat (**A**); native species impact (**B**); invasive ability (**C**); number of native plant species potentially at risk, or biodiversity at risk (**D**), and; habitat type invaded (**E**). These attributes are all assessed on a regional basis (being the botanical regions in NSW – Figure 1) and then summed to give a state-wide value which is then weighted based on the threat potential (**A1**).

The model for ranking the ability of weeds to impact upon biodiversity is presented in Equation 1 below.

The value for each attribute is derived from a range of scores with the highest score implying the highest priority. A short description of each attribute and the value range assigned to each is presented below.

A. Spatial threat The threat and impact a weed species has on native species is not homogeneous across either the distribution of the alien or the native species at risk. For example some native species have distributions that extend outside

that of the alien species which threaten them, and thus are only subjected to a potential impact in part of their range (see DEC 2006, Turner and Downey 2010). Whilst other weed species cause localized impacts in part of their range, and no or little impact over their remaining range (i.e. especially on the fringes of their distributional limits). Thus the distribution pattern of a weed, while showing its geographical range, is not a reflection of the level of threat or impact to the native species present. Such variation is accounted for in the model with attribute A, which determines the current and potential distribution of each weed species relative to the spatial nature of the threat on a regional basis. The likely nature of the impact to native species is not considered here, but is accounted for through attributes B and C.

The current distribution of each weed species was determined using PlantNET (BGT 2007), AVH (2007) and the authors' knowledge. The distribution of each weed species was separated into the botanical divisions and subdivisions of NSW (see

Figure 1), the exceptions being the combination of the north and south subdivisions within the Western Plains and Far Western Plains divisions, giving a total of 11 botanical divisions (Figure 1); these divisions are used for the regional component of the model. The potential distribution of each weed species was determined for these 11 divisions based on the current distribution pattern, the authors' knowledge and the available literature (e.g. Blood 2001, PlantNET (BGT 2007) for where locations were within close proximity to the boundary between botanical divisions).

Lastly, the spatial nature of the threat posed by each weed species was assessed for each botanical division they occupied, using the scoring system outlined below:

Score	Weighted spatial threat (A) for each of the 11 botanical divisions in NSW
0	no threat – species not present and unlikely to invade the division,
0.5	potential threat only – species not present in the division, but has been assessed as having the potential to invade the division in the future,
1	present, threat unlikely – species only known from a few very small infestations in the division (e.g. <5),
3	low threat – species suspected of posing a threat in the division, with no assumption or evidence of impacts,
7.5	medium threat – species acknowledged as posing a threat to native species in part or all of the division and impacts suspected but not observed, or
16.5	high threat – species known to threaten and impact upon native species in the division.

The spatial threat level was determined based on the authors' knowledge on the species distribution and threat, combined with the available literature (e.g. Blood 2001) and the number of herbarium collections in each division (e.g. from PlantNET (BGT 2007), AVH 2007). To reflect the variation between the potential impact of newly naturalized and that of widespread weeds the values were weighted increasingly towards the highest value (see above).

B. Native species impact This and the next attribute (C), when combined provide a basis for assessing the likely impact of each weed species to biodiversity. Attribute B assesses the likely degree of impact to native species from each weed species using the following criteria:

$$\text{Priority rank} = \sum (\text{weighted spatial threat [A]} \times \text{species impact [B]} \times \text{invasive ability [C]} \times (\text{biodiversity at risk [D]} \times \text{habitat type [E]} / \text{maximum habitat type [E}_{\text{max}}])) \times \text{botanical divisions} \times \text{threat potential [A1]}$$

Equation 1.



Figure 1. Botanical divisions and subdivisions in New South Wales (after Harden 2002).

Score	Degree of native species impact (B)
1	low or limited degree of threat or impact observed to date,
2	moderate degree of impact (e.g. impact is to specific individuals of a native species, rather than to populations or ecosystems),
3	high degree of impact (e.g. where a weed species has a significant negative impact on populations of native species, but not to the level of 4), or
4	transformer species (e.g. weed species that are considered capable of, or are presently modifying the invaded ecosystem to such an extent that they alter ecosystem processes. For example, fire regimes, nutrients, water flows, physical habitat modification, facilitation of other weed species (see Richardson <i>et al.</i> 2000)).

In some instances, weed species were given a score between two of these categories because they were deemed to be between them and it was difficult to put them into one or the other category (e.g. 2.5 was deemed to be between some impacts and having a significant impact).

C. Invasive ability This attribute describes the weed species ability to invade an ecosystem. For example, some weed species can invade intact vegetation communities in the absence of any kind of physical disturbance, while others are restricted to the edges only. This attribute is inter-linked with attribute B, for example transformer species do not typically experience invasion barriers, but this does not mean that either B or C alone is sufficient to assess all weed species. The invasive ability of each weed species was determined based on the following criteria:

Score	Invasive ability (C)
1	invasive ability restricted (e.g. to the edges of vegetation communities only),
2	invasive with limitations (e.g. while the weed species can invade intact or undisturbed vegetation communities, it typically does not do well in such situations, invasion is often aided by other factors like disturbance), or
3	ability to invade without limitations (e.g. invasion is not subject to biotic barriers or invasion constraints, or requires a disturbance event).

Some weed species were given a score between two categories (i.e. 1.5) as they were deemed to lie between the two categories when their invasive ability was assessed and averaged across their entire distribution.

D. Number of native plant species potentially at risk The biodiversity within NSW is not homogenous across the state, with a greater diversity and number of plant species occurring in the North Coast botanical division (i.e. north-east of the state – Figure 1) compared with the Far Western Plains botanical division (being 42 and 18% respectively, Table 3). Such variability can greatly influence the number of native species a weed species could potentially impact upon. Information on the number of native plant species present within each of the 11 botanical divisions was obtained from herbarium records held at the National Herbarium of NSW (BGT unpublished data). Only taxa at the species level were used (i.e. subspecies, varieties and forms were excluded).

E. Habitat type The ability to invade a range of habitat types influences the scale of threat posed to biodiversity. The number and types of habitats invaded by each weed species varies greatly, with some weed species invading a diverse range of habitats, while others are constrained by habitat type (e.g. restricted to aquatic and semi-aquatic ecosystems only). Information was compiled on the number and types of habitats invaded by each weed species, using 11 generic habitat types based on structural vegetation elements as outlined in Table 4.

The proportion of habitats invaded is used in the model by dividing the number of habitat types invaded (E) by the maximum number of habitats present (being

E_{max}). This assumes that all habitat types are equal in importance.

A1. Threat potential This attribute is used as a final weighting in the model (i.e. after all 11 individual botanical division values are summed). The weighting score is calculated by summing the values of A for each botanical division (giving the total (T) spatial threat (or A_T)). The total spatial threat (A_T) is then divided by the maximum value observed for T (being T_{max}) which gives the value A1.

Ranking weeds and establishing priorities

The model output was ranked to provide a priority order. Natural breaks in the ordering of the values (i.e. between two species) were used to establish five different priorities, being extreme, very high, high, medium and low priority with respect to the weed species threat and ability to impact upon biodiversity from a state-wide perspective (see Appendix 1).

Table 4. Generic habitat types used to reflect the diversity of habitats a weed can invade.

Habitat type
Aquatic
Foredune / coastal vegetation
Grasslands (including Alpine)
Wetlands / swampy areas / semi-aquatic
Heath
Woodlands
Open forest
Rainforest (closed forest)
Riparian
Shrublands / Mallee
Arid / desert

Table 3. Number of native plant species present in each of the 11 botanical divisions of New South Wales (BGT unpublished data as at 14 July 2005).

Botanical division in New South Wales	Number of native plant species present	Percentage of the total flora in New South Wales
North Coast	2505	42.4
Central Coast	2053	34.7
South Coast	1566	26.5
Northern Tablelands	1631	27.6
Central Tablelands	1767	29.9
Southern Tablelands	1701	28.8
North Western Slopes	1311	22.2
Central Western Slopes	1497	25.3
South Western Slopes	810	13.7
Western Plains	1519	25.7
Far Western Plains	1065	18.0
Statewide totals	5910 ^{A,B}	100

^A This number only includes species.

^B The individual botanical division values are not cumulative as many species occur in more than one division.

The list of weed species

This assessment of the 1665 naturalized weed species in NSW resulted in a list of 340 weed species with an ability to have an impact on biodiversity in the state (see Appendix 1). The model output predicted the top three (3) weed species as having an extreme impact upon biodiversity in NSW (being Madeira vine (*Anredera cordifolia* (Ten.) Steenis), lantana (*Lantana camara* L.) and bitou bush (*Chrysanthemoides monilifera* subsp. *rotundata* (DC.) Norl.), respectively). The next 19 weed species are predicted as having a very high ability to impact upon biodiversity, whilst the following 28 have a high ability (Table 5). While the remainder pose a threat to biodiversity their ability to pose significant impacts on a state-wide scale within the next five years is low, however, many may have an ability to impact upon biodiversity in a localized area.

Discussion

At present there are considerable resources being channelled into the management of a large number of weed species for the conservation of biodiversity across all levels of government and the community. However, the majority of these management decisions are being made in the absence of robust data on the threat or impact to biodiversity (Grice *et al.* 2004, Downey and Grice 2008). Rectification of this situation requires either significant amounts of new data (i.e. for the vast majority of these weed species) or better decision making tools. The collection and dissemination of large amount of data on impacts is a difficult task (see Adair and Groves 1998, Parker *et al.* 1999, Downey and Grice 2008) especially in the short term and without significant additional resources, which is why other measures to assess the threats or impacts have recently been developed. For example, DEC (2006) and Coutts-Smith and Downey (2006) both initiated processes to assess such threats and impacts as there was no other mechanisms developed, that could deliver such outcomes within a short timeframe. The list presented here will assist in rectifying this situation by providing a comprehensive assessment of all the weed species within one of the Australian states. Whilst the prioritized list of weed species can be used to make informed management decisions about individual species and justify individual programs, it can also be used to focus efforts for those weed species that pose landscape scale impacts.

The creation of a model to encompass all weed species that pose a threat and potential impact upon biodiversity will unwillingly have inherent biases towards one or more groups of species. Our model contains a bias against aquatic weeds as they only have the potential to invade a small number of the habitat types (i.e.

Table 5. Five statewide priority groups of weed species based on their potential impact on biodiversity in New South Wales and the number in each group.

Statewide priority	Number of weed species	Rank order (cumulative total) base on the model output
Extreme	3	3
Very high	19	22
High	28	50
Medium	85	135
Low	205	340
Total	340	340

aquatic and semi-aquatic habitats, see Table 4). However, as several aquatic weeds ranked high in the model, for example *Salvinia molesta* D.S.Mitch. is ranked 12th, we believe that the other attributes in the model help reduce this bias.

Managing the highest priority weed species for biodiversity conservation outcomes

All three extreme priority weed species (see Appendix 1) are currently listed as Key Threatening Processes (KTPs) under the NSW *Threatened Species Conservation Act 1995* (TSC Act), either as individual species as in the case of bitou bush and lantana or as part of a generic weed listing for exotic vines which includes Madeira vine. While significant progress has been made towards abating the impact of bitou bush and lantana to biodiversity (see DEC 2006, Turner and Downey 2010), little has been done at a similar scale for Madeira vine, partly because it was only recently listed as a KTP (see NSW SC 2007) and information on its biology and ecology had also not been collated until recently (Vivian-Smith *et al.* 2007).

Three other KTPs listed in NSW relate to weed species; individual species listings for Scotch broom (*Cytisus scoparius* (L.) Link), and listings for exotic perennial grasses and garden escapes. These listings cover over 80 weed species in the list of 340 weed species examined here (excluding the garden escapes KTP), 51 of which are exotic perennial grasses and 27 are vines or scramblers. A key threatening process listing does not currently cover ten of the 19 very high priority weed species, and thus this list could be used to investigate the potential for nominating them as KTPs.

This prioritized list of weed species highlights the need for managing some of the worst species (i.e. those that have an ability to impact upon biodiversity at a landscape scale) in a collective manner, for example, the three extreme and 19 very high priority species. Whilst weed listings

under the TSC Act can help (Downey *et al.* 2009), their management will require co-ordination and inputs from all stakeholders to succeed (Strehling *et al.* 2008). In addition management programs need to better ensure that conservation outcomes are achieved for such weed species. Also this list could be used to justify new listings or strengthen the control classification of weeds already listed under the NSW *Noxious Weeds Act 1993*. Lastly given that many of these alien species occur in other states and territories within Australia this list could also be used to support similar listings under the relevant legislation (e.g. threatened species and/or noxious weeds).

Comparisons with other lists of weeds in Australia

In 2000 a list of the Weeds of National Significance (WoNS) was published in Australia (Thorp and Lynch 2000). Of the list of 71 weeds (including several groups of related species e.g. willows) considered during this assessment, 42 were recorded in our list of weeds threatening biodiversity and 15 of the 20 priority WoNS (see Appendix 1). All three of the weed species ranked as extreme priority here, were also considered in the list of WoNS, with lantana and bitou bush being in the top twenty and Madeira vine at number 41. The low ranking of Madeira vine in the WoNS list is to a large extent based on the current and potential distribution range used in the WoNS assessment (see Thorp and Lynch 2000), which was much smaller than the revised versions produced by Vivian-Smith *et al.* (2007).

Twelve of the WoNS were ranked here as very high priority for control, eight of which were in the top 20 WoNS. The other four are Scotch broom, large-leaved privet (*Ligustrum lucidum* W.T.Aiton), narrow-leaf privet (*Ligustrum sinense* Lour.) and cat's claw creeper (*Macfadyena unguis-cati* (L.) A.H.Gentry), while the seven high priority weed species not listed under the WoNS are ground asparagus (*Asparagus aethiopicus* L.), Japanese honeysuckle (*Lonicera japonica* Thunb.), cape ivy (*Delairea odorata* Lem.), blue morning glory (*Ipomoea indica* (Burm.) Merr.), balloon vine (*Cardiospermum grandiflorum* Sw.), ochna (*Ochna serrulata* (Hochst.) Walp.), and turkey rhubarb (*Acetosa sagittata* (Thunb.) L.A.S.Johnson & B.G.Briggs). The combination of updated data and a more focused assessment (i.e. with respect to impacts to biodiversity, and within one state rather than nationally) contributed to their higher ranks here. Irrespective any revision of the WoNS list should include such information.

Of the 340 weed species identified here, 121 were identified by Coutts-Smith and Downey (2006) as posing an impact to native species in NSW. All three extreme

priority species were among the 20 most commonly identified weed threats in Coutts-Smith and Downey (2006), with lantana and bitou bush at the top and Madeira vine at number 13. This however, may be a reflection of the emerging status of Madeira vine as a significant weed in NSW as opposed to both lantana and bitou bush which have been established over a wider area for a longer period and thus have had a greater timeframe over which to pose a threat and impact on native species. It also could be a reflection of the greater weighting towards the north eastern part of the state where there are more native species potentially at risk and the main part of Madeira vine's distribution.

Four of the 20 most commonly identified weed species in Coutts-Smith and Downey (2006) were ranked as very high, eight as high and five as medium priority here, supporting their conclusion that their assessment only formed part of the assessment of impacts. For example an individual weed species could not be identified for over half of the weed threats to biodiversity assessed and the list of threatened species only accounts for about 15% of the total flora and fauna in NSW, all of which could be at risk from weeds (Coutts-Smith and Downey 2006).

Nine of the 10 highest priority weed species identified by Batianoff and Butler (2003) for south-east Queensland were included here. Of the three extreme weed species (see Appendix 1), lantana was ranked their highest species and Madeira vine fourth, whilst bitou bush is under eradication in Queensland and thus not considered by Batianoff and Butler (2003). Two very high priority species were also in their top ten, being cat's claw creeper and ground asparagus. The remaining five species in their top 10 were here ranked as high (three species), medium (one) and low (one), in part because some of them are not widespread in NSW.

Comparisons with other assessment systems

The vast majority of weed prioritization assessments to date have been based around answering a series of questions about individual weed species (e.g. Hiebert 1997, Pheloung 2001, Randall *et al.* 2008). Such assessments rarely include outputs (e.g. lists of ranked alien species – exceptions include Randall *et al.* (2008) but only via a weblink), in part because they are either set up for a species-by-species assessment (e.g. weed risk assessment) or as a protocol only. In addition, those schemes that have assessed species rarely assess all the species in a given area or region, instead using a subset, the selection of which is seldom justified. To avoid this situation we provided the protocol or model for assessing weed species as well as an assessment of all 1665 naturalized weeds in one State (NSW).

Part of a broader state-wide initiative for managing weeds that threaten biodiversity

This project comprises one of three main initiatives developed to manage weeds and their impacts on biodiversity in NSW. This project aimed to determine which weeds posed a threat or impact on biodiversity and rank them in priority order for management at a state-wide level. The second initiative provides an indicative assessment of the threat or likely impacts to biodiversity; Coutts-Smith and Downey (2006) assessed the threat of weeds on native species listed under the TSC Act. While these two initiatives provide an excellent basis for managing weeds threatening or impacting on biodiversity, they do not provide guidance on how best to reduce the threat specifically from an on-ground perspective. The last initiative aims to do this and is showcased by the NSW Bitou Bush Threat Abatement Plan (TAP) (DEC 2006), which establishes a system to prioritize sites for control. This approach aims to deliver on-ground weed management which is focused on biodiversity conservation outcomes across land tenures based on a triage model for control (see Downey *et al.* 2010). The TAP process is now being adopted for lantana nationally in Australia (NLMG 2009, Turner and Downey 2010) and for all weed species at a regional scale (being the 13 Natural Resource Management regions in NSW which are based on catchments – see Williams *et al.* 2008).

Conclusion

Information on weed species and their threats and impacts on biodiversity is desperately needed especially on a landscape scale. The current assessment goes a long way to rectifying this situation in NSW, however, a lot of additional information is still needed. For example, better data on impacts is needed for many weed species, specifically information on the native species at risk and the processes by which these species are experiencing a decline. It is hoped that this list will stimulate further discussion on weed species and their impacts to native species, as well as to guide and determine investment priorities, rather than the current piecemeal approach. This list should be used to help ensure that weed management in natural ecosystems delivers conservation outcomes, especially when combined with the other measures established within NSW to protect biodiversity during weed control. This assessment and the others developed to date for NSW are applicable to any other State, region or country.

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Appendix 1. List of weed species that pose a threat and have an ability to impact on biodiversity in New South Wales, ranked in priority order (see text for details on the model).

Scientific name	Common name	Family name	Score from the model	Rank order (from model)	Priority ^A	Covered in a KTP listing in NSW ^B	Known to pose a threat and number of species at risk ^C	Weeds of National Significance ^D	
								Top 20 species	71 candidates
<i>Anredera cordifolia</i>	Maderia vine	Basellaceae	634.4	1	E	vs	7		41
<i>Lantana camara</i>	lantana	Verbenaceae	592.8	2	E	l	96	1	4
<i>Chrysanthemoides monilifera</i> subsp. <i>rotundata</i>	bitou bush	Asteraceae	583.1	3	E	bb	46	1	6
<i>Asparagus aethiopicus</i>	ground asparagus	Asparagaceae	467.4	4	VH		3		
<i>Rubus fruticosus</i> species aggregate	blackberry	Rosaceae	453.0	5	VH		21	1	3
<i>Cytisus scoparius</i> subsp. <i>scoparius</i>	Scotch broom	Fabaceae	408.8	6	VH	sb	12		37
<i>Lonicera japonica</i>	Japanese honeysuckle	Caprifoliaceae	405.3	7	VH	vs	5		
<i>Ligustrum lucidum</i>	large-leaved privet	Oleaceae	397.3	8	VH		4		56
<i>Ligustrum sinense</i>	narrow-leaf privet (small leaved privet)	Oleaceae	371.4	9	VH		11		56
<i>Alternanthera philoxeroides</i>	alligator weed	Amaranthaceae	364.4	10	VH		1	1	20
<i>Macfadyena unguis-cati</i>	cat's claw creeper	Bignoniaceae	343.8	11	VH	vs	4		23
<i>Salvinia molesta</i>	salvinia	Salviniaceae	323.2	12	VH		2	1	9
<i>Ulex europaeus</i>	gorse	Fabaceae	304.8	13	VH			1	18
<i>Chrysanthemoides monilifera</i> subsp. <i>monilifera</i>	boneseed	Asteraceae	245.4	14	VH	bb		1	6
<i>Nassella trichotoma</i>	serrated tussock	Poaceae	230.8	15	VH	eg	2	1	15
<i>Delairea odorata</i>	cape ivy	Asteraceae	222.8	16	VH	vs	4		
<i>Ipomoea indica</i>	blue morning glory	Convolvulaceae	198.8	17	VH	vs			
<i>Cardiospermum grandiflorum</i>	balloon vine	Sapindaceae	194.9	18	VH	vs	3		
<i>Phyla canescens</i>	lippia	Verbenaceae	191.4	19	VH		1		61
<i>Asparagus asparagoides</i>	bridal creeper	Asparagaceae	181.4	20	VH	vs	5	1	19
<i>Ochna serrulata</i>	ochna	Ochnaceae	179.2	21	VH		1		
<i>Acetosa sagittata</i>	turkey rhubarb / rambling dock	Polygonaceae	178.7	22	VH		1		
<i>Anthoxanthum odoratum</i>	sweet vernal grass	Poaceae	150.8	23	H	eg	2		
<i>Eragrostis curvula</i>	African love grass	Poaceae	135.4	24	H	eg	9		50
<i>Hyparrhenia hirta</i>	Coolatai grass	Poaceae	129.9	25	H	eg	7		
<i>Caesalpinia decapetala</i>	mysore thorn	Caesalpinaceae	119.7	26	H				
<i>Lycium ferocissimum</i>	African boxthorn	Solanaceae	108.7	27	H		5		24
<i>Schinus terebinthifolius</i>	broad leaf pepper tree	Anacardiaceae	105.9	28	H				29
<i>Nassella neesiana</i>	Chilean needlegrass	Poaceae	99.1	29	H	eg		1	12
<i>Ipomoea cairica</i>	coastal morning glory	Convolvulaceae	98.6	30	H	vs	4		
<i>Pueraria lobata</i>	kudzu	Fabaceae	94.3	31	H	vs			
<i>Genista monspessulana</i>	Montpellier broom / French broom / cape broom	Fabaceae	92.2	32	H		1		
<i>Olea europea</i> subsp. <i>cuspidata</i>	African olive	Oleaceae	86.6	33	H		5		
<i>Pyracantha angustifolia</i>	orange firethorn	Rosaceae	84.5	34	H				

continued/...

Appendix 1 continued/...

Scientific name	Common name	Family name	Score from the model	Rank order (from model)	Priority ^A	Covered in a KTP listing in NSW ^B	Known to pose a threat and number of species at risk ^C	Weeds of National Significance ^D	
								Top 20 species	71 candidates
<i>Cinnamomum camphora</i>	camphor laurel	Lauraceae	73.8	35	H		11		
<i>Gloriosa superba</i>	glory lily	Colchicaceae	72.5	36	H	vs	1		
<i>Hedera helix</i>	English ivy	Araliaceae	72.1	37	H	vs	3		
<i>Salix babylonica</i>	weeping willow	Salicaceae	71.2	38	H			1	14
<i>Tradescantia fluminensis</i>	wandering jew / trad	Commelinaceae	70.2	39	H	vs	8		
<i>Pennisetum clandestinum</i>	kikuyu	Poaceae	69.0	40	H	eg	16		
<i>Myriophyllum aquaticum</i>	parrot's feather (Brazilian water-milfoil)	Haloragaceae	68.5	41	H				
<i>Pistia stratiotes</i>	water lettuce	Araceae	66.7	42	H				
<i>Schinus areira</i>	pepper tree	Anacardiaceae	64.8	43	H				
<i>Thunbergia grandiflora</i>	blue trumpet vine	Acanthaceae	64.5	44	H	vs			
<i>Gleditsia triacanthos</i>	honey locust tree	Fabaceae	63.0	45	H		2		38
<i>Ipomoea purpurea</i>	purple morning glory (common morning glory)	Convolvulaceae	62.3	46	H	vs			
<i>Eichhornia crassipes</i>	water hyacinth	Pontederiaceae	61.7	47	H		3		25
<i>Ageratina riparia</i>	mistflower	Asteraceae	59.6	48	H		9		
<i>Cabomba caroliniana</i>	cabomba	Cabombaceae	58.2	49	H			1	11
<i>Ipomoea alba</i>	moon flower	Convolvulaceae	57.5	50	H	vs			
<i>Cotoneaster glaucophyllus</i>	cotoneaster	Rosaceae	50.9	51	M				
<i>Ehrharta calycina</i>	perennial veldt grass	Poaceae	49.8	52	M	eg			
<i>Araujia sericifera</i>	moth vine / plant	Asclepiadaceae	49.1	53	M	vs	6		
<i>Elodea canadensis</i>	Canadian pond weed / elodea	Hydrocharitaceae	48.3	54	M				
<i>Echium plantagineum</i>	Paterson's curse	Boraginaceae	47.8	55	M				32
<i>Ageratina adenophora</i>	crofton weed	Asteraceae	47.7	56	M		12		
<i>Senna pendula</i> var. <i>glabrata</i>	senna (winter)	Caesalpiniaceae	46.5	57	M		3		
<i>Cenchrus incertus</i>	spiny burr grass	Poaceae	44.2	58	M	eg			
<i>Prosopis velutina</i>	mesquite (velvet)	Mimosaceae	43.8	59	M			1	2
<i>Sporobolus fertilis</i>	giant Parramatta grass	Poaceae	40.5	60	M	eg	2		48
<i>Pinus radiata</i>	radiata pine	Pinaceae	39.1	61	M		3		
<i>Salix × rubens</i>	basket willow	Salicaceae	36.7	62	M			1	14
<i>Hygrophila costata</i>	glush weed	Acanthaceae	33.3	63	M		1		
<i>Paspalum dilatatum</i>	paspalum	Poaceae	32.7	64	M	eg	8		
<i>Passiflora subpeltata</i>	passionflower (white)	Passifloraceae	32.6	65	M	vs	1		
<i>Celtis sinensis</i>	celtis / Japanese hackberry	Ulmaceae	31.3	66	M				35
<i>Salix fragilis</i> var. <i>fragilis</i>	crack willow	Salicaceae	30.9	67	M			1	14
<i>Thunbergia alata</i>	black-eyed Susan	Acanthaceae	29.2	68	M	vs	1		
<i>Crataegus monogyna</i>	hawthorn	Rosaceae	29.0	69	M				
<i>Briza minor</i>	little quacking grass	Poaceae	28.2	70	M	eg			
<i>Marrubium vulgare</i>	horehound	Lamiaceae	27.7	71	M		1		
<i>Asparagus plumosus</i>	climbing asparagus	Asparagaceae	27.7	72	M	vs	1		
<i>Triadica sebifera</i>	Chinese tallow	Euphorbiaceae	25.1	73	M				
<i>Robinia pseudoacacia</i>	black locust	Fabaceae	24.2	74	M				

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Appendix 1 continued/...

Scientific name	Common name	Family name	Score from the model	Rank order (from model)	Priority ^A	Covered in a KTP listing in NSW ^B	Known to pose a threat and number of species at risk ^C	Weeds of National Significance ^D	
								Top 20 species	71 candidates
<i>Erythrina crista-galli</i>	cockspur coral tree/ Indian coral tree	Fabaceae	23.0	75	M		1		
<i>Setaria pumila</i>	pale pigeon grass	Poaceae	22.8	76	M	eg			
<i>Baccharis halimifolia</i>	groundsel bush	Asteraceae	22.2	77	M		6		
<i>Buddleja madagascariensis</i>	buddleia	Scrophulariaceae	20.8	78	M				
<i>Juncus acutus</i>	spiny rush grass/ sharp rush	Juncaceae	20.8	79	M	eg	2		
<i>Xanthium occidentale</i>	Noogoora burr	Asteraceae	19.9	80	M		1		28
<i>Holcus lanatus</i>	Yorkshire fog	Poaceae	19.5	81	M	eg	4		
<i>Canna indica</i>	canna lily	Cannaceae	19.3	82	M				
<i>Ehrharta longiflora</i>	annual veldt grass	Poaceae	19.1	83	M	eg			
<i>Paspalum wettsteinii</i>	broad leaf paspalum	Poaceae	18.9	84	M	eg	1		
<i>Sporobolus africanus</i>	Parramatta grass	Poaceae	18.4	85	M	eg			
<i>Macroptilium atropurpureum</i>	siratro	Fabaceae	17.9	86	M				
<i>Cuscuta campestris</i>	golden dodder	Convolvulaceae	17.1	87	M				36
<i>Ailanthus altissima</i>	tree of heaven	Simaroubaceae	17.1	88	M		1		
<i>Hypericum perforatum</i>	common St John's wort	Clusiaceae	17.1	89	M		1		
<i>Gymnocoronis spilanthoides</i>	Senegal tea	Asteraceae	16.9	90	M				
<i>Paraserianthes lophantha</i>	cape wattle	Mimosaceae	16.9	91	M				
<i>Acacia saligna</i>	golden willow wattle	Mimosaceae	16.8	92	M				
<i>Juncus articulatus</i>	jointed rush grass	Juncaceae	16.7	93	M				
<i>Bromus diandrus</i>	great brome	Poaceae	16.7	94	M	eg	2		
<i>Cenchrus longispinus</i>	spiny burr grass	Poaceae	16.1	95	M	eg			
<i>Echinochloa crus-galli</i>	barnyard grass	Poaceae	16.0	96	M	eg	1		
<i>Sphagneticola trilobata</i>	Singapore daisy	Asteraceae	15.8	97	M	vs			
<i>Egeria densa</i>	dense waterweed	Hydrocharitaceae	15.7	98	M				
<i>Asphodelus fistulosus</i>	onion weed	Asphodelaceae	15.7	99	M		1		
<i>Salix alba</i> var. <i>vitellina</i>	golden willow	Salicaceae	14.9	100	M			1	14
<i>Rosa rubiginosa</i>	sweet briar/briar rose	Rosaceae	14.4	101	M		2		
<i>Opuntia aurantiaca</i>	tiger pear	Cactaceae	14.4	102	M				
<i>Cyperus eragrostis</i>	umbrella sedge	Cyperaceae	14.4	103	M		1		
<i>Salix nigra</i>	black willow	Salicaceae	14.3	104	M			1	14
<i>Tagetes minuta</i>	stinking roger	Asteraceae	14.2	105	M				
<i>Parkinsonia aculeata</i>	parkinsonia	Fabaceae	13.8	106	M				1
<i>Passiflora tarminiana</i>	banana passionfruit	Passifloraceae	13.7	107	M	vs			
<i>Bryophyllum delagoense</i>	mother-of-millions	Crassulaceae	12.9	108	M		1		54
<i>Chamaecytisus palmensis</i>	tagasaste/ tree lucerne	Fabaceae	12.6	109	M				
<i>Buddleja davidii</i>	butterfly bush	Scrophulariaceae	12.6	110	M				
<i>Cenchrus echinatus</i>	Mossman river grass	Poaceae	12.1	111	M	eg			
<i>Cortaderia selloana</i>	pampas grass	Poaceae	12.1	112	M	eg			47
<i>Briza maxima</i>	Large quacking grass	Poaceae	11.8	113	M	eg			

continued/...

Appendix 1 continued/...

Scientific name	Common name	Family name	Score from the model	Rank order (from model)	Priority ^A	Covered in a KTP listing in NSW ^B	Known to pose a threat and number of species at risk ^C	Weeds of National Significance ^D	
								Top 20 species	71 candidates
<i>Salix cinerea</i> subsp. <i>cinerea</i>	pussy willow	Salicaceae	11.7	114	M			1	14
<i>Solanum pseudocapsicum</i>	Jerusalem cherry / Maderia winter cherry	Solanaceae	11.5	115	M		1		
<i>Trifolium repens</i>	white clover	Fabaceae	11.5	116	M				
<i>Nephrolepis cordifolia</i>	fishbone fern	Davalliaceae	11.3	117	M				
<i>Chloris gayana</i>	Rhodes grass	Poaceae	11.3	118	M	eg	1		
<i>Solanum nigrum</i>	blackberry nightshade	Solanaceae	10.8	119	M		3		
<i>Alternanthera pungens</i>	khaki weed	Amaranthaceae	10.8	120	M				
<i>Cestrum parqui</i>	green cestrum	Solanaceae	10.3	121	M				
<i>Opuntia stricta</i>	prickly pear	Cactaceae	10.3	122	M				
<i>Hymenachne amplexicaulis</i>	hymenachne / olive hymenachne	Poaceae	10.2	123	M	eg	1	1	8
<i>Olea europaea</i> subsp. <i>europaea</i>	common olive	Oleaceae	10.1	124	M				
<i>Callitriche stagnalis</i>	water starwort	Callitricheaceae	10.1	125	M				
<i>Setaria sphacelata</i>	South African pigeon grass / setaria	Poaceae	9.9	126	M	eg			
<i>Cotoneaster franchetii</i>	grey cotoneaster	Rosaceae	9.9	127	M				
<i>Genista linifolia</i>	flax broom	Fabaceae	9.9	128	M				
<i>Pyracantha crenulata</i>	Nepal firethorn	Rosaceae	9.8	129	M				
<i>Lolium perenne</i>	perennial ryegrass	Poaceae	9.7	130	M	eg	2		
<i>Anagallis arvensis</i>	scarlet pimpernel	Primulaceae	9.6	131	M				
<i>Aristolochia elegans</i>	Dutchman's pipe	Aristolochiaceae	9.2	132	M	vs	1		
<i>Passiflora edulis</i>	purple granadilla (common passionfruit)	Passifloraceae	9.1	133	M	vs			
<i>Ludwigia peploides</i> subsp. <i>montevideensis</i>	water primrose	Onagraceae	9.0	134	M				
<i>Schefflera actinophylla</i>	umbrella tree	Araliaceae	8.9	135	M		1		
<i>Asparagus scandens</i>	asparagus fern (climbing asparagus)	Asparagaceae	7.7	136	L	vs			
<i>Ehrharta erecta</i>	panic veldt grass	Poaceae	7.5	137	L	eg	1		
<i>Berula erecta</i>	water parsnip	Apiaceae	7.2	138	L				
<i>Ammophila arenaria</i>	marram grass	Poaceae	7.1	139	L	eg			
<i>Solanum seaforthianum</i>	Brazilian nightshade / climbing nightshade	Solanaceae	7.1	140	L		1		
<i>Lantana montevidensis</i>	creeping lantana	Verbenaceae	7.0	141	L				67
<i>Commelina benghalensis</i>	hairy commelina	Commelinaceae	6.7	142	L				
<i>Verbena bonariensis</i>	purple top	Verbenaceae	6.3	143	L		4		
<i>Passiflora suberosa</i>	passionfruit (corky)	Passifloraceae	6.2	144	L	vs	1		
<i>Plantago lanceolata</i>	plantain, lamb's tongue	Plantaginaceae	6.1	145	L		2		
<i>Cirsium vulgare</i>	spear thistle	Asteraceae	6.1	146	L		2		
<i>Cotoneaster pannosus</i>	sliver-leaf cotoneaster	Rosaceae	6.0	147	L				
<i>Bidens pilosa</i>	farmers friend (cobblers peg)	Asteraceae	6.0	148	L		4		
<i>Equisetum arvense</i>	common horsetail	Equisetaceae	5.9	149	L				

continued/...

Appendix 1 continued/...

Scientific name	Common name	Family name	Score from the model	Rank order (from model)	Priority ^A	Covered in a KTP listing in NSW ^B	Known to pose a threat and number of species at risk ^C	Weeds of National Significance ^D	
								Top 20 species	71 candidates
<i>Pyracantha crenatoserrata</i>	Chinese firethorn	Rosaceae	5.8	150	L				
<i>Paspalum urvillei</i>	vasey grass	Poaceae	5.7	151	L	eg	2		
<i>Senecio madagascariensis</i>	fireweed	Asteraceae	5.6	152	L		4		66
<i>Ranunculus repens</i>	creeping buttercup	Ranunculaceae	5.5	153	L		1		
<i>Vulpia myuros</i>	rat's tail fescue	Poaceae	5.5	154	L	eg	1		
<i>Psidium cattleianum</i>	cherry guava	Myrtaceae	5.3	155	L		1		
<i>Veronica anagallis-aquatica</i>	blue water speedwell	Scrophulariaceae	5.2	156	L				
<i>Prosopis pallida</i>	algaroba/ mesquite	Mimosaceae	5.1	157	L		1		
<i>Heliotropium amplexicaule</i>	blue heliotrope	Boraginaceae	5.1	158	L				
<i>Lilium formosanum</i>	Formosa lily	Liliaceae	5.1	159	L		4		
<i>Stenotaphrum secundatum</i>	buffalo grass	Poaceae	5.0	160	L	eg	2		
<i>Polypogon monspeliensis</i>	beard grass	Poaceae	4.9	161	L	eg	1		
<i>Pinus elliotii</i>	slash pine	Pinaceae	4.8	162	L				
<i>Ludwigia peruviana</i>	ludwigia (primrose)	Onagraceae	4.8	163	L		3		
<i>Vicia sativa</i>	common vetch	Fabaceae	4.8	164	L		1		
<i>Crocasmia × crocosmiiflora</i>	montbretia	Iridaceae	4.7	165	L				
<i>Senna septemtrionalis</i>	senna (smooth)	Caesalpinaceae	4.5	166	L		1		
<i>Erica lusitanica</i>	Spanish heath	Ericaceae	4.5	167	L				68
<i>Ligustrum vulgare</i>	European privet	Oleaceae	4.5	168	L				
<i>Phalaris aquatica</i>	bulbous canary grass/ phalaris	Poaceae	4.4	169	L	eg	2		
<i>Convolvulus arvensis</i>	field bindweed	Convolvulaceae	4.2	170	L				
<i>Myosotis laxa</i> subsp. <i>caespitosa</i>	water forget me not	Boraginaceae	4.2	171	L				
<i>Setaria parviflora</i>	slender pigeon grass	Poaceae	4.1	172	L	eg	2		
<i>Tecoma stans</i>	yellow bells	Bignoniaceae	4.0	173	L				
<i>Panicum repens</i>	torpedo grass	Poaceae	3.9	174	L	eg	1		
<i>Phyla nodiflora</i>	carpet weed, lippia	Verbenaceae	3.9	175	L				
<i>Celtis occidentalis</i>	hackberry	Ulmaceae	3.8	176	L				
<i>Galium aparine</i>	cleavers	Rubiaceae	3.7	177	L				
<i>Acetosella vulgaris</i>	sheep sorrel	Polygonaceae	3.7	178	L				
<i>Juncus microcephalus</i>	rush	Juncaceae	3.6	179	L				
<i>Solanum mauritianum</i>	wild tobacco	Solanaceae	3.5	180	L		4		
<i>Asparagus africanus</i>	asparagus fern	Asparagaceae	3.4	181	L		4		
<i>Aster subulatus</i>	aster weed	Asteraceae	3.4	182	L		1		
<i>Pennisetum macrourum</i>	African feather grass	Poaceae	3.2	183	L	eg			
<i>Psoralea pinnata</i>	blue psoralea/ African scurf-pea	Fabaceae	3.2	184	L				
<i>Prunus cerasifera</i>	cherry plum	Rosaceae	3.2	185	L				
<i>Opuntia elata</i>	Riverina pear	Cactaceae	3.2	186	L				
<i>Hordeum leporinum</i>	barley grass	Poaceae	3.1	187	L	eg			
<i>Cardaria draba</i>	hoary cress	Brassicaceae	3.1	188	L				
<i>Glyceria declinata</i>	manna grass	Poaceae	3.0	189	L	eg			
<i>Leucaena leucocephala</i>	leucaena	Mimosaceae	3.0	190	L				
<i>Conyza sumatrensis</i>	tall fleabane	Asteraceae	2.9	191	L		1		

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Appendix 1 continued/...

Scientific name	Common name	Family name	Score from the model	Rank order (from model)	Priority ^A	Covered in a KTP listing in NSW ^B	Known to pose a threat and number of species at risk ^C	Weeds of National Significance ^D	
								Top 20 species	71 candidates
<i>Lotus uliginosus</i>	bird's foot trefoil	Fabaceae	2.9	192	L		1		
<i>Watsonia meriana</i> var. <i>bulbillifera</i>	watsonia (bulbil)	Iridaceae	2.9	193	L				43
<i>Phalaris arundinacea</i> var. <i>arundinacea</i>	reed canary grass	Poaceae	2.8	194	L	eg			
<i>Morus alba</i>	white mulberry	Moraceae	2.7	195	L				
<i>Bryophyllum pinnatum</i>	live plant	Crassulaceae	2.6	196	L				
<i>Parapholis incurva</i>	coast barb grass, curved sickle-grass	Poaceae	2.6	197	L	eg	1		
<i>Sporobolus pyramidalis</i>	giant rat's tail grass	Poaceae	2.5	198	L	eg			58
<i>Senecio angulatus</i>	climbing groundsel	Asteraceae	2.5	199	L	vs			
<i>Impatiens walleriana</i>	busy Lizzy / impatiens	Balsaminaceae	2.5	200	L		1		
<i>Acacia podalyriifolia</i>	Mount Morgan wattle	Mimosaceae	2.5	201	L				
<i>Eriobotrya japonica</i>	loquat	Rosaceae	2.4	202	L				
<i>Arundo donax</i>	giant reed	Poaceae	2.3	203	L	eg			
<i>Andropogon virginicus</i>	broom sedge / whisky grass	Poaceae	2.3	204	L	eg	5		
<i>Parthenium hysterophorus</i>	parthenium weed	Asteraceae	2.2	205	L			1	16
<i>Allium triquetrum</i>	three-corner garlic	Alliaceae	2.2	206	L				
<i>Conium maculatum</i>	hemlock	Apiaceae	2.2	207	L				
<i>Ricinus communis</i>	castor oil plant	Euphorbiaceae	2.1	208	L				
<i>Celtis australis</i>	European hackberry or nettle tree	Ulmaceae	2.1	209	L				
<i>Lagarosiphon major</i>	lagarosiphon	Hydrocharitaceae	2.1	210	L				
<i>Solanum linnaeanum</i>	apple-of-Sodom	Solanaceae	2.1	211	L				
<i>Hedychium gardnerianum</i>	kahili ginger	Zingiberaceae	2.0	212	L		1		
<i>Duranta erecta</i>	duranta	Verbenaceae	2.0	213	L				
<i>Bryophyllum × houghtonii</i>	mother-of-millions (hybrid)	Crassulaceae	2.0	214	L				54
<i>Chenopodium album</i>	fat hen	Chenopodiaceae	1.9	215	L				
<i>Eleocharis minuta</i>	variable spike sedge	Cyperaceae	1.8	216	L				
<i>Erythrina × sykesii</i>	coral tree	Fabaceae	1.8	217	L				
<i>Dioscorea bulbifera</i>	aerial yam	Dioscoreaceae	1.7	218	L	vs			
<i>Tamarix aphylla</i>	athel pine	Tamaricaceae	1.7	219	L			1	13
<i>Cestrum nocturnum</i>	Night flowering cestrum / lady of the night	Solanaceae	1.7	220	L				
<i>Verbena rigida</i>	wild verbena	Verbenaceae	1.7	221	L				
<i>Hypericum elodes</i>	marsh St John's wort	Clusiaceae	1.7	222	L				
<i>Urochloa mutica</i>	Para grass	Poaceae	1.5	223	L	eg			
<i>Ardisia crenata</i>	coral berry	Myrsinaceae	1.5	224	L				
<i>Arctotheca calendula</i>	cape weed	Asteraceae	1.5	225	L		1		
<i>Ammi majus</i>	bishop's weed	Apiaceae	1.4	226	L		1		
<i>Echinochloa polystachya</i>	aleman grass	Poaceae	1.4	227	L	eg	1		
<i>Psidium guajava</i>	guava	Myrtaceae	1.4	228	L				
<i>Hydrocotyle bonariensis</i>	pennywort / large-leaf pennywort	Apiaceae	1.4	229	L		2		

continued/...

Appendix 1 continued/...

Scientific name	Common name	Family name	Score from the model	Rank order (from model)	Priority ^A	Covered in a KTP listing in NSW ^B	Known to pose a threat and number of species at risk ^C	Weeds of National Significance ^D	
								Top 20 species	71 candidates
<i>Pennisetum setaceum</i>	fountain grass	Poaceae	1.4	230	L	eg			
<i>Solanum laxum</i>	Jasmine nightshade/ potato climber	Solanaceae	1.3	231	L				
<i>Salix viminalis</i>	common osier/ basket willow	Salicaceae	1.3	232	L			1	14
<i>Sida rhombifolia</i>	paddy's lucerne	Malvaceae	1.3	233	L		4		
<i>Abrus precatorius</i>	crabs-eye creeper	Fabaceae	1.2	234	L				
<i>Conyza bonariensis</i>	flaxleaf fleabane	Asteraceae	1.2	235	L		2		
<i>Rhaponticum repens</i>	creeping knapweed/ hardhead	Asteraceae	1.2	236	L				
<i>Cylindropuntia rosea</i>	hudson pear	Cactaceae	1.1	237	L				
<i>Polygala myrtifolia</i>	myrtle-leaf milkwort	Polygalaceae	1.1	238	L				71
<i>Ambrosia artemisiifolia</i>	annual ragweed	Asteraceae	1.1	239	L		1		
<i>Dactylis glomerata</i>	cocksfoot	Poaceae	1.0	240	L	eg	1		
<i>Conyza canadensis</i>	Canadian fleabane	Asteraceae	1.0	241	L				
<i>Ludwigia palustris</i>	false loosestrife	Onagraceae	1.0	242	L				
<i>Schoenoplectus californicus</i>	California tule	Cyperaceae	1.0	243	L				
<i>Cuphea carthagenensis</i>	cuphea	Lythraceae	1.0	244	L				
<i>Rivina humilis</i>	coral berry/ pidgeonberry	Phytolaccaceae	1.0	245	L		2		
<i>Juncus acutiflorus</i>	juncus	Juncaceae	0.9	246	L		1		
<i>Arctotheca populifolia</i>	beach daisy/ beach cape weed	Asteraceae	0.9	247	L				
<i>Artemisia verlotiorum</i>	Chinese wormwood	Asteraceae	0.9	248	L				
<i>Phytolacca octandra</i>	inkweed	Phytolaccaceae	0.8	249	L				
<i>Coreopsis lanceolata</i>	tickseed/ coreopsis	Asteraceae	0.8	250	L		1		
<i>Plantago major</i>	broad-leaf plantain	Plantaginaceae	0.8	251	L				
<i>Ageratum houstonianum</i>	blue billygoat weed	Asteraceae	0.8	252	L				
<i>Ludwigia longifolia</i>	longleaf ludwigia	Onagraceae	0.8	253	L		1		
<i>Murraya paniculata</i>	orange jessamine	Rutaceae	0.8	254	L				
<i>Parthenocissus quinquefolia</i>	Virginia creeper	Vitaceae	0.8	255	L				
<i>Batrachium trichophyllum</i>	water buttercup	Ranunculaceae	0.8	256	L				
<i>Euphorbia cyathophora</i>	painted spurge	Euphorbiaceae	0.7	257	L				
<i>Zantedeschia aethiopica</i>	arum lily	Araceae	0.7	258	L				69
<i>Juncus effusus</i>	soft rush	Juncaceae	0.7	259	L				
<i>Spartium junceum</i>	Spanish broom	Fabaceae	0.6	260	L				
<i>Prunus laurocerasus</i>	cherry laurel	Rosaceae	0.6	261	L				
<i>Alhagi maurorum</i>	camelthorn	Fabaceae	0.6	262	L				
<i>Mimulus moschatus</i>	musk honey flower	Scrophulariaceae	0.6	263	L				
<i>Axonopus fissifolius</i>	narrow-leaved carpet grass	Poaceae	0.6	264	L		1		
<i>Galenia pubescens</i>	galenia	Aizoaceae	0.6	265	L				
<i>Billardiera heterophylla</i>	bluebell creeper	Pittosporaceae	0.6	266	L				
<i>Dipogon lignosus</i>	dolichos pea	Fabaceae	0.6	267	L				
<i>Leycesteria formosa</i>	Himalayan honeysuckle	Caprifoliaceae	0.5	268	L				
<i>Cortaderia jubata</i>	pink pampas grass	Poaceae	0.5	269	L	eg	2		

continued/...

Appendix 1 continued/...

Scientific name	Common name	Family name	Score from the model	Rank order (from model)	Priority ^A	Covered in a KTP listing in NSW ^B	Known to pose a threat and number of species at risk ^C	Weeds of National Significance ^D	
								Top 20 species	71 candidates
<i>Tephrosia glomeruliflora</i>	pink tephrosia	Fabaceae	0.5	270	L				
<i>Nymphaea caerulea</i>	cape waterlily	Nymphaeaceae	0.5	271	L		1		
<i>Pennisetum villosum</i>	feather grass, feathertop	Poaceae	0.5	272	L	eg	1		
<i>Syagrus romanzoffiana</i>	cocos palm	Arecaceae	0.5	273	L				
<i>Lobularia maritima</i>	sweet alyssum	Brassicaceae	0.5	274	L				
<i>Salvia coccinea</i>	red salvia	Lamiaceae	0.4	275	L				
<i>Lupinus polyphyllus</i>	Russell lupin	Fabaceae	0.4	276	L				
<i>Ilex aquifolium</i>	English holly	Aquifoliaceae	0.4	277	L		1		
<i>Euphorbia paralias</i>	sea spurge	Euphorbiaceae	0.4	278	L				49
<i>Fraxinus angustifolia</i> subsp. <i>angustifolia</i>	desert ash	Oleaceae	0.4	279	L				
<i>Catharanthus roseus</i>	Madagascar periwinkle	Apocynaceae	0.4	280	L				
<i>Erica arborea</i>	tree heath	Ericaceae	0.4	281	L				
<i>Plantago coronopus</i>	buck's horn plantain	Plantaginaceae	0.4	282	L		1		
<i>Hypericum androsaemum</i>	tutsan	Clusiaceae	0.4	283	L				
<i>Neonotonia wightii</i>	glycine/ perennial soybean	Fabaceae	0.4	284	L				
<i>Nassella tenuissima</i>	Mexican feather grass	Poaceae	0.4	285	L	eg			
<i>Agave americana</i>	century plant	Agavaceae	0.4	286	L				
<i>Acer negundo</i>	box elder	Aceraceae	0.3	287	L				
<i>Populus alba</i>	white poplar	Salicaceae	0.3	288	L				
<i>Lagurus ovatus</i>	hare's tail grass	Poaceae	0.3	299	L				
<i>Coprosma repens</i>	mirror bush/ looking-glass bush	Rubiaceae	0.3	290	L		1		
<i>Lotus corniculatus</i>	bird's foot trefoil	Fabaceae	0.3	291	L				
<i>Gazania rigens</i>	coastal gazania/ treasure flower	Asteraceae	0.3	292	L				
<i>Berberis pinnata</i>		Berberidaceae	0.3	293	L				
<i>Potentilla indica</i>	Indian strawberry	Rosaceae	0.3	294	L		1		
<i>Erigeron karvinskianus</i>	Mexican daisy/ bony-tip fleabane	Asteraceae	0.3	295	L				
<i>Cardamine hirsuta</i>	common bittercress	Brassicaceae	0.3	296	L				
<i>Sparaxis bulbifera</i>	harlequin flower	Iridaceae	0.3	297	L				
<i>Aptenia cordifolia</i>	heartleaf ice plant	Aizoaceae	0.3	298	L		1		
<i>Coffea arabica</i>	coffee	Rubiaceae	0.2	299	L				
<i>Eugenia uniflora</i>	Brazilian cherry	Myrtaceae	0.2	300	L				
<i>Cakile edentula</i>	American sea rocket	Brassicaceae	0.2	301	L				
<i>Rhamnus alaternus</i>	Italian buckthorn	Rhamnaceae	0.2	302	L				
<i>Persicaria capitata</i>	persicaria	Polygonaceae	0.2	303	L				
<i>Jacaranda mimosifolia</i>	Jacaranda	Bignoniaceae	0.2	304	L				
<i>Aeschynomene indica</i>	budda pea	Fabaceae	0.2	305	L				
<i>Carrichtera annua</i>	Ward's weed	Brassicaceae	0.2	306	L				
<i>Parietaria judaica</i>	wall pellitory/ asthma weed	Urticaceae	0.2	307	L				
<i>Arbutus unedo</i>	strawberry tree	Ericaceae	0.2	308	L				
<i>Viola riviniana</i>	common dog violet	Violaceae	0.2	309	L				

continued/...

Appendix 1 continued/...

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								Top 20 species	71 candidates
<i>Amelichloa brachychaeta</i>	espartillo	Poaceae	0.2	310	L				
<i>Aegopodium podagraria</i>	goutweed	Apiaceae	0.2	311	L				
<i>Arecastrum romanzoffianum</i>	queen palm	Areaceae	0.2	312	L		1		
<i>Pinus contorta</i>	lodgepole pine	Pinaceae	0.1	313	L				
<i>Inga edulis</i>	ice cream bean	Fabaceae	0.1	314	L				
<i>Digitalis purpurea</i>	foxglove	Scrophulariaceae	0.1	315	L				
<i>Alectryon tomentosus</i>	woolly rambutan/ hairy bird's eye	Sapindaceae	0.1	316	L				
<i>Melianthus major</i>	cape honey flower	Melianthaceae	0.1	317	L				
<i>Ficus pumila</i>	climbing fig	Moraceae	0.1	318	L				
<i>Toxicodendron succedaneum</i>	rhus	Anacardiaceae	0.1	319	L				
<i>Cakile maritima</i> subsp. <i>maritima</i>	sea rocket	Brassicaceae	0.1	320	L				
<i>Watsonia borbonica</i>	rosy watsonia/ bugle lily	Iridaceae	0.1	321	L				
<i>Chasmanthe floribunda</i>	African cornflag	Iridaceae	0.1	322	L				
<i>Pistacia chinensis</i>	pistachio nut tree	Anacardiaceae	0.1	323	L				
<i>Allium vineale</i>	crow garlic	Alliaceae	0.1	324	L				
<i>Chlorophytum comosum</i>	Spider plant/ ribbon plant	Anthericaceae	0.1	325	L				
<i>Myosotis sylvatica</i>	wood forget me not	Boraginaceae	0.1	326	L				
<i>Citrus × taitensis</i>	lemon	Rutaceae	0.1	327	L		1		
<i>Paulownia fortunei</i>	Paulownia	Scrophulariaceae	0.1	328	L				
<i>Alisma lanceolatum</i>	water plantain	Alismataceae	0.1	329	L				
<i>Asystasia gangetica</i> subsp. <i>micrantha</i>	Chinese violet (form)	Acanthaceae	0.1	330	L				
<i>Polygala virgata</i>	polygala	Polygalaceae	0.1	331	L				
<i>Senecio glastifolius</i>	large senecio	Asteraceae	0.1	332	L				
<i>Physalis peruviana</i>	cape gooseberry	Solanaceae	0.1	333	L		1		
<i>Acer pseudoplatanus</i>	sycamore maple	Aceraceae	<0.1	334	L				
<i>Berberis darwinii</i>	Darwin's barberry	Berberidaceae	<0.1	335	L				
<i>Senecio elegans</i>	purple groundsel	Asteraceae	<0.1	336	L				
<i>Eryngium maritimum</i>	sea holly	Apiaceae	<0.1	337	L				
<i>Pelargonium capitatum</i>	African pelargonium	Geraniaceae	<0.1	338	L				
<i>Callisia fragrans</i>	Fragrant inch plant	Commelinaceae	<0.1	339	L				
<i>Tetragonia decumbens</i>	sea spinach	Aizoaceae	<0.1	340	L				

^A Priority groups are E = extreme, VH = very high, H = high, M = medium, or L = low.

^B KTP = Key threatening process listing under the NSW *Threatened Species Conservation Act 1995* – codes for the five weed KTP listing are vs = vines and scramblers, l = lantana, bb = bitou bush and boneseed, sb = Scotch broom, and eg = exotic perennial grasses.

^C As identified in Coutts-Smith and Downey (2006) for New South Wales.

^D Weeds of National Significance (WoNS), being the 20 WoNS and full list of 71 weed candidates used to determine the 20 WoNS (see Thorp and Lynch 2000).