

Impact of weeds on threatened biodiversity in New South Wales

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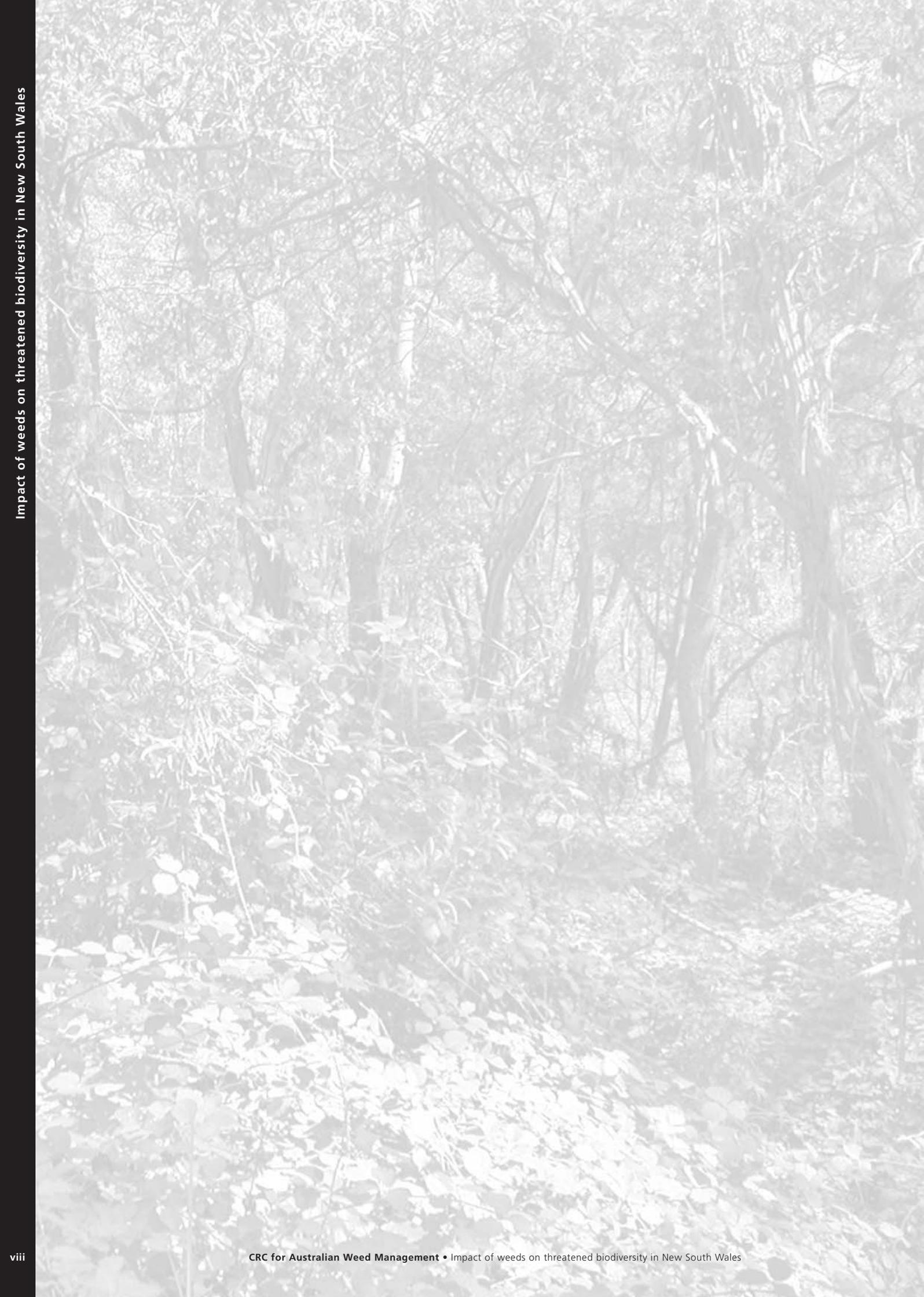
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List of acronyms

| | |
|-----------|---|
| agg. | Aggregate – with reference to an aggregate of species (eg blackberry) |
| ARMCANZ | Agriculture and Resource Management Council of Australia and New Zealand |
| ANZECC | Australia and New Zealand Environment Conservation Council |
| BGT | Botanic Gardens Trust (NSW) |
| Bitou TAP | Bitou Bush Threat Abatement Plan (see DEC 2006) |
| CMA | Catchment Management Authority |
| DEC | NSW Department of Environment and Conservation |
| DPI | NSW Department of Primary Industries |
| EEC | Endangered Ecological Community, as described under the TSC and EPBC Act |
| EPBC Act | Commonwealth <i>Environment Protection and Biodiversity Conservation Act 1999</i> |
| FM Act | NSW <i>Fisheries Management Act 1994</i> |
| IUCN | International Union for the Conservation of Nature |
| KTP | Key Threatening Process, as defined under the TSC and EPBC Acts |
| NPWS | former NSW National Parks and Wildlife Service |
| NSW | New South Wales |
| NSW SC | New South Wales Scientific Committee |
| NRM | Natural Resource Management, used collectively to refer to the 13 CMAs |
| ROTAP | Rare or Threatened Australian Plants |
| spp. | Species, with reference to all species in a particular genus |
| TAP | Threat abatement plan (eg the Bitou TAP) |
| TSC Act | NSW <i>Threatened Species Conservation Act 1995</i> |
| WINS | Weed Impacts to Native Species assessment process |
| WONS | Weeds of National Significance |
| WWF | World Wide Fund for Nature |



Executive summary

Alien species (weeds and pest animals) are acknowledged as the second greatest cause of biodiversity decline, after habitat loss. Despite this, there is a lack of information on the biodiversity at risk from alien species. This lack has hampered effective management of invasive species at all levels from government policy to on-ground control. Given that the number of new introductions of alien species has increased dramatically over the past century, it is imperative that proper information on their impacts be compiled and disseminated.

In Australia, there are approximately 2,800 naturalised alien plant species, of which 71 are recognised as being of national significance. However, information on their impact on biodiversity has not been formally assessed, with the exception of bitou bush (*Chrysanthemoides monilifera* subsp. *rotundata*). This lack of information has hampered the ability both to manage weeds and to meet the aims of Goal 2 of the National Weeds Strategy – to reduce the impact of existing weed problems of national significance.

This report aims to comprehensively assess the weed threats to biodiversity within New South Wales (NSW), using the biodiversity listed under NSW threatened species legislation. This is a new approach to assessing the biodiversity impacts of weeds, which should now be applied in other jurisdictions.

Method

A data set was compiled of the threats to the biodiversity listed under Schedules 1 and 2 of the *Threatened Species Conservation Act 1995* (NSW) and Schedules 4 and 5 of the *Fisheries Management Act 1994* (NSW). These schedules listed 945 threatened species, populations and ecological communities, as at January 1, 2005, that span a broad range of biodiversity (mammals, birds, fish, insects, plants). Throughout this report, unless otherwise stated, this collective list of threatened biodiversity is referred to as threatened species for ease of reading.

Information on threats to these 945 listed threatened species was compiled from a range of sources (scientific papers, determinations by the NSW Scientific Committee, recovery plans, threatened species profiles and fact sheets). This process resulted in the identification of approximately 5,300 individual threat descriptions. A threat hierarchy was developed in order to group threats

of a similar nature (eg weed invasion) and to enable analysis of the data set. In addition, this process allowed an analysis of the relative impact of each threat. The data set was also reclassified to compare the threats listed as Key Threatening Processes under the *Threatened Species Conservation Act 1995* (NSW).

Threatened biodiversity examined

Of the 945 listed threatened species, 569 are plants, fungi or algae, 271 are animals (including invertebrates), 72 are Endangered Ecological Communities and 33 are Endangered Populations. Approximately half of these threatened species were also listed under the *Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth).

Weeds relative to other threats

Weeds posed a threat to 45% of the biodiversity examined. The threat posed by weeds as a single factor was ranked second after land clearing, was similar to that of altered fire regimes, and was greater than that from alien pest animals. In addition, weeds ranked highly when compared with broader threatening processes such as the destruction and modification of native vegetation.

Weeds threatened 419 listed threatened species, comprising 279 threatened plant species (166 Endangered and 113 Vulnerable species), 62 animal species (30 Endangered and 32 Vulnerable species), 14 Endangered Populations and 64 Endangered Ecological Communities.

Weeds

A total of 127 individual weed species from 120 genera and 51 families were identified as threatening 204 threatened species. For the remaining 215 species threatened by weeds, a specific weed species could not be identified; rather the threat was described as 'weed invasion' or as a weed genus only (eg *Salix*). The five weed species most commonly identified here as threatening biodiversity in New South Wales were:

- lantana (96 threatened species)
- bitou bush (46)
- blackberry (21)
- kikuyu (16)
- Scotch broom (12).

As approximately half the threats did not identify a specific weed species, the impacts of some weed species may be under represented and other weed species that are currently posing a threat may not have been identified here.

Garden escapes

Eighty-two of the 127 weed species identified as threatening biodiversity were deemed to have been deliberately introduced as ornamental plants and are referred to as escaped garden plants. These garden escapees were identified as a threat to 190 threatened species (or 93% of the species for which a defined weed species was identified). If we assume constant proportions for the remaining 215 species threatened by weeds more generally (ie no specific weed identified), the number of threatened species impacted by garden escapees in New South Wales may be as high as 390.

The continuing threat to biodiversity posed by these deliberate introductions is highlighted by the fact that 56 of these 127 weed species are still available for purchase in Australia, with 36 available in New South Wales. In addition, seven of these were previously identified as in the 10 most invasive weeds still for sale in New South Wales.

Spatial analysis

There are 1,386 naturalised alien plants in New South Wales, which constitute 21% of the total number of plant species in the state. Approximately 9% of these species (the 127 species identified above) were identified as impacting on threatened biodiversity. Using three broad geographic zones in New South Wales, namely coastal, central and western, a spatial analysis of weed impacts was undertaken. This revealed a decrease in weed species and impacts to biodiversity from east to west (ie from coastal to arid western New South Wales).

An analysis of the 13 Catchment Management Authorities (CMAs) in New South Wales was undertaken, which provided a list for each CMA of:

- weed species
- weed species threatening biodiversity
- the biodiversity threatened by weeds.

The Sydney Metropolitan CMA contained the greatest number of weed species ($n = 758$), while the lowest number was found in the Lower Murray–Darling CMA ($n = 187$).

Concluding comment

This report attempts, for the first time in Australia, to quantify the impact of weeds on biodiversity across a broad range of taxa. It illustrates the scale of the weed problem in terms of the number and diversity of species at risk. Whilst the data have some limitations, the information presented provides a long overdue baseline from which informed management and policy decisions can now be made. It is anticipated that the information presented here will stimulate discussion on the management of weed impacts on biodiversity, including the description of threats which is not currently standardised. Finally, while the data presented here illustrate the weed problem for New South Wales at a specific point in time, what is now required is a national analysis, with regular revisions and updates.

1. Introduction: biodiversity decline and weeds

1.1 Causes of biodiversity decline

At present the planet is experiencing a period of major biodiversity decline (Wilson 1992). Whilst there have been a number of major biodiversity declines associated with the past five great extinction events, the current decline differs from these earlier events in two ways:

1. the driver for the majority of the decline has been attributed to anthropogenic activities
2. the rate of extinction is greater (Wilson 1992).

The World Resources Institute, in conjunction with the World Conservation Union and United Nations Environment Programme, identified in order of importance the major anthropogenic causes of biodiversity loss as:

- habitat destruction (loss and fragmentation)
- accelerated rate of introduction of alien species
- habitat modification (eg altered fire regimes or desertification)
- climate change
- pollution
- over-consumption and unsustainable use of natural resources
- some combination of these (WRI et al 1992).

It has been forecast that more than one fifth of all plant and animal species currently living will become extinct by the year 2020 (Wilson 1992). Other predictions for plant species loss are equally dire, especially when wider impacts, such as alteration of soil nutrient levels, increases in atmospheric CO₂ and altered disturbance regimes associated with human activities, are incorporated (Tilman and Lehman 2001).

Despite the identification of these major causes of biodiversity loss (WRI et al 1992), little information has been presented on the specifics of their impact (namely, the species or groups of species that are most at risk). One of the few attempts to determine such impacts, across a range of threats, was based on an examination of those species listed as 'threatened' in the United States (ie those listed under the US *Endangered Species Act 1973*) for which literature on impacts was available. This study found that habitat degradation or loss threatened 85% of species examined (total species = 1,880), whilst alien species were the second major threat, affecting 49% of the total (Wilcove et al 1998).

1.2 Alien species introductions

The homogenisation of the global flora and fauna through the mass movement of species is creating one of the greatest environmental challenges facing the planet (Wilson 1992). Whilst plants and animals can disperse vast distances to new environments (Ridley 1930), human actions are now the main dispersal mechanism (Heywood 1989; Panetta and Scanlan 1995). The movement of species by humans, either deliberately or accidentally, has increased dramatically the scale and rate of dispersal events, especially over the last 200 years (di Castri 1989; Reichard and Hamilton 1997). Significant progress has been made towards understanding the ecology of alien species invasions (Elton 1958), but information on the specific biodiversity threatened by alien species remains inadequate (Downey submitted).

Alien species pose both a direct and indirect threat to native species, either from competition or through altered disturbance regimes respectively (Vitousek 1986; Gordon 1998; Mack and D'Antonio 1998; Downey 2002). The majority of alien species introductions are irreversible, with most ecosystems at risk of invasion (Lonsdale 1999). Only new incursions or newly naturalised species are likely to be at a stage of invasion where eradication is possible (Hobbs 1993; Weiss 1999; Myers et al 2000; Rejmánek 2001; Timmins et al 2002). However, successful eradications have typically been the result of early detection or of special circumstances (Myers et al 2000). Whilst several successful eradication programs have been recorded on islands (Veitch and Clout 2002), few such successes have occurred over large areas or on continents.

1.3 Alien plants: an Australian perspective

Australia's native biodiversity has suffered dramatically from the introduction of alien species following the European settlement of Australia some 220 years ago. Many native species are now extinct as a result of introduced predators (Burbidge and McKenzie 1989; Morton 1990) and the large number of alien species has placed significant pressure on many other species. For example, the number and diversity of species that comprise Australia's vascular flora has increased significantly as a result of alien plant introductions.

These introduced plants now comprise more than 10% of the total flora (Amor and Piggin 1977; Michael 1981; Groves 1986; Humphries et al 1991; Groves et al 2003). Approximately 70% of these 2,800 alien plant species (or weeds) were deliberately introduced to Australia for economic (agricultural and horticultural) and/or aesthetic (garden) purposes (Groves et al 2005).

1.4 Assessing the impacts of alien plants on biodiversity

Whilst the main threats to biodiversity have been identified (see 1.1), detailed information on the biodiversity threatened by each of these factors and their relative importance is lacking, despite calls for such information (Grice et al 2004; Groves 2004; Downey submitted). Historically, attempts to assess the impacts of weeds on biodiversity have been either through scientific investigation of a specific alien species on a single native species (Weiss and Noble 1984a, b; French and Zubovic 1997; Matarczyk 1999; Vranjic et al 2000; Franks 2002) or through reviews of such studies (Grice et al 2004; Vidler 2004). Impacts occur at a number of different levels; for example genetic, individual, population, community and ecosystem, as well as from the cumulative and indirect effects from multiple invasions of species (Adair and Groves 1998; Parker et al 1999). More recently, extensive systematic reviews have been published that use a process referred to as the Weed Impacts to Native Species (WINS) assessment (Downey 2004; Downey 2006).

The paucity of current data derived from studies on the impacts of alien plants or weeds on biodiversity makes it difficult to determine broader impacts or trends across diverse taxonomic groups of plant species, whether native or alien. In fact, information on the specific biodiversity threatened by individual weed species is so lacking that it has not even been compiled for the 20 Weeds of National Significance (WONS) (Downey and Cherry 2005; Downey 2006) even though many of the WONS each occupy >5% of the area of the Australian continent (Sinden et al 2004). Given the urgent need for such information (Grice et al 2004) a new approach is clearly needed. Here we present such an approach to collating information on the biodiversity threatened by weeds, using New South Wales as a case study.

2. Development of a data set on the threats to biodiversity within New South Wales

One approach to assessing the impacts of weeds on biodiversity is to compile lists of taxonomically diverse native species which have information readily available on their threats. Such lists presently exist in the schedules of threatened biodiversity encompassed by the NSW *Threatened Species Conservation Act 1995* (TSC Act) and similar legislation. The current study reports on the first attempt to use these schedules of threatened species to assess weed impacts on biodiversity. This chapter outlines the methods used to collate, verify and assess the data.

2.1 The data set

The list of biodiversity examined

The schedules of the TSC Act make an ideal list of biodiversity for which threats could be examined because:

- the species are known to be threatened
- information on their threats was documented as part of the justification for them being listed as threatened (NPWS 2004)
- these listings provided the full extent of threats across a broad range of biodiversity (ie flora, fauna and ecological communities) for which comparisons of threats could be made.

The listings under the TSC Act were supplemented with those under the schedules of the NSW *Fisheries Management Act 1994* (FM Act) because the TSC Act does not cover fish or aquatic invertebrates. This combined list was compared with the listings under the schedules of the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) for those species which occurred in New South Wales, to ensure that all threatened biodiversity in New South Wales was assessed. For ease of reading, the combined threatened species legislation in New South Wales will hereafter be referred to as the NSW threatened species Acts.

Schedules 1 of the TSC Act and 4 of the FM Act contain those species listed as Endangered and Presumed Extinct, as well as Endangered Populations and Endangered Ecological Communities, whilst Schedules 2 of the TSC Act and 5 of the FM Act contain species listed as Vulnerable.

As at January 1, 2005, there was a total of 1,021 listings under the NSW threatened species schedules (hereafter the collective list of threatened biodiversity will be referred to as threatened species for ease of reading, unless otherwise stated). These threatened species comprised 76 Presumed Extinct species, 436 Endangered species, 404 Vulnerable species, 72 Endangered Ecological Communities and 33 Endangered Populations. The 76 Presumed Extinct species were excluded from the data set, as information on the cause of their presumed extinction could not be ascertained. Thus, the list of biodiversity examined here comprises 945 threatened species.

Sources of threat information examined

Using this list of threatened species, information was then assembled on the threats for each species, population and ecological community by examining a wide range of data sources. Initially, threat information was derived from determinations by the NSW Scientific Committee (eg NSW SC 2001, 2002). The Scientific Committee is responsible for assessing nominations of potentially threatened species to determine which ones should be listed in accordance with the Act.

This information was then augmented with threat information contained in other data sources, specifically:

- fact sheets (eg NPWS 2002a)
- species profiles (eg NPWS 1999)
- fish notes (eg NSW Fisheries 2002)
- recovery plans (eg NPWS 2002b)
- threat abatement plans (eg DEC 2004a)
- threatened species books (eg NPWS 2002c, d)
- scientific studies (eg Ayers et al 1996; Matarczyk 1999; Willis et al 2003).

A total of 2,038 data sources were examined for the 945 threatened species listed (Table 2.1). On average, threat information for each listing was obtained from at least two sources. Unfortunately, less than 2% of the sources examined came from scientific studies, thereby highlighting the need for assessments such as those presented here to provide an overview. The different sources of data contributed different levels of information on threats. For example, fact sheets, species profiles and fish notes collectively contributed approximately half of the threat information, whilst determinations by the NSW Scientific Committee contributed only 25% of the information (Table 2.1).

Table 2.1 The number and sources of threat information used and the number of threat descriptions identified

| Sources of threat information ^a | Number examined ^b | Total number of threat descriptions identified ^b |
|--|------------------------------|---|
| NSW Scientific Committee determinations | 945 (46) | 1,305 (25) |
| Fact sheets, fish notes and species profiles | 945 (46) | 2,702 (51) |
| NSW recovery plans | 115 (6) | 444 (8) |
| NSW threat abatement plans | 3 (<0.1) | 45 (<1) |
| Scientific studies | 30 (1.5) | 821 (15) |
| Total | 2,038 (100) | 5,317 (100) |

a See text for further details.

b Values in brackets are percentages of the total.

Despite extensive investigation of a wide range of data sources information was not available on the threats to four threatened species (Appendix 1). All four plant species were listed in the first list of threatened species under the TSC Act in 1996, prior to which they were listed as Rare or Threatened Australian Plants (ROTAP) (Briggs and Leigh 1996). These four species were thus transferred to the TSC Act without further evaluation. Based on the present examination it appears that no other evaluations have occurred in the intervening period. Given the fact that no threats were identified, these four species were excluded from further analysis, thereby reducing the list of biodiversity examined to 941 threatened species.

Each of the Endangered Ecological Communities (EECs) listed under the TSC Act contains many diverse species and the threats described do not identify the components, or specific species of the EEC at risk; it was thus assumed that all species present are affected equally by the threats identified.

Limitations to the data

There are some important limitations to the data examined. The attribution of a specific threat is typically based on expert judgement, which may not be based on experimental evidence or quantitative data. Such data rarely exist. In addition, as the quality of the threat information contained within each of these different data sources examined varied, a summary of our assessment of the quality and accuracy of each is presented below:

- **Scientific studies:** threat information derived from scientific studies of impacts has the highest level of credibility/accuracy. In many cases this information is subjected to peer review before publication.
- **NSW Scientific Committee determinations:** threat information outlined within each determination,

whilst not a scientific study of the threats, is reviewed and assessed by a range of experts with specialised knowledge prior to a determination being finalised (eg NSW SC 2004). In addition, all determinations are subjected to public exhibition prior to listing. It is therefore assumed that the information within each determination was accurate and credible at the time of gazettal.

- **Recovery plans and threat abatement plans:** threat information contained within recovery plans and threat abatement plans have been subjected to extensive investigation, consultation, assessment and review, based on information derived from the determinations by the NSW Scientific Committee. It is therefore assumed that the information provided, whilst not necessarily collected from scientific experiments, is accurate and credible.
- **Fact sheets, species profiles, fish notes and threatened species books:** whilst the same level of scientific scrutiny cannot be assured for the information contained within fact sheets, species profiles, fish notes and threatened species books, the information was typically prepared by person/s having specific knowledge of the threatened species, populations or ecological communities. Therefore, it is assumed that this information was accurate at the time of writing, although it was not always verifiable.

Information on the threats to biodiversity

The information compiled for the 941 threatened species revealed a total of 5,317 individual threat descriptions (eg competition by *Lantana camara*); this result equated to an average of 6 different threats per listing. However, many threats were similar in nature but were identified separately due to the wording used to describe a threat. For example, the threat descriptions 'competition by *L. camara*', 'at risk due to the presence of lantana', and 'lantana smothers seedlings' can be

grouped together to describe the threat posed by lantana. Such a system of grouping of similar threats was needed before any analysis could be undertaken.

2.2 Assessment of the threat information

The terminology used to describe each threat varied greatly between the different sources and between threat descriptions for each listing; a variation that hindered interrogation of the data set. To account for this variability, a threat hierarchy was devised to group similar threat descriptions using standardised terminology and to break the specific threats into a hierarchical order, based around standard terms or descriptions.

The threat hierarchy

The concept of threat hierarchies is not new and several examples already exist (Wilcove et al 1998; Lawler et al 2002; IUCN 2004). Whilst these previous hierarchies have been used to assess threats to biodiversity, they have not expanded the hierarchy sufficiently to assess individual threats, like the impact of alien species on biodiversity or that of specific threats like lantana. For example, Wilcove et al (1998) described only the major

categories, whilst Lawler et al (2002) included a list of the threats that are encompassed within each major category. These hierarchies were also developed for different purposes. In an attempt to obtain information on the major threats to biodiversity in the United States Wilcove et al (1998) examined 2,500 threatened species to determine which were affected by five broad categories, whereas Lawler et al (2002) reviewed the threats outlined in 181 recovery plans for threatened species in the United States to ascertain how threats were addressed across multiple species and plans. Our system encompassed all threats described for all threatened species with an examination of more than just the broad categories (Table 2.2).

The threat hierarchy developed here thus varies from those already established in that the nature of the threat forms the upper levels of the hierarchy and the agents responsible for these actions form the lower levels (see below). It should be noted that the threat hierarchy developed here and those already established are based on subjective assessments of groups of threats which could be grouped in a different manner as there are many ways of grouping threat descriptions and forming a hierarchy.

Table 2.2 The seven main threat categories used in the threat hierarchy developed here, compared with those used by Wilcove et al (1998) and Lawler et al (2002)

| The major threat categories in the threat hierarchy developed here ^a | The equivalent threat category of Wilcove et al (1998) | The equivalent threat category of Lawler et al (2002) |
|---|--|---|
| [1] Anthropogenic destruction and disturbance of native vegetation | Habitat loss, over-exploitation | Resource use, construction, agriculture, and altered habitat dynamics |
| [2] Anthropogenic destruction and disturbance of native fauna | Over-exploitation | Resource use |
| [3] Anthropogenic modification and degradation of abiotic factors | Habitat degradation, pollution | Water diversions, altered habitat dynamics, pollution |
| [4] Introduction of alien species | Alien species | Exotic species |
| [5] Diseases | Disease | Species interactions |
| [6] 'Natural' phenomena | No category described | Species interactions, and other factors |
| [7] Other threats ^b | No category described | Other factors |

^a The numerical representation for each threat category (eg [4]) is used only to make comparisons within the text and not as a representation of order or ranking.

^b Other threats: eg not in a formal reserve/conservation or protected area.

Table 2.3 A summary of the threat hierarchy for alien species

| Structure of the threat hierarchy | | | |
|------------------------------------|--|--|--|
| Major threat category ^a | 1 st sub-category (mode of action) ^b | 2 nd sub-category (type of agent) | 3 rd sub-category (specific agent posing the threat) ^c |
| [4] introduction of alien species | predation | animal introduced predator | fox na |
| | competition | animal plant | gambusia lantana |
| | grazing | animal | rabbit |
| | degradation of habitat | animal plant | goat salvinia |
| | control of alien species | animal plant | accidental bait take accidental herbicide application |
| | new association (ie poor pollination) | insect | honey bee |
| | undetermined | na | na |

na: insufficient information to sub-divide the threat further.

a The numerical representation for this threat category (eg [4]) is used only to make comparisons within the text and not as a representation of order or ranking.

b Where a threat description used the term "invasion" the threat was categorised by the action of competition for alien plant species only.

c Common names are used here for presentation, but the data set used both scientific and common names for each alien species.

The initial stage in the development of the threat hierarchy involved grouping all threats into a core set of major threats. Six of the seven major threat categories outlined were based on the specific nature of the threat, with the seventh category encompassing the remaining unrelated threats. The process of grouping like threats was repeated within each major threat category, and subsequent sub-categories until the threat description could not be broken down further. The threat hierarchy thus contained a series of sub-categories, to a maximum of three, nested within each of the major threat categories (ie a total of four levels). Each sub-category allowed each threat to be broken down into specific groups based on the nature of the threat.

For example, 'competition by lantana invasion' is broken down as:

- introduction of alien species [main category]
- competition [1st sub-category – mode of action]
- plants [2nd sub-category – type of agent posing the threat]
- *L. camara* [3rd sub-category – specific agent posing the threat] (Table 2.3).

A complete outline of the threat hierarchy developed is presented in Appendix 2.

Applying the threat hierarchy to the data set

The 5,317 threat descriptions were systematically allocated to one of the seven major categories, and then into the respective nested sub-categories based on the description of the threat. However, information was not always available to allocate every threat to the 3rd sub-category, in part because some threat descriptions were either poorly articulated (eg threatened by weeds), too broad (eg exotic grasses) or lacking sufficient information (eg weed invasion). Despite these caveats, 73% ($n = 3,902$) of threat descriptions could be allocated to a 3rd sub-category and 93% ($n = 4,958$) to a 2nd.

Using the threat hierarchy as described, the 5,317 threat descriptions were condensed into 376 threat categories (Appendix 2). This number is inflated as the 3rd sub-category contains the names of individual alien species as separate agents posing a threat (Table 2.4); being 162 for alien species (127 plant and 35 animal species) out of 290 sub-categories across the hierarchy (note: not all threats could be broken down to the 3rd level, thus the total (376) is greater than the number of 3rd level sub-categories). The number of sub-categories will change with the addition of each new alien species identified as a threat to biodiversity.

Threat descriptions classified under more than one threat category

The allocation of a threat into a major or sub-category within the threat hierarchy is not exclusive.

For example, impacts from livestock (eg sheep, cattle and goats) could be categorised into three of the six major categories, these categories being:

- [1] anthropogenic destruction and disturbance of native vegetation
- [3] anthropogenic modification and degradation of abiotic factors
- [4] introduction of alien species – however domesticated livestock were not included in the alien species category.

Where possible the threat was allocated according to the primary nature of the threat. However, in some cases the threat could not be categorised into just one category

and thus it was allocated to more than one. In the current example, livestock was allocated into both categories [1] and [3], as farmed livestock graze on native vegetation and also modify habitats through trampling, soil compaction and addition of nutrients.

At the higher levels of the threat hierarchy, some threatened species were encompassed more than once. For example, a species identified as threatened by the threat category 'clearing of native vegetation' could be encompassed under both the agriculture and development sub-categories, or the major category anthropogenic destruction and disturbance of native vegetation. Thus, when it came to creating lists of biodiversity under each category or sub-category, duplicate threatened species were removed to prevent 'double counting' of the same species under one action.

Table 2.4 The number of threats within each threat category of the hierarchy

| Structure of the threat hierarchy | | | | |
|--|---|--|---|--|
| Major threat category ^{a, b} | Number of threats in 1 st sub-category (mode of action) ^c | Number of threats in 2 nd sub-category (type of agent) ^d | Number of threats in 3 rd sub-category (specific agent posing the threat) ^e | Total number of threat categories ^f |
| [1] Anthropogenic destruction and disturbance of native vegetation | 5 | 20 | 21 | 39 |
| [2] Anthropogenic destruction and disturbance of native fauna | 3 | 12 | 28 | 33 |
| [3] Anthropogenic modification and degradation of abiotic factors | 3 | 9 | 48 | 51 |
| [4] Introduction of alien species | 7 | 11 | 172 ^g | 195 |
| [5] Diseases | 5 | 15 | 2 | 18 |
| [6] 'Natural' phenomena | 4 | 21 | 19 | 38 |
| [7] Other threats | 2 | 0 | 0 | 2 |
| Total | 29 | 88 | 290 | 376 |

a The numerical representation for each threat category (eg [4]) is used only to make comparisons within the text and is not a representation of order or ranking.

b Total number of threat descriptions encompassed = 5,317.

c Total number of threat descriptions encompassed = 5,301.

d Total number of threat descriptions encompassed = 4,958.

e Total number of threat descriptions encompassed = 3,902.

f Values are not cumulative (either down or across columns) as not all threats are broken down to the 3rd level sub-categories.

g Value includes 162 different alien species, being 127 plant and 35 animal species, plus 10 unspecified or broad threats.

2.3 Analysis of the data set

Statistical analysis of the data set

Statistical analysis was restricted to comparisons of percentages as formal tests of significance were not used because of the subjective nature of the threat descriptions used in the data set. In addition, the process of public nomination for listing threatened biodiversity is inherently biased as it is not based on a systematic census of all biodiversity under threat.

Grouping the threatened biodiversity for analysis

The 941 threatened species were grouped based on taxonomic classifications to allow broader trends to be established. For example, animal species were grouped into amphibians, birds, reptiles, mammals, marine mammals, fish and invertebrates, whilst plants were grouped into ferns and fern allies, gymnosperms, fungi, algae, monocotyledons and dicotyledons.

Spatial data analysis of threatened biodiversity

Spatial analysis of the data set was undertaken using the 13 Catchment Management Authority (CMA) or Natural Resource Management (NRM) regions within New South Wales (Figure 2.1a). NRM regions are used hereafter to refer to the collective CMAs. Each of the 941 threatened species was assigned to their respective CMAs based on their known distribution. The geographic data on the distribution of each listing was



Figure 2.1(a) Boundaries of the 13 Natural Resource Management (NRM) or Catchment Management Authority (CMA) regions within New South Wales

obtained from the NSW Department of Environment and Conservation's (DEC) Atlas of NSW Wildlife, which includes herbarium data from the NSW Royal Botanic Gardens (DEC 2005a).

To enable geographic assessments, particularly at a level between the entire state and the NRM regions, the 13 CMAs were grouped into three geographic zones – coastal, central (ie tablelands and slopes) and western (ie rangelands) New South Wales (Figure 2.1b).

Spatial analysis of threats

As very few threat descriptions (eg impact of weeds) contained geographically specific information on where the threat was active, spatial analysis of specific threats could not be achieved. However, a surrogate assessment was made by selecting threatened species whose distributions were confined to an individual NRM region, or to one of the three geographic zones outlined above. Thus, it was assumed that the threat was active within a region or zone in which the species at risk occurred.

Native species

The species diversity for native vertebrate fauna and the vascular flora within each of the 13 NRM regions was also assessed, as this information could help land managers to understand the species present and the likely impact derived from weeds. Floristic data were obtained from the NSW flora census and herbarium records (BGT 2005), whilst the faunal data were obtained from the DEC Atlas of NSW Wildlife (DEC 2005a) and supplemented with information in Cogger (1994), Strahan (1995), and Simpson and Day (1996).

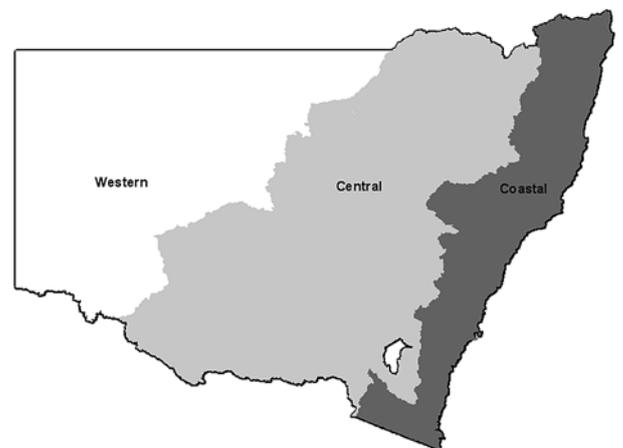


Figure 2.1(b) The 13 NRM regions grouped into three geographic zones (coastal, central and western)

Threatened biodiversity other than species

Threatened populations and ecological communities were not considered during the spatial analysis as distribution data of ecological communities were insufficient to allow an accurate assessment and there was no need to determine the spatial threat of weeds to populations.

Reclassifying the threats within the threat hierarchy to enable comparisons with other threat categories

As outlined above, there are other threat hierarchies and other ways of grouping threats. In order to compare the threats within the data set with other conventional threat categories (eg land clearing), the data set was reclassified. This reclassification was based on the threat categories listed as Key Threatening Processes (KTPs) in New South Wales under Schedules 3 of the TSC Act and 6 of the FM Act in order to assess the representative nature of KTP listings with respect to the threats contained within the data set.

On January 1, 2005 there were 30 KTPs listed, which could be grouped into seven threat categories, namely:

1. clearing of native vegetation
2. changes to natural fire regimes
3. changes to hydrology
4. competition from, and predation by, alien species
5. climate change
6. removal of bushrock and deadwood
7. diseases.

The data set was reclassified using these seven categories to allow comparisons with those threats listed as KTPs. This reassessment involved allocating all biodiversity within the data set into these KTP categories, not just the ones identified in the KTP determinations or those that were actually listed as KTPs. This is especially important for alien species as not every alien species identified in the data set is listed as a KTP. Thus, the reclassification of the data set represents all biodiversity that could be allocated into each KTP category, irrespective of whether the specific threats are listed as a KTP; for example at the time of writing there are only two weed KTPs, but the data set encompasses all weeds present under a single KTP category (see above).



3. An overview of threatened biodiversity in New South Wales

The threatened species legislation in New South Wales deals with the identification, conservation and recovery of threatened species and their populations and communities. Identification is achieved through listing species, populations and ecological communities under the Schedules of the TSC Act and FM Act, from which conservation and recovery actions are achieved primarily through recovery plans and the priorities action statement. In addition, the TSC Act also aims to reduce the threats faced by threatened biodiversity, primarily through the listing of threats as Key Threatening Processes (KTPs) and the preparation of threat abatement plans.

Listing biodiversity as threatened

Schedules of the threatened species legislation categorise biodiversity as Extinct, Endangered or Vulnerable (DEC 2004b), based on definitions given in the IUCN 'Red list of threatened species' (IUCN 2004). In New South Wales the biodiversity deemed to be threatened, as represented by species and ecological communities, is listed under the schedules of the TSC Act or FM Act or, if deemed to be at risk nationally, under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

Whilst individual plant and animal populations can be listed under the TSC and FM Acts, they cannot be listed under the EPBC Act. A recent provision of the TSC Act allows for the listing of Critically Endangered species, but none had been listed as at June 2006. For information on the listing processes for the three Acts see NPWS (2004), DPI (2005a) and DEH (2005), respectively.

An overview of the biodiversity listed under the schedules of each of the threatened species legislation is presented here as background information to the data set and as a baseline for the analysis to be presented subsequently. Although the data set in this report is based on the NSW threatened species legislation, the national legislation is also presented here to provide a broader context and subsequent discussion of the implications of this report.

3.1 Nationally threatened species that occur within New South Wales

There were 1,683 species and 32 ecological communities listed under the EPBC Act on January 1, 2005. Of these 1,715 threatened species, 484 occur or occurred (extinct species) in New South Wales (Table 3.1). As a percentage of the total number of nationally threatened species or ecological communities, the value for New South Wales is high (28%: being 484 of 1,715), given the state's relative landmass (11% of Australia). Fifty-one of these species were not listed under either the TSC or FM Acts at that time. This absence may simply be an artefact of the listing process, rather than being a discrepancy between the processes of the different legislations; once listed under the EPBC Act, a decision is made by the NSW Scientific Committee to list or not list in New South Wales. As determinations under the EPBC Act were not easily accessible and species profiles were not available for many of these threatened species, the 51 species not listed under the TSC Act were not included, as the level of threat information was not comparable with those listed under the TSC Act (see Chapter 2).

3.2 Biodiversity listed under New South Wales threatened species legislation

There were 1,001 threatened species listed under the TSC Act and 20 under the FM Act on January 1, 2005 (total threatened species = 1,021). Of these threatened species, 76 were Presumed Extinct, 436 were Endangered species, 404 were Vulnerable species, 33 were Endangered Populations of plants and animals and 72 were Endangered Ecological Communities (Table 3.2). These threatened species accounted for approximately 26% (242 of 936) of the native vertebrates and 11% (555 of 5,248) of the native terrestrial vascular plants in New South Wales. Examination of threatened invertebrates ($n = 17$), fish ($n = 12$), fungi ($n = 9$), algae ($n = 1$) and aquatic plants ($n = 4$), were excluded from many of the analyses as the exact numbers (non-threatened) are not known.

Table 3.1 The status of the biodiversity listed under the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999* as at January 1, 2005

| Geographic breakdown | Type of biodiversity listed under the EPBC Act ^{a, b, c} | Number listed under the EPBC Act | | | | Total |
|----------------------|---|----------------------------------|---------------------------------------|-------------------------|-------------------------|--------------|
| | | Presumed Extinct ^d | Critically Endangered ^{d, e} | Endangered ^d | Vulnerable ^d | |
| Australia | Plant species ^f | 61 | 57 | 509 | 676 | 1,303 |
| | Animal species (incl. invertebrates) | 55 | 14 | 118 | 193 | 380 |
| | Ecological communities | 0 | 3 | 28 | 1 | 32 |
| | Total | 116 | 74 | 655 | 870 | 1,715 |
| NSW ^g | Plant species ^f | 11 | 5 | 124 | 212 | 352 |
| | Animal species | 20 | 4 | 33 | 65 | 122 |
| | Ecological communities | 0 | 0 | 10 | 0 | 10 |
| Total | | 31 | 9 | 167 | 277 | 484 |

a EPBC Act refers to the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*.

b Biodiversity as listed on Schedules 1 and 2 of the EPBC Act, as at January 1, 2005 (ie species and ecological communities).

c Populations cannot be listed under the EPBC Act.

d The definition of Presumed Extinct, Critically Endangered, Endangered and Vulnerable is given under the EPBC Act (Attorney-General's Department 2005), based on definitions given in the IUCN 'Red list of threatened species' (IUCN 2004).

e As at January 1, 2005 there was no legislative provision to list biodiversity as Critically Endangered under the TSC Act or FM Act. Of the nine species listed as Critically Endangered under the EPBC Act that occurred in NSW, eight were listed as Endangered under the TSC Act and one was not listed in NSW at all.

f At the time of writing no fungi and algae were listed under the EPBC Act.

g EPBC Act listings that occur in NSW.

Table 3.2 Status of the biodiversity listed under the NSW *Threatened Species Conservation Act 1995* and the NSW *Fisheries Management Act 1994*, as at January 1, 2005

| Type of biodiversity listed under the TSC and FM Acts ^{a, b} | Number listed under the TSC and FM Acts | | | Total ^d |
|---|---|-------------------------|-------------------------|--------------------|
| | Presumed Extinct ^c | Endangered ^c | Vulnerable ^c | |
| Plant species (incl. fungi and algae) | 36 | 343 | 226 | 605 (569) |
| Animal species (incl. invertebrates) | 40 | 93 | 178 | 311 (271) |
| Total | 76 | 436 | 404 | 916 (840) |
| Plant populations | na | 17 | 0 | 17 |
| Animal populations | na | 16 | 0 | 16 |
| Total | na | 33 | 0^e | 33 |
| Ecological communities | na | 72 | na | 72 |
| Total | 76 | 541 | 404 | 1,021 (945) |

na: populations or ecological communities cannot be listed as Presumed Extinct. In addition ecological communities could not be listed as Vulnerable, as at January 1, 2005.

a TSC Act refers to the NSW *Threatened Species Conservation Act 1995* and the FM Act to the NSW *Fisheries Management Act 1994*.

b Biodiversity as listed on Schedules 1 and 2 of the TSC Act and 4 and 5 of the FM Act, as at January 1, 2005 (ie species, populations and ecological communities).

c The definition of Presumed Extinct, Endangered and Vulnerable are given in the TSC Act (PCO 2003), based on definitions in the IUCN 'Red list of threatened species' (IUCN 2004).

d The values in brackets are the total minus the number of Presumed Extinct species.

e The listing of populations as Vulnerable was made possible in an amendment to the TSC Act in 2004, although none was listed as at January 1, 2005.

Presumed Extinct species

Since European settlement of Australia, 116 native species (61 plant and 55 animal species, excluding subspecies) have been driven to extinction nationally, that is they have not been observed for >50 years (NPWS 2004). Of these 116 nationally Presumed Extinct species, 31 (11 plant and 20 animal) were formerly distributed within New South Wales. An additional 45 species that once occurred in New South Wales are listed as Presumed Extinct under the NSW legislation, bringing the total of Presumed Extinct species in New South Wales to 76. As stated earlier (Chapter 2), those species Presumed Extinct were excluded from the data set.

Endangered and Vulnerable species

As part of the listing process for threatened species, an assessment was made of the degree to which the species is at risk as well as their ability to recover, based on criteria and the threat categories outlined in the IUCN 'Red list of threatened species' (IUCN 2004). The NSW threatened species legislation contains only the categories Endangered and Vulnerable. However, species that occur in New South Wales can be listed as Critically Endangered under the EPBC Act. Of the nine species listed as Critically Endangered under the EPBC Act that occurred in New South Wales, eight are listed under the TSC Act as Endangered, and one was not listed at all (see Section 3.1).

Table 3.3 Status of plant and animal species in New South Wales

| Type of biodiversity listed under the TSC and FM Acts ^{a, b} | Taxonomic grouping ^c | Number listed under the TSC and FM Acts as | | | Total number threatened in NSW | Total number of species in NSW incl. Presumed Extinct | Threatened species (%) excl. Presumed Extinct |
|---|---------------------------------|--|-------------------------|-------------------------|--------------------------------|---|---|
| | | Presumed Extinct ^d | Endangered ^d | Vulnerable ^d | | | |
| Plant species | aquatic plants | 0 | 3 | 1 | 4 | na | na |
| | algae, mosses and lichens | 0 | 1 | 0 | 1 | na | na |
| | fungi | 0 | 5 | 4 | 9 | na | na |
| | ferns and allies | 1 | 14 | 2 | 17 | 177 | 9 |
| | gymnosperms | 0 | 5 | 1 | 6 | 27 | 22 |
| | monocotyledons | 3 | 47 | 34 | 84 | 1,302 | 6 |
| | dicotyledons | 32 | 268 | 184 | 484 | 3,742 | 12 |
| | Total | 36 | 343 | 226 | 605 | 5,248 ^e | 11 |
| Animal species | aquatic invertebrates | 0 | 1 | 2 | 3 | na | na |
| | invertebrates | 1 | 14 | 0 | 15 | na | na |
| | fish | 0 | 7 | 5 | 12 | na | na |
| | amphibians | 0 | 11 | 14 | 25 | 72 | 35 |
| | reptiles | 1 | 15 | 26 | 42 | 208 | 20 |
| | marine mammals | 0 | 2 | 5 | 7 | 37 | 19 |
| | mammals | 26 | 16 | 41 | 83 | 147 | 47 |
| birds | 12 | 27 | 85 | 124 | 472 | 24 | |
| | Total | 40 | 93 | 178 | 311 | 936 ^e | 26 |
| Total | | 76 | 436 | 404 | 916 | 6,184 ^f | 14 |

na: the exact number of species is unknown.

a TSC Act refers to the NSW *Threatened Species Conservation Act 1995* and the FM Act to the NSW *Fisheries Management Act 1994*.

b Biodiversity as listed on Schedules 1 and 2 of the TSC Act and 4 and 5 of the FM Act, as at January 1, 2005 (ie species, populations and ecological communities).

c The main taxonomic grouping of plant and animal species as outlined in Chapter 2.

d The definitions of Presumed Extinct, Endangered and Vulnerable are given in the TSC Act (PCO 2003), based on definitions in the IUCN 'Red list of threatened species' (IUCN 2004).

e Excludes those species marked with 'na' as there was insufficient information on the numbers of species present in NSW.

f The total number of species in NSW was derived from several sources for example BGT (2005) and DEC (2005a), also see Chapter 2. Presumed Extinct species were derived from the TSC and FM Acts.

Endangered plants made up the majority (60%) of threatened plant species, whilst the majority of animal species (65%) were classified as Vulnerable (Table 3.2). This result implies that the majority of threatened plants are at a greater risk of extinction than the majority of listed animals. However, as outlined above, more animals are listed as Presumed Extinct, therefore those animals most at risk are likely to have disappeared already. In addition, threatened plants comprise a smaller percentage of the total flora, compared to the same percentage for animals of the total fauna (Table 3.3).

Endangered Populations

Individual populations of species that are of conservation significance can also be listed under the NSW threatened species legislation, irrespective of the threatened status of the species. To date, populations have been listed only as Endangered. As at January 1, 2005, 33 Endangered Populations were listed under the NSW threatened species legislation, of which plants account for slightly more than half (Table 3.2). Such populations typically contain plant forms that are only known from one location (eg the broad-leafed form of *Glycine clandestina* growing in coastal grasslands at Scotts Head: NSW SC 2001), or are geographically isolated populations (eg North Head long-nosed bandicoot population: NSW SC 1997).

Endangered Ecological Communities

Ecological communities can also be listed as Endangered under the NSW threatened species legislation, but recent amendments (2002 and 2004) to the TSC Act enable them to be listed as Critically Endangered or Vulnerable. Of the 72 Endangered Ecological Communities (EECs) listed at January 1, 2005, all were listed as Endangered, and the vast majority were listed in the period 2000–2004, illustrating a recent move towards listing entire ecological communities, rather than individual species.

In addition, the vast majority of EECs listed are located either within the Sydney Basin or along the coast. Not all of the species present in an EEC are necessarily threatened, rather it is the main species that characterise the ecological community, or the combination of the species present that are at risk. These species are not necessarily listed separately as threatened. For example, there are 82 species contained in the listing for the EEC montane peatlands and swamps, of which 24 are listed as threatened, not one of which is characteristic of the community (NSW SC 2004).

3.3 Distribution of threatened and non-threatened species throughout New South Wales

Spatial information on the native species present in New South Wales (terrestrial vascular plants and vertebrates only, as distribution data for other taxa were unavailable) was used to allocate them into the 13 NRM regions, for both threatened species and the total number present. In addition, the 13 NRM regions were grouped into three geographic zones – coastal, central and western New South Wales (see Chapter 2).

The percentage of native species (both plant and animal) present in the three geographic zones increased toward the coast (Table 3.4). There was a similar trend in the number of threatened species present in each of these three geographic zones (Table 3.4). However, the proportions of threatened native species within each zone showed that a greater proportion of plants species in the coastal zone were threatened, while threatened native animals were more uniform (Figure 3.1a and 3.1b). Whilst the proportions of the total number of plant and animal species were similar in the coastal zone (80% and 85% for plant and animal species respectively), there was a greater proportion of animal species than plant species in the western zone (51% and 25% respectively).

Table 3.4 The proportion of species listed as threatened in each of the three geographic zones in New South Wales

| Geographic zone in NSW ^a | Number of native plants present | Proportion of native plants present (%) | Number of threatened plants present ^b | Proportion of threatened plants present (%) | Number of native animals present ^c | Proportion of native animals present (%) | Number of threatened animals present ^d | Proportion of threatened animals present (%) |
|-------------------------------------|---------------------------------|---|--|---|---|--|---|--|
| Coastal | 4,173 | 80 | 421 | 76 | 761 | 85 | 161 | 69 |
| Central | 3,177 | 61 | 157 | 28 | 614 | 68 | 117 | 50 |
| Western | 1,335 | 25 | 65 | 12 | 455 | 51 | 89 | 38 |
| Total ^e | 5,248 | na | 555 | na | 899 | na | 235 | na |

na: not applicable.

a geographic zones as defined in Chapter 2.

b Threatened plants refers to terrestrial vascular plant species listed under the NSW *Threatened Species Conservation Act 1995* (TSC Act) only.

c Excludes all aquatic and marine organisms and invertebrates.

d Threatened animals refers to terrestrial vertebrates listed under the TSC Act only.

e Values are not cumulative as many species occur in more than one Natural Resource Management region.

Finer geographic trends are apparent when the number of native species present in each NRM region are examined. For example, the greatest number of plant and animal species occurred along the north coast of the state (ie the Northern Rivers and Hunter–Central CMAs: Table 3.5). The lowest number occurred in the

southwest of the state (ie the Lower Murray–Darling CMA). The northern coastal NRM regions also contained the greatest number of threatened species (plant and animal) and the southwest NRM region the lowest. This trend was less clear when the proportions of threatened plant and animal species were examined (Table 3.5).

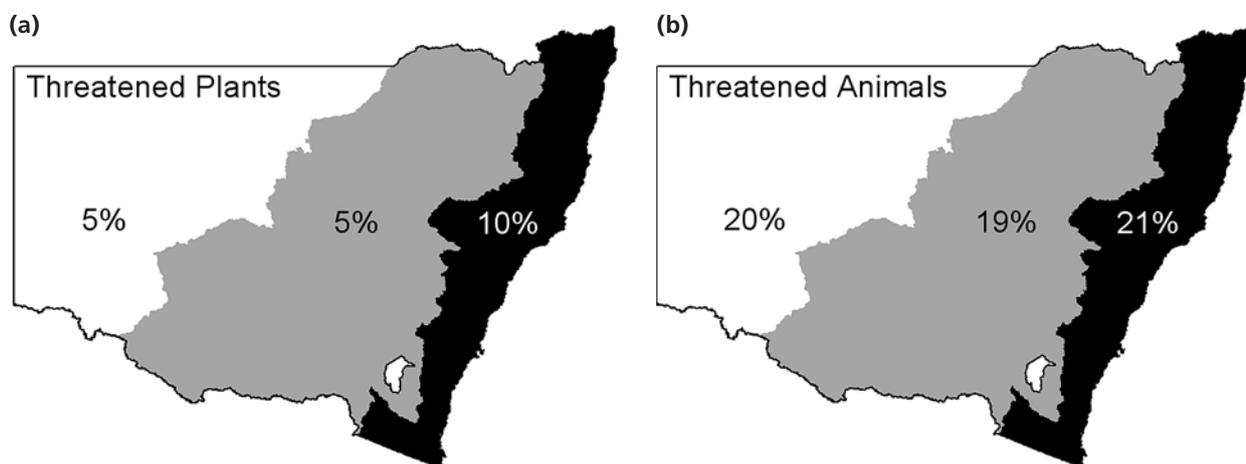


Figure 3.1 The proportion of native (a) terrestrial vascular plants and (b) vertebrates, in the three geographic zones of New South Wales – coastal, central and western, based on the number listed as threatened under the NSW *Threatened Species Conservation Act 1995*

Table 3.5 The proportions of species listed as threatened in each of the 13 Natural Resource Management regions in New South Wales

| Natural Resource Management regions in NSW ^a | Number of native plants present | Number of threatened plants | Proportion of plants threatened (%) ^b | Number of native animals present ^c | Number of threatened animals ^c | Proportion of animals threatened (%) ^d |
|---|---------------------------------|-----------------------------|--|---|---|---|
| Northern Rivers CMA | 2,655 | 208 | 8 | 695 | 134 | 19 |
| Hunter Central Rivers CMA | 2,313 | 85 | 4 | 610 | 107 | 18 |
| Hawkesbury–Nepean CMA | 2,279 | 132 | 6 | 538 | 93 | 17 |
| Sydney Metropolitan CMA | 1,598 | 52 | 3 | 519 | 73 | 14 |
| Southern Rivers CMA | 2,330 | 104 | 5 | 545 | 96 | 18 |
| Border Rivers–Gwydir CMA | 1,602 | 59 | 4 | 481 | 68 | 14 |
| Namoi CMA | 1,442 | 24 | 2 | 470 | 63 | 13 |
| Central West CMA | 1,695 | 44 | 3 | 517 | 63 | 12 |
| Lachlan CMA | 1,334 | 33 | 3 | 485 | 66 | 14 |
| Murrumbidgee CMA | 1,628 | 48 | 3 | 488 | 74 | 15 |
| Murray CMA | 1,202 | 31 | 3 | 432 | 60 | 14 |
| Western CMA | 1,221 | 49 | 4 | 446 | 71 | 16 |
| Lower Murray–Darling CMA | 709 | 25 | 4 | 394 | 56 | 14 |
| Total ^e | 5,248 | 555 | 11 | 899 | 235 | 26 |

a CMA is short for Catchment Management Authority.

b Threatened plants refers to terrestrial vascular plant species listed under the NSW *Threatened Species Conservation Act 1995* (TSC Act) only.

c Excludes all aquatic and marine organisms and invertebrates.

d Threatened animals refers to terrestrial vertebrates listed under the TSC Act only.

e Values are not cumulative as many species occur in more than one CMA.



4. An overview of the major threats to biodiversity in New South Wales

In this chapter the major threat categories, using both the threat hierarchy and the key threatening processes, were analysed to determine the relative importance of each threat to the threatened biodiversity in New South Wales (see Chapter 2 for further information on the data set and the threat categories).

4.1 Analysis of the major threat categories

An assessment of the listed biodiversity

Of the seven major threat categories, anthropogenic destruction and disturbance of native vegetation represented the greatest threat, affecting 87% of all the threatened species examined (Figure 4.1). This threat category encompasses large-scale threats such as land clearing, which is recognised globally as the greatest cause of biodiversity decline (WRI et al 1992). The introduction of alien species (pest animals and weeds) posed the second greatest threat, affecting 70% of biodiversity examined. Again, this threat is recognised globally as a major cause of biodiversity decline. The only other major category to threaten more than half the biodiversity examined was anthropogenic modification and degradation of abiotic factors (65%), illustrating the importance of abiotic factors to biological processes which underpin the survival of biodiversity.

The threat posed by 'natural' phenomena to biodiversity was greatly influenced by the compounding effect of stochastic events such as drought, flood and fire on small or isolated populations of threatened species. If these populations were excluded, the threat posed by 'natural' phenomena would affect only 9% of the biodiversity examined, as opposed to almost 50%.

An assessment of threatened plant and animal species

The degree of vulnerability to each threat exhibited by different groups of species was examined. The threat from anthropogenic destruction and modification of native vegetation affected more than twice the number of plant than animal species and, more specifically, three times the number of Endangered plant than animal species. However, the proportions were very similar (Table 4.1). In addition, the proportions of Threatened Populations and Endangered Ecological Communities at risk from this process were also high, thereby highlighting the pervasive nature of this threat. In contrast, anthropogenic destruction and disturbance of native fauna affected only native fauna, although such disturbances to fauna may have flow-on effects to native flora. In many instances, these flow-on effects are not well known or documented, let alone captured in data sets like these, as illustrated by the absence of plant species impacted by this threat.

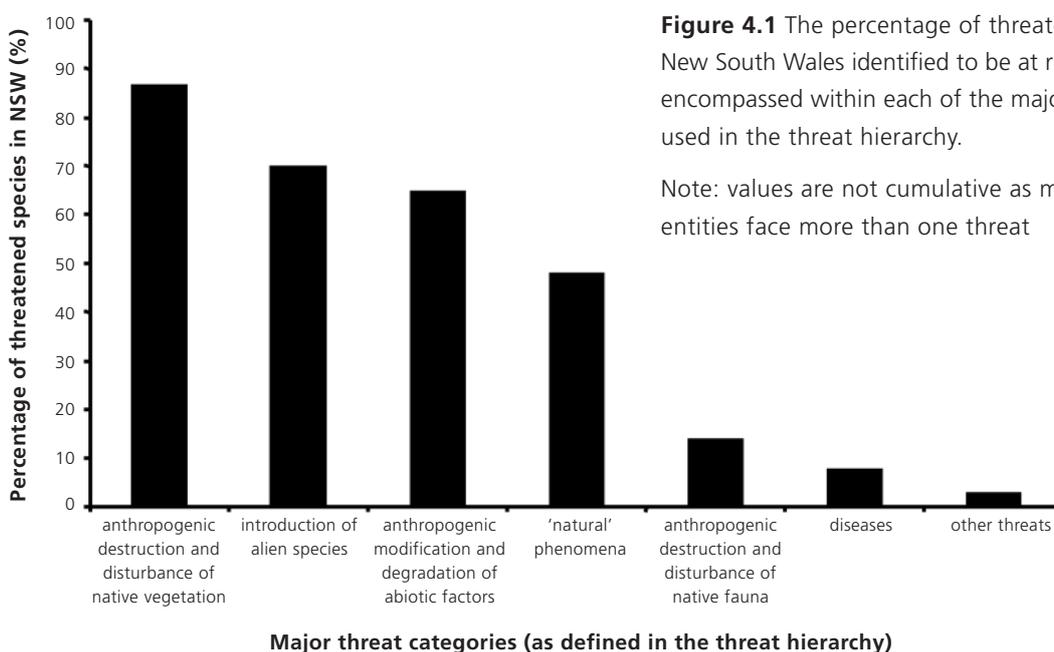


Figure 4.1 The percentage of threatened biodiversity in New South Wales identified to be at risk from the threats encompassed within each of the major threat categories used in the threat hierarchy.

Note: values are not cumulative as many biological entities face more than one threat

Table 4.1 Threatened biodiversity in New South Wales encompassed by each of the seven major threat categories in the threat hierarchy

| Major threat category ^a | Number listed under the TSC and FM Acts ^{b, c} | | | | | | | Total number of threatened species ^e |
|--|---|------------|------------------------------------|-------------|--|------------|---|---|
| | Endangered species ^{d, e} | | Vulnerable species ^{d, e} | | Endangered populations ^{d, e} | | Endangered ecological communities ^{d, e} | |
| | plant ^f | animal | plant ^f | animal | plant | animal | | |
| [1] Anthropogenic destruction and disturbance of native vegetation | 301 (88) | 76 (81) | 194 (86) | 149 (84) | 16 (94) | 15 (94) | 69 (96) | 820 (87) |
| [2] Anthropogenic destruction and disturbance of native fauna | 0 | 48 (52) | 0 | 73 (41) | 0 | 8 (50) | 4 (6) | 133 (14) |
| [3] Anthropogenic modification and degradation of abiotic factors | 200 (59) | 62 (66) | 143 (64) | 116 (66) | 12 (71) | 12 (75) | 66 (92) | 611 (65) |
| [4] Introduction of alien species | 223 (65) | 84 (89) | 139 (62) | 116 (66) | 14 (82) | 13 (81) | 68 (94) | 657 (70) |
| [5] 'Natural' phenomena | 232 (68) | 39 (41) | 104 (46) | 46 (26) | 6 (35) | 7 (44) | 15 (21) | 449 (48) |
| [6] Diseases | 16 (5) | 20 (21) | 13 (6) | 14 (8) | 0 | 4 (25) | 8 (11) | 75 (8) |
| [7] Other threats | 13 (4) | 0 | 3 (1) | 0 | 1 (6) | 0 | 6 (8) | 2 (2) |
| Total ^g | 340 | 93 | 225 | 178 | 17 | 16 | 72 | 941 |

a The numerical representation for each threat category (eg [4]) is used only to make comparisons within the text and is not a representation of order or ranking. The major threat categories in the threat hierarchy are outlined in Chapter 2.

b TSC Act refers to the NSW *Threatened Species Conservation Act 1995* and the FM Act to the NSW *Fisheries Management Act 1994*.

c Biodiversity as listed on Schedules 1 and 2 of the TSC Act and 4 and 5 of the FM Act, as at January 1, 2005 (ie species, populations and ecological communities).

d The definition of Endangered and Vulnerable are given in the TSC Act (PCO 2003), based on definitions in the IUCN 'Red list of threatened species' (IUCN 2004).

e The percentages of the total are presented in brackets.

f The nine species of fungi have been included within the plant totals.

g This excludes the four plant species for which no threats were determined, being three Endangered and one Vulnerable species.

The impact of the introduction of alien species was consistently high across all types of biodiversity examined (Table 4.1). The impact of 'natural' phenomena was greatest on Endangered plant and animal species. As outlined above, many of the species threatened by 'natural' phenomena have small or isolated populations and thus are more likely to be listed as Endangered, as well as being more susceptible to stochastic events.

An assessment of the different groups of plants and animals

All the major taxonomic groups of plants and animals, with the exception of fungi, amphibians, marine mammals and mammals, were threatened more by anthropogenic destruction and modification of native vegetation than any other major threat (Table 4.2). Anthropogenic modification and degradation of abiotic factors posed the greatest threat to fungi and amphibians (Table 4.2).

As both fungi and amphibians are known to be sensitive to chemical changes in their physical environment (Mann and Bidwell 1999; NSW SC 2000) this result was not unexpected.

The two taxonomic groups affected most by diseases were frogs and dicotyledons, primarily the result of the introduced Chytrid fungus and *Phytophthora cinnamomi*, respectively (Berger et al 1999; NSW SC 2002).

'Natural' phenomena were most commonly identified as threatening threatened plants, in part because many of the species are naturally rare. The threat from alien species was greatest to dicotyledons and comprised the second greatest threat across the majority of plant and animal groups, with the exception of marine mammals and aquatic invertebrates (Table 4.2). A further breakdown of the impact of weeds on each of these plant and animal groups is presented in Chapter 5.

Table 4.2 Threat posed by the processes within each of the major threat categories in the threat hierarchy to threatened plant and animal species in New South Wales

| Biodiversity threatened in NSW ^{a, b} | Taxonomic grouping ^c | Number listed under the TSC and FM Acts at threat in each major threat category ^{a, d} | | | | | | |
|--|---------------------------------|---|--|--|--------------------------------------|----------------------------|-----------------|--------------|
| | | [1] Anthropogenic destruction and disturbance of native vegetation | [2] Anthropogenic destruction and disturbance of native fauna | [3] Anthropogenic modification and degradation of abiotic factors | [4] Introduction of alien species | [5] 'Natural' phenomena | [6] Diseases | [7] Other |
| Plant species | algae | 0 | 0 | 1 | 1 | 0 | 0 | 0 |
| | aquatic | 3 | 0 | 4 | 3 | 1 | 0 | 0 |
| | fungi | 0 | 0 | 9 | 9 | 0 | 0 | 0 |
| | gymnosperms | 5 | 0 | 6 | 4 | 5 | 1 | 0 |
| | ferns and fern allies | 14 | 0 | 8 | 7 | 9 | 0 | 1 |
| | monocotyledons | 76 | 0 | 43 | 50 | 51 | 0 | 1 |
| | dicotyledons | 397 | 2 | 272 | 288 | 270 | 28 | 18 |
| Animal species | aquatic invertebrates | 1 | 0 | 2 | 0 | 2 | 0 | 0 |
| | birds | 97 | 51 | 71 | 81 | 37 | 6 | 0 |
| | invertebrates | 13 | 5 | 10 | 13 | 5 | 1 | 0 |
| | fish | 5 | 9 | 6 | 7 | 4 | 3 | 0 |
| | amphibians | 21 | 6 | 25 | 18 | 9 | 18 | 0 |
| | mammals | 57 | 32 | 31 | 43 | 10 | 5 | 0 |
| | marine mammals | 1 | 7 | 6 | 0 | 4 | 0 | 0 |
| | reptiles | 32 | 11 | 27 | 38 | 14 | 1 | 0 |
| Total | | 722 | 123 | 521 | 562 | 421 | 63 | 20 |

a Biodiversity as listed on Schedules 1 and 2 of the TSC Act and 4 and 5 of the FM Act, as at January 1, 2005 (ie species, populations and ecological communities). TSC Act refers to the NSW *Threatened Species Conservation Act 1995* and the FM Act to the NSW *Fisheries Management Act 1994*.

b Values for populations and ecological communities are presented in Table 4.1.

c The main taxonomic grouping of plant and animal species as outlined in Chapter 2.

d The numerical representation for each threat category (eg [4]) is used only to make comparisons within the text and is not a representation of order or ranking. The major threat categories in the threat hierarchy are outlined in Chapter 2.

4.2 Examination of the data set using the threats listed as Key Threatening Processes in New South Wales

As outlined in Chapter 2, the data set was reclassified to allow comparisons to be made with other threat classifications. For this section of the analysis, the data set was reclassified to align with the 30 threatening processes listed as Key Threatening Processes (KTPs) under Schedule 3 of the TSC Act and Schedule 6 of the FM Act, as at January 1, 2005. The assessment of these KTPs against the data set was based on which threats could be allocated to a specific threatening process generically, not what is actually allocated to a specific

KTP listing. Thus, the results presented for the KTPs analysis are categories of threats based around the currently listed KTPs (see Chapter 2). For example, when the weed species listed as KTPs (eg bitou bush and exotic grasses) are examined in the database they threaten 102 of the threatened species, but if weeds as a whole is considered as a KTP category then the number is increased to 419. This increased value is referred to here as the KTP category. Thus, the KTP categories encompassed 87% of the data set (or 821 threatened species). Irrespective, at least 13% of threatened species are not currently accounted for under a KTP listing. However, this percentage is likely to be much higher as these KTP categories include a greater number of threats than are actually listed (eg as is the case for weeds).

Using this reclassification, alien species posed the greatest threat to biodiversity in New South Wales as a single process ($n = 657$ threatened species, being 562 species, 27 populations and 68 EECs), followed by the threat of land clearing ($n = 619$ threatened species: Figure 4.2). This result differs from the analysis of the threat hierarchy (see above), because land clearing, as used here, does not include other similar or related threats such as habitat disturbance or degradation, as used elsewhere (eg WRI et al 1992; Wilcove et al 1998).

The next greatest threat was from the alteration of fire regimes, which affected 44% of threatened species (Figure 4.2). Within the threat hierarchy, alteration of fire regimes was encompassed within the main threat category of anthropogenic modification and degradation of abiotic factors, where this specific threat contributed to the large number of plant species impacted by that category.

The biodiversity threatened by climate change, as presented here, accounts only for those species currently identified in the data set as being at risk although potentially all biodiversity could be at risk in the future (NRMCC 2004). The future threat of climate change was thus not accounted for here, but should be considered when discussing the broader implications of these results.

4.3 Threatening processes not currently listed as Key Threatening Processes

In section 4.2 above, an assessment was undertaken of the data set in relation to KTP listings. However, the KTP listings do not reflect the major threats to biodiversity identified in the data set. For example, environmental degradation to land and water due to pollution threatened 20% ($n = 185$) of the biodiversity examined; the collection of native species (ie of species, seeds and eggs – mostly illegal), threatened 12% ($n = 109$); and the dumping of rubbish and garden waste threatened 8% ($n = 72$). In addition, many more weed species could be listed as over 300 threatened species threatened by weeds are not currently addressed in a weed KTP listing. Given that these threats meet the requirements for listing as KTPs (PCO 2003), consideration should be given to having them listed as such in New South Wales (see Chapter 8 for further discussion).

The identification of major threats not listed as KTPs highlights the value of the current threat hierarchy and assessment of threats, as it encompasses all threats to biodiversity based on the actual threats identified, rather than the KTP-listing process, which is not based on a systematic review of the threats. For example, the

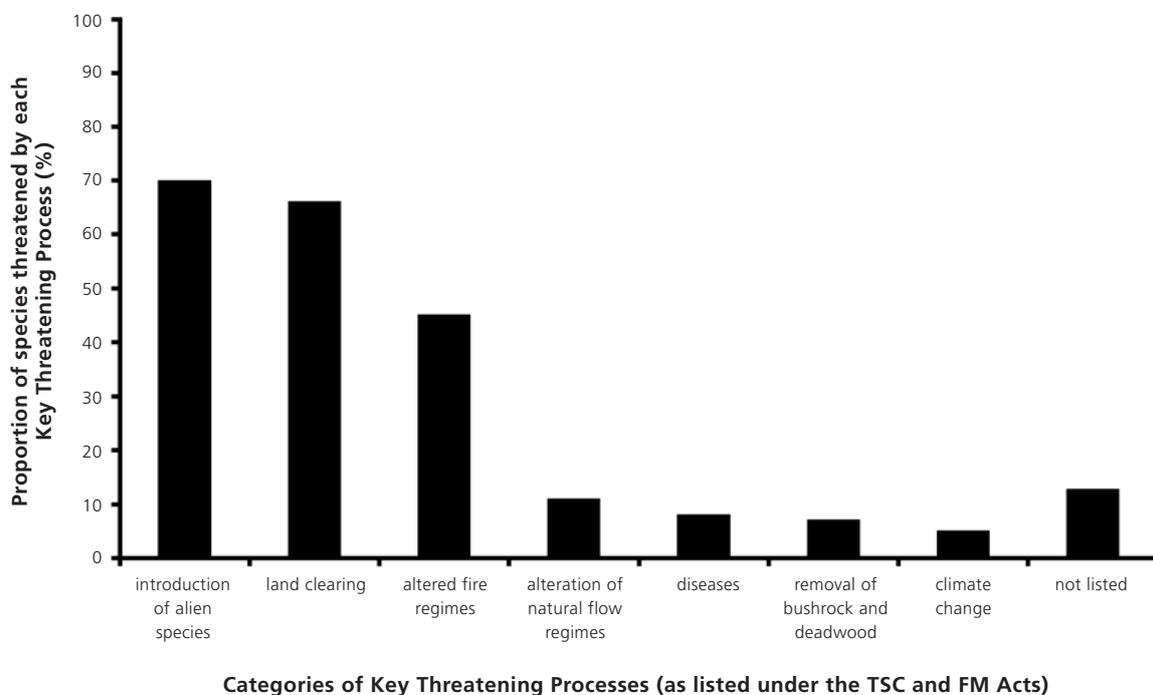


Figure 4.2 Reclassification of the data set to align with the categories of Key Threatening Processes as listed under the NSW *Threatened Species Conservation Act 1995* and the NSW *Fisheries Management Act 1994*

Note: values are not cumulative as many threatened species face more than one threat

current KTP listings for weeds only account for 102 threatened species out of a possible 419 (see below for further discussion).

The impact of salinity on biodiversity in New South Wales

In Australia, one of the major issues confronting land managers over the past few decades has been the impact of salinity. Whilst salinity has been identified as a significant problem to agriculture in New South Wales (with 178,000 hectares being at risk: Littleboy et al 2001) and Australia (NLWRA 2000; ABS 2002), the impact of salinity on biodiversity has not been determined. It is assumed to be significant however, given the area affected in Australia. The present study identified only four species threatened by dryland salinity, which suggests that the impact of salinity on biodiversity is either poorly understood or is not as significant a problem to biodiversity as has been assumed. Whilst this study could not determine which explanation was the case, a recent survey of biodiversity in the Western Australia agricultural zone identified 450 plant species and 400 invertebrates as being impacted by salinity, as well as a 50% decrease in the numbers of waterbird species using wetlands in saline affected areas (Keighery et al 2000). This finding points to an under-appreciation of the impact of salinity on biodiversity. However, given the differences in the extent of saline land between Western Australia and New South Wales (land affected by salinity is an order of magnitude greater in Western Australia (1.8 M hectares) (ANZECC 2001), the impact to biodiversity in New South Wales is not expected to be as high.



5. The impacts of weeds on threatened biodiversity

As established in the previous chapter, alien species (weeds and pest animals) pose a significant threat to biodiversity in New South Wales. When compared with other broad categories of threatening processes, such as the destruction and modification of native vegetation, alien species comprised the second greatest threat. However, when compared with individual threats such as land clearing, alien species were the greatest threat. In this chapter, the impacts of alien species on biodiversity are assessed more closely, in particular the relative impact of weeds.

5.1 The impact of weeds relative to the threat from alien animals

In order to determine the relative impacts of each group of alien species, an assessment was undertaken of the impacts of weeds and alien pest animals, excluding livestock. Weeds posed the greatest threat, affecting 419 threatened species, or 45% of the biodiversity examined (Figure 5.1). This number is an order of magnitude greater than a previous study which identified only 41 species nationally, and 14 within New South Wales at risk from weed invasions (Vidler 2004). The number of species identified here is consistent, however,

with the results of recent attempts to identify biodiversity impacted by weeds using the newly developed Weed Impacts to Native Species (WINS) assessment process (DEC 2006; Downey 2006), which will be discussed further on. This suggests that weed impacts on biodiversity have been grossly under-estimated.

Whilst the impact of alien pest animals was less than that of weeds, in terms of the total number of species identified at risk, pest animals still posed a significant threat to biodiversity, affecting 356 threatened species examined (or 38% of threatened biodiversity: Figure 5.1). One reason for the difference between the threat posed by weeds and that posed by pest animals may simply be an artefact of the numbers of alien species present (ie there being 2,800 naturalised plants in Australia (Groves et al 2003), compared with 80 vertebrates (Bomford and Hart 2002). A further examination of the impact of pest animals, based on the data set used for this study, is presented by Coutts-Smith et al (*unpublished data*).

Approximately 12% (or 117 threatened species) of the species examined were threatened by both weeds and pest animals (Figure 5.1). For example, *Atriplex sturtii* was threatened by weed invasion and grazing by rabbits.

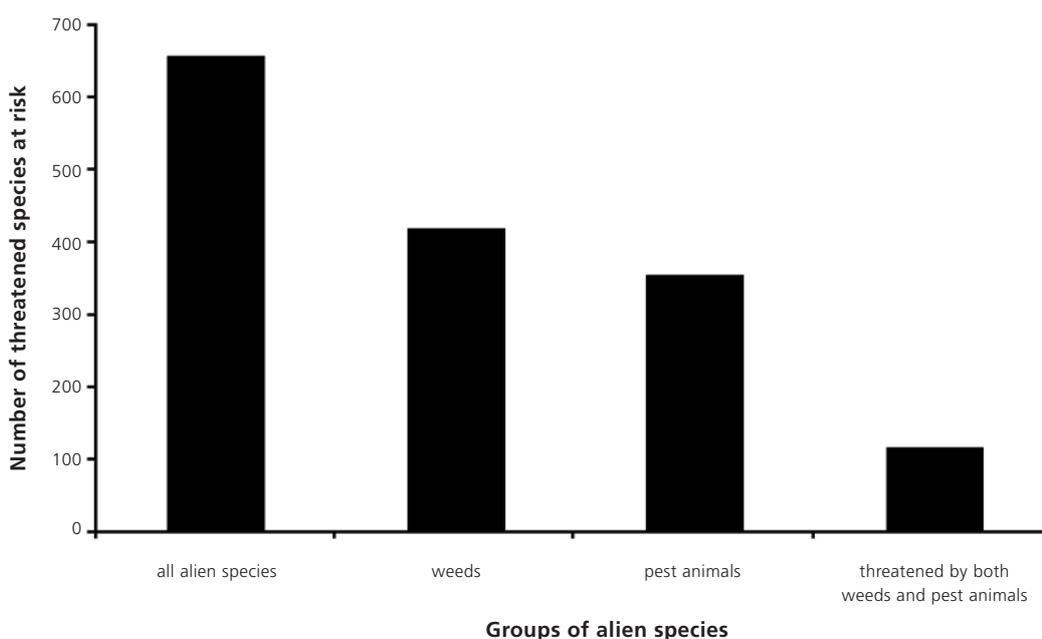


Figure 5.1 A breakdown of the main groups of alien species posing a threat to threatened biodiversity in New South Wales

Note: values are not cumulative as species are threatened by both weeds and pest animals

5.2 The relative threat posed by weeds compared to other threats

As outlined above, weeds pose a major threat to biodiversity, but how do they compare with other threatening processes such as the destruction and modification of native vegetation, or to other individual threats such as land clearing?

A comparison of weed impacts with the major threat hierarchy categories revealed that weeds pose the third greatest threat to biodiversity, behind the anthropogenic destruction and disturbance of native vegetation and anthropogenic modification and degradation of abiotic factors. It should be noted that the major threat categories encompass a broad range of processes, whilst weeds are a single threat action. Their ranking as third highlights the significance of weeds as a threat to biodiversity in New South Wales.

The examination of the KTP categories revealed that weeds collectively pose an equal second greatest threat in terms of the number of threatened species at risk, along with altered fire regimes (Table 5.1).

Weeds actually listed as Key Threatening Processes

As at January 1, 2005 there were only two weed KTPs listed under the TSC Act, one being 'invasion of native plant communities by *Chrysanthemoides monilifera* (bitou bush/boneseed)' (NSW SC 1999) and the other 'invasion of native plant communities by exotic perennial grasses' (NSW SC 2003). These two listings encompassed only a small number of weed species present in New South Wales, namely two subspecies of *C. monilifera* (bitou bush and boneseed) and all exotic perennial grasses. This determination was based around only five exotic perennial grass species however: African lovegrass (*Eragrostis curvula*), serrated tussock (*Nassella trichotoma*),

Table 5.1 The relative threat of weeds to biodiversity listed under the NSW *Threatened Species Conservation Act 1995* and NSW *Fisheries Management Act 1994*, compared with other Key Threatening Process categories

| Key Threatening Processes categories ^a | Classification under the threat hierarchy ^b | Number of threatened biodiversity affected ^{c, d} | Number of biological entities listed in Key Threatening Processes determination as being at risk |
|--|--|--|--|
| Land clearing | 1 | 619 | 0 ^e |
| Altered fire regimes | 3 | 419 | 66 |
| Alien species ^f | 4 | 657 | 172 ^e |
| Weeds ^g | 4 | 419 | 24 ^e |
| Altered natural flow regimes | 3 | 108 | 10 ^e |
| Diseases | 5 | 75 | 18 ^e |
| Removal of bush rock and dead wood | 3 | 66 | 49 ^e |
| Climate change ^h | 3 | 45 | 16 ^e |
| Not encompassed in a Key Threatening Process listing | na | 122 | na |

na: not applicable.

a Key Threatening Processes (KTP) categories based on the KTPs listed under Schedule 3 of the NSW *Threatened Species Conservation Act 1995* and Schedule 6 of the NSW *Fisheries Management Act 1994* (see text for further details).

b The numerical representation for each threat category (eg [4]) is used only to make comparisons within the text and is not a representation of order or ranking. The wording for each is presented in Chapter 2.

c As identified in the data set (see Chapter 2 for more details).

d Values are not cumulative as many species are threatened by more than one process. Total: $n = 941$ threatened species.

e These Key Threatening Process listings include lists of species at risk as well as generic statements that encompass other species. For example, many species not currently listed as threatened could become so if the threat is not addressed. Thus, only the actual number of species identified in the determination is presented here.

f This includes all alien species.

g All weed threats in the data set are encompassed here, not just those for weed species listed as KTPs as at January 1, 2005.

h The numbers presented here are for those species identified in the data set as at risk currently, but potentially all biodiversity could be at risk in the future (NRMCC 2004).

Coolatai grass (*Hyparrhenia hirta*), buffel grass (*Cenchrus ciliaris*) and Chilean needle grass (*Nassella neesiana*).

The under-representation of weeds as KTPs is not only reflected by the massive discrepancy between the number listed and the number present, but also by the difference in the number of threatened species at risk. For example, the data set contained 419 biological entities affected by all weeds, whilst the two current KTP listings only accounted for 102 (Table 5.2). In addition the two KTP listings only identified 24 species at risk, while the data set encompassed an additional 78. It should be noted that the KTP listings and the data set were compiled at different times, which may explain part of the variation.

5.3 The threat posed by weeds

As outlined above, weeds threaten 419 threatened species or 45% of all threatened biodiversity in New South Wales. Specifically, weeds threaten 341 native species (279 plant and 62 animal species), 14 threatened populations and 64 Endangered Ecological Communities (EECs) (Table 5.3). Whilst native plants are the most affected by weeds, the greatest impact in terms of the proportion threatened is on EECs, with 89% threatened, compared to only 49% of threatened native plants.

Table 5.2 The biodiversity threatened by weeds listed as Key Threatening Processes under the NSW *Threatened Species Conservation Act 1995*, as at January 1, 2005

| Weed Key Threatening Process listings ^a | Number of weed species encompassed by the Key Threatening Process listing | Number of biological entities threatened | |
|--|---|--|-------------------------|
| | | Key Threatening Process determination ^b | Data set ^c |
| Bitou bush/boneseed ^d | 1 | 7 | 46 |
| Exotic perennial grasses | 5 ^e | 17 | 65 ^f |
| Total | 6 ^e | 24 | 102 ^g |

a Key Threatening Processes (KTP) as listed under Schedule 3 of the NSW *Threatened Species Conservation Act 1995*, as at January 1, 2005.

b Note: Bitou bush/boneseed was listed in 1999 and exotic perennial grasses in 2003, whilst the data set was compiled in 2005, which may partially explain the differences.

c The data set is described in Chapter 2.

d Bitou bush and boneseed are both subspecies of *Chrysanthemoides monilifera* (Weiss et al 1998).

e This Key Threatening Process listing includes a list of five main weed species as well as generic statements that encompass all other exotic perennial grass species. Thus, only the actual number of species identified are presented here, being African lovegrass, Coolatai grass, buffel grass, serrated tussock and Chilean needle grass (NSW SC 2003).

f Note: This value is the collective threat posed by the 27 exotic perennial grasses contained in the data set.

g Values are not cumulative as some biological entities are threatened by both weed KTP listings.

Table 5.3 The threatened biodiversity threatened by weeds in New South Wales

| Type of biodiversity listed under the TSC and FM Acts ^{a, b} | Number of threatened species examined ^b | Number threatened by weeds | Percentage threatened by weeds (%) |
|---|--|----------------------------|------------------------------------|
| Plant species (incl. fungi and algae) | 565 ^c | 279 | 49 |
| Animal species (incl. invertebrates) | 271 | 62 | 23 |
| Plant populations | 17 | 12 | 71 |
| Animal populations | 16 | 2 | 13 |
| Ecological communities | 72 | 64 | 89 |
| Total | 941 ^c | 419 | 45 |

a TSC Act refers to the NSW *Threatened Species Conservation Act 1995* and the FM Act to the NSW *Fisheries Management Act 1994*.

b Biodiversity as listed on Schedules 1 and 2 of the TSC Act and 4 and 5 of the FM Act, as at January 1, 2005 (ie species, populations and ecological communities).

c Note: An additional four plants species were examined, for which threats could not be determined (see Chapter 2 for further details).

Table 5.4 Endangered and Vulnerable species threatened by weeds in New South Wales

| Type of biodiversity listed under the TSC and FM Acts ^{a, b} | Number threatened by weeds and listed under the TSC and FM Acts | | | | | | Total number threatened ^e |
|---|---|-------------|----------------------------|-------------|-----------------------|-------------|--------------------------------------|
| | Endangered ^{c, d} | | Vulnerable ^{c, d} | | Total ^{c, d} | | |
| Plant species (incl. fungi and algae) | 166 | (49) | 113 | (50) | 279 | (49) | 565 ^f |
| Animal species (incl. invertebrates) | 30 | (32) | 32 | (18) | 62 | (23) | 271 |
| Total | 196 | (45) | 145 | (36) | 341 | (41) | 836 ^f |

a TSC Act refers to the NSW *Threatened Species Conservation Act 1995* and the FM Act to the NSW *Fisheries Management Act 1994*.

b Biodiversity as listed on Schedules 1 and 2 of the TSC Act and 4 and 5 of the FM Act, as at January 1, 2005 (ie species, populations and ecological communities).

c The definitions of Endangered and Vulnerable are given in the TSC Act (see PCO 2003), based on definitions in the IUCN 'Red list of threatened species' (IUCN 2004).

d Values in brackets are percentages of the total.

e The total number of threatened species under the TSC Act and FM Act, as at January 1, 2005. These values exclude the four species with no threats identified. Total number examined was thus 840.

f Note: An additional four plants species were examined, for which threats could not be determined (see Chapter 2 for further details).

The threat of weeds to Endangered and Vulnerable species

As outlined in Chapter 3, threatened species are categorised based on the degree to which they are threatened, being classified as Endangered or Vulnerable. Weeds pose a threat to 45% of native species listed as Endangered and 36% of those listed as Vulnerable in New South Wales (Table 5.4). More specifically, this equates to 49% and 50% respectively, for Endangered and Vulnerable plant species, and 32% and 18% respectively, for Endangered and Vulnerable animal species.

5.4 The impact of weeds on threatened plant and animal species

In total, weeds posed a threat to 341 threatened species, excluding populations and ecological communities in New South Wales (or 81% of all the biodiversity threatened by weeds ($n = 419$)); being 279 plant species including fungi and algae, and 62 animal species including invertebrates. The remaining 19% ($n = 78$) comprised 64 ecological communities, 12 plant populations and two animal populations listed under the TSC Act.

Threatened plant species

Of the 5,248 plant species, excluding aquatic plants, fungi and algae recorded in New South Wales, 555 are listed as threatened under the TSC Act, and this study found 267 (48% when the nine threatened fungi, two aquatic plants and one alga are excluded from the threatened plant totals) to be threatened by weeds

(Table 5.5). The threat posed by weeds, in terms of the total number of plant groups threatened, was greatest for dicotyledons with 215 species or 77% (215 of 279) of all threatened plant species threatened by weeds (Table 5.5). However, in terms of a proportion of the total number of threatened plants, fungi and then gymnosperms were most affected by weeds (Table 5.5). Whilst weeds threatened all fungi listed as threatened, the number listed is only a very small number of the total species; estimates for Australia are >25,000 species. The impact of weeds was not uniform across plant groups. For example, weeds affected four of the six threatened gymnosperm species, which represents 15% (4 of 27) of all gymnosperms in New South Wales; whereas 215 species of 452 dicotyledons were affected, being 6% (215 of 3,742) of all dicotyledons in New South Wales (Table 5.5).

Threatened animal species

Of the 936 animal species recorded in New South Wales, 271 are listed as threatened and this study found 62 (23%) to be threatened by weeds (Table 5.5). The threat posed by weeds, in terms of the total number of animal groups threatened, was greatest to native bird species (25 species or 22% of threatened birds: Table 5.5). However, in terms of the proportion of an animal group threatened by weeds, invertebrates were most affected (Table 5.5). Of the eight mammals threatened by weeds, four bat species were at risk as a result of weed damage to roosts and the weed out-competing food source plant species. Such impacts of weeds on animals have been documented elsewhere.

Examples include:

- out-competing food sources, especially for herbivores, frugivorous and nectivorous birds, and host and nest trees for native birds and invertebrates (Garnett and Crowley 2000; NPWS 2001)
- reduction of basking sites for native frogs and reptiles (Hunter and Gillespie 1999)
- the use of pesticides to control weed species (DEC 2005b).

Threatened animal and plant populations, and ecological communities

Weeds posed a significant threat to both threatened plant populations (71%) and Endangered Ecological Communities (89%), whilst affecting only 2 of the 16 threatened animal populations (13%: Table 5.5). The impact of weeds on threatened plant populations constituted the main alien threat, being 71% compared to 82% for all alien species (Table 4.1). A similar situation existed for Endangered Ecological Communities, being 89% compared to 94% for all alien species (Table 4.1).

Table 5.5 The threat posed by weeds to threatened species in New South Wales

| Type of biodiversity listed under the TSC and FM Acts ^{a, b} | Taxonomic Grouping ^{c, d} | Number of native species in NSW ^{e, f} | | Number listed as threatened ^{b, g} | | Number listed as threatened that are threatened by weeds ^{b, h} | | |
|---|---|---|---------------------------|---|-------------------------|--|------------|--------------------------|
| Plant species | algae | na | na | 1 | na | 1 | (100) | |
| | aquatic | na | na | 4 | na | 2 | (50) | |
| | fungi | na | na | 9 | na | 9 | (100) | |
| | ferns and fern allies | 177 | (3) | 16 | (9) | 6 | (38) | |
| | gymnosperms | 27 | (1) | 6 | (22) | 4 | (67) | |
| | monocotyledons | 1,302 | (25) | 81 | (6) | 42 | (52) | |
| | dicotyledons | 3,742 | (71) | 452 | (12) | 215 | (48) | |
| | Total | | 5,248 ⁱ | (100 ⁱ) | 569 | (11 ⁱ) | 279 | (49) |
| Animal species | invertebrates (aquatic and terrestrial) | na | na | 17 | na | 11 | (65) | |
| | fish | na | na | 12 | na | 1 | (8) | |
| | amphibians | 72 | (8) | 25 | (35) | 7 | (28) | |
| | marine mammals | 37 | (4) | 7 | (19) | 0 | (0) | |
| | mammals | 147 | (16) | 57 | (39) | 8 | (14) | |
| | birds | 472 | (50) | 112 | (24) | 25 | (22) | |
| | reptiles | 208 | (22) | 41 | (20) | 10 | (24) | |
| | Total | | 936 ⁱ | (100 ⁱ) | 271 | (29 ⁱ) | 62 | (23) |
| Plant populations | | na | na | 17 | | 12 | (71) | |
| Animal populations | | na | na | 16 | | 2 | (13) | |
| Ecological communities | | na | na | 72 | | 64 | (89) | |
| Total | | | 6,187 ⁱ | (100 ⁱ) | 945 ^j | (15 ^{i, j}) | 419 | (44 ^j) |

na: a value was not available, as the total number in NSW could not be determined.

a TSC Act refers to the NSW *Threatened Species Conservation Act 1995* and the FM Act to the NSW *Fisheries Management Act 1994*.

b Biodiversity as listed on Schedules 1 and 2 of the TSC Act and 4 and 5 of the FM Act (ie species, populations and ecological communities).

c The main taxonomic grouping of plant and animal species as outlined in Chapter 2.

d Information for non-vascular plants (mosses, lichen and liverworts) are not presented.

e The total number of species in NSW was derived from several sources for example BGT (2005) and DEC (2005a) (also see Chapter 2).

f Values in brackets are percentages of the total native species.

g Values in brackets are percentages of the number of native species for each taxonomic group.

h Values in brackets are percentages of the number of threatened species.

i Total and percentage exclude fungi, algae, aquatic plants, fish and invertebrates, because the number of species could not be determined.

j This includes four species for which a threat was not identified.

5.5 Actions identified by which weeds threaten biodiversity

Examination of the second level of the threat hierarchy (ie the first threat sub-category: see Chapter 2 for more details) revealed the action by which particular weeds posed a threat to biodiversity in New South Wales. These threatening actions for weeds were classified into one of three categories, namely competition, habitat degradation and the control of weeds. Of these three actions, competition by weeds following invasion was the major action by which weeds posed a threat to biodiversity, threatening 339 threatened species, or 81% of the biodiversity threatened by weeds (Table 5.6). More specifically, weed competition comprised the main threat to native plant species, plant populations and EECs, by affecting 97% (263 of 279), 100% and 100% respectively, but did not affect animal species in any way. Conversely, habitat degradation as a result of weed invasions posed a threat to 21% (58 of 271) of all threatened animal species in New South Wales or 94% (58 of 62) of animal species threatened by weeds (Table 5.6). Weeds degrade habitat for animals in many ways;

for example, by reducing basking sites for native frogs and reptiles (Hunter and Gillespie 1999). Ten of the 58 animal species threatened by weed-initiated habitat degradation were terrestrial invertebrates; being 71% of the total threatened terrestrial invertebrates in New South Wales.

The control of weeds through actions such as bush regeneration was identified as a threat to 31 threatened species (Table 5.6), thereby lending support to calls for better integration of weed management with biodiversity conservation (Downey submitted). Weed control measures affected most groups of threatened biodiversity (Table 5.6). More specifically, bush regeneration was identified as a threat to 15 plant species, whilst the mis-identification of native species and the control of weed species each threatened a further eight plant species. The information presented thus highlights the significance of weed control as a threat to biodiversity and the need for education (including plant identification) and caution when undertaking weed control programs, particularly using bush regeneration methods, in areas where threatened species are present.

Table 5.6 The actions by which weeds were identified to pose a threat to threatened biodiversity in New South Wales

| Type of biodiversity listed under the TSC and FM Acts ^{a, b} | The number threatened by weeds through | | | | | | Number threatened by weeds ^d |
|---|--|--------------------------|-------------------------------------|--------------------------|----------------------------------|-------------------------|---|
| | competition ^{c, d} | | habitat degradation ^{c, d} | | control of weeds ^{c, d} | | |
| Plant species (incl. fungi and algae) | 263 | (77) | 10 | (14) | 24 | (77) | 279 (67) |
| Animal species (incl. invertebrates) | 0 | | 58 | (83) | 4 | (13) | 62 (15) |
| Plant populations | 12 | (4) | 0 | | 0 | | 12 (3) |
| Animal populations | 0 | | 2 | (3) | 1 | (3) | 2 (1) |
| Ecological communities | 64 | (19) | 0 | | 2 | (7) | 64 (15) |
| Total | 339 | (81 ^e) | 70 | (17 ^e) | 31 | (7 ^e) | 419 ^f (100) |

a TSC Act refers to the NSW *Threatened Species Conservation Act 1995* and the FM Act to the NSW *Fisheries Management Act 1994*.

b Biodiversity as listed on Schedules 1 and 2 of the TSC Act and 4 and 5 of the FM Act, as at January 1, 2005 (ie species, populations and ecological communities).

c Actions were derived from the second level of the threat hierarchy (see Chapter 2 for further details).

d Values in brackets are percentages of the total.

e Values in brackets are percentages of the total biodiversity threatened by weeds. Total number examined was 419.

f Values are not cumulative (either down or across columns) as some weeds posed a threat through more than one action.

6. The impact of specific weed species on biodiversity

In the previous chapter the impact of weeds on threatened biodiversity in New South Wales was quantified in terms of the biodiversity threatened and the processes by which weeds pose a threat. In this chapter, a closer examination of the actual weed species responsible for the threat will be undertaken. In addition, further examinations are undertaken of the source and origin of introduction of these weed species and their current availability for sale. Whilst the mode of weed introductions have been determined by past studies, such as those of Groves et al (2005), the analysis below will, for the first time, outline the number of species affected by such introductions.

6.1 Weeds impacting on biodiversity

Whilst weeds were stated as threatening 419 threatened species, the specific weed species posing the threat were not identified for 215, or just over half (51%) of them. Instead, the threat identified was described more broadly, such as 'weed invasion', with no reference to a specific weed species (Table 6.1). The group most affected by the lack of specificity with respect to the weed threat, was native plant species. However, proportionally, animal populations and animal species

had the greatest number for which weed species were not identified, being 83% and 69%, respectively.

In addition, 25 weed genera were identified which collectively posed a threat to 27 threatened species. This lack of data on specific weed threats reflects findings identified by others (eg Vidler 2004) and hampers our ability to establish priorities and manage weed threats for conservation purposes (Downey submitted).

The number of weed species threatening each threatened species

The number of weed species threatening each threatened species ranged from one weed species to 30 for the Endangered Ecological Community (EEC) of riverflat eucalypt forest on coastal floodplains of the NSW North Coast, Sydney Basin, and South East Corner bioregions. EECs typically had larger numbers of weed species identified as posing a threat (ie over 10 weed threats) than individual threatened species (Figure 6.1 and Appendix 4). Whilst the majority of threatened species were threatened by only one weed species, 43% were threatened by more than one (Figure 6.1), with the average being 2 weed species for threatened species and 4 for EECs.

Table 6.1 Threatened biodiversity for which a specific weed threat was identified

| Type of biodiversity listed under the TSC and FM Acts ^{a, b} | Number of weed threats described as | | Total threatened biodiversity threatened by weeds |
|---|-------------------------------------|-----------------------|---|
| | a specific weed species | a generic weed threat | |
| Plant species (incl. fungi and algae) | 150 | 129 | 279 |
| Animal species (incl. invertebrates) | 19 | 43 | 62 |
| Plant populations | 2 | 10 | 12 |
| Animal populations | 2 | 0 | 2 |
| Ecological communities | 31 | 33 | 64 |
| Total | 204 | 215 | 419 |

a TSC Act refers to the NSW *Threatened Species Conservation Act 1995* and the FM Act to the NSW *Fisheries Management Act 1994*.

b Biodiversity as listed on Schedules 1 and 2 of the TSC Act and 4 and 5 of the FM Act, as at January 1, 2005 (ie species, populations and ecological communities).

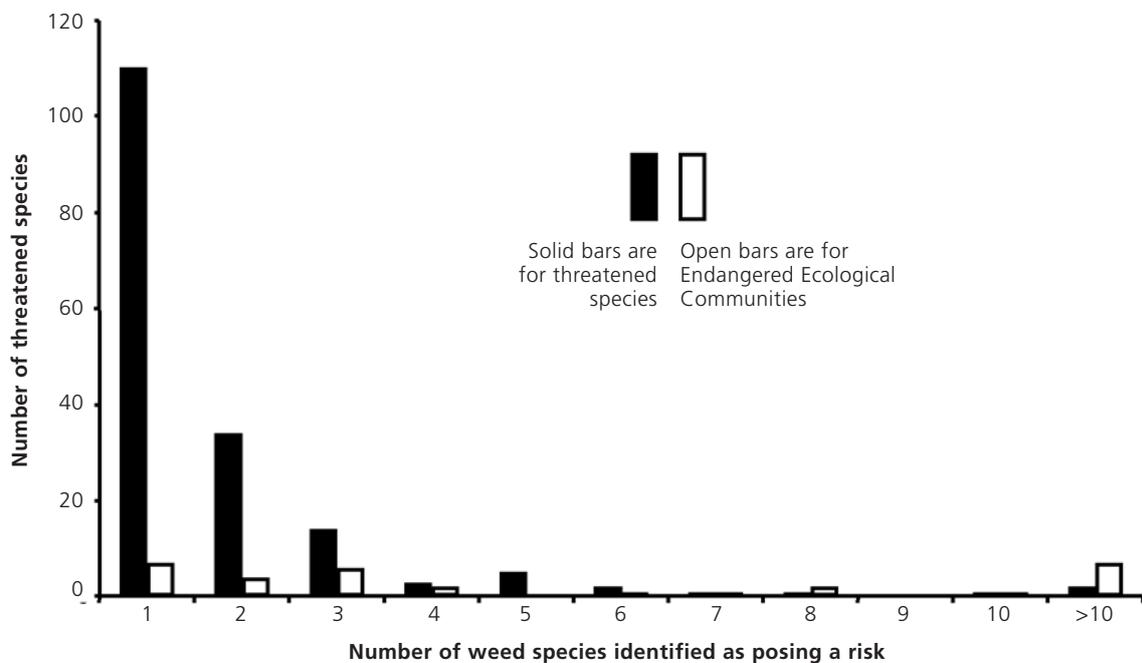


Figure 6.1 The number of weed threats identified per threatened species

6.2 Number of weed species threatening biodiversity in New South Wales

As outlined above, for more than half the biodiversity threatened by weeds there was no information on the particular weed species posing the threat. Thus, the information presented below is not necessarily definitive or representative of the actual impact. Furthermore, some weed species that are actually impacting on biodiversity may not have been identified and/or the actual impact of some weed species may be under- or over-stated, relative to the data presented. Therefore, the data presented below on the impact of individual weed species should be used only as a guide.

A total of 127 different weed species were identified from the data set, which represented 120 different genera and 51 families (a full list of the weed species threatening biodiversity and the biodiversity threatened is presented in Appendix 3). The number and diversity of weeds threatening biodiversity, as identified here, greatly eclipses previous attempts to determine the weed problem. For example, Adair and Groves (1998) outlined 22 weed species threatening biodiversity listed under the *Victorian Flora and Fauna Guarantee Act 1998* and Vidler (2004) identified 40 weed species nationally. In both cases the number of weed species closely matched the number of native species examined, being 23 and 41 respectively, which was not the case here where the number of species threatened was three times the number of weed species.

Impact of various weed groups

Of the 127 weed species identified, several major groups were evident which together represented 57% (72 of 127) of the weed species identified (Table 6.2), but only 47% (96 of 204) of the biodiversity was threatened by a specific weed species. Perennial and annual exotic grasses were found to pose the single greatest weed threat to biodiversity, comprising 33 species (27 perennial and six annual grass species) and threatening 65 threatened species. Not all the weed threats identified, however, listed specific grass species; instead, the threats to 13 threatened species are described only as exotic grasses. Four exotic grass species were among the 20 most identified weed species posing a threat to biodiversity (see below). In addition, the threat posed by exotic grasses is reflected with three grass species being listed as Weeds of National Significance. The level of threat posed by exotic grasses to biodiversity is reflected in their listing as a KTP under the TSC Act (NSW SC 2003), although the determination only identified five grass species and 17 threatened species at risk (see Table 5.2).

Exotic vines and climbers also posed a serious threat to biodiversity, comprising 23 species and a collective threat to 26 threatened species. Three vine species were among the 20 most identified weed species posing a threat to biodiversity (see below). The level of threat posed by exotic vines has been reflected in the preliminary determination by the NSW Scientific Committee to list exotic vines and scramblers as a KTP under the TSC Act (NSW SC 2005a).

Table 6.2 The major weed groups threatening biodiversity in New South Wales

| Weed group | Number of weed species identified as posing a threat to biodiversity ^a | Number of biodiversity at risk ^{b, c} |
|-----------------------------|---|--|
| Aquatics | 5 | 5 (2) |
| Exotic grasses ^d | 33 | 65 (13) |
| Legumes | 11 | 25 |
| Vines and climbers | 23 | 26 (1) |
| Total | 72 | 96 ^e (16) |

a The number of weed species identified in the data set (see Chapter 2 for further details).

b Biodiversity as listed on Schedules 1 and 2 of the TSC Act and 4 and 5 of the FM Act, as at January 1, 2005 (ie species, populations and ecological communities). TSC Act refers to the NSW *Threatened Species Conservation Act 1995* and the FM Act to the NSW *Fisheries Management Act 1994*.

c Values in brackets are the number that were threatened by a generic threat description only (ie grasses or vines) and not a specific weed species.

d The total number of exotic grasses comprises 27 perennial and six annual exotic grass species.

e Values are not cumulative as some threatened species were threatened by more than one weed.

The other major group was the legumes, which comprised 11 species posing a collective threat to 25 threatened species with one species the fifth most identified weed species posing a threat to biodiversity (see below). Globally, the legumes are a major weed group, both economically and environmentally.

Aquatic weeds posed a threat to five threatened species, but their impacts are probably understated here due to the difficult nature of determining the impacts.

6.3 The most commonly identified weed species posing a threat to biodiversity

Of the 127 weed species recorded as posing a threat to biodiversity in New South Wales, 20 are a threat to five or more threatened species and eight threaten more than 10 threatened species (Table 6.3). It should be noted that this list of weed species is not a 'top 20' list of the worst weed species in New South Wales in terms of their impact on biodiversity, but rather a list of weed species that were most frequently identified as a threat in the data set. It was not possible to develop a list of the worst weeds because:

- Approximately half of the weed threats did not list a specific weed species (see Section 6.1), so the number threatened may not reflect the actual level of threat posed by each. Some species may threaten a greater number than those presented here, or some weed species which threaten biodiversity may not have been recorded.
- Some data sources specifically targeted a weed species and thus the impacts of those weed species were better quantified in the data set. For example, the

Bitou Bush Threat Abatement Plan (Bitou TAP) included a thorough assessment of the impacts of bitou bush on native species (DEC 2006) and, at the time of compilation of the data set, this resulted in the identification of 31 threatened species at risk. In addition, assessments done on the impacts of lantana to biodiversity using the Weed Impacts to Native Species (WINS) assessment tool (Downey 2006) identified 42 threatened species at risk (P. Downey and A. Clark *unpublished data*).

- This project was an assessment/review of the threats to threatened species, not an assessment of weed impacts *per se*. Whilst the prioritisation process undertaken by Downey et al (*unpublished data*) provides an assessment of the likely impact of a weed species on biodiversity, an assessment of the actual species impacted is far more difficult. For example, the development of the Bitou TAP increased the knowledge of the species at risk from bitou bush from six to 158 (DEC 2006). Whilst the methodology of the WINS assessment process is now being adopted for other weeds such as bridal creeper and ground asparagus (Downey 2006), the number of weed species assessed is small (<5) and other than bitou bush none has been subjected to a complete assessment throughout their entire range.

Thus the list of species presented here (ie Table 6.3) must not be used as a 'top-20' list of weeds posing the greatest threat to biodiversity, but rather as the most commonly identified weeds posing a threat to biodiversity.

The 20 most commonly identified weed species posed a collective threat to 183 threatened species, or 90% of the 204 threatened species at risk from a specific weed species (Tables 6.1 and 6.3). More specifically,

these 20 weed species threatened 138 plant species, 13 animal species, four populations and 28 EECs, which represents 92% of the 150 plant species, 68% of the 19 animal species, all of the populations and 90% of the 31 EECs for which a specific weed species has been identified as a threat (Table 6.1). The eight weed species identified as each threatening more than 10 threatened species are discussed in detail below. The three most commonly identified weeds are also Weeds of National Significance.

Lantana camara

Lantana is a perennial shrub of tropical American origin (Swarbrick et al 1998). In Australia, lantana is a species complex with many forms derived from wild and

cultivated varieties (Swarbrick et al 1998). The first recorded introduction of lantana in Australia was in 1841 and by 1889 it had naturalised in the Brisbane area (DNMRE 2004). Today, lantana covers an estimated 5.1% of the continent (Sinden et al 2004), stretching from far north Queensland to Eden near the NSW–Victorian border and extending inland to the Great Dividing Range. In addition, there are disjunct populations around Melbourne, Perth and Darwin. There is a significant potential for lantana to expand its distribution further inland within New South Wales, Victoria and in Queensland across Cape York. There is also potential for new infestations to spread in the Northern Territory and in Western Australia around the Kimberley and the southern part of the state (DNMRE 2004).

Table 6.3 The 20 most commonly identified weed threats to threatened biodiversity in New South Wales

| Most commonly identified weed species ^a | Number of biodiversity at risk ^b | | | | Total |
|--|---|----------------|-------------|------------------------|------------|
| | Plant species | Animal species | Populations | Ecological communities | |
| <i>Lantana camara</i> (lantana) | 83 | 2 | nr | 11 | 96 |
| <i>Chrysanthemoides monilifera</i> (bitou bush and boneseed) | 34 | 4 | 3 | 5 | 46 |
| <i>Rubus fruticosus</i> agg. (blackberry) | 14 | 3 | nr | 4 | 21 |
| <i>Pennisetum clandestinum</i> (kikuyu) | 8 | 1 | 1 | 6 | 16 |
| <i>Cytisus scoparius</i> (Scotch broom) | 8 | 2 | 1 | 1 | 12 |
| <i>Ageratina adenophora</i> (crofton weed) | 10 | nr | nr | 2 | 12 |
| <i>Cinnamomum camphora</i> (camphor laurel) | 6 | 1 | nr | 4 | 11 |
| <i>Ligustrum sinense</i> (small-leaved privet) | 5 | 1 | nr | 5 | 11 |
| <i>Ageratina riparia</i> (mistflower) | 7 | 1 | nr | 1 | 9 |
| <i>Eragrostis curvula</i> (African lovegrass) | 5 | nr | nr | 4 | 9 |
| <i>Paspalum dilatatum</i> (paspalum) | 2 | 1 | nr | 5 | 8 |
| <i>Tradescantia fluminensis</i> (tradescantia) | 2 | 1 | nr | 5 | 8 |
| <i>Anredera cordifolia</i> (Madeira vine) | 3 | 1 | nr | 3 | 7 |
| <i>Hyparrhenia hirta</i> (Coolatai grass) | 4 | 1 | nr | 2 | 7 |
| <i>Opuntia</i> spp. (prickly pear) | 3 | nr | nr | 4 | 7 |
| <i>Araujia sericiflora</i> (moth vine) | 2 | nr | nr | 4 | 6 |
| <i>Baccharis halimifolia</i> (groundsel bush) | nr | 1 | nr | 5 | 6 |
| <i>Lonicera japonica</i> (Japanese honeysuckle) | 1 | nr | nr | 4 | 5 |
| <i>Lycium ferocissimum</i> (African boxthorn) | nr | nr | nr | 5 | 5 |
| <i>Olea europaea</i> (African olive/common olive) | 1 | nr | nr | 4 | 5 |
| Total ^c | 138 | 13 | 4 | 28 | 183 |

nr: not recorded in the data set as being threatened by the weed species.

a These species are the most commonly identified weed species in the data set which is not the same as the worst weed species, as this is not an assessment of weed species, and many of the threats did not describe the weed species posing the threat. Weed species are presented in scientific name (common name) format.

b Biodiversity as listed on Schedules 1 and 2 of the TSC Act and 4 and 5 of the FM Act, as at January 1, 2005 (ie species, populations and ecological communities). TSC Act refers to the NSW *Threatened Species Conservation Act 1995* and the FM Act to the NSW *Fisheries Management Act 1994*.

c Values are not cumulative as some threatened species were threatened by more than one weed.

Lantana is primarily spread by fruit-eating birds such as silver eyes and, to a lesser extent, locally through layering, where horizontal stems develop roots when in contact with soil (DNMRE 2004). Lantana has invaded a broad range of habitats where it typically forms dense impenetrable thickets. The impact, distribution and potential threat posed by lantana has led to its listing as one of the 20 Weeds of National Significance (WONS) (Thorp and Lynch 2000) and a national management strategy has been developed (ARMCANZ et al 2001e). The national strategy identifies five species at risk along with 67 entities, such as ecological communities at risk.

The present study identified lantana as posing the most commonly identified weed threat, threatening >10% (96 of 941) of the biodiversity examined (see Table 6.3). Of the 96 threatened species at risk from lantana, native plants represented 86% (Table 6.4), or 15% of all threatened plant species (86 of 569). The number of species threatened by lantana is twice that of the next most commonly identified weed threat, suggesting that lantana is significantly more of a threat, but this is not necessarily a correct assumption. Many weed threats which only described the threat as from 'weeds' were identified as being at threat from lantana after a trial of the WINS assessment tool (Downey and Clark unpublished data). A nationally funded project is about to undertake a WINS assessment for lantana over its entire range in Australia which is likely to dramatically increase the biodiversity thought to be at risk.

Chrysanthemoides monilifera

Two subspecies of the South African shrub *C. monilifera* have now become such invasive alien species in Australia that they are jointly listed as WONS. It is estimated that these two subspecies cover approximately 3% of Australia (Sinden et al 2004).

The coastal shrub bitou bush (subsp. *rotundata*) was first recorded in Australia in 1908 near Newcastle, New South Wales (Weiss et al 1998). Since then its distribution has rapidly expanded, in part assisted by deliberate plantings between 1946–1968 (Weiss et al 1998). By 1984, bitou bush occupied about 600 km of the NSW coastline (Love 1984) and by 2001 it had expanded to occupy over 900 km (Thomas 2002; Thomas and Leys 2002). The diversity of native species is greatest within the coastal strip; thus the potential threat posed by bitou bush invasions to biodiversity was thought to be very high. This rapid expansion and potential threat led to bitou bush being listed as a Key Threatening Process (KTP) under the TSC Act (NSW SC 1999), a Weed of National Significance (WONS: Thorp and Lynch 2000)

and a Noxious Weed in all coastal areas in New South Wales under the NSW *Noxious Weeds Act 1993*. The KTP listing led to the development of a draft TAP (Downey 2004; DEC 2004a) and a final TAP (DEC 2006), which greatly enhanced our understanding of the biodiversity at risk.

Whilst boneseed (subsp. *monilifera*) occurs in New South Wales it is currently not a major problem, despite its ability to invade non-coastal areas. However, it is a major problem in other states of Australia, particularly Victoria, Tasmania and South Australia, and has been identified as posing a threat to native seedling recruitment in New Zealand (McAlpine and Timmins 2002).

The present study identified bitou bush and boneseed collectively as the second most commonly identified weed threat in New South Wales, threatening 46 threatened species under the NSW threatened species legislation, the majority of which were native plants (74%: Table 6.4). However, the full extent of the threat posed by bitou bush and boneseed to biodiversity, not just those listed under the legislation, is much greater, being 158 species, three populations and 26 ecological communities (DEC 2006).

***Rubus fruticosus* aggregate (agg.)**

In Australia, blackberry is a species complex comprised of up to 15 closely related taxa, all of which have been introduced from Europe. The first record of blackberry in Australia is from Bathurst in New South Wales in the late 1830s (Parsons and Cuthbertson 1992). By 1887 blackberry had become naturalised and was causing problems (Amor et al 1998). The spread of blackberry is such that it now covers an estimated 9% of the Australian continent (Sinden et al 2004), extending from far north Queensland to the Victorian–South Australian border, with disjunct populations around Adelaide and Perth as well as at many locations in Tasmania. Where present, blackberry covers large areas with a dense canopy, thereby excluding light from the soil surface, impeding regeneration of native species and harbouring introduced pest animals such as foxes and rabbits, which can have flow-on effects to native species. The main vector of dispersal for blackberry is fruit-eating birds and foxes, with secondary dispersal along watercourses (Parsons and Cuthbertson 1992). The impact, distribution and potential threat posed by blackberry led to its determination as a WONS (Thorp and Lynch 2000). The present study identified blackberry as the third most identified weed threat in New South Wales, threatening 21 threatened species, the majority of which were native plants (67%: Table 6.4).

Pennisetum clandestinum

Kikuyu is a perennial grass that was introduced to Australia from East Africa as a pastoral and amenity species, useful for applications such as lawn (Randall 2002). It is now widely planted in all states of Australia and is still valued as a pasture species. However, kikuyu has naturalised in many areas as a result of dumping of garden waste, for instance grass cuttings (Muyt 2001), and to a lesser extent as escapes from deliberate plantings. The scale of the problem in Australia has not been quantified, although there is localised evidence of the potential threat to biodiversity from kikuyu, for example to *Pimelea spicata* (Matarczyk 1999). The present study identified kikuyu as the fourth most commonly identified weed threat in New South Wales, threatening 16 threatened species, half of which were native plants and 38% being EECs (Table 6.4).

Cytisus scoparius

The European leguminous shrub, Scotch broom, was first recorded as naturalised in Australia some time after 1800, although the exact date of introduction is not known (Hosking et al 1998). Scotch broom is a fast-growing (Sheppard et al 2002), long-lived plant (>30 years) (Downey and Smith 2000). It has the ability to form dense monocultures and produce large seedbanks (Downey 2002) that are highly dormant for more than 80 years (Turner 1933). Whilst fire can be used to reduce seedbanks, sufficient seed remains to sustain populations (Downey 2000). Scotch broom has the ability to modify disturbance regimes (Downey 2002), which can result in greater impacts to biodiversity than the actual invasion (Mack and D'Antonio 1998). It has higher densities (Paynter et al 2003) and larger seeds (Buckley et al 2003), both of which contribute to its overall impact. It is known to affect seven threatened species under the TSC Act and 33 non-threatened species (Heinrich and Dowling 2000; Schroder and Howard 2000). Within New South Wales the main infestations occur in the alpine region, the headwaters of the Shoalhaven River, the Blue Mountains and the Barrington Tops; the latter being the largest infestation that covers in excess of 14,000 hectares. Many of these are World Heritage areas, illustrating the significance of its threat to biodiversity. The present study identified Scotch broom as the equal fifth most commonly identified weed threat in New South Wales, negatively impacting on 12 threatened species, the majority of which (67%) were native plants (Table 6.4).

Ageratina adenophora

Crofton weed is a herbaceous short-lived perennial plant that was introduced to Australia from England in 1875 for ornamental purposes. The first record of crofton weed being naturalised was in 1904 from Sydney's north shore area (Parsons and Cuthbertson 1992). At present, crofton weed is restricted to the coastal regions, extending from Sydney to the Mary River, north of Brisbane in Queensland and major infestations around the Sydney area and the NSW–Queensland border. Crofton weed produces a great number of seeds that are dispersed primarily by wind and water and it has the ability to generate large seedbanks (Parsons and Cuthbertson 1992). The present study identified crofton weed as the equal fifth most commonly identified weed threat in New South Wales, threatening 12 threatened species, the majority of which (83%) were native plants (Table 6.4). It should be noted that the closely related and often mis-identified species, mistflower (*Ageratina riparia*) threatens nine threatened species (see Table 6.3) and there is a possibility that some identified weed threats may be attributed incorrectly. Irrespective of any erroneous attribution, these two species threaten 21 threatened species which illustrates the threat this genus poses more broadly to biodiversity.

Cinnamomum camphora

Camphor laurel is a long-lived (>400 years) tree of sub-tropical regions which was introduced to New South Wales from Asia in the mid-1800s (Muyt 2001). Camphor laurel produces large quantities of seed that are dispersed primarily by fruit-eating birds such as pigeons (Muyt 2001). Once established, camphor laurel grows aggressively and can dominate moist habitats, ultimately producing a dense overstorey that all but eliminates under-storey growth (Muyt 2001). Camphor laurel extends north from the Illawarra, New South Wales to Bundaberg, Queensland with major infestations occurring around the NSW–Queensland border. Whilst scientific studies have shown camphor laurel to be poisonous to fish fingerlings (Bishop 1993), no listed fish species were identified as being affected by this weed. Other anecdotal evidence suggests poisoning of native frogs and bird species by camphor laurel although we know of no scientific publications that support these claims. The present study identified camphor laurel as the equal seventh most commonly identified weed threat in New South Wales, threatening 11 threatened species, the majority of which (55%) were native plants (Table 6.4). Ironically, the native rose-crowned fruit dove (*Ptilinopus regina*) has become reliant on camphor laurel fruits in its diet and so removal of camphor laurel may have negative impacts on this native bird (DEC 2005c).

Ligustrum sinense

Small-leaved privet is a small tree of Chinese and Japanese origin. It is reported to have been first introduced during the 1800s for ornamental purposes. In Australia, small-leaved privet is now considered to be highly invasive in moist habitats (Swarbrick et al 1999). Fruit-eating birds, which are the primary dispersal agent for small-leaved privet (Carr et al 1992), have aided its spread. Small-leaved privet is now widely distributed in sub-coastal eastern Australia from Victoria to Queensland (Carr et al 1992). The present study identified small-leaved privet as the equal seventh most commonly identified weed threat in New South Wales, threatening 11 threatened species, the majority of which (45%) were native plants (Table 6.4). It should be noted that the closely related species, large-leaved privet (*Ligustrum lucidum*), threatened four threatened species (Appendix 3), illustrating the negative impact this genus poses more broadly to biodiversity.

6.4 Impact of the Weeds of National Significance on threatened biodiversity in New South Wales

In 2000 the Australian Government identified the 20 WONS (Thorp and Lynch 2000), 16 of which are known to occur within New South Wales although only 12 are widely distributed. Whilst each of these WONS has a national strategy that contains actions to reduce impacts, few of the strategies have adequately assessed the biodiversity at risk (Downey and Cherry 2005).

Ten of the WONS were identified in the present study as posing a threat to biodiversity in New South Wales and three of these were the most commonly listed weed threats (lantana, bitou bush/boneseed and blackberry). For all of these 10 WONS additional elements of biodiversity were identified as being at risk in New South Wales (Table 6.5). Excluding lantana, bitou bush/boneseed and blackberry, the number of new

Table 6.4 Breakdown of the biodiversity at risk from the most commonly identified weed threats to biodiversity in New South Wales

| Most commonly identified weed species ^a | Number of biodiversity threatened by weeds and listed under the TSC and FM Acts ^{b, c} | | | | | | Ecological Communities ^e | Total number threatened |
|--|---|----------|---------------------------------|----------|-------------------------|----------|-------------------------------------|-------------------------|
| | Endangered species ^d | | Vulnerable species ^d | | Population ^e | | | |
| | plant | animal | plant | animal | plant | animal | | |
| <i>Lantana camara</i> | 55 | 2 | 28 | 0 | 0 | 0 | 11 | 96 |
| <i>Chrysanthemoides monilifera</i> | 19 | 1 | 15 | 3 | 2 | 1 | 5 | 46 |
| <i>Rubus fruticosus</i> agg. | 7 | 2 | 7 | 1 | 0 | 0 | 4 | 21 |
| <i>Pennisetum clandestinum</i> | 6 | 0 | 2 | 1 | 1 | 0 | 6 | 16 |
| <i>Cytisus scoparius</i> | 1 | 1 | 7 | 1 | 0 | 1 | 1 | 12 |
| <i>Ageratina adenophora</i> | 8 | 0 | 2 | 0 | 0 | 0 | 2 | 12 |
| <i>Cinnamomum camphora</i> | 6 | 1 | 0 | 0 | 0 | 0 | 4 | 11 |
| <i>Ligustrum sinense</i> | 5 | 1 | 0 | 0 | 0 | 0 | 5 | 11 |
| Total^f | 97 | 5 | 54 | 6 | 2 | 2 | 18 | 166 |

a These species are the most commonly identified weed species in the data set, which threaten >10 threatened species, which is not the same as the worst weed species; this is not an assessment of weed species, and many of the threats did not describe the weed species posing the threat. Weed species are presented as scientific names.

b TSC Act refers to the NSW *Threatened Species Conservation Act 1995* and the FM Act to the NSW *Fisheries Management Act 1994*.

c Biodiversity as listed on Schedules 1 and 2 of the TSC Act and 4 and 5 of the FM Act, as at January 1, 2005 (ie species, populations and ecological communities).

d The definition of Endangered and Vulnerable are given in the TSC Act (PCO 2003), based on definitions in the IUCN 'Red list of threatened species' (IUCN 2004).

e The definitions of populations and ecological communities are given in the TSC Act (PCO 2003).

f Values are not cumulative as some threatened species were threatened by more than one weed.

threatened species at risk for the other WONS was low (an average increase of 2 threatened species per WONS species).

In addition, a further 11 of the 71 weed species identified during the determination of the WONS (Thorp and Lynch 2000) were identified as posing a threat to biodiversity in New South Wales. Five of these (African boxthorn, African lovegrass, Madeira vine, Scotch broom and small-leaved privet) were found to threaten five or more threatened species (Table 6.3).

6.5 Impact of weeds on biodiversity listed under the *Environment Protection and Biodiversity Conservation Act 1999* that occur in New South Wales

Those threatened species listed under the TSC Act that were also listed under the EPBC Act (Table 3.1) were assessed to illustrate the impact of weeds on nationally threatened species. Of the 453 that were listed under

Table 6.5 Biodiversity threatened by the Weeds of National Significance in New South Wales

| Weed of National Significance ^a | Number of threatened biodiversity identified prior to this study ^{b, c} | Number threatened in New South Wales ^d |
|--|--|---|
| Present in New South Wales | | |
| <i>Alternanthera philoxeroides</i> (alligator weed) | 0 | 1 |
| <i>Asparagus asparagoides</i> (bridal creeper) | 1 | 4 |
| <i>Chrysanthemoides monilifera</i> (bitou bush/boneseed) | 21 | 46 |
| <i>Cabomba caroliniana</i> (cabomba) | 0 | 0 |
| <i>Nassella neesiana</i> (Chilean needle grass) | 3 | 0 |
| <i>Nassella trichotoma</i> (serrated tussock) | 0 | 2 |
| <i>Lantana camara</i> (lantana) | 5 | 96 |
| <i>Parthenium hysterophorus</i> (parthenium weed) | 0 | 0 |
| <i>Rubus fruticosus</i> agg. (blackberry) | 0 | 21 |
| <i>Salix</i> spp. (willow) | 2 | 3 |
| <i>Salvinia molesta</i> (salvinia) | 0 | 2 |
| <i>Ulex europaeus</i> (gorse) | 0 | 0 |
| Restricted distribution within New South Wales | | |
| <i>Tamarix aphylla</i> (athel pine) | 0 | 0 |
| <i>Hymenachne amplexicaulis</i> (hymenachne) | 0 | 1 |
| <i>Parkinsonia aculeata</i> (parkinsonia) | 1 | 0 |
| <i>Prosopis pallida</i> (mesquite) | 0 | 1 |
| Not present in New South Wales | | |
| <i>Mimosa pigra</i> (mimosa) | 2 | na |
| <i>Acacia nilotica</i> subsp. <i>indica</i> (prickly acacia) | 25 | na |
| <i>Annona glabra</i> (pond apple) | 5 | na |
| <i>Cryptostegia grandiflora</i> (rubber vine) | 17 | na |
| Total | 82 | 154 ^e |

na: these species are not present in NSW.

a Weeds of National Significance (Thorp and Lynch 2000). Weed species are presented in scientific name (common name) format.

b Source: Downey and Cherry (2005) based on a review of the 20 WONS National Strategies, also see ARMCANZ et al (2000a–g, 2001a–l, 2003).

c The values presented are for the whole of Australia.

d Biodiversity as listed on Schedules 1 and 2 of the TSC Act and 4 and 5 of the FM Act, as at January 1, 2005 (ie species, populations and ecological communities). TSC Act refers to the NSW *Threatened Species Conservation Act 1995* and the FM Act to the NSW *Fisheries Management Act 1994*.

e Values are not cumulative as some threatened species were threatened by more than one weed.

the Commonwealth and NSW threatened species Acts (excluding the 31 Presumed Extinct species), 192 or 42% were threatened by weeds; a slightly lower proportion than for all of the biodiversity listed under the TSC Act (45%). The majority of these were threatened plants (Table 6.6). In addition, this assessment identified 56 specific weed species threatening those 192 species, whilst the weed threats for 82 (45%) of these species did not identify a specific weed species.

6.6 Assessing the origins of introduction of the weeds threatening biodiversity in New South Wales

The country of origin of the weeds threatening biodiversity

The origins of each of the 127 weed species threatening biodiversity was determined using Randall (2002).

The countries of origin were then grouped into four broad geographic regions for ease of reporting:

- the Americas
- Africa
- Eurasia
- the Pacific (including Australia).

South America was the greatest source for weeds impacting on the threatened species within New South Wales, representing 41%. The next major sources, in

order, were Europe, Asia and South Africa (Table 6.7). Of the 204 threatened species for which the threat from a specific weed species was identified, the majority were threatened by weeds originating from the Americas (mainly Central and South America: Table 6.7). It should be noted that *L. camara* threatened 86% of the species threatened by weeds of South American origin and *C. monilifera* threatened 57% of the species threatened by weeds of South African origin (Table 6.7).

Introduction source

The means by which each of the 127 weed species identified as posing a threat arrived in Australia was identified from Randall (2002). The majority of these weeds were considered to be garden escapes (82 species or 65%: Table 6.8) and a further six species originated from importations for cultivation purposes. Thus, the number of deliberate introductions now threatening biodiversity in New South Wales is 88 species, or 70% of the weed species identified. The origin of each weed species is presented in Appendix 3. These 82 garden escapes threaten 190 threatened species.

The proportion of weeds that are garden escapes is consistent with the findings of Groves et al (2005), who found 72% of environmental weed species were once garden plants or deliberately introduced for horticulture, 66% and 6% respectively. However, Groves et al (2005) were not able to demonstrate the impact of these 'garden escapees', especially to specific biodiversity values.

Table 6.6 Number and status of those threatened species listed under both the NSW *Threatened Species Conservation Act 1995* and the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* threatened by weeds

| Type of biodiversity listed under the EPBC, TSC and FM Acts ^{a, b} | Number threatened by weeds and listed under the EPBC, TSC and FM Acts | | | Total number of threatened species threatened by weeds |
|---|---|-------------------------|-------------------------|--|
| | Critically endangered ^{c, d} | Endangered ^c | Vulnerable ^c | |
| Plant species | 1 | 69 | 90 | 160 |
| Animal species | 3 | 10 | 10 | 23 |
| Ecological communities | 0 | 9 | na | 9 |
| Total | 4 | 88 | 100 | 192 |

na: at the time of writing EECs could not be listed as vulnerable under either the EPBC Act or the TSC Act.

a EPBC Act refers to the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*. TSC Act refers to the NSW *Threatened Species Conservation Act 1995*.

b Biodiversity as listed on Schedules 1 and 2 of the EPBC Act and the TSC Act and 4 and 5 of the FM Act, as at January 1, 2005 (ie species and ecological communities).

c The definitions of Critically Endangered, Endangered and Vulnerable are given under the EPBC Act (Attorney-General's Department 2005), based on definitions given in the IUCN 'Red list of threatened species' (IUCN 2004).

d Those species listed as Critically Endangered under the EPBC Act and Endangered under the TSC Act are presented here under their EPBC Act threat classification.

Table 6.7 Countries of origin of weed species identified as threatening biodiversity in New South Wales

| Origin of weed species threatening biodiversity in NSW ^{a, b} | Number of weed species ^{c, d} | | Number of biodiversity threatened in New South Wales ^{c, e, f} | |
|--|--|--------------|---|--------------|
| Northern America | 17 | (13) | 32 | (16) |
| Central (tropical) America | 15 | (11) | 106 | (52) |
| Southern America | 40 | (30) | 112 | (55) |
| Total for Americas | 54 | (41) | 124 ^g | (61) |
| Northern Africa | 16 | (12) | 23 | (11) |
| Eastern Africa (including Madagascar) | 8 | (6) | 26 | (13) |
| Southern Africa | 20 | (15) | 81 | (40) |
| Total for Africa | 34 | (26) | 94 ^h | (46) |
| Mediterranean (excluding northern Africa) | 11 | (8) | 14 | (7) |
| Europe | 35 | (27) | 47 | (23) |
| Asia | 32 | (24) | 49 | (24) |
| Total for Eurasia | 45 | (34) | 60 | (29) |
| Australia | 4 | (3) | 5 | (2) |
| New Zealand | 1 | (<1) | 1 | (<0) |
| Total for Pacific | 5 | (4) | 6 | (3) |
| Obscure or indeterminable origin | 11 | (8) | 21 | (10) |
| Total | 127 | (100) | 204 | (100) |

Source: Randall (2002).

a Data on species' origins derived from Randall (2002).

b Where a weed species has a wide native range which encompasses several of the regions examined here, the weed species was reported under each (eg if the origin was the Americas then the species was reported for Northern, Central and Southern America).

c The values are not cumulative, see point b above.

d Values in brackets are percentages of the total ($n = 127$).

e Biodiversity as listed on Schedules 1 and 2 of the TSC Act and 4 and 5 of the FM Act, as at January 1, 2005 (ie species, populations and ecological communities). TSC Act refers to the NSW *Threatened Species Conservation Act 1995* and the FM Act to the NSW *Fisheries Management Act 1994*.

f Values in brackets are percentages of the total ($n = 204$: see text for further details).

g Includes *Lantana camara* which threatens 96 threatened species.

h Includes *Chrysanthemoides monilifera* which threatens 46 threatened species.

6.7 The impact of garden escapes on threatened biodiversity

As outlined above (Section 6.6), garden escapes accounted for 65% of the weeds threatening biodiversity in New South Wales, posing a collective threat to 190 threatened species. Approximately 35% of garden escapes threatened more than one threatened species (Appendix 4). For example, Scotch broom threatens 12 threatened species (Table 6.3). In addition, some threatened species are subjected to more than one weed which has escaped from cultivation. For example, *Pterostylis gibbosa* is threatened by four garden escapes namely *Lantana camara*, *Holcus lanatus*, *Rubus fruticosus* agg. and *Salix* spp., and *Pimelea spicata* is threatened by three; *Asparagus asparagoides*, *Hypericum perforatum* and *Pennisetum clandestinum*.

An assessment was made using Hibbert (2004) as to which of the 127 weed species threatening biodiversity in New South Wales were available for sale or purchase. Just under half (43%), or 56 species, are still readily available for purchase within Australia (Table 6.9). One example is *Lonicera japonica* which threatens one threatened species and four EECs in New South Wales, but remains available for sale there, and across Australia. Of these 56 weed species, 36 are available for sale in New South Wales. As long as they remain for sale, the longer-term survival of 44 threatened species cannot be guaranteed, despite active control and rehabilitation. This also does not account for plants still in gardens undergoing naturalisation that will now, or in the future, become foci for invasions.

The list of 127 weed species was also assessed against weed species listed as prohibited for sale in New South

Wales, either across the entire state or part thereof, under the NSW *Noxious Weeds Act 1993* using DPI (2005b). Of the 106 weed species, including subspecies and varieties and genera currently prohibited from sale in New South Wales (all or part thereof), 34 are identified as threatening biodiversity in New South Wales. However, eight of these 34 are listed as still available for sale in Australia, or part thereof (Hibbert 2004).

In a recent review, the 10 most serious invasive garden plants that were still available for sale in New South Wales were identified (Groves et al 2005). Of these 10 weeds, seven are identified as a threat to biodiversity in New South Wales (Table 6.10); two were also listed in

the 10 worst for the whole of Australia namely *Gloriosa superba* and *Cytisus* spp. Of these seven, Scotch broom (*Cytisus scoparius*) posed the greatest threat and threatened 12 threatened species. In addition, 12 other weed species and two genera that threatened biodiversity in New South Wales were listed among either the Australian or other state and territory lists of the 10 most invasive garden escapes (Table 6.11). Also a number of other closely related weed species in Groves et al (2005) were recorded in the data set, such as several *Asparagus* species, highlighting the serious nature of the problem.

Table 6.8 The mode by which each weed species posing a threat to biodiversity in New South Wales was introduced to Australia

| Mode of introduction ^a | Number of weed species threatening biodiversity in New South Wales ^b | Percentage of total (%) | Number of threatened species ^b |
|-----------------------------------|---|-------------------------|---|
| Garden escape | 82 | 65 | 190 |
| Weed | 39 | 30 | 33 |
| Cultivation | 6 | 5 | 10 |
| Total | 127 | 100 | 204 ^c |
| Unclear | 25 ^d | na | 27 ^d |
| Indeterminable | na | na | 215 |
| Total | 127 (+10 ^e) | na | 419 |

Source: Randall (2002).

na: a percentage was not calculated for weeds with an undetermined means of introduction.

a Categories as described by Randall (2002), being:

Garden escape – species known to have escaped from gardens directly or through dumping of garden waste

Weed – term used when no evidence exists of escape from garden or cultivation

Cultivation – may have escaped from gardens or cultivation ie agricultural crop or pasture species.

Two additional categories were added here to account for those weed species for which the means of introduction could not be established:

Unclear – weeds listed only to genus (eg *Salix* spp. and *Opuntia* spp.) whose species originate from vastly different geographical regions

Indeterminable – weed threats for which no specific weed species or genera were identified in the data set.

b Biodiversity as listed on Schedules 1 and 2 of the TSC Act and 4 and 5 of the FM Act, as at January 1, 2005 (ie species, populations and ecological communities). TSC Act refers to the NSW *Threatened Species Conservation Act 1995* and the FM Act to the NSW *Fisheries Management Act 1994*.

c Values are not cumulative as a threatened species may be affected by weeds from more than one origin.

d Weeds listed as unclear were excluded from the totals.

e Number of genera with no species identified (*Salix* spp. or *Opuntia* spp.).

Table 6.9 The availability for sale of weeds posing a threat to biodiversity in New South Wales

| Availability for sale | Number of weed species posing a threat to biodiversity ^a | Number of threatened species in New South Wales at risk from weed species available for sale ^b |
|-----------------------|---|---|
| Australia | 56 | 135 |
| New South Wales | 36 | 44 |

Source: Hibbert (2004).

a The total number of weeds threatening biodiversity in NSW was 127 species.

b Biodiversity as listed on Schedules 1 and 2 of the TSC Act and 4 and 5 of the FM Act, as at January 1, 2005 (ie species, populations and ecological communities). TSC Act refers to the NSW *Threatened Species Conservation Act 1995* and the FM Act to the NSW *Fisheries Management Act 1994*.

Table 6.10 The 10 most invasive garden plants in New South Wales and the biodiversity threatened by each

| The 10 most invasive garden plants available for sale in New South Wales ^a | Number of biodiversity threatened in New South Wales ^b | Available for sale as of July 2006 ^c |
|---|---|---|
| <i>Anredera cordifolia</i> (Madeira vine) | 7 | no |
| <i>Bryophyllum daigremontianum</i> x <i>B. delagoense</i> (hybrid mother of millions) | na | no |
| <i>Bryophyllum delagoense</i> (mother of millions) | 1 | no |
| <i>Cytisus scoparius</i> (Scotch broom) | 12 | yes |
| <i>Gloriosa superba</i> (glory lily) | 1 | yes |
| <i>Hygrophila costata</i> (yerba de hicotea – glush weed) | 1 | no |
| <i>Macfadyena unguis-cati</i> (cat's claw creeper) | 4 | no |
| <i>Passiflora tarminiana</i> (banana passionfruit) | na ^d | yes |
| <i>Phyla canescens</i> (lippia) | 1 | no |
| <i>Senecio glastifolius</i> (holly-leaved senecio) | na ^d | yes |

Source: Groves et al (2005).

na: the weed species was not identified in the data set (see Chapter 2 for further information).

a These weed species were identified by Groves et al (2005) as the 10 most invasive garden escapes that were available for sale in NSW. Weed species are presented in scientific name (common name) format.

b Biodiversity as listed on Schedules 1 and 2 of the TSC Act and 4 and 5 of the FM Act, as at January 1, 2005 (ie species, populations and ecological communities). TSC Act refers to the NSW *Threatened Species Conservation Act 1995* and the FM Act to the NSW *Fisheries Management Act 1994*.

c Based on the list of prohibited species under the NSW *Noxious Weeds Act 1993*.

d Whilst this weed species was not identified in the data set, several closely related weed species were (Appendix 3).

6.8 The impact of 'weedy' native species

One other group of weeds posing a threat to biodiversity are those that are native to Australia and known to have established populations outside their natural ranges or are expanding their current range. Four such species were identified as a threat to biodiversity in New South Wales, affecting four threatened species (Appendix 3, Table D). One species, golden wreath wattle (*Acacia saligna*), has been deliberately introduced into New South Wales from Western Australia and was identified as a threat to two threatened species. Fire suppression has enabled sweet pittosporum (*Pittosporum undulatum*) to expand its range (Mullet 1999). Whilst this weed may, in turn, contribute to broader impacts on native species, only one species was identified at risk here. In addition, concerns over its impact on biodiversity are reflected in the listing of sweet pittosporum as a serious garden escape still available for sale in Australia (see Groves et al 2005; and above). The exact change in distribution/abundance of the other two natives (*Callitris glaucophylla* and *Lythrum salicaria*) has not been documented.

Table 6.11 The most invasive garden plants in each state, territory and the whole of Australia that threatened biodiversity and are available for sale in New South Wales

| The most invasive garden plants available for sale in Australia and each state and territory ^a | State or territory in which the weed species is identified in the garden escapes 'Top 10' ^b | Number of biodiversity threatened in New South Wales ^c | Available for sale in New South Wales as of July 2006 ^d |
|---|--|---|--|
| <i>Acacia saligna</i> (golden wreath wattle) | SA | 2 | yes |
| <i>Coprosma repens</i> (looking-glass bush) | Tas. | 1 | yes |
| <i>Coreopsis lanceolata</i> (coreopsis) | Qld | 1 | yes |
| <i>Cotoneaster</i> spp. | ACT | 1 | no |
| <i>Cytisus</i> spp. (broom) | Aust., NSW, Tas., ACT | 12 ^e | yes |
| <i>Eragrostis curvula</i> (African lovegrass) | Vic. | 9 | yes |
| <i>Genista</i> spp. (broom) | ACT | 1 | no |
| <i>Gloriosa superba</i> (glory lily) | Aust., NSW, Qld | 1 ^e | yes |
| <i>Lonicera japonica</i> (Japanese honeysuckle) | Aust., Qld, ACT | 6 ^f | yes |
| <i>Ochna serrulata</i> (mickey mouse plant) | Qld | 1 | no |
| <i>Olea europaea</i> (olive) | SA, ACT | 5 | yes |
| <i>Opuntia</i> spp. (prickly pear) | Vic. | 7 | no |
| <i>Pennisetum clandestinum</i> (kikuyu) | SA | 16 | yes |
| <i>Pinus radiata</i> (radiata pine) | Tas., ACT | 3 | yes |
| <i>Pittosporum undulatum</i> (sweet pittosporum) | Aust., Tas., WA | 1 | yes |
| <i>Pyracantha</i> spp. | ACT | 1 | no |

Source: Groves et al (2005).

a These weed species were identified by Groves et al (2005) as the 10 most invasive garden escapes that were available for sale in Australia. Weed species are presented in scientific name (common name) format.

b Groves et al (2005) presented a 'Top-10' list for Australia and each state and territory. NSW specific species are presented in Table 6.10. Aust. = Australia, SA = South Australia, Tas. = Tasmania, Vic. Victoria, NSW = New South Wales, Qld = Queensland, ACT = Australian Capital Territory, WA = Western Australia.

c Biodiversity as listed on Schedules 1 and 2 of the TSC Act and 4 and 5 of the FM Act, as at January 1, 2005 (ie species, populations and ecological communities). TSC Act refers to the NSW *Threatened Species Conservation Act 1995* and the FM Act to the NSW *Fisheries Management Act 1994*.

d Based on the list of prohibited species under the NSW *Noxious Weeds Act 1993*.

e Also presented in Table 6.10.

f This value includes one threatened species under a generic listing of *Lonicera* spp.



7. A spatial analysis of weed threats

In the previous chapter the specific weed species which posed a threat to biodiversity in New South Wales were identified in terms of the species, their individual impact, origins and the continued threat posed by those weeds that are still available for sale.

In this chapter, the regional nature of the weed threat to biodiversity is explored, based on the 13 Natural Resource Management (NRM) regions in New South Wales (also referred to as Catchment Management Authorities: CMAs). By presenting information at the regional level we hope to enable better management of such areas through reduced weed impacts on biodiversity.

7.1 Regional distribution of weeds

The botanical census data (being terrestrial vascular plant species only) (BGT 2005) was used to determine the number and distribution of weed species within New South Wales. Analysis of the census data revealed that there are at least 1,386 naturalised plant species in New South Wales representing 21% of the total plant species, native and alien. The number of weed species identified as posing a threat to threatened biodiversity in New South Wales represents only 9% of the total naturalised flora (ie the 127 weed species identified in Chapter 6).

Weed distributions across the three broad geographic zones

In Chapter 2 three broad geographic zones were established for New South Wales, based on the NRM regions, to enable geographic assessments at a level between the state and the individual NRM regions. These zones were coastal, central (tablelands and slopes) and western (rangelands) (Figure 2.1b) and the botanical census data were then allocated to these zones. The number of weed species decreased from east to west, away from the coast as did the number of weed species posing a threat to biodiversity (Table 7.1). This may be because of favourable climatic conditions in the coastal zone, or the close proximity to invasion foci such as a

larger population base and thus potentially greater probability of garden escapes, or a combination of both. However, as a proportion of the total flora there was only a slight difference between the coastal zone and western New South Wales (Table 7.1).

The number of weed species posing a threat to biodiversity was greatest in the coastal zone (as defined in Chapter 2), being 125 weed species or 98% of the total number identified as posing a threat in New South Wales. Again, the proportion of the total weed flora showed no difference between coastal and western New South Wales (Table 7.1).

Weed distributions within each NRM region in New South Wales

The botanical census data (BGT 2005) were split into the 13 NRM regions in New South Wales to determine the regional impacts of weeds. The largest number of weed species occurred within the Sydney Metropolitan CMA with 758 weed species, closely followed by the Hawkesbury–Nepean CMA with 733 weed species. The Lower Murray–Darling CMA contained the lowest number with 187 weed species (Table 7.2). The number of weed species as a proportion of the total flora (alien and native) in each NRM was also highest in the Sydney Metropolitan CMA (32%), but lowest in the Western CMA (17%). The high number of species and percentage of weeds in the Sydney Metropolitan CMA supports the notion of large population centres acting as foci for invasions, or that weed invasions are an artefact of time since European settlement (ie Sydney was the first city in Australia). This finding also supports calls for an examination of plants currently grown in gardens to determine their weediness (Downey and Glanznig *in press*).

Proportions of weed species threatening biodiversity in each of the 13 NRM regions were all higher than the average for the state (9%), as many of the species occurred in more than one NRM region.

Table 7.1 Number of weed species present in three geographic zones in New South Wales

| Geographic zones of New South Wales ^a | Number of weed species present ^{b, c, d} | | Contributions of weeds to total flora (%) ^{e, f} | Number of weeds threatening biodiversity ^{c, d, g} | | Percentage of weeds posing a threat to biodiversity present (%) ^h |
|--|---|------|---|---|------|--|
| Coastal | 1,213 | (88) | 23 | 125 | (10) | 98 |
| Central | 904 | (65) | 22 | 93 | (10) | 73 |
| Western | 307 | (22) | 19 | 34 | (11) | 27 |

a As defined in Chapter 2, based on a collective of Natural Resource Management regions.

b Data derived from the botanical census data (being terrestrial vascular plant species only: BGT 2005).

c Values in brackets are percentages of the total naturalised flora (or weeds) present in NSW [$n = 1,386$] for each geographic zone.

d The values are not cumulative, as many weed species occurred in more than one geographic zone.

e The total flora present includes both native and alien plant species.

f The percentage of the total flora present – coastal $n = 5,386$, central $n = 4,081$, and western $n = 1,642$.

g Biodiversity as listed on Schedules 1 and 2 of the TSC Act and 4 and 5 of the FM Act, as at January 1, 2005 (ie species, populations and ecological communities). TSC Act refers to the NSW *Threatened Species Conservation Act 1995* and the FM Act to the NSW *Fisheries Management Act 1994*.

h The percentage of the total number of weeds posing a threat to biodiversity in NSW ($n = 127$).

Table 7.2 Number of weed species in each Natural Resource Management region of New South Wales

| Natural Resource Management region of NSW ^a | Number of weed species present ^{b, c, d} | | Total flora ^e | Contribution of weeds to total flora (%) | Number of weeds threatening biodiversity ^{d, f, g} | |
|--|---|--------------|--------------------------|--|---|------------|
| Northern Rivers CMA | 627 | (45) | 3,282 | 19 | 100 | (16) |
| Hunter Central Rivers CMA | 580 | (42) | 2,893 | 20 | 96 | (17) |
| Hawkesbury–Nepean CMA | 733 | (53) | 3,012 | 24 | 98 | (13) |
| Sydney Metropolitan CMA | 758 | (55) | 2,356 | 32 | 101 | (13) |
| Southern Rivers CMA | 577 | (42) | 2,907 | 20 | 98 | (17) |
| Border Rivers–Gwydir CMA | 427 | (31) | 2,029 | 21 | 63 | (15) |
| Namoi CMA | 475 | (34) | 1,917 | 25 | 72 | (15) |
| Central West CMA | 502 | (36) | 2,197 | 23 | 59 | (12) |
| Lachlan CMA | 447 | (32) | 1,781 | 25 | 54 | (12) |
| Murrumbidgee CMA | 531 | (38) | 2,159 | 25 | 67 | (13) |
| Murray CMA | 439 | (32) | 1,641 | 27 | 55 | (13) |
| Western CMA | 242 | (17) | 1,463 | 17 | 29 | (12) |
| Lower Murray–Darling CMA | 187 | (13) | 896 | 21 | 25 | (13) |
| Total ^h | 1,386 | (100) | 6,634 | 21 | 127 | (9) |

a CMA is short for Catchment Management Authority.

b Data derived from the botanical census data (being terrestrial vascular plant species only: BGT 2005).

c Values in brackets are percentages of the total naturalised flora (or weeds) present in NSW [$n = 1,386$] for each NRM region.

d The values are not cumulative as many weed species occurred in more than one NRM region.

e The total flora is the number of plant species in each NRM region (see Table 3.3) added to the number of weeds present in each NRM region.

f Biodiversity as listed on Schedules 1 and 2 of the TSC Act and 4 and 5 of the FM Act, as at January 1, 2005 (ie species, populations and ecological communities). TSC Act refers to the NSW *Threatened Species Conservation Act 1995* and the FM Act to the NSW *Fisheries Management Act 1994*.

g Values in brackets are the percentage of total weed species in each NRM region threatening biodiversity.

h Values are not cumulative, as many weeds occur in more than one CMA.

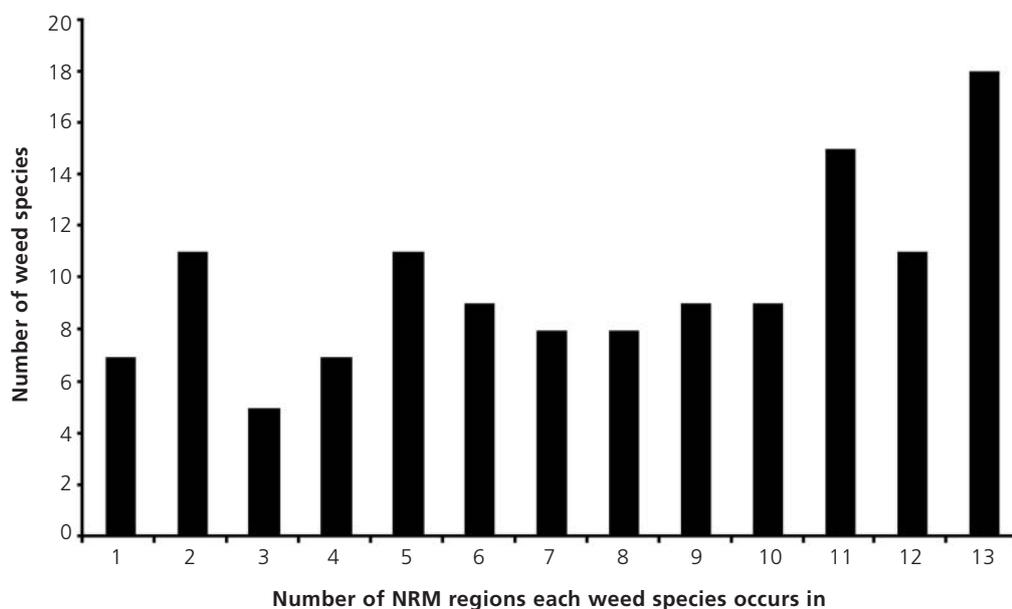


Figure 7.1 Number of Natural Resource Management regions and the number of weeds that threaten biodiversity

On average, each weed species was reported within seven of the 13 NRM regions (Figure 7.1). Of the 127 weed species identified, seven were found in only one NRM region, whilst 18 were found across all 13 and just over half occur in 8 or more NRMs. This result suggests that the majority of weed species affecting biodiversity in New South Wales are widespread.

Whilst the 127 weed species threatening biodiversity are distributed across the whole of the state (based on the botanical census data: BGT 2005 – Figure 7.2), the highest density of observations were adjacent to the coast and more specifically the Sydney Basin (ie the Sydney Metropolitan CMA). The distribution of these weed species corresponds to that of the threatened species (namely, a greater concentration in eastern New South Wales).

Distributions of the most commonly recorded weed species in New South Wales

Distributions of the eight most commonly identified weed species threatening biodiversity in New South Wales, that is posing a threat to >10 threatened species (Chapter 6), were mapped using point data obtained from the Australian Virtual Herbarium (CHAH 2005). Five of these eight weed species were restricted to the coastal NRM regions, the exceptions being blackberry,

kikuyu and to a lesser extent Scotch broom (Figures 7.3a–h). The herbarium data for several of these weed species revealed extensive collections over a defined area and thus may be indicative of the actual range, in particular that for lantana and bitou bush (Figures 7.3a and b). For the other species the collections are more dispersed and thus their actual range is not as clearly defined, for example for blackberry and kikuyu (Figures 7.3c and d). All eight weed species occurred in the Northern Rivers, Hunter Central Rivers, Sydney Metropolitan and Hawkesbury–Nepean CMAs.

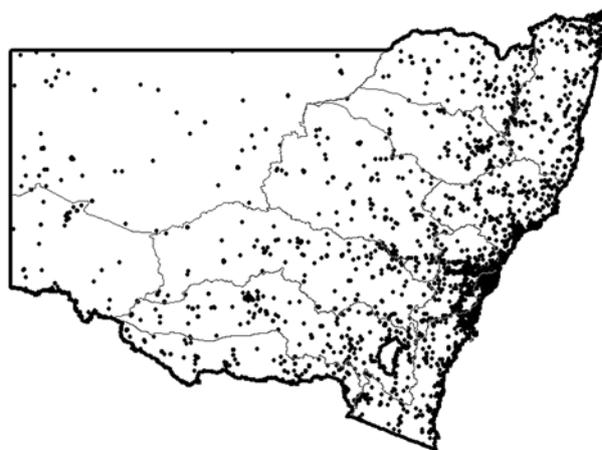


Figure 7.2 Locations of the 127 weed species threatening biodiversity in New South Wales (after BGT 2005). Boundaries are Natural Resource Management regions

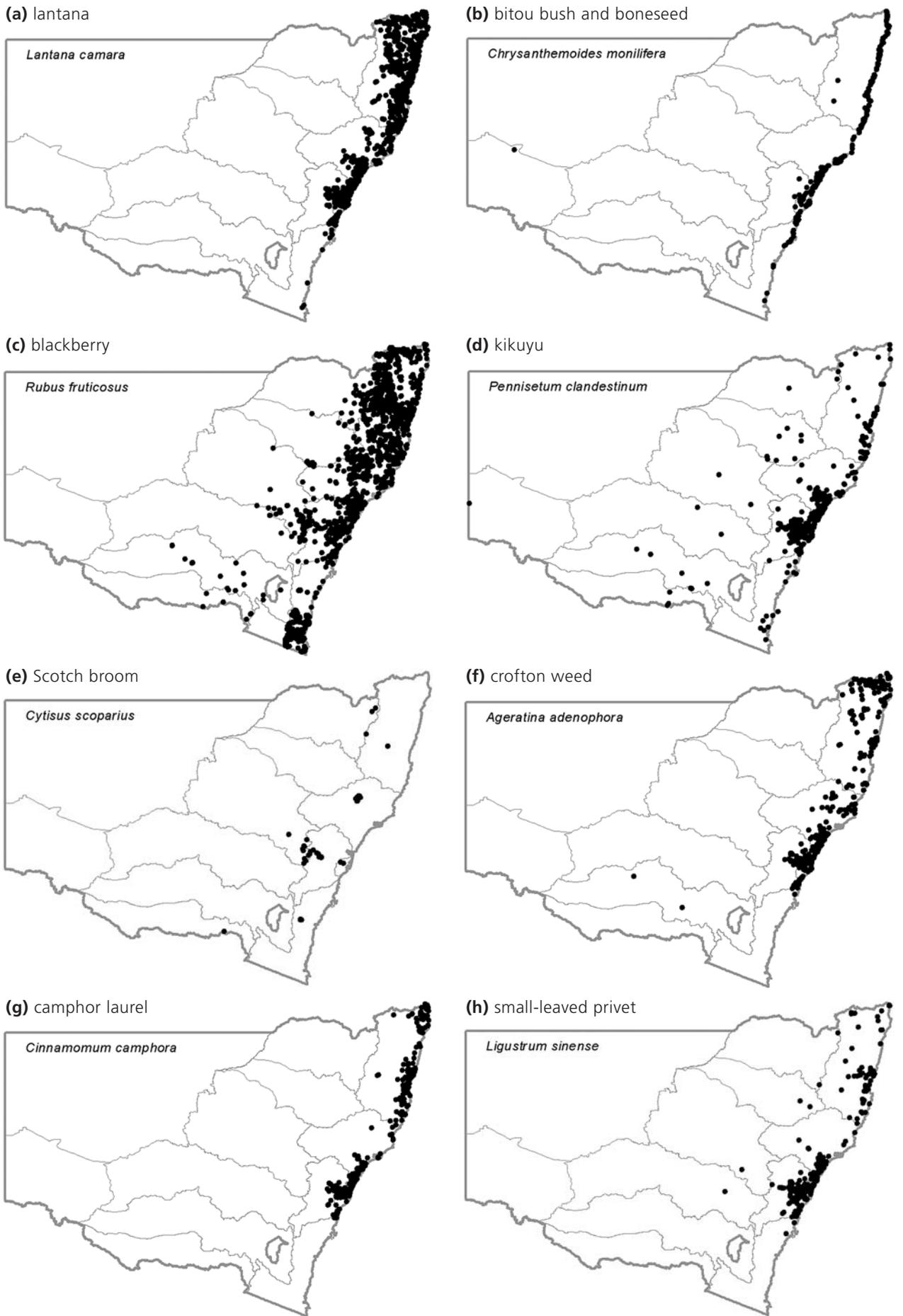


Figure 7.3 Distribution maps for the eight weed species posing a threat to more than 10 threatened species in New South Wales (Chapter 6: after CHAH 2005). Boundaries define the 13 Natural Resource Management regions

7.2 Spatial comparisons between threatened species and weeds

Distribution of threatened species impacted by weeds

The distribution of each threatened species identified as being at risk from weeds was split into the 13 NRM regions in New South Wales (BGT 2005; DEC 2005a). Threatened ecological communities were not mapped because quality distribution data were not available and the distribution of populations are confined to single locations. The Northern Rivers CMA contained the largest number of threatened species (plant and

animal) threatened by weeds ($n = 166$) followed by the other coastal NRM regions, whilst the Lower Murray–Darling CMA contained the lowest number ($n = 14$: Table 7.3).

As outlined above, the number of weed species decreased from east to west in New South Wales, both in total numbers and those identified to threaten biodiversity. This trend is mirrored both in the number of threatened plant and animal species present and in those threatened by weeds at the NRM region (Table 7.3). Despite the Sydney Metropolitan CMA having the greatest number of weed species (Table 7.2), it did not have the highest proportion of species threatened by weeds (Table 7.3).

Table 7.3 The number of threatened species identified as threatened by weeds within each Natural Resource Management region of New South Wales

| Natural Resource Management region of NSW ^a | Number of threatened plant and animal species ^b | Threatened plant and animal species threatened by weeds ^{c, d, e} | |
|--|--|--|--------------------------|
| Northern Rivers CMA | 342 | 166 | (49) |
| Hunter Central Rivers CMA | 192 | 68 | (35) |
| Hawkesbury–Nepean CMA | 225 | 99 | (44) |
| Sydney Metropolitan CMA | 125 | 57 | (46) |
| Southern Rivers CMA | 200 | 58 | (29) |
| Border Rivers–Gwydir CMA | 127 | 29 | (23) |
| Namoi CMA | 87 | 22 | (25) |
| Central West CMA | 107 | 28 | (26) |
| Lachlan CMA | 99 | 27 | (27) |
| Murrumbidgee CMA | 122 | 39 | (32) |
| Murray CMA | 91 | 24 | (26) |
| Western CMA | 120 | 26 | (22) |
| Lower Murray–Darling CMA | 81 | 14 | (17) |
| Total | 790 ^f | 317 ^f | (40 ^f) |

a CMA is short for Catchment Management Authority.

b The total number of threatened plant species was derived from BGT (2005) and the threatened animal species from the NSW Wildlife Atlas (DEC 2005a).

c Values in brackets are percentages of the total threatened plant and animal species present in NSW [$n = 790$] within each NRM region threatened by weeds.

d Biodiversity as listed on Schedules 1 and 2 of the TSC Act and 4 and 5 of the FM Act, as at January 1, 2005 (ie species, populations and ecological communities). TSC Act refers to the NSW *Threatened Species Conservation Act 1995* and the FM Act to the NSW *Fisheries Management Act 1994*.

e The values are not cumulative as many species occurred in more than one NRM region.

f The totals exclude fish, marine mammals, invertebrates, algae, fungi and aquatic plants, as the exact numbers of these species in NSW are not known.

Comparisons between the distribution of a weed species and the threatened species at risk

Whilst it would be ideal to compare the distributions of weeds and the species threatened by each for all 127 weed species threatening biodiversity in New South Wales, this was considered impractical, especially as many weeds were identified as threatening only one threatened species ($n = 110$ or 54%: Figure 6.1) and thus a small selection of weeds was used to illustrate the trends.

Six weed species were selected, representing three groups:

1. weeds threatening >10 threatened species, namely lantana and bitou bush/boneseed
2. weeds threatening five threatened species, namely Japanese honeysuckle (*Lonicera japonica*) and olive (*Olea europaea*)
3. weeds threatening two or fewer threatened species namely Parramatta grass (*Sporobolus fertilis*) and lippia (*Phyla canescens*).

These weed species also covered a variety of life forms such as shrub, vine and grass. The distributions of the threatened plant and animal species for each of these six weed species were mapped using presence/absence for each NRM region. The distribution patterns of the weed species were then superimposed over the top to illustrate the degree of overlap.

The 96 threatened species threatened by lantana occurred across nine NRM regions, whilst lantana occurred only within seven (Figure 7.4a). Therefore, those species that also occur outside of lantana's distribution are not threatened by lantana in at least part of their range. The majority of threatened species threatened by lantana occurred in the Northern Rivers CMA ($n = 80$) and, given the extensive distribution of lantana in this CMA, most were likely to be impacted across their entire range (Figure 7.4a).

The 46 threatened species threatened by bitou bush/boneseed occurred across nine NRM regions, whilst bitou bush/boneseed occurred within only five (Figure 7.4b). As bitou bush is restricted to the coastal strip within 10 km of the coastline (Thomas and Leys 2002) and boneseed is not yet widespread, the impact for many threatened species was not across their entire range (Figure 7.4b). However, many of the species threatened are themselves also restricted to the coastal strip (DEC 2006). These species include *Senecio spathulatus* (coastal groundsel), *Zieria prostrata* (headland zieria) and *Chamaesyce psammogeton* (sand spurge).

Whilst the other four weed species examined; Japanese honeysuckle, olive, lippia and Parramatta grass, have similar or larger distributions in New South Wales than bitou bush/boneseed and lantana (Figure 7.4), the number of threatened species at risk was significantly lower. Interestingly however, the species threatened by three of these four weed species (Japanese honeysuckle, olive, and Parramatta grass) are within the distribution of the weed. This suggests that, whilst few threatened species were identified at risk, those that were are potentially at risk across their entire distribution. Three of these four weed species covered large areas of New South Wales where they are reportedly not posing a threat to biodiversity. Thus, either these weed species do not pose a threat to biodiversity in these areas or the values presented here are underestimates of the actual impact. Given that investigations into the impacts of lantana and bitou bush/boneseed on biodiversity have seen significant increases in the species at risk, the latter explanation is more likely for these other weed species. Similar trends are likely to extend to the other 121 weeds threatening biodiversity.

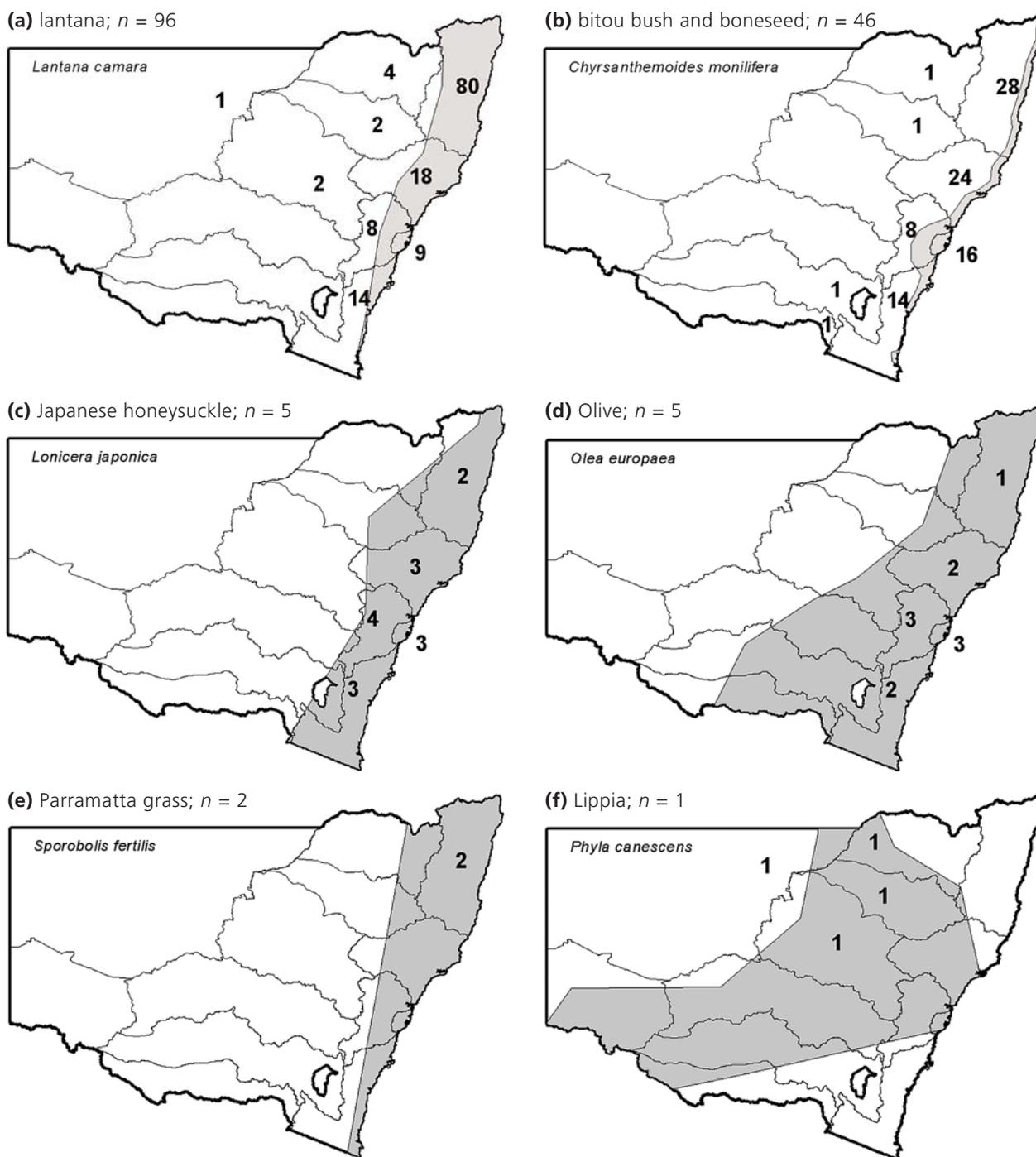


Figure 7.4 The relationship between the distributions of threatened species and specific weed species within each Natural Resource Management region

Note: n equals the number of threatened species impacted. Distribution information is coloured grey for each weed species, and as a number for the threatened species present in each NRM region threatened by that weed.



8. Discussion and implications

In the previous three chapters an assessment was presented of the impact of weeds on threatened biodiversity in New South Wales with respect to the threat posed by weeds relative to other threats to biodiversity (Chapter 5), the specific weeds posing a threat to biodiversity (Chapter 6) and the spatial scale of weed threats (Chapter 7). Here, the main results of this study are discussed with respect to weed management, weed policy and biodiversity conservation.

8.1 The relative threat of weeds compared with other threatening processes

Alien species (pest animals and weeds) have been acknowledged as the second greatest threat to global biodiversity, behind habitat destruction (WRI et al 1992). This acknowledgment has not led, however, to substantial changes in management, funding or policy initiatives for alien species, despite an abundance of historical data highlighting the increasing phenomenon of alien species introductions (Ridley 1930; Elton 1958; di Castri 1989; Heywood 1989; Panetta and Scanlan 1995; Reichard and Hamilton 1997; Mack 1999). One reason for this failure is that there has not been any quantitative analysis of the main threats to biodiversity in terms of the relative importance of alien species based on the actual species or biodiversity at risk (Downey submitted).

The present study aimed to rectify this problem by quantifying the biodiversity threatened by weeds relative to the other threats to biodiversity in New South Wales. Results of the current study supported the finding of the assessment of WRI et al (1992) in that alien species posed the second greatest threat to biodiversity by threatening 70% of the biodiversity listed under the TSC Act and the FM Act.

The relative threat of weeds

The present study showed that weeds posed a significant threat to biodiversity in that they comprised the majority of the alien species identified and threatened similar numbers of species to that of other major threatening processes, such as habitat destruction. Weeds threatened 46% of the threatened biodiversity in New South Wales. Not only has this analysis enabled direct comparisons to be made, but it can also help establish management priorities related to threatening processes. Interestingly,

salinity, which is one of the major natural resource management issues in Australia and considered to be a significant threat to biodiversity, was identified as a threat to only a small proportion (0.4%) of threatened species in New South Wales. A similar result was also observed for climate change.

8.2 Assessing the impact of weeds on biodiversity

The role of weeds in biodiversity decline has been widely acknowledged (IUCN 2000). However, there has been limited assessment of the actual impacts, at least in Australia (Downey submitted), despite calls for such information (Grice et al 2004; Groves 2004). Whilst there have been many studies of the individual species threatened by weeds, both in terms of the specific impacts associated with a specific weed (Weiss and Noble 1984a, b) and the impacts of weeds on a specific native species (Matarczyk 1999), and recent reviews of such studies (Grice et al 2004; Vidler 2004), what is needed to influence management and policy initiatives is a broad assessment across many taxonomic groups (Downey submitted). The biodiversity listed under the schedules of threatened species legislation enables such an assessment to be undertaken as these lists are taxonomically diverse and information on threats to the listed species is readily available. The current report presents an assessment of the weed threats to the biodiversity listed under the Schedules of the TSC Act and the FM Act. This analysis of these Schedules highlights the success of our approach to quantifying the impacts to biodiversity and the value of such lists. Whilst this approach has quantified the impacts for New South Wales, a national perspective is now needed to influence weed management and policy development more generally. In order to compile a national account for Australia, examination is needed of schedules under each of the states' threatened species legislation, for example, the Victorian *Flora and Fauna Guarantee Act 1998*, in conjunction with the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). Whilst the EPBC Act encompasses nationally threatened biodiversity, it does not cover all the threatened biodiversity in Australia. For example, half of the threatened species under the TSC Act were not listed under the EPBC Act. In addition, state legislation also does not encompass all the biodiversity contained under the EPBC Act (eg RAMSAR wetlands).

Other than the current study for New South Wales, several other attempts have been made to try and identify the biodiversity impacted by weeds in Australia from threatened species lists; none has occurred on the same scale, however. Leigh and Briggs' (1992) initial study identified 69 Rare or Threatened Australian Plants (ROTAP) as endangered by competition from weeds. However, neither the weeds nor the native species at risk were presented. In another attempt, Adair and Groves (1998) presented a summary of 23 threatened species under the Victorian *Flora and Fauna Guarantee Act 1998* that were deemed to be threatened by 29 specific weed species. Sixteen of these weed species were also identified to threaten threatened biodiversity in New South Wales. Vidler's (2004) study of weed impacts to threatened species not necessarily listed under a specific Act, revealed 43 threatened species at risk from 41 weeds. Those species identified by Vidler (2004) that occurred in New South Wales were added to the data set of this study.

A brief assessment of the EPBC Act by Downey (submitted) illustrated that the process developed in this report could be replicated. It revealed 291 threatened species at risk from weed invasions, 33% of which contained information on a specific weed species. Whilst this value is considerably less than the 50% presented here, this may be because the current study went to greater lengths to identify the full range of threats, while Downey's study was only a brief assessment. In addition, Downey identified only 57 weed species posing a threat, with bitou bush/boneseed the most commonly identified weed threat. Of these weed species, 26 were also listed as threatening EPBC-listed biodiversity that occurred in New South Wales. In this study of the EPBC Act only 13 of the WONS were listed, with bitou bush/boneseed being the only one listed as a threat to more than 10 threatened species. This supports the finding of Downey and Cherry (2005) that information on the biodiversity threatened by the WONS was poorly known. This, in turn, supports findings from the United States in which a review of threatened species showed that many listings lacked important information on threats (Easter-Pilcher 1996), which can undermine recovery efforts (Lawler et al 2002). In addition, of the 20 most commonly listed weeds posing a threat to biodiversity listed here (Table 6.3) 12 of the top 13 were also identified as posing a threat to biodiversity listed under the EPBC Act (Downey submitted). These two studies illustrate that the approach undertaken in the current study can be replicated in each state, territory and nationally across Australia.

Assessments of weed impacts on biodiversity have historically occurred either through specific scientific investigations for weed species (Weiss and Noble 1984a, b; French and Zubovic 1997; Matarczyk 1999; Vranjic et al 2000; Franks 2002), as reviews of such studies (Grice et al 2004; Vidler 2004), or as extensive systematic reviews using the Weed Impacts to Native Species (WINS) assessment tool (Downey 2004, 2006). These three approaches all have limitations when it comes to collating a baseline for assessing the impacts of weeds on biodiversity. For example, this study identified 419 threatened species at risk from weed invasions in New South Wales, which is an order of magnitude more than Vidler's (2004) assessment for the whole of Australia. In addition, the WINS assessment tool has been used to date only for individual weed species and then only to assess impacts to native plants and ecological communities (Downey 2006). Whilst the current study provides such a baseline assessment across many taxonomic groups, it too has limitations in that the data are not based on an assessment of weed impacts but rather on threatened species listings. Thus, it is important that the previous approach of studying individual species is maintained and extended to determine the full extent of the weed problem and the nature of the impacts. For example, the only thorough examination of a single weed species to date using the WINS assessment tool revealed 158 plant species, three populations and 26 ecological communities at risk from bitou bush invasion (DEC 2006). Again, the number of species identified at risk far exceeded the 41 nationally reported previously (Vidler 2004) or, more specifically, the six for bitou bush (ARMCANZ et al 2000b), thereby highlighting the deficiencies in our present knowledge and the need for dedicated assessments such as that presented here or using the WINS assessment tool. In addition, the WINS assessment tool provides for the examination of all flora at risk; not just those listed as threatened under the TSC Act. For example, of the 158 species examined during the bitou bush assessment, only 55 were listed under the TSC Act. Such a thorough examination provides a greater understanding of the weed impact as well as enabling management directed towards conservation purposes (DEC 2006).

In addition to determining the biodiversity at risk, the current study also provides information on the weed species posing the threat. Information on the weed species threatening biodiversity has not been previously compiled, despite some of it being published as part of a broader study by Vidler (2004). In the latter study, 41 weed species were described, plus the generic collective

threat of introduced perennial and annual grasses that threaten biodiversity. Grice et al (2004) outlined a further seven weed species to give a total of 50 nationally, 13 of which are WONS.

The present study identifies 127 weed species; this number is only interim however as:

- at least half of the threat descriptions did not identify a specific weed species, rather they simply described the threat from weeds
- the present study examined only threatened species and not all native species at risk.

Given that there are 1,386 naturalised plants in New South Wales, it is improbable that the 9% identified here are an exhaustive list. An estimate of the likely number is suggested by the findings of a recent study that identified approximately 300 weeds as posing a threat to biodiversity in New South Wales (Downey et al *unpublished data*). Unfortunately these species were assessed by a mathematical model, which did not include specifics on the actual biodiversity threatened.

The current approach nevertheless still has some limitations due in part to:

- the data being derived from a number of different sources, the reliability of which could not always be verified
- the information being based on schedules of threatened species in Acts rather than on an actual assessment of the biodiversity at risk from each threat.

Irrespective of these two limitations however, the information provided here can be used as a baseline for the relative threat posed by weeds, from which detailed examinations can be made to determine the actual threat.

8.3 Weeds of National Significance and their impacts on biodiversity

One of the three goals of the National Weeds Strategy (ARMCANZ et al 1997) was to 'reduce the impact of existing weed problems of national significance'. A short list of 20 WONS was identified from a list of 71 weed species based on their invasiveness, potential for spread, and socioeconomic and environmental impacts (Thorp and Lynch 2000). Each of these WONS has had a National Management Strategy developed (ARMCANZ et al (2000a-g, 2001a-l, 2003), which together describe a range of impacts, including those on biodiversity. A recent review of the 20 WONS National Strategies highlighted the lack of available information on the impact of the WONS on biodiversity, especially with respect to actual species at risk (Downey and Cherry 2005). This review found that the 20 WONS collectively

posed a threat to 82 native species nationally, although actions specifically relating to reducing impacts on biodiversity within these strategies were limited. For example, the athel pine (*Tamarix aphylla*) strategy did not contain any specific actions for reducing its impacts on biodiversity (ARMCANZ et al 2001a). In many cases, however, reducing impacts on biodiversity was implied through broader actions. One way to meet the goal of the National Weeds Strategy, as outlined above, is to identify the biodiversity at risk and develop actions and appropriate strategies to reduce such impacts (Downey and Cherry 2005). The present study highlighted the impact of the WONS on biodiversity by increasing the number of species identified as being threatened by WONS from 82 nationally to 145 for New South Wales alone.

In addition, the three most commonly identified weed threats are WONS:

- lantana (threatens 96 species)
- bitou bush/boneseed ($n = 46$)
- blackberry ($n = 21$).

This finding implies that the WONS pose the greatest threat to biodiversity, although it should be noted that the numbers presented for bitou bush and lantana were gained following targeted assessments using the WINS assessment process (Downey 2006). We conclude that greater emphasis is needed through the WONS program to identify the biodiversity at risk and develop appropriate actions and plans to reduce impacts on biodiversity in a manner similar to that developed for bitou bush (DEC 2006). In addition, a test of this system greatly increased the number of species known to be at risk for bridal creeper (Downey 2006), further discussed below and a recently funded project will undertake such an assessment for lantana, nationally.

8.4 Increasing our knowledge

Following the completion of the majority of this report, new data became available which were not added to the database or analysed in this study but are presented here to illustrate the continual expansion of our knowledge in this area. For example, a trial of the WINS system, using only stages one to three, was undertaken for bridal creeper, another WONS species, which identified an additional 51 species that were deemed to be potentially at risk (Downey 2006). As only two of these native species at risk were listed under the TSC Act, this trial would not change the order of 'the weed species most identified', although it did illustrate the level of threat posed to currently non-threatened species. The same study also identified 95 species that are

potentially at risk from invasion by ground asparagus (*Asparagus aethiopicus*), two of which were listed under the TSC Act (Downey 2006).

In addition, the development of the Bitou TAP saw another 96 species, one population and 15 ecological communities identified as being at risk, between the draft (DEC 2004a) and the final plan (DEC 2006). Of the 186 entities at risk, 55 species, three populations and 14 ecological communities were listed under the TSC Act. These additions increase the biodiversity threatened by bitou bush from 46 (as presented in Chapter 6) to 72, many of which were listed as threatened generically by 'weed invasion' in the data set. These additions further highlight the need for on-going and detailed assessments, and their value in determining the threat weeds pose to biodiversity.

8.5 Limiting future impacts

Identifying the source of weed invasions

Garden escapes are a major source of alien plant introductions and several recent studies have highlighted their contribution to local weed floras (eg 75% of terrestrial weeds and 50% of aquatic weeds in New Zealand (DOC 2003); over 50% in the United States (Randall and Marinelli 1996)) and to the world's worst invasive plants (56% according to ISSG 2000). A recent review found that 66% of the weed species in Australia originated from garden plants (Groves et al 2005). This number increased to 72% when weeds with origins in agriculture and horticulture were also considered. The current study found a similar proportion of weeds originating from gardens threatening biodiversity (65%), and this percentage increased to 70% when all cultivated plants were considered. Whilst these values are similar, Groves et al (2005) were not able to demonstrate the impact of these 'garden escapes' on biodiversity, thereby limiting the impetus for change. The present study, however, clearly illustrates the impact of 'garden escapes' on 190 threatened species under the TSC Act, or 93% of the species for which a specific weed species was identified. If we assume constant proportions for the remaining 215 species with no specific listing, the number of threatened species impacted by garden escapes may be as high as 390. Whilst considerable work has gone into preventing new introductions through the development of a national Weed Risk Assessment system (Pheloung 2001, 2002) and closing importation loop holes (Spafford Jacob et al 2004), little has been done to address the issue of the continual threat posed by garden escapes (Groves 2004) or to understand what the future threat is likely to be (Downey and Glanznig *in press*). In part, this is because biodiversity impacts

have not been adequately addressed across all weed management areas (Downey submitted). It is anticipated that identifying native species directly at risk will aid in addressing this issue, especially given that seven of the 10 worst invasive garden escapes still for sale in New South Wales (as identified by Groves et al 2005) also threaten threatened species in that state.

The continuing nature of the threat

Any attempt to eradicate, contain or manage weed species requires consideration and management of re-invasion potential as well as sources of re-introduction. As outlined above, gardens are a major source of introduction although analysis of those weed species threatening biodiversity as presented here shows that 56 of the 127 weeds species can still be purchased in Australia, 36 of which are for sale in New South Wales (Hibbert 2004). This result shows that gardens are likely to continue to be a source of invasion in the future. The data presented in this report can be used by policy makers and weed managers to lobby for changes to the sale of plants that pose a serious threat to biodiversity; for example, those 56 species identified here. Prohibition of these weeds from sale will reduce their invasive risk and such early intervention would be a cost-effective option. The cost, either economically or environmentally, would be far greater further down the invasion pathway.

A recent review aimed at banning weeds that threaten biodiversity from sale identified the 10 most serious invasive garden plants that were still available for sale in New South Wales (Groves et al 2005). Of these 10 weeds, seven are identified in the current study as a threat to biodiversity in New South Wales. In addition, 12 other weed species and two genera were listed among the worst weeds in other states.

Active intervention is required for those weed species threatening biodiversity which are still for sale, as identification of such species (Groves et al 2005) and voluntary approaches have not worked in the past (Caton 2005) or are unlikely to work (Moss and Walmsley 2005).

Limiting or halting the sale of weeds that threaten biodiversity will require:

- pro-active use of the information presented here, in conjunction with information from a broader geographic area such as nationally or from national assessments (Groves et al 2005; Downey and Glanznig *in press*)
- intensive education through programs like the 'grow me instead' (Nursery and Garden Industry NSW and ACT n.d.) and 'bushland friendly nursery' schemes (NCWAC 2002) in which native alternatives are suggested as replacement garden plants for known weeds

- extensive cooperation between many stakeholders
- a better understanding of the future threat from garden plants (Downey and Glanznig *in press*).

Given the recent success in banning the sale of the 20 WONS, a precedent has been set that should be used to ban the sale of weeds that are known to threaten biodiversity. Alternatively, in the absence of such bans, plants could be labelled to highlight their potential to escape from gardens, such as was detailed by the WWF in a recent investigation of the feasibility of a mandatory labelling scheme to help address such a problem (Martin et al 2005).

8.6 Implications for managing weed threats under the *Threatened Species Conservation Act 1995*

Listing weeds as Key Threatening Processes

Any threat to biodiversity in New South Wales can be listed as a Key Threatening Process (KTP) under the TSC Act (NPWS 2004; Downey and Leys 2004). Threats can also be listed as KTPs under the EBPC Act and several of the other states' threatened species legislation. Presently in New South Wales, only one weed species (bitou bush/boneseed) and one group of related weed species (exotic perennial grasses) have been listed as KTPs under the TSC Act. Preliminary determinations to list one other weed species (lantana) and a group of weeds (exotic vines and scramblers) have also been made by the NSW Scientific Committee (NSW SC 2005a, b).

The current study identified the number of species threatened by each as being:

- bitou bush 46 species
- exotic perennial grasses 65 species
- lantana 96 species
- exotic vines 26 species.

Given that the primary criteria for listing a threat as a KTP only requires the identification of only two or more species at threat and/or evidence that species currently not at threat would become so (NPWS 2004), 59 other weed species identified here satisfy the criteria for nomination (eg blackberry threatens 21 species). To avoid listing lower-level weed threats before major threats, a weed prioritisation process has been developed in New South Wales (Downey et al *unpublished data*). This system models approximately 300 environmental weeds to determine those posing the greatest threat

to biodiversity. It is important to note that the weeds identified in the present report have not been assessed for their relative threat, other than as reflected in the number of times they were identified as a threat to biodiversity. Thus, the information presented here should not be used in any way as an assessment of the worst environmental weeds but instead the reader should refer to the list presented in Downey et al (*unpublished data*).

Whilst the TSC Act contains a list of KTPs in Schedule 3, such as invasion of native plant communities by bitou bush, the information used to list these KTPs was not derived from any analysis of the major threats to the biodiversity, particularly those listed in Schedules 1 and 2 of the Act. Thus, the information contained in the present data set should be used to aid determination of KTP listings in future.

Describing and documenting threats

During the compilation of the threat data set it quickly became apparent that there was no consistency in the way in which threats were documented and described not even by the NSW Scientific Committee. For example, the threat description was either poorly articulated or inadequate for analysis or management, using statements such as the species was threatened by 'weed invasion' or 'by exotic grasses'. Indeed, several species were listed for which no threat could be determined despite extensive examination. In addition, approximately half the species threatened by weeds did not have a specific weed species identified when an assessment of the weed threat was undertaken; the threat was simply described as 'weed invasion'. The identification of at least the main weed species would be useful; for example 'the species was threatened by lantana and other weeds'.

We therefore recommend that the description of threats be standardised, not just in New South Wales, but whenever a threat is described. The minimum requirement for describing a threat should include identification of the threat which, for biological organisms, means the species must be named (eg *Lantana camara*) and the mode of the threat described in a meaningful manner (eg competition from *L. camara*). The failure to describe a threat adequately is inexcusable and is detrimental to the recovery of threatened species. If the specifics are unknown then investigations must be carried out or, in certain circumstances, descriptions might be accompanied by caveats to reflect the likely threat, such as 'it is suspected that competition by *L. camara* and other weeds has led to the decline in the species'.

When it comes to weed threats, it is imperative that, as a minimum, the main weed be described to species level but ultimately as many weeds as possible should be thus identified. The present lack of information on specific weed species has serious consequences for the management of those species threatened, as well as for assessments made in this report.

8.7 Assessing the impact to biodiversity more generally

Whilst this project provides an assessment of the impacts of weeds on the biodiversity listed under Schedules 1 and 2 of the TSC Act and 3 and 4 of FM Act in New South Wales, these threatened species account for only 13% (790 of 6,147) of the total biodiversity of vascular plants and vertebrates present in the state. For example, there are 4,689 native plant species in New South Wales that are not listed as threatened. Therefore, in order to understand the full extent of the threat posed by weeds or other threatening processes to biodiversity, a measure is needed other than that presented here. One approach has recently been developed which examines all plant species at risk. The Weed Impacts to Native Species assessment process (Downey 2006) was derived during the development of the draft NSW Bitou Bush Threat Abatement Plan (Bitou TAP), in which 52% of the plant species identified to be at risk were not formally listed as threatened under the TSC Act (DEC 2004b). Likewise, 65% of plant species in the final Bitou TAP were not listed (DEC 2006). Extrapolation of this final percentage (65%) to the 279 plant species threatened by weeds as presented in this report indicates that the total threatened could be approximately 800 species when species currently not classified as threatened are considered. Further analysis is required, however, before such estimates can be made with any confidence.

8.8 Conclusion

The current study has attempted to quantify the impact of weeds on biodiversity. Part of this analysis included an assessment of the relative importance of weeds compared to other threats on biodiversity, which showed that weeds are considered a major cause of biodiversity decline. In addition, this study has illustrated the scale of the weed problem in terms of the number and diversity of species at risk. Whilst the data have some limitations, the information presented provides a long overdue baseline from which informed management and policy decisions can now be made. It is anticipated that the information presented here will stimulate robust discussions on the management of weed impacts on biodiversity, which should include the description of threats. Finally, whilst the data presented here illustrate the weed problem for New South Wales at a specific point in time, what is actually required is a national analysis including every state and territory, with regular revisions and updates.

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Appendix 1

Threatened species for which no threat information could be found

Table A Threatened species for which no threat information could be found

| Scientific name | Common name | Plant type | Threatened Status under the TSC Act |
|------------------------------|---------------------|------------|-------------------------------------|
| <i>Babingtonia granitica</i> | granite babingtonia | shrub | Vulnerable |
| <i>Lastreopsis hispida</i> | bristly shield fern | fern | Endangered |
| <i>Senecio squarrosus</i> | swamp groundsel | herb | Endangered |
| <i>Viola cleistogamoides</i> | hidden violet | herb | Endangered |



Threat hierarchy

Explanatory notes on the threat hierarchy

1. The threat hierarchy is outlined in Chapter 2.
2. The numerical representation for each threat category (eg [4]) is used only to make comparisons within the text and is not a representation of order or ranking.
3. When a sub-category of the threat hierarchy could not be determined the letter **X** was used.
4. For ease of presentation the individual alien species identified in the 3rd sub-category of the alien species category [4] were truncated to animals and/or plants. The number of each is presented in brackets after the word 'animals' or 'plants' in the outline of the hierarchy below.

Structure of the threat hierarchy

[1] Anthropogenic destruction and disturbance of native vegetation

- 1.1 Destruction (clearing)
 - 1.1.1 Agriculture
 - 1.1.2 Urban and industrial development
 - 1.1.3 Forestry/logging
 - 1.1.4 Mining
 - 1.1.5 Infrastructure development
 - 1.1.5.1 Roads
 - 1.1.5.2 Powerlines
 - 1.1.5.3 Pipelines
 - 1.1.5.X Unspecified
 - 1.1.6 Private landholders
 - 1.1.X Unspecified
- 1.2 Disturbance/modification
 - 1.2.1 Agriculture
 - 1.2.1.1 Grazing
 - 1.2.1.2 Ploughing
 - 1.2.1.X Unspecified
 - 1.2.2 Development
 - 1.2.3 Infrastructure maintenance
 - 1.2.3.1 Roads
 - 1.2.3.2 Powerlines
 - 1.2.3.X Unspecified
 - 1.2.4 Forestry/logging
 - 1.2.5 Human activity
 - 1.2.5.1 Use of vehicles
 - 1.2.5.2 Visitation
 - 1.2.5.3 Recreation
 - 1.2.5.4 Access
 - 1.2.5.5 Illegal tracks
 - 1.2.5.6 Mowing
 - 1.2.5.7 Vandalism
 - 1.2.5.X Unspecified
 - 1.2.6 Mining
 - 1.2.X Unspecified
- 1.3 Collection
 - 1.3.1 Plants
 - 1.3.2 Seeds
 - 1.3.3 Flowers
- 1.4 Other
- 1.X Unspecified

[2] Anthropogenic destruction and disturbance of native fauna

- 2.1 Destruction
 - 2.1.1 Hunting
 - 2.1.2 Fishing
 - 2.1.2.1 Bycatch
 - 2.1.2.2 Commercial
 - 2.1.2.3 Recreational
 - 2.1.2.4 Entanglement
 - 2.1.2.5 Illegal
 - 2.1.3 Human Activity
 - 2.1.3.1 Boat mortality
 - 2.1.3.2 Road mortality
 - 2.1.3.3 Shark nets
 - 2.1.4 Pest Control
 - 2.1.4.1 Targeted
 - 2.1.4.2 Non-targeted
 - 2.1.5 Other
 - 2.1.5.1 Electrocution
 - 2.1.5.2 Collision with powerlines
 - 2.1.5.3 Military operations
 - 2.1.5.4 Food source
 - 2.1.5.5 Loss of pollinator
- 2.2 Disturbance
 - 2.2.1 Roosting
 - 2.2.1.1 Human activity
 - 2.2.1.2 Mining
 - 2.2.1.3 Domestic animals
 - 2.2.2 Nesting
 - 2.2.2.1 Human activity
 - 2.2.2.2 Domestic animals
 - 2.2.2.3 Aircraft
 - 2.2.3 Competition
 - 2.2.3.1 Livestock
 - 2.2.3.2 Unspecified
 - 2.2.X Unspecified
 - 2.2.X.1 A human activity
 - 2.2.X.2 Mining
 - 2.2.X.3 Livestock
 - 2.2.X.4 Domestic dogs
- 2.3 Collection
 - 2.3.1 Eggs
 - 2.3.2.1 Illegal
 - 2.3.2 Individuals
 - 2.3.2.1 Illegal
 - 2.3.2.2 Scientific
 - 2.3.2.X Unspecified
 - 2.3.3 Feathers

Structure of the threat hierarchy

[3] Anthropogenic modification and degradation of physical factors

- 3.1 Modification
 - 3.1.1 Hydrology
 - 3.1.1.1 Wetland/swamp drainage
 - 3.1.1.2 Infilling/reclamation wetlands/swamps
 - 3.1.1.3 Tidal flow regulation
 - 3.1.1.4 River flow/drainage regulation (dams and weirs)
 - 3.1.1.5 Flood regime (mitigation)
 - 3.1.1.6 Up/downstream access
 - 3.1.1.7 Water extraction
 - 3.1.1.8 Debris removal
 - 3.1.1.9 Altered
 - 3.1.1.10 Dumping
 - 3.1.1.11 Permanent water
 - 3.1.2 Geomorphology
 - 3.2.1 Erosion
 - 3.2.2 Soil moisture levels
 - 3.2.3 Removal of ground cover
 - 3.2.4 Soil compaction (livestock trampling)
 - 3.1.3 Fire regime
 - 3.1.3.1 Altered
 - 3.1.3.2 Inappropriate
 - 3.1.3.3 Hazard reduction
 - 3.1.3.4 Fire suppression
 - 3.1.3.5 High intensity
 - 3.1.3.6 Too infrequent
 - 3.1.3.7 Too frequent
 - 3.1.3.8 Management
 - 3.1.3.9 Fire/wildfire
 - 3.1.3.10 Arson
 - 3.1.3.11 Peat fire
- 3.2 Degradation (Pollution)
 - 3.2.1 Air pollution
 - 3.2.1.1 Global warming/climate change
 - 3.2.1.2 Ozone depletion
 - 3.2.1.3 Atmospheric
 - 3.2.2 Water pollution
 - 3.2.2.1 Chemical – heavy metals or organo-chlorines
 - 3.2.2.2 Nutrients
 - 3.2.2.3 Sediment/siltation
 - 3.2.2.4 Oil spills
 - 3.2.2.5 Marine pollution
 - 3.2.2.6 Thermal pollution
 - 3.2.2.7 Runoff
 - 3.2.2.8 Pesticide/herbicide
 - 3.2.2.9 Unspecified
 - 3.2.3 Land pollution
 - 3.2.3.1 Nutrients
 - 3.2.3.2 Rubbish/waste dumping and landfill
 - 3.2.3.3 Salinity
 - 3.2.3.4 Acid sulfate soil
 - 3.2.3.5 Sediment
 - 3.2.X Unspecified
 - 3.2.X.1 Herbicides and pesticides
 - 3.2.X.2 Nutrients
 - 3.2.X.3 Runoff/stormwater
- 3.3 Collection
 - 3.3.1 Dead wood/dead trees
 - 3.3.2 Bush rock

[4] Introduction of alien species

- 4.1 Predation
 - 4.1.1 Animals (23 species)
 - 4.1.X Unspecified
- 4.2 Competition
 - 4.2.1 Animals (18 species)
 - 4.2.2 Plants (124 species)
 - 4.2.X Unspecified
- 4.3 Grazing
 - 4.3.1 Animals (6 species)
 - 4.3.X Unspecified
- 4.4 Degradation by trampling, compaction and invasion and disturbance
 - 4.4.1 Animals (6 species)
 - 4.4.2 Plants (34 species)
 - 4.4.X Unspecified
- 4.5 Control of introduced alien species
 - 4.5.1 Manual control of introduced alien species
 - 4.5.1.1 Bush regeneration
 - 4.5.1.2 Weed control
 - 4.5.1.3 Rabbits control – burrow ripping
 - 4.5.1.4 Mis-identification
 - 4.5.2 Chemical control of introduced alien species
 - 4.5.2.1 Dog and fox baiting (1080)
 - 4.5.2.2 Pesticides (insect and herb)
 - 4.5.2.3 Rodents
- 4.6 New associations
 - 4.6.1 Dependence on introduced alien species
 - 4.6.2 Poor pollinator
- 4.X Unspecified
 - 4.X.1 Mammals
 - 4.X.1.1 Rabbits
 - 4.X.1.2 Pigs
 - 4.X.1.3 Goats

[5] Diseases

- 5.1 Alien
 - 5.1.1 Chytrid fungus
 - 5.1.2 *Phytophthora cinnamomi*
 - 5.1.3 Psittacine circoviral (Beak and Feather)
 - 5.1.4 Unspecified
 - 5.1.4.1 Cats
 - 5.1.4.2 Introduced pathogen
 - 5.1.5 Toxoplasmosis
- 5.2 Native
 - 5.2.1 Dieback – Noisy miner
 - 5.2.2 EHNV – Epizootic haematopoietic necrosis
 - 5.2.3 Chlamydia
- 5.3 Undetermined
 - 5.4.1 Soil borne pathogens
 - 5.4.2 Causes growths
 - 5.4.4 Dieback
- 5.X Unspecified

Structure of the threat hierarchy

[6] Natural Phenomena

- 6.1 Stochastic Events
 - 6.1.1 Flood
 - 6.1.2 Drought
 - 6.1.3 Extreme temperature
 - 6.1.4 Landslip/rockfalls
 - 6.1.5 Cyclone
- 6.2 Native Species
 - 6.2.1 Competition
 - 6.2.2 Grazing
 - 6.2.3 Predation
 - 6.2.4 Habitat degradation
- 6.3 Unnatural native animal effects
 - 6.3.1 Expansion of native ranges
 - 6.3.1.1 Animals
 - 6.3.1.2 Plants
 - 6.3.2 Abnormal increases in native abundance
 - 6.3.2.1 Animals
- 6.4 Intrinsic factors
 - 6.4.1 Low genetic diversity
 - 6.4.2 Low population
 - 6.4.3 Limited distribution
 - 6.4.4 Limited suitable habitat
 - 6.4.5 Poor reproductivity
 - 6.4.6 Low seed viability/production
 - 6.4.7 Remnant populations
 - 6.4.8 Low regenerative capacity
 - 6.4.9 Hybridisation

[7] Other

- 7.1 Lack of knowledge
- 7.2 Outside of conservation area



Appendix 3

Weed species identified as posing a threat to threatened biodiversity in New South Wales

Information on weed threats to threatened biodiversity in NSW that is the biodiversity listed under the NSW *Threatened Species Conservation Act 1995* was compiled from a wide range of sources (see Chapter 2 for further information). The weed species identified and the biodiversity threatened by each is presented in Table B, along with information on the noxious status of each weed species, the source of introduction (see Chapter 6: after Randall 2002), and the availability of each weed for sale in both NSW and Australia (after Hibbert 2004).

Note: The list of 127 weed species in Table B only accounts for 204 of the 419 threatened species threatened by weeds, as the weed threats to the remaining 215 were only described as weeds generally.

Table B Weed species identified in the data set as impacting on threatened biodiversity in New South Wales and the biodiversity identified as at risk

| Weed species identified as posing a threat to biodiversity in New South Wales ^a | Noxious listing ^b | Intro. source ^c | Availability for sale ^d in Aust. NSW | | Total biodiversity threatened | Type ^e | Biodiversity at risk ^f |
|--|----------------------------------|----------------------------|---|---|-------------------------------|-------------------|---|
| <i>Acetosa sagittata</i> (rambling dock) | y | g | n | n | 1 | Plant | <i>Allocasuarina portuensis</i> |
| <i>Ageratina adenophora</i> (crofton weed) | y | g | n | n | 12 | Plant | <i>Daphandra</i> sp. C Illawarra |
| | | | | | | Plant | <i>Brachyscome ascendens</i> |
| | | | | | | Plant | <i>Calystegia affinis</i> |
| | | | | | | Plant | <i>Carmichaelia exsul</i> |
| | | | | | | Plant | <i>Coprosma inopinata</i> |
| | | | | | | Plant | <i>Doryanthes palmeri</i> |
| | | | | | | Plant | <i>Geniostoma huttonii</i> |
| | | | | | | Plant | <i>Plectranthus alloplectus</i> |
| | | | | | | Plant | <i>Rapanea</i> sp. A Richmond River |
| | | | | | | Plant | <i>Sarcochilus hartmannii</i> |
| | | | | | | EEC | Illawarra subtropical rainforest |
| | | | | | | EEC | Swamp sclerophyll forest on the coastal floodplains |
| <i>Ageratina riparia</i> (mistflower) | y | g | n | n | 9 | Plant | <i>Brachyscome ascendens</i> |
| | | | | | | Plant | <i>Daphandra</i> sp. C Illawarra |
| | | | | | | Plant | <i>Doryanthes palmeri</i> |
| | | | | | | Plant | <i>Euphrasia bella</i> |
| | | | | | | Plant | <i>Irenepharsus trypherus</i> |
| | | | | | | Plant | <i>Rapanea</i> sp. A Richmond River |
| | | | | | | Plant | <i>Sarcochilus hartmannii</i> |
| | | | | | | Animal | <i>Dasyornis brachypterus</i> |
| EEC | Illawarra subtropical rainforest | | | | | | |
| <i>Ailanthus altissima</i> (tree of heaven) | y | g | n | n | 1 | Plant | <i>Zieria obcordata</i> |
| <i>Alternanthera philoxeroides</i> (alligator weed) | y | g | n | n | 1 | EEC | Freshwater wetlands on coastal floodplains |
| <i>Ambrosia artemisifolia</i> (annual ragweed) | n | w | n | n | 1 | EEC | Littoral rainforest |
| <i>Ammi majus</i> (bishop weed) | n | w | n | n | 1 | EEC | Native vegetation on cracking clay soils |

| Weed species identified as posing a threat to biodiversity in New South Wales ^a | Noxious listing ^b | Intro. source ^c | Availability for sale ^d | | Total biodiversity threatened | Type ^e | Biodiversity at risk ^f |
|--|------------------------------|----------------------------|------------------------------------|---|-------------------------------|-------------------|---|
| <i>Andropogon virginicus</i> (whiskey grass) | y | g | n | n | 5 | Plant | <i>Acacia pubescens</i> |
| | | | | | | Plant | <i>Angophora inopina</i> |
| | | | | | | Plant | <i>Prostanthera junonis</i> |
| | | | | | | EEC | Howell Shrublands |
| | | | | | | EEC | Swamp sclerophyll forest on the coastal floodplains |
| <i>Anredera cordifolia</i> (Madeira vine) | y | g | n | n | 7 | Plant | <i>Allocasuarina portuensis</i> |
| | | | | | | Plant | <i>Daphnandra</i> sp. C Illawarra |
| | | | | | | Plant | <i>Rapanea</i> sp. A Richmond River |
| | | | | | | Animal | <i>Cyclopsitta diophthalma coxeni</i> |
| | | | | | | EEC | Littoral rainforest |
| | | | | | | EEC | Riverflat eucalypt forest on coastal floodplains |
| <i>Anthoxanthum odoratum</i> (sweet vernal grass) | n | g | y | y | 2 | Plant | <i>Prasophyllum petilum</i> |
| | | | | | | EEC | Montane peatlands and swamps |
| <i>Aptenia cordifolia</i> (heartleaf ice plant) | n | g | y | y | 1 | Plant | <i>Acacia georgensis</i> |
| <i>Araujia sericiflora</i> (moth vine) | y | g | n | n | 6 | Plant | <i>Rapanea</i> sp. A Richmond River |
| | | | | | | Plant | <i>Solanum limitare</i> |
| | | | | | | EEC | Illawarra subtropical rainforest |
| | | | | | | EEC | Riverflat eucalypt forest on coastal floodplains |
| | | | | | | EEC | Sub-tropical coastal floodplain forest |
| EEC | Swamp-oak floodplain forest | | | | | | |
| <i>Arctotheca calendula</i> (Cape weed) | n | g | n | n | 1 | Plant | <i>Swainsona plagiotropis</i> |
| <i>Arecastrum romanzoffianum</i> (queen palm) | n | g | n | n | 1 | EEC | Littoral rainforest |
| <i>Aristolochia elegans</i> (Dutchman's pipe) | n | g | n | n | 1 | Animal | <i>Cyclopsitta diophthalma coxeni</i> |
| <i>Asparagus africanus</i> (asparagus fern) | n | w | n | n | 4 | Plant | <i>Rapanea</i> sp. A Richmond River |
| | | | | | | Animal | <i>Cyclopsitta diophthalma coxeni</i> |
| | | | | | | Animal | <i>Pterodroma nigripennis</i> |
| | | | | | | Animal | <i>Puffinus assimilus</i> |
| <i>Asparagus asparagoides</i> (bridal creeper) | y | g | n | n | 5 | Plant | <i>Pimelea spicata</i> |
| | | | | | | Animal | <i>Ocybadistes knightorum</i> |
| | | | | | | EEC | Riverflat eucalypt forest on coastal floodplains |
| | | | | | | EEC | Sub-tropical coastal floodplain forest |
| EEC | Swamp-oak floodplain forest | | | | | | |
| <i>Asparagus aethiopicus</i> (asparagus fern) | y | g | y | y | 3 | Plant | <i>Allocasuarina portuensis</i> |
| | | | | | | Plant | <i>Endiandra floydii</i> |
| | | | | | | Plant | <i>Desmodium acanthocladum</i> |

| Weed species identified as posing a threat to biodiversity in New South Wales ^a | Noxious listing ^b | Intro. source ^c | Availability for sale ^d Aust. NSW | Total biodiversity threatened | Type ^e | Biodiversity at risk ^f | |
|--|------------------------------|----------------------------|---|-------------------------------|----------------------------------|--|---|
| <i>Chrysanthemoides monilifera</i> (bitou bush/boneseed) [continued] | | | | | Plant | <i>Fontainea oraria</i> | |
| | | | | | Plant | <i>Geodorum densiflorum</i> | |
| | | | | | Plant | <i>Grevillea hilliana</i> | |
| | | | | | Plant | <i>Melaleuca groveana</i> | |
| | | | | | Plant | <i>Olax angulata</i> | |
| | | | | | Plant | <i>Phaius australis</i> | |
| | | | | | Plant | <i>Phaius tankarvilleae</i> | |
| | | | | | Plant | <i>Pimelea spicata</i> | |
| | | | | | Plant | <i>Prostanthera densa</i> | |
| | | | | | Plant | <i>Pterostylis</i> sp. 15 Botany Bay | |
| | | | | | Plant | <i>Pultenaea maritima</i> | |
| | | | | | Plant | <i>Senecio spathulatus</i> | |
| | | | | | Plant | <i>Senna acclinis</i> | |
| | | | | | Plant | <i>Sophora tomentosa</i> | |
| | | | | | Plant | <i>Syzygium moorei</i> | |
| | | | | | Plant | <i>Syzygium paniculatum</i> | |
| | | | | | Plant | <i>Tetratheca juncea</i> | |
| | | | | | Plant | <i>Thesium australe</i> | |
| | | | | | Plant | <i>Zieria granulata</i> | |
| | | | | | Plant | <i>Zieria prostrata</i> | |
| | | | | | Animal | <i>Dasyornis brachypterus</i> | |
| | | | | | Animal | <i>Nyctophilus bifax</i> | |
| | | | | | Animal | <i>Syconycteris australis</i> | |
| | | | | | Animal | <i>Phaethon rubricauda</i> | |
| | | | | | Popn | <i>Glycine clandestina</i> (broad leaf form) | |
| | | | | | Popn | <i>Phascolarctos cinereus</i> | |
| | | | | | Popn | <i>Zieria smithii</i> | |
| | | | | | EEC | Eastern suburbs banksia scrub | |
| | | | | | EEC | Kurnell dune forest | |
| | | | | | EEC | Kurri sand swamp woodland | |
| | | | | EEC | Littoral rainforest | | |
| | | | | EEC | Umina coastal sandplain woodland | | |
| <i>Cinnamomum camphora</i> (camphor laurel) | y | g | y | n | 11 | Plant | <i>Angiopteris evecta</i> |
| | | | | | | Plant | <i>Davidsonia jerseyana</i> |
| | | | | | | Plant | <i>Davidsonia johnsonii</i> |
| | | | | | | Plant | <i>Elaeocarpus williamsianus</i> |
| | | | | | | Plant | <i>Endiandra floydii</i> |
| | | | | | | Plant | <i>Endiandra muelleri</i> subsp. <i>bracteata</i> |
| | | | | | | Animal | <i>Cyclopsitta diophthalma coxeni</i> |
| | | | | | | EEC | Illawarra subtropical rainforest |
| | | | | | | EEC | Sub-tropical coastal floodplain forest |
| | | | | | | EEC | Swamp sclerophyll forest on the coastal floodplains |
| | | | | | | EEC | Swamp-oak floodplain forest |

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|--|------------------------------|----------------------------|---|---|-------------------------------|---|--|
| <i>Cirsium vulgare</i> (spear thistle) | n | w | n | n | 2 | EEC EEC | Montane peatlands and swamps Riverflat eucalypt forest on coastal floodplains |
| <i>Citrus limon</i> (bush lemon) | n | g | y | y | 1 | Plant | <i>Rapanea</i> sp. A Richmond River |
| <i>Conyza bonariensis</i> (flaxleaf fleabane) | n | w | n | n | 2 | EEC EEC | Montane peatlands and swamps Riverflat eucalypt forest on coastal floodplains |
| <i>Conyza sumatrensis</i> (tall fleabane) | n | w | n | n | 1 | EEC | Riverflat eucalypt forest on coastal floodplains |
| <i>Coprosma repens</i> (looking-glass bush) | n | g | y | y | 1 | EEC | Littoral rainforest |
| <i>Coreopsis lanceolata</i> (coreopsis) | n | g | y | n | 1 | EEC | Umina coastal sandplain woodland |
| <i>Cortaderia selloana</i> (pampas grass) | y | g | y | n | 2 | EEC EEC | Coastal saltmarsh Sydney freshwater wetlands |
| <i>Cyperus eragrostis</i> (umbrella sedge) | n | w | y | n | 1 | EEC | Swamp-oak floodplain forest |
| <i>Cytisus scoparius</i> (Scotch broom) | y | g | y | y | 12 | Plant Plant Plant Plant Plant Plant Plant Plant Animal Animal Popn EEC | <i>Callitris oblonga</i> <i>Chiloglottis platyptera</i> <i>Diuris venosa</i> <i>Epacris hamiltonii</i> <i>Euphrasia ciliolata</i> <i>Pterostylis cucullata</i> <i>Tasmannia glaucifolia</i> <i>Tasmannia purpurascens</i> <i>Mastacomys fuscus</i> <i>Paralucia spinifera</i> Broad-toothed Rat, <i>Mastacomys fuscus</i> , population at Barrington Tops Ben Halls Gap National Park sphagnum moss cool temperate rainforest |
| <i>Dactylis glomerata</i> (cocksfoot) | n | g | y | y | 1 | EEC | Montane peatlands and swamps |
| <i>Delairea odorata</i> (Cape ivy) | y | g | n | n | 4 | Plant Plant Plant EEC | <i>Allocasuarina portuensis</i> <i>Daphandra</i> sp. C Illawarra <i>Irenepharsus trypherus</i> Illawarra subtropical rainforest |
| <i>Duchesnia indica</i> (Indian strawberry) | n | g | n | n | 1 | Plant | <i>Calystegia affinis</i> |
| <i>Echinochloa crus-galli</i> (barnyard grass) | n | w | n | n | 1 | EEC | Freshwater wetlands on coastal floodplains |
| <i>Echinochloa polystachya</i> (aleman grass) | n | w | n | n | 1 | Animal | <i>Nettapus coromandelianus</i> |
| <i>Ehrharta erecta</i> (panic veldgrass) | n | w | n | n | 1 | EEC | Umina coastal sandplain woodland |

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|--|------------------------------|----------------------------|------------------------------------|-----|-------------------------------|---|--|
| | | | Aust. | NSW | | | |
| <i>Eichhornia crassipes</i> (water hyacinth) | y | g | n | n | 3 | Animal EEC EEC | <i>Nettapus coromandelianus</i> Freshwater wetlands on coastal floodplains Sydney freshwater wetlands |
| <i>Eragrostis curvula</i> (African lovegrass) | y | c | n | n | 9 | Plant Plant Plant Plant Plant EEC EEC EEC EEC | <i>Acacia georgensis</i> <i>Acacia pubescens</i> <i>Dichanthium setosum</i> <i>Polygala linariifolia</i> <i>Pultenaea pedunculata</i> Bega dry grass forest Eastern suburbs banksia scrub Elderslie banksia scrub forest community Howell Shrublands |
| <i>Erythrina crista-galli</i> (Indian coral tree) | y | g | y | y | 1 | Plant | <i>Angiopteris evecta</i> |
| <i>Genista monspessulana</i> (Cape broom) | y | g | n | n | 1 | EEC | Mount Gibraltar forest |
| <i>Gleditsia triacanthos</i> (honey locust) | n | c | y | n | 2 | Plant EEC | <i>Rapanea</i> sp. A Richmond River Riverflat eucalypt forest on coastal floodplains |
| <i>Gloriosa superba</i> (glory lily) | y | g | y | n | 1 | EEC | Littoral rainforest |
| <i>Hedera helix</i> (ivy) | n | g | y | y | 3 | Plant EEC EEC | <i>Epacris hamiltonii</i> Mount Gibraltar forest Robertson Rainforest |
| <i>Hedychium gardnerianum</i> (Kahili ginger) | n | g | y | y | 1 | EEC | Illawarra subtropical rainforest |
| <i>Holcus lanatus</i> (Yorkshire fog) | n | g | n | n | 4 | Plant Plant Plant EEC | <i>Prasophyllum petilum</i> <i>Prasophyllum uroglossum</i> <i>Pterostylis gibbosa</i> Montane peatlands and swamps |
| <i>Hydrocotyle bonariensis</i> (large-leaf pennywort) | n | w | y | y | 2 | EEC EEC | Coastal saltmarsh Swamp-oak floodplain forest |
| <i>Hygrophila costata</i> (glush weed) | n | w | n | n | 1 | EEC | Freshwater wetlands on coastal floodplains |
| <i>Hymanachne amplexicaulis</i> (olive hymanachne) | n | w | n | n | 1 | Animal | <i>Nettapus coromandelianus</i> |
| <i>Hypericum perforatum</i> (St John's wort) | y | g | y | n | 1 | Plant | <i>Pimelea spicata</i> |
| <i>Hyparrhenia hirta</i> (Coolatai grass) | n | w | n | n | 7 | Plant Plant Plant Plant Animal EEC EEC | <i>Dichanthium setosum</i> <i>Eucalyptus caleyi</i> subsp. <i>ovendenii</i> <i>Microtis angusii</i> <i>Polygala linariifolia</i> <i>Anomalopus mackayi</i> Fuzzy box woodland on alluvial soils Howell shrublands |

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|--|------------------------------|----------------------------|---|---|-------------------------------|-----------------------------|--|
| <i>Ilex aquifolium</i> (holly) | n | g | y | y | 1 | EEC | Robertson rainforest |
| <i>Impatiens walleriana</i> (busy lizzy) | n | g | y | n | 1 | EEC | Littoral rainforest |
| <i>Ipomoea cairica</i> (morning glory) | y | g | n | n | 4 | Animal EEC EEC EEC | <i>Dryococelus australis</i> Swamp sclerophyll forest on the coastal floodplains Swamp-oak floodplain forest Umina coastal sandplain woodland |
| <i>Juncus acutus</i> (spiny rush) | n | w | n | n | 2 | Plant EEC | <i>Wilsonia backhousei</i> Coastal saltmarsh |
| <i>Juncus articulatus</i> (jointed rush) | n | w | y | n | 1 | EEC | Montane peatlands and swamps |
| <i>Lantana camara</i> (lantana) | y | g | y | n | 96 | Plant | <i>Acacia bakeri</i> <i>Acacia chrysotricha</i> <i>Acalypha eremorum</i> <i>Acronychia littoralis</i> <i>Allocasuarina portuensis</i> <i>Amorphospermum whitei</i> <i>Angiopteris evecta</i> <i>Angophora robur</i> <i>Archidendron hendersonii</i> <i>Arthraxon hispidus</i> <i>Austromyrtus fragrantissima</i> <i>Baloghia marmorata</i> <i>Belvisia mucronata</i> <i>Boronia umbellata</i> <i>Bosistoa selwynii</i> <i>Bosistoa transversa</i> <i>Calophanoides hygrophiloides</i> <i>Cassia brewsteri</i> var. <i>marksiana</i> <i>Clematis fawcettii</i> <i>Corynocarpus rupestris</i> subsp. <i>rupestris</i> <i>Cryptocarya foetida</i> <i>Cynanchum elegans</i> <i>Cyperus semifertilis</i> <i>Daphnandra</i> sp. C Illawarra <i>Davidsonia jerseyana</i> <i>Davidsonia johnsonii</i> <i>Desmodium acanthocladum</i> <i>Diospyros mabacea</i> <i>Diospyros major</i> var. <i>ebenus</i> <i>Diploglottis campbellii</i> <i>Doryanthes palmeri</i> <i>Drynaria rigidula</i> <i>Eidothea hunteriana</i> <i>Elaeocarpus</i> sp. Rocky Creek <i>Elaeocarpus williamsianus</i> <i>Endiandra floydii</i> |

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|--|------------------------------|----------------------------|--|-------------------------------|-------------------|---|
| <i>Lantana camara</i> (lantana) | | | | | Plant | <i>Endiandra hayesii</i> |
| [continued] | | | | | Plant | <i>Endiandra muelleri</i> subsp. <i>bracteata</i> |
| | | | | | Plant | <i>Eucalyptus glaucina</i> |
| | | | | | Plant | <i>Eucalyptus parramattensis</i> subsp. <i>decadens</i> |
| | | | | | Plant | <i>Eucalyptus tetrapleura</i> |
| | | | | | Plant | <i>Fontainea australis</i> |
| | | | | | Plant | <i>Fontainea oraria</i> |
| | | | | | Plant | <i>Geijera paniculata</i> |
| | | | | | Plant | <i>Hibbertia procumbens</i> |
| | | | | | Plant | <i>Hicksbeachia pinnatifolia</i> |
| | | | | | Plant | <i>Irenepharsus trypherus</i> |
| | | | | | Plant | <i>Isoglossa eranthemoides</i> |
| | | | | | Plant | <i>Lepiderema pulchella</i> |
| | | | | | Plant | <i>Macadamia tetraphylla</i> |
| | | | | | Plant | <i>Macrozamia johnsonii</i> |
| | | | | | Plant | <i>Marsdenia longiloba</i> |
| | | | | | Plant | <i>Melichrus hirsutus</i> |
| | | | | | Plant | <i>Melichrus</i> sp. Gibberagee |
| | | | | | Plant | <i>Melicope vitiflora</i> |
| | | | | | Plant | <i>Niemeyera chartacea</i> |
| | | | | | Plant | <i>Ochrosia moorei</i> |
| | | | | | Plant | <i>Owenia cepiodora</i> |
| | | | | | Plant | <i>Parsonsia dorrigoensis</i> |
| | | | | | Plant | <i>Phaius australis</i> |
| | | | | | Plant | <i>Phaius tankarvilleae</i> |
| | | | | | Plant | <i>Phyllanthus microcladus</i> |
| | | | | | Plant | <i>Plectranthus alloplectus</i> |
| | | | | | Plant | <i>Plectranthus nitidus</i> |
| | | | | | Plant | <i>Polygala linariifolia</i> |
| | | | | | Plant | <i>Pomaderris queenslandica</i> |
| | | | | | Plant | <i>Pterostylis gibbosa</i> |
| | | | | | Plant | <i>Quassia</i> sp. Mooney Creek |
| | | | | | Plant | <i>Randia moorei</i> |
| | | | | | Plant | <i>Rapanea</i> sp. A Richmond River |
| | | | | | Plant | <i>Rhynchosia acuminatissima</i> |
| | | | | | Plant | <i>Senna acclinis</i> |
| | | | | | Plant | <i>Solanum celatum</i> |
| | | | | | Plant | <i>Solanum limitare</i> |
| | | | | | Plant | <i>Sophora fraseri</i> |
| | | | | | Plant | <i>Syzygium paniculatum</i> |
| | | | | | Plant | <i>Tinospora smilacina</i> |
| | | | | | Plant | <i>Tinospora tinosporoides</i> |
| | | | | | Plant | <i>Triplarina imbricata</i> |
| | | | | | Plant | <i>Tylophora linearis</i> |
| | | | | | Plant | <i>Tylophora woollsii</i> |
| | | | | | Plant | <i>Typhonium</i> sp. aff. <i>Brownii</i> |
| | | | | | Plant | <i>Zieria prostrata</i> |

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|--|------------------------------|----------------------------|---|---|-------------------------------|---|---|
| <i>Lantana camara</i> (lantana) [continued] | | | | | | Animal | <i>Ocybadistes knightorum</i> |
| | | | | | | Animal | <i>Dasyornis brachypterus</i> |
| | | | | | | EEC | Eastern suburbs banksia scrub |
| | | | | | | EEC | Illawarra subtropical rainforest |
| | | | | | | EEC | Littoral rainforest |
| | | | | | | EEC | Lower Hunter spotted gum – Ironbark forest |
| | | | | | | EEC | Lowland Rainforest on floodplain |
| | | | | | | EEC | Pittwater spotted gum forest |
| | | | | | | EEC | Riverflat eucalypt forest on coastal floodplains |
| | | | | | | EEC | Sub-tropical coastal floodplain forest |
| | | | | | | EEC | Swamp sclerophyll forest on the coastal floodplains |
| | | | | | | EEC | Swamp-oak floodplain forest |
| | | | | | | EEC | Umina coastal sandplain woodland |
| <i>Ligustrum lucidum</i> (large-leaved privet) | y | g | n | n | 4 | Animal | <i>Cyclopsitta diophthalma coxeni</i> |
| | | | | | | EEC | Illawarra subtropical rainforest |
| | | | | | | EEC | Riverflat eucalypt forest on coastal floodplains |
| | | | | | | EEC | Sub-tropical coastal floodplain forest |
| <i>Ligustrum sinense</i> (small-leaved privet) | y | g | y | n | 11 | Plant | <i>Elaeocarpus williamsianus</i> |
| | | | | | | Plant | <i>Endiandra floydii</i> |
| | | | | | | Plant | <i>Rapanea</i> sp. A Richmond River |
| | | | | | | Plant | <i>Triplarina imbricata</i> |
| | | | | | | Plant | <i>Tylophora linearis</i> |
| | | | | | | Animal | <i>Cyclopsitta diophthalma coxeni</i> |
| | | | | | | EEC | Illawarra subtropical rainforest |
| | | | | | | EEC | Riverflat eucalypt forest on coastal floodplains |
| | | | | | | EEC | Robertson rainforest |
| | | | | | | EEC | Sub-tropical coastal floodplain forest |
| | | | | | EEC | Swamp sclerophyll forest on the coastal floodplains | |
| <i>Lilium formosanum</i> (Formosa lily) | y | g | y | n | 4 | Plant | <i>Carmichaelia exsul</i> |
| | | | | | | Plant | <i>Coprosma inopinata</i> |
| | | | | | | Plant | <i>Geniostoma huttonii</i> |
| | | | | | | Plant | <i>Solanum limitare</i> |
| <i>Lolium perenne</i> (perennial ryegrass) | n | g | n | n | 2 | Plant | <i>Swainsona plagiotropis</i> |
| | | | | | | EEC | Fuzzy box woodland on alluvial soils |
| <i>Lonicera japonica</i> (Japanese honeysuckle) | n | g | y | y | 5 | Plant | <i>Acacia pubescens</i> |
| | | | | | | EEC | Riverflat eucalypt forest on coastal floodplains |

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|--|------------------------------|----------------------------|---|---|-------------------------------|-------------------|---|
| <i>Lonicera japonica</i> (Japanese honeysuckle) [continued] | | | | | | EEC | Robertson rainforest |
| | | | | | | EEC | Sub-tropical coastal floodplain forest |
| | | | | | | EEC | Swamp sclerophyll forest on the coastal floodplains |
| <i>Lotus uliginosis</i> (lotus) | n | w | n | n | 1 | EEC | Montane peatlands and swamps |
| <i>Ludwigia longifolia</i> (ludwigia) | n | w | y | n | 1 | EEC | Freshwater wetlands on coastal floodplains |
| <i>Ludwigia peruviana</i> (ludwigia) | y | g | n | n | 3 | EEC | Freshwater wetlands on coastal floodplains |
| | | | | | | EEC | Swamp sclerophyll forest on the coastal floodplains |
| | | | | | | EEC | Sydney freshwater wetlands |
| <i>Lycium ferocissimum</i> (African boxthorn) | y | g | n | n | 5 | EEC | Carbeen open forest community |
| | | | | | | EEC | Coolibah-Blackbox woodland |
| | | | | | | EEC | Hunter lowland redgum forest |
| | | | | | | EEC | O'Hares Creek shale forest |
| | | | | | | EEC | Southern highlands shale woodlands |
| <i>Macfadyena unguis-cati</i> (cat's claw creeper) | y | g | y | n | 4 | Plant | <i>Phyllanthus microcladus</i> |
| | | | | | | Animal | <i>Cyclopsitta diophthalma coxeni</i> |
| | | | | | | EEC | Littoral rainforest |
| | | | | | | EEC | Riverflat eucalypt forest on coastal floodplains |
| <i>Marrubium vulgare</i> (horehound) | y | g | y | n | 1 | EEC | Fuzzy box woodland on alluvial soils |
| <i>Nassella trichotoma</i> (serrated tussock grass) | y | g | n | n | 2 | Plant | <i>Gentiana baeuerlenii</i> |
| | | | | | | Plant | <i>Geodorum densiflorum</i> |
| <i>Nymphaea caerulea</i> (Cape waterlily) | n | w | y | y | 1 | EEC | Freshwater wetlands on coastal floodplains |
| <i>Ochna serrulata</i> (mickey mouse plant) | y | g | n | n | 1 | Animal | <i>Cyclopsitta diophthalma coxeni</i> |
| <i>Olea europaea</i> (African olive) | y | g | y | y | 5 | Plant | <i>Acacia pubescens</i> |
| | | | | | | EEC | Illawarra subtropical rainforest |
| | | | | | | EEC | Riverflat eucalypt forest on coastal floodplains |
| | | | | | | EEC | Sub-tropical coastal floodplain forest |
| | | | | | | EEC | Western Sydney dry rainforest |
| <i>Panicum repens</i> (torpedo grass) | n | w | n | n | 1 | EEC | Freshwater wetlands on coastal floodplains |
| <i>Parapholis incurva</i> (curved sickle-grass) | n | w | n | n | 1 | EEC | Coastal saltmarsh |
| <i>Paspalum dilatatum</i> (paspalum) | n | c | n | n | 8 | Plant | <i>Acacia pubescens</i> |
| | | | | | | Plant | <i>Pultenaea pedunculata</i> |
| | | | | | | Animal | <i>Synemon plana</i> |
| | | | | | | EEC | Fuzzy box woodland on alluvial soils |

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|--|------------------------------|----------------------------|--|---|-------------------------------|-------------------|--|
| <i>Paspalum dilatatum</i> (paspalum) [continued] | | | | | | EEC | Montane peatlands and swamps |
| | | | | | | EEC | Riverflat eucalypt forest on coastal floodplains |
| | | | | | | EEC | Sub-tropical coastal floodplain forest |
| | | | | | | EEC | Swamp-oak floodplain forest |
| <i>Paspalum urvillei</i> (paspalum) | n | c | n | n | 2 | EEC | Riverflat eucalypt forest on coastal floodplains |
| | | | | | | EEC | Umina coastal sandplain woodland |
| <i>Paspalum wittsteinii</i> (broad-leaf paspalum) | n | w | n | n | 1 | Animal | <i>Ocybadistes knightorum</i> |
| <i>Passiflora suberosa</i> (corky passionfruit) | n | g | n | n | 1 | Plant | <i>Rapanea</i> sp. A Richmond River |
| <i>Passiflora subpeltata</i> (passionflower) | n | g | n | n | 1 | EEC | Illawarra subtropical rainforest |
| <i>Pennisetum clandestinum</i> (kikuyu) | n | g | n | n | 16 | Plant | <i>Acacia pubescens</i> |
| | | | | | | Plant | <i>Arthraxon hispidus</i> |
| | | | | | | Plant | <i>Caesalpinia bonduc</i> |
| | | | | | | Plant | <i>Calystegia affinis</i> |
| | | | | | | Plant | <i>Carmichaelia exsul</i> |
| | | | | | | Plant | <i>Pimelea spicata</i> |
| | | | | | | Plant | <i>Pultenaea pedunculata</i> |
| | | | | | | Plant | <i>Zieria prostrata</i> |
| | | | | | | Animal | <i>Puffinus carneipes</i> |
| | | | | | | Popn | <i>Zieria smithii</i> |
| | | | | | | EEC | Bega dry grass forest |
| | | | | | | EEC | Freshwater wetlands on coastal floodplains |
| | | | | | | EEC | Littoral rainforest |
| | | | | | | EEC | Riverflat eucalypt forest on coastal floodplains |
| | | | | | | EEC | Sub-tropical coastal floodplain forest |
| | | | | | | EEC | Swamp-oak floodplain forest |
| <i>Pennisetum villosum</i> (feather grass) | y | g | n | n | 1 | EEC | Umina coastal sandplain woodland |
| <i>Phalaris aquatica</i> (bulbous canary grass) | n | w | n | n | 2 | Plant | <i>Swainsona plagiotropis</i> |
| | | | | | | Animal | <i>Synemon plana</i> |
| <i>Phyla canescens</i> (lippia) | y | w | n | n | 1 | EEC | Coolibah-Blackbox woodland |
| <i>Physalis peruviana</i> (Cape gooseberry) | n | w | y | y | 1 | Plant | <i>Rapanea</i> sp. A Richmond River |
| <i>Pinus radiata</i> (white pine) | n | g | y | y | 3 | Plant | <i>Callitris oblonga</i> |
| | | | | | | Plant | <i>Eucalyptus canobolensis</i> |
| | | | | | | EEC | Montane peatlands and swamps |
| <i>Plantago coronopus</i> (buckhorn plantain) | n | g | y | y | 1 | EEC | Coastal saltmarsh |

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|--|------------------------------|----------------------------|---|---|-------------------------------|-------------------|--|
| <i>Plantago lanceolata</i> (narrow-leaf plantain) | n | g | y | n | 2 | EEC | Fuzzy box woodland on alluvial soils |
| | | | | | | EEC | Riverflat eucalypt forest on coastal floodplains |
| <i>Polypogon monspeliensis</i> (rabbitsfoot grass) | n | w | n | n | 1 | EEC | Coastal saltmarsh |
| <i>Propolis pallida</i> (mesquite) | y | w | n | n | 1 | Plant | <i>Aponogeton queenslandicus</i> |
| <i>Psidium cattleianum</i> (cherry guava) | y | g | y | y | 1 | Plant | <i>Carmichaelia exsul</i> |
| <i>Ranunculus repens</i> (creeping buttercup) | n | g | y | y | 1 | EEC | Montane peatlands and swamps |
| <i>Rivina humilis</i> (pidgeonberry) | n | g | n | n | 2 | Animal | <i>Cyclopsitta diophthalma coxeni</i> |
| | | | | | | EEC | Littoral rainforest |
| <i>Rosa rubiginosa</i> (briar rose) | y | g | y | n | 2 | Plant | <i>Discaria nitida</i> |
| | | | | | | Animal | <i>Paralucia spinifera</i> |
| <i>Rubus fruticosus</i> (blackberry) | y | g | n | n | 21 | Plant | <i>Acacia clunies-rossiae</i> |
| | | | | | | Plant | <i>Acacia pubescens</i> |
| | | | | | | Plant | <i>Callitris oblonga</i> |
| | | | | | | Plant | <i>Discaria nitida</i> |
| | | | | | | Plant | <i>Epacris hamiltonii</i> |
| | | | | | | Plant | <i>Eucalyptus canobolensis</i> |
| | | | | | | Plant | <i>Euphrasia scabra</i> |
| | | | | | | Plant | <i>Gentiana wingecarribiensis</i> |
| | | | | | | Plant | <i>Grevillea rivularis</i> |
| | | | | | | Plant | <i>Grevillea scortechinii</i> subsp. <i>sarmentosa</i> |
| | | | | | | Plant | <i>Haloragis exalata</i> subsp. <i>velutina</i> |
| | | | | | | Plant | <i>Pimelea spicata</i> |
| | | | | | | Plant | <i>Prasophyllum uroglossum</i> |
| | | | | | | Plant | <i>Pterostylis gibbosa</i> |
| | | | | | | Animal | <i>Litoria spenceri</i> |
| | | | | | | Animal | <i>Paralucia spinifera</i> |
| | | | | | | Animal | <i>Pseudophryne pengilleyi</i> |
| | | | | | | EEC | Montane peatlands and swamps |
| | | | | | | EEC | Riverflat eucalypt forest on coastal floodplains |
| | | | | | | EEC | Sub-tropical coastal floodplain forest |
| | | | | | | EEC | Swamp-oak floodplain forest |
| <i>Salvinia molesta</i> (salvinia) | y | g | n | n | 2 | EEC | Freshwater wetlands on coastal floodplains |
| | | | | | | EEC | Sydney freshwater wetlands |
| <i>Schefflera actinophylla</i> (umbrella plant) | n | g | y | y | 1 | EEC | Littoral rainforest |
| <i>Senecio madagascariensis</i> (fireweed) | y | w | n | n | 4 | Plant | <i>Polystichum moorei</i> |
| | | | | | | Plant | <i>Prostanthera junonis</i> |
| | | | | | | EEC | Riverflat eucalypt forest on coastal floodplains |
| | | | | | | EEC | Sub-tropical coastal floodplain forest |

| Weed species identified as posing a threat to biodiversity in New South Wales ^a | Noxious listing ^b | Intro. source ^c | Availability for sale ^d | | Total biodiversity threatened | Type ^e | Biodiversity at risk ^f |
|--|------------------------------|----------------------------|------------------------------------|-----|-------------------------------|---|---|
| | | | Aust. | NSW | | | |
| <i>Senna pendula</i> var. <i>glabrata</i> (senna) | y | g | n | n | 1 | EEC | Riverflat eucalypt forest on coastal floodplains |
| <i>Senna septemtrionalis</i> (senna) | n | g | n | n | 3 | Plant Plant EEC | <i>Pomaderris queenslandica</i> <i>Rapanea</i> sp. A Richmond River Littoral rainforest |
| <i>Setaria parviflora</i> (slender pigeon grass) | n | w | n | n | 2 | EEC EEC | Riverflat eucalypt forest on coastal floodplains Sub-tropical coastal floodplain |
| <i>Sida rhombifolia</i> (paddy's lucerne) | n | g | n | n | 4 | Plant Plant EEC EEC | <i>Acacia pubescens</i> <i>Pultenaea pedunculata</i> Riverflat eucalypt forest on coastal floodplains Sub-tropical coastal floodplain forest |
| <i>Solanum dulcamara</i> (climbing nightshade) | n | c | y | y | 1 | Plant | <i>Rapanea</i> sp. A Richmond River |
| <i>Solanum mauritianum</i> (nightshade) | n | g | n | n | 4 | EEC EEC EEC EEC | Illawarra subtropical rainforest Littoral rainforest Lower Hunter spotted gum – Ironbark forest Sub-tropical coastal floodplain forest |
| <i>Solanum nigrum</i> (black nightshade) | n | g | n | n | 3 | Plant EEC EEC | <i>Carmichaelia exsul</i> Sub-tropical coastal floodplain forest Swamp-oak floodplain forest |
| <i>Solanum pseudocapsicum</i> (Madeira winter cherry) | n | g | n | n | 1 | EEC | Swamp-oak floodplain forest |
| <i>Solanum seforthianum</i> (Brazilian nightshade) | n | g | y | y | 1 | Plant | <i>Rapanea</i> sp. A Richmond River |
| <i>Sonchus oleraceus</i> (common sowthistle) | n | g | n | n | 1 | EEC | Riverflat eucalypt forest on coastal floodplains |
| <i>Sporobolus fertilis</i> (Parramatta grass) | y | w | n | n | 2 | Plant Popn | <i>Zieria prostrata</i> <i>Zieria smithii</i> |
| <i>Stenotaphrum secundatum</i> (buffalo grass) | n | c | y | y | 2 | Plant Plant | <i>Caesalpinia bonduc</i> <i>Calystegia affinis</i> |
| <i>Taraxacum officinale</i> (dandelion) | n | g | y | y | 1 | EEC | Montane peatlands and swamps |
| <i>Thunbergia alata</i> (black-eyed susan vine) | n | g | y | n | 1 | EEC | Littoral rainforest |
| <i>Tradescantia fluminensis</i> (tradescantia) | y | g | n | n | 8 | Plant Plant Animal EEC EEC EEC EEC EEC | <i>Allocasuarina portuensis</i> <i>Rapanea</i> sp. A Richmond River <i>Cyclopsitta diophthalma coxeni</i> Illawarra subtropical rainforest Littoral rainforest Riverflat eucalypt forest on coastal floodplains Sub-tropical coastal floodplain forest Swamp-oak floodplain forest |

| Weed species identified as posing a threat to biodiversity in New South Wales ^a | Noxious listing ^b | Intro. source ^c | Availability for sale ^d Aust. NSW | | Total biodiversity threatened | Type ^e | Biodiversity at risk ^f |
|--|------------------------------|----------------------------|---|---|-------------------------------|-------------------|--|
| <i>Verbena bonariensis</i> (purpletop) | n | g | y | n | 4 | EEC | Fuzzy box woodland on alluvial soils |
| | | | | | | EEC | Riverflat eucalypt forest on coastal floodplains |
| | | | | | | EEC | Sub-tropical coastal floodplain forest |
| | | | | | | EEC | Swamp-oak floodplain forest |
| <i>Vicia sativa</i> (spring vetch) | n | w | n | n | 1 | Plant | <i>Calystegia affinis</i> |
| <i>Vulpia myuros</i> (rat-tailed fescue) | n | w | n | n | 1 | EEC | Fuzzy box woodland on alluvial soils |
| <i>Xanthium occidentale</i> (Noogoora burr) | y | w | n | n | 1 | Plant | <i>Aponogeton queenslandicus</i> |

- a Weed species posing a threat to biodiversity as identified in the data set (see Chapter 2 for further details). Weed species are presented in alphabetical order in scientific name (common name) format.
- b An assessment of whether the weed species was listed under the NSW *Noxious Weeds Act 1993*, as at March 1, 2006, where y = yes and n = no.
- c The introduction source for each weed species was determined using Randall (2002: see Chapter 6 for further details). Categories are as described by Randall (2002), being:
g = Garden escape – species known to have escaped from gardens directly or through dumping of garden waste
w = Weed – term used when no evidence exists of escape from garden or cultivation
c = Cultivation – may have escaped from gardens or cultivation ie agricultural crop or pasture species.
- d The availability for sale of each of the 127 weed species identified were assessed using Hibbert (2004: see Chapter 6 for further details). Each weed species was assessed for availability for sale in NSW and Australia (Aust.), where y = yes and n = no.
- e The type of biodiversity is described as: Plant = plant species, Animal = animal species, Popn = Threatened Population, and EEC = Endangered Ecological Community, based on listings under the TSC and FM Acts (see below).
- f Biodiversity as listed on Schedules 1 and 2 of the TSC Act and 4 and 5 of the FM Act, as at January 1, 2005 (ie species, populations and ecological communities). TSC Act refers to the NSW *Threatened Species Conservation Act 1995* and the FM Act to the NSW *Fisheries Management Act 1994*.

Table C Weed threats identified only to genus in the data set that were impacting on threatened biodiversity in New South Wales and the biodiversity identified as at risk

| Weed genus identified as posing a threat to biodiversity in New South Wales ^a | Total biodiversity threatened | Type ^e | Biodiversity at risk ^f |
|--|-------------------------------|-------------------|--|
| <i>Asparagus</i> spp. | 1 | EEC | Littoral rainforest |
| <i>Avena</i> spp. | 1 | Animal | <i>Synemon plana</i> |
| <i>Axonopus</i> spp. | 1 | EEC | Sub-tropical coastal floodplain forest |
| <i>Berberis</i> spp. | 1 | EEC | Mount Gibraltar forest |
| <i>Briza</i> spp. | 1 | Plant | <i>Caladenia concolor</i> |
| <i>Cenchrus</i> spp. | 4 | EEC | Carbeen open forest community |
| | | EEC | Hunter lowland redgum forest |
| | | EEC | O'Hares creek shale forest |
| | | EEC | Southern highlands shale woodlands |
| <i>Conyza</i> spp. | 2 | EEC | Sub-tropical coastal floodplain forest |
| | | EEC | Swamp-oak floodplain forest |
| <i>Cotoneaster</i> spp. | 1 | Animal | <i>Paralucia spinifera</i> |
| <i>Crataegus</i> spp. | 1 | Animal | <i>Paralucia spinifera</i> |
| <i>Ehrharta</i> spp. | 1 | EEC | Littoral rainforest |
| <i>Gamochaeta</i> spp. | 1 | Plant | <i>Calystegia affinis</i> |
| <i>Glycine</i> spp. | 1 | Plant | <i>Rapanea</i> sp. A Richmond River |
| <i>Holcus</i> spp. | 1 | Plant | <i>Gentiana wingecarribiensis</i> |
| <i>Hypochaeris</i> spp. | 1 | Plant | <i>Swainsona plagiotropis</i> |
| <i>Ipomoea</i> spp. | 3 | EEC | Littoral rainforest |
| | | EEC | Riverflat eucalypt forest on coastal floodplains |
| | | EEC | Sub-tropical coastal floodplain forest |
| <i>Ligustrum</i> spp. | 1 | Plant | <i>Pterostylis gibbosa</i> |
| <i>Lonicera</i> spp. | 1 | EEC | Mount Gibraltar forest |
| <i>Opuntia</i> spp. | 7 | Plant | <i>Acacia pubescens</i> |
| | | Plant | <i>Lepidium aschersonii</i> |
| | | Plant | <i>Pterostylis gibbosa</i> |
| | | EEC | Carbeen open forest community |
| | | EEC | Hunter lowland redgum forest |
| | | EEC | O'Hares creek shale forest |
| | | EEC | Southern highlands shale woodlands |
| <i>Paspalum</i> spp. | 3 | Plant | <i>Arthraxon hispidus</i> |
| | | Plant | <i>Calophanoides hygrophiloides</i> |
| | | Plant | <i>Calystegia affinis</i> |
| <i>Pyracantha</i> spp. | 1 | EEC | Mount Gibraltar forest |
| <i>Salix</i> spp. | 3 | Plant | <i>Discaria nitida</i> |
| | | Animal | <i>Litoria booroolongensis</i> |
| | | EEC | Montane peatlands and swamps |
| <i>Senna</i> spp. | 2 | Plant | <i>Pterostylis gibbosa</i> |
| | | EEC | Illawarra subtropical rainforest |
| <i>Trifolium</i> spp. | 1 | Plant | <i>Swainsona plagiotropis</i> |
| <i>Verbena</i> spp. | 2 | Plant | <i>Calystegia affinis</i> |
| | | Plant | <i>Pultenaea pedunculata</i> |
| <i>Vulpia</i> spp. | 1 | Plant | <i>Caladenia arenaria</i> |

Footnotes as per Table B with the exception of the following:

- a Weed genera posing a threat to biodiversity as identified in the data set (see Chapter 2 for further details). Weed genera are presented in alphabetical order in scientific name format.

Table D 'Weedy' native species identified in the data set that were impacting on threatened biodiversity in New South Wales, and the biodiversity identified as at risk

| Weedy native species identified as posing a threat to biodiversity in New South Wales ^a | Noxious listing ^b | Intro. source ^c | Availability for sale ^d | | Total biodiversity threatened | Type ^e | Biodiversity at risk ^f |
|---|-------------------------------------|-----------------------------------|---|------------|--------------------------------------|--------------------------|---|
| | | | Aust. | NSW | | | |
| <i>Acacia saligna</i> (golden wreath wattle) | n | g | y | y | 2 | Plant EEC | <i>Microtis angusii</i> Pittwater spotted gum forest |
| <i>Callitris glaucophylla</i> (white cypress pine) | n | na | y | y | 1 | Plant | <i>Hakea pulvinifera</i> |
| <i>Lythrum salicaria</i> (purple loosestrife) | n | g ^g | y | y | 1 | Plant | <i>Euphrasia scabra</i> |
| <i>Pittosporum undulatum</i> (sweet pittosporum) | y | g ^g | y | y | 1 | Plant | <i>Pterostylis gibbosa</i> |

Footnotes as per Table B with the exception of the following:

na: native in NSW and not expanding its range dramatically.

a Weedy native species posing a threat to biodiversity as identified in the data set (see Chapter 2 for further details). Weedy native species are presented in alphabetical order in scientific name (common name) format.

g While native in New South Wales these species have also been sold in the state.

Table E Weed threats identified in the data set as general groups only, that were impacting on threatened biodiversity in New South Wales, and the biodiversity identified as at risk

| General groups of weed threats identified as posing a threat to biodiversity in New South Wales ^a | Total biodiversity threatened | Type ^e | Biodiversity at risk ^f |
|---|--------------------------------------|---|--|
| aquatics | 2 | Plant Plant | <i>Acacia clunies-rossiae</i> <i>Aldrovandra vesiculosa</i> |
| exotic grasses | 12 | Plant Plant Plant Plant Plant Plant Plant Plant Plant Plant Plant Animal | <i>Austrostipa wakoolica</i> <i>Eleocharis tetraquetra</i> <i>Grevillea banyabba</i> <i>Grevillea masonii</i> <i>Hedyotis galioides</i> <i>Lepidium aschersonii</i> <i>Melaleuca tamariscina</i> subsp. <i>irbyana</i> <i>Rutidosis leptorrhynchoides</i> <i>Solanum limitare</i> <i>Swainsona recta</i> <i>Zieria obcordata</i> <i>Irediparra gallinacea</i> |
| exotic vines | 1 | EEC | Lowland rainforest on floodplain |

Footnotes as per Table B with the exception of the following:

a These weed threats were identified as general groups only and are not an amalgamation of all the species in these groups within the data set.

The impact of weeds on threatened species

The number of weed species threatening each threatened species in New South Wales encompassed the full gamut of weed threats identified, for example those identified to species (eg *Dactylis glomerata*), genus (eg *Briza* spp.), a group of weeds (eg introduced grasses), or weeds generally. The total number of threatened species at risk, as posing at January 1, 2005 was 419, and the total number of weeds identified was 127. Table F outlines the threatened species ($n = 204$) at risk from specific weed species, and Table G outlines the threatened species ($n = 215$) at risk from a generic weed threat.

Table F The number of weed species identified as posing a threat for each threatened species

| Type ^a | Threatened species ^b | Number of weed threats ^c |
|-------------------|---|-------------------------------------|
| Plant species | <i>Acacia bakeri</i> | 1 |
| | <i>Acacia chrysotricha</i> | 1 |
| | <i>Acacia clunies-rossiae</i> | 2 |
| | <i>Acacia georgensis</i> | 3 |
| | <i>Acacia pubescens</i> | 10 |
| | <i>Acacia terminalis</i> | 1 |
| | <i>Acalypha eremorum</i> | 1 |
| | <i>Acronychia littoralis</i> | 2 |
| | <i>Aldrovandra vesiculosa</i> | 1 |
| | <i>Allocasuarina defungens</i> | 1 |
| | <i>Allocasuarina portuensis</i> | 6 |
| | <i>Allocasuarina simulans</i> | 1 |
| | <i>Amorphospermum whitei</i> | 1 |
| | <i>Angiopteris evecta</i> | 3 |
| | <i>Angophora inopina</i> | 1 |
| | <i>Angophora robur</i> | 1 |
| | <i>Aponogeton queenslandicus</i> | 2 |
| | <i>Archidendron hendersonii</i> | 1 |
| | <i>Arthraxon hispidus</i> | 3 |
| | <i>Austromyrtus fragrantissima</i> | 1 |
| | <i>Austrostipa wakoolica</i> | 1 |
| | <i>Baloghia marmorata</i> | 1 |
| | <i>Belvisia mucronata</i> | 1 |
| | <i>Boronia umbellata</i> | 1 |
| | <i>Bosistoa selwynii</i> | 1 |
| | <i>Bosistoa transversa</i> | 1 |
| | <i>Brachyscome ascendens</i> | 2 |
| | <i>Caesalpinia bonduc</i> | 2 |
| | <i>Caladenia arenaria</i> | 2 |
| | <i>Caladenia concolor</i> | 1 |
| | <i>Caladenia tessellata</i> | 1 |
| | <i>Callitris oblonga</i> | 3 |
| | <i>Calophanoides hygrophiloides</i> | 2 |
| | <i>Calystegia affinis</i> | 8 |
| | <i>Carmichaelia exsul</i> | 6 |
| | <i>Cassia brewsteri</i> var. <i>marksiana</i> | 1 |
| | <i>Casuarina obesa</i> | 1 |

| Type ^a | Threatened species ^b | Number of weed threats ^c |
|---------------------------|---|-------------------------------------|
| Plant species [continued] | <i>Chamaesyce psammogeton</i> | 1 |
| | <i>Chiloglottis platyptera</i> | 1 |
| | <i>Clematis fawcettii</i> | 1 |
| | <i>Coprosma inopinata</i> | 2 |
| | <i>Corynocarpus rupestris</i> subsp. <i>rupestris</i> | 1 |
| | <i>Cryptocarya foetida</i> | 2 |
| | <i>Cryptostylis hunteriana</i> | 1 |
| | <i>Cynanchum elegans</i> | 2 |
| | <i>Cyperus semifertilis</i> | 1 |
| | <i>Daphnandra</i> sp. C Illawarra | 5 |
| | <i>Davidsonia jerseyana</i> | 2 |
| | <i>Davidsonia johnsonii</i> | 2 |
| | <i>Desmodium acanthocladum</i> | 2 |
| | <i>Dichanthium setosum</i> | 2 |
| | <i>Diospyros mabacea</i> | 1 |
| | <i>Diospyros major</i> var. <i>ebenus</i> | 1 |
| | <i>Diploglottis campbellii</i> | 1 |
| | <i>Discaria nitida</i> | 3 |
| | <i>Diuris praecox</i> | 1 |
| | <i>Diuris</i> sp. aff. <i>chrysantha</i> | 1 |
| | <i>Diuris venosa</i> | 1 |
| | <i>Doryanthes palmeri</i> | 3 |
| | <i>Drynaria rigidula</i> | 1 |
| | <i>Eidothea hunteriana</i> | 1 |
| | <i>Elaeocarpus</i> sp. Rocky Creek | 1 |
| | <i>Elaeocarpus williamsianus</i> | 3 |
| | <i>Eleocharis tetraquetra</i> | 1 |
| | <i>Endiandra floydii</i> | 4 |
| | <i>Endiandra hayesii</i> | 1 |
| | <i>Endiandra muelleri</i> subsp. <i>bracteata</i> | 2 |
| | <i>Epacris hamiltonii</i> | 3 |
| | <i>Eucalyptus caleyi</i> subsp. <i>ovendenii</i> | 1 |
| | <i>Eucalyptus camfieldii</i> | 1 |
| | <i>Eucalyptus canobolensis</i> | 2 |
| | <i>Eucalyptus glaucina</i> | 1 |
| | <i>Eucalyptus parramattensis</i> subsp. <i>decadens</i> | 2 |
| | <i>Eucalyptus tetrapleura</i> | 1 |
| | <i>Euphrasia bella</i> | 1 |
| | <i>Euphrasia ciliolata</i> | 1 |
| | <i>Euphrasia scabra</i> | 2 |
| | <i>Fontainea australis</i> | 1 |
| | <i>Fontainea oraria</i> | 2 |
| | <i>Geijera paniculata</i> | 1 |
| | <i>Geniostoma huttonii</i> | 2 |
| | <i>Gentiana baeuerlenii</i> | 1 |
| | <i>Gentiana wingecarribiensis</i> | 2 |
| | <i>Geodorum densiflorum</i> | 2 |
| | <i>Grevillea banyabba</i> | 1 |
| | <i>Grevillea hilliana</i> | 1 |
| | <i>Grevillea masonii</i> | 1 |
| | <i>Grevillea rivularis</i> | 1 |
| | <i>Grevillea scortechinii</i> subsp. <i>sarmentosa</i> | 1 |
| | <i>Hakea pulvinifera</i> | 1 |

| Type ^a | Threatened species ^b | Number of weed threats ^c |
|-------------------------------|--|-------------------------------------|
| Plant species [continued] | <i>Haloragis exalata</i> subsp. <i>velutina</i> | 1 |
| | <i>Hedyotis galioides</i> | 1 |
| | <i>Hibbertia procumbens</i> | 1 |
| | <i>Hicksbeachia pinnatifolia</i> | 1 |
| | <i>Irenepharsus trypherus</i> | 3 |
| | <i>Isoglossa eranthemoides</i> | 1 |
| | <i>Lepiderema pulchella</i> | 1 |
| | <i>Lepidium aschersonii</i> | 2 |
| | <i>Macadamia tetraphylla</i> | 1 |
| | <i>Macrozamia johnsonii</i> | 1 |
| | <i>Marsdenia longiloba</i> | 1 |
| | <i>Melaleuca groveana</i> | 1 |
| | <i>Melaleuca tamariscina</i> subsp. <i>irbyana</i> | 1 |
| | <i>Melichrus hirsutus</i> | 1 |
| | <i>Melichrus</i> sp. <i>Gibberagee</i> | 1 |
| | <i>Melicope vitiflora</i> | 1 |
| | <i>Microtis angusii</i> | 2 |
| | <i>Niemeyera chartacea</i> | 1 |
| | <i>Ochrosia moorei</i> | 1 |
| | <i>Olax angulata</i> | 1 |
| | <i>Owenia cepiodora</i> | 1 |
| | <i>Parsonsia dorrigoensis</i> | 1 |
| | <i>Phaius australis</i> | 2 |
| | <i>Phaius tankarvilleae</i> | 2 |
| | <i>Phyllanthus microcladus</i> | 2 |
| | <i>Pimelea spicata</i> | 5 |
| | <i>Plectranthus alloplectus</i> | 2 |
| | <i>Plectranthus nitidus</i> | 1 |
| | <i>Polygala linariifolia</i> | 3 |
| | <i>Polystichum moorei</i> | 1 |
| | <i>Pomaderris queenslandica</i> | 2 |
| | <i>Prasophyllum petilum</i> | 2 |
| | <i>Prasophyllum uroglossum</i> | 2 |
| | <i>Prostanthera densa</i> | 1 |
| | <i>Prostanthera junonis</i> | 2 |
| | <i>Pterostylis cucullata</i> | 1 |
| | <i>Pterostylis gibbosa</i> | 7 |
| | <i>Pterostylis</i> sp. 15 Botany Bay | 1 |
| | <i>Pultenaea maritima</i> | 1 |
| | <i>Pultenaea pedunculata</i> | 5 |
| | <i>Quassia</i> sp. Mooney Creek | 1 |
| | <i>Randia moorei</i> | 1 |
| | <i>Rapanea</i> sp. A Richmond River | 16 |
| | <i>Rhynchosia acuminatissima</i> | 1 |
| | <i>Rutidosis leptorrhynchoides</i> | 1 |
| | <i>Sarcochilus hartmannii</i> | 2 |
| | <i>Senecio spathulatus</i> | 1 |
| | <i>Senna acclinis</i> | 2 |
| | <i>Solanum celatum</i> | 1 |
| | <i>Solanum limitare</i> | 4 |
| <i>Sophora fraseri</i> | 1 | |
| <i>Sophora tomentosa</i> | 1 | |
| <i>Swainsona plagiotropis</i> | 5 | |

| Type ^a | Threatened species ^b | Number of weed threats ^c |
|-------------------------------|--|-------------------------------------|
| Plant species [continued] | <i>Swainsona recta</i> | 1 |
| | <i>Syzygium moorei</i> | 1 |
| | <i>Syzygium paniculatum</i> | 2 |
| | <i>Tasmannia glaucifolia</i> | 1 |
| | <i>Tasmannia purpurascens</i> | 1 |
| | <i>Tetradlea juncea</i> | 1 |
| | <i>Thesium australe</i> | 1 |
| | <i>Tinospora smilacina</i> | 1 |
| | <i>Tinospora tinosporoides</i> | 1 |
| | <i>Triplarina imbricata</i> | 2 |
| | <i>Tylophora linearis</i> | 2 |
| | <i>Tylophora woolfsii</i> | 1 |
| | <i>Typhonium</i> sp. aff. <i>brownii</i> | 1 |
| | <i>Wilsonia backhousei</i> | 1 |
| | <i>Zieria granulata</i> | 1 |
| | <i>Zieria obcordata</i> | 2 |
| | <i>Zieria prostrata</i> | 4 |
| Animal species | <i>Anomalopus mackayi</i> | 1 |
| | <i>Cyclopsitta diophthalma coxeni</i> | 11 |
| | <i>Dasyornis brachypterus</i> | 3 |
| | <i>Dryococelus australis</i> | 1 |
| | <i>Irediparra gallinacea</i> | 1 |
| | <i>Litoria booroolongensis</i> | 1 |
| | <i>Litoria spenceri</i> | 1 |
| | <i>Mastacomys fuscus</i> | 1 |
| | <i>Nettapus coromandelianus</i> | 3 |
| | <i>Nyctophilus bifax</i> | 1 |
| | <i>Ocybadistes knightorum</i> | 4 |
| | <i>Panesthia lata</i> | 1 |
| | <i>Paralucia spinifera</i> | 5 |
| | <i>Phaethon rubricauda</i> | 1 |
| | <i>Pseudophryne pengilleyi</i> | 1 |
| | <i>Pterodroma nigripennis</i> | 1 |
| | <i>Puffinus assimilus</i> | 1 |
| <i>Puffinus carneipes</i> | 1 | |
| <i>Syconycteris australis</i> | 1 | |
| <i>Synemon plana</i> | 3 | |
| Plant population | <i>Glycine clandestina</i> (broad leaf form) | 1 |
| | <i>Zieria smithii</i> (low growing form) | 3 |
| Animal population | Broad-toothed rat (<i>Mastacomys fuscus</i>) population at Barrington Tops | 1 |
| | <i>Phascolarctos cinereus</i> (Hawks Nest and Tea Gardens) | 1 |
| Ecological community | Bega dry grass forest | 2 |
| | Ben Halls Gap National Park sphagnum moss cool temperate rainforest | 1 |
| | Carbeen open forest community | 3 |
| | Coastal saltmarsh | 7 |
| | Coolibah-blackbox woodland | 2 |
| | Eastern suburbs banksia scrub | 3 |
| | Elderslie banksia scrub forest community | 1 |
| | Freshwater wetlands on coastal floodplains | 11 |
| | Fuzzy box woodland on alluvial soils | 8 |
| | Howell shrublands | 3 |

| Type ^a | Threatened species ^b | Number of weed threats ^c |
|----------------------------------|---|-------------------------------------|
| Ecological community [continued] | Hunter lowland redgum forest | 3 |
| | Illawarra subtropical rainforest | 14 |
| | Kurnell dune forest | 1 |
| | Kurri sand swamp woodland | 1 |
| | Littoral rainforest | 20 |
| | Lower Hunter spotted gum – ironbark forest | 2 |
| | Lowland rainforest on floodplain | 2 |
| | Montane peatlands and swamps | 14 |
| | Mount Gibraltar forest | 5 |
| | Native vegetation on cracking clay soils | 2 |
| | O'Hares creek shale forest | 3 |
| | Pittwater spotted gum forest | 2 |
| | Riverflat eucalypt forest on coastal floodplains | 30 |
| | Robertson rainforest | 4 |
| | Southern highlands shale woodlands | 3 |
| | Sub-tropical coastal floodplain forest | 25 |
| | Swamp sclerophyll forest on the coastal floodplains | 10 |
| | Swamp-oak floodplain forest | 16 |
| | Sydney freshwater wetlands | 4 |
| | Umina coastal sandplain woodland | 8 |
| Western Sydney dry rainforest | 1 | |

a The type of biodiversity is described as: Plant species, animal species, Threatened Population, and Endangered Ecological Community, based on listings under the TSC and FM Acts (see below).

b Biodiversity as listed on Schedules 1 and 2 of the TSC Act and 4 and 5 of the FM Act, as at January 1, 2005 (ie species, populations and ecological communities). TSC Act refers to the NSW *Threatened Species Conservation Act 1995* and the FM Act to the NSW *Fisheries Management Act 1994*.

c The weed threats to threatened species in NSW from the data set (see Chapter 2 for further details). $n = 127$ species.

Table G The threatened species at risk from a generic threat of weeds

| Type ^a | Threatened species ^b |
|------------------------------------|--|
| Algae species | <i>Nitella partita</i> |
| Fungi species | <i>Camarophyllopsis kearneyi</i> |
| | <i>Hygrocybe anomala</i> var. <i>ianthinomarginata</i> |
| | <i>Hygrocybe aurantipes</i> |
| | <i>Hygrocybe austropratensis</i> |
| | <i>Hygrocybe collucera</i> |
| | <i>Hygrocybe griseoramosa</i> |
| | <i>Hygrocybe lanecovensensis</i> |
| | <i>Hygrocybe reesiaie</i> |
| | <i>Hygrocybe rubronivea</i> |
| | Plant species |
| <i>Acacia bynoeana</i> | |
| <i>Acrophyllum australe</i> | |
| <i>Alexfloydia repens</i> | |
| <i>Allocasuarina glareicola</i> | |
| <i>Ammobium craspedioides</i> | |
| <i>Ancistrachne maidenii</i> | |
| <i>Asperula asthenes</i> | |
| <i>Asterolasia buxifolia</i> | |
| <i>Asterolasia elegans</i> | |
| <i>Atriplex sturtii</i> | |
| <i>Bertya</i> sp. A Cobar-Coolabah | |

| Type ^a | Threatened species ^b |
|---------------------------|---|
| Plant species [continued] | <i>Boronia hapalophylla</i> <i>Cadellia pentastylis</i> <i>Caesia parviflora</i> var. <i>minor</i> <i>Calotis glandulosa</i> <i>Chiloglottis anaticeps</i> <i>Choricarpia subargentea</i> <i>Corchorus cunninghamii</i> <i>Corokia whiteana</i> <i>Cupaniopsis serrata</i> <i>Darwinia biflora</i> <i>Darwinia glaucophylla</i> <i>Darwinia peduncularis</i> <i>Dendrocnide moroides</i> <i>Deyeuxia appressa</i> <i>Dillwynia glaucula</i> <i>Dillwynia tenuifolia</i> <i>Diuris pedunculata</i> <i>Diuris tricolor</i> <i>Dodonaea microzyga</i> <i>Dodonaea procumbens</i> <i>Dodonaea sinuolata</i> subsp. <i>acrodentata</i> <i>Dodonaea stenozyga</i> <i>Eleocharis obicis</i> <i>Elyonurus citreus</i> <i>Eucalyptus benthamii</i> <i>Eucalyptus copulans</i> <i>Eucalyptus saxicola</i> <i>Floydia praealta</i> <i>Galium australe</i> <i>Goodenia macbarronii</i> <i>Goodenia</i> sp. <i>Nocochele</i> <i>Grevillea caleyi</i> <i>Grevillea iaspicula</i> <i>Grevillea juniperina</i> subsp. <i>juniperina</i> <i>Grevillea parviflora</i> subsp. <i>parviflora</i> <i>Grevillea parviflora</i> subsp. <i>supplicans</i> <i>Grevillea wilkinsonii</i> <i>Gyrostemon thesioides</i> <i>Haloragis exalata</i> subsp. <i>exalata</i> <i>Haloragodendron lucasii</i> <i>Hibbertia superans</i> <i>Irenepharsus magicus</i> <i>Kunzea rupestris</i> <i>Lasiopetalum behrii</i> <i>Leionema lachnaeoides</i> <i>Lepidium peregrinum</i> <i>Lepidosperma evansianum</i> <i>Leptorhynchus orientalis</i> <i>Leptospermum deanei</i> <i>Leucopogon fletcheri</i> subsp. <i>fletcheri</i> <i>Maundia triglochiniodes</i> <i>Melaleuca deanei</i> <i>Melaleuca</i> sp. nov. Megalong Valley |

| Type ^a | Threatened species ^b |
|---------------------------|--|
| Plant species [continued] | <i>Micromyrtus blakelyi</i> |
| | <i>Micromyrtus grandis</i> |
| | <i>Micromyrtus minutiflora</i> |
| | <i>Microstrobos fitzgeraldii</i> |
| | <i>Mitrasacme pygmaea</i> |
| | <i>Olearia cordata</i> |
| | <i>Olearia flocktoniae</i> |
| | <i>Peristeranthus hillii</i> |
| | <i>Persoonia glaucescens</i> |
| | <i>Persoonia marginata</i> |
| | <i>Persoonia mollis</i> subsp. <i>maxima</i> |
| | <i>Persoonia nutans</i> |
| | <i>Phyllanthus maderaspatanus</i> |
| | <i>Picris evae</i> |
| | <i>Pimelea curviflora</i> var. <i>curviflora</i> |
| | <i>Pomaderris adnata</i> |
| | <i>Pomaderris pallida</i> |
| | <i>Prasophyllum fuscum</i> |
| | <i>Prostanthera askania</i> |
| | <i>Prostanthera cryptandroides</i> |
| | <i>Psilotum complanatum</i> |
| | <i>Pterostylis cobarensis</i> |
| | <i>Pterostylis elegans</i> |
| | <i>Pterostylis nigricans</i> |
| | <i>Pterostylis saxicola</i> |
| | <i>Pultenaea glabra</i> |
| | <i>Pultenaea parviflora</i> |
| | <i>Rutidosia leiolepis</i> |
| | <i>Sarcochilus dilatatus</i> |
| | <i>Sclerolaena napiformis</i> |
| | <i>Solanum karsense</i> |
| | <i>Swainsona murrayana</i> |
| | <i>Swainsona sericea</i> |
| | <i>Syzygium hodgkinsoniae</i> |
| | <i>Tarenna cameronii</i> |
| | <i>Velleia perfoliata</i> |
| | <i>Wollemia nobilis</i> |
| | <i>Xanthosia scopulicola</i> |
| | <i>Xylosma parvifolium</i> |
| | <i>Xylosma terrae-reginae</i> |
| | <i>Zieria baeuerlenii</i> |
| <i>Zieria involucreta</i> | |
| Animal species | <i>Amauornis olivaceus</i> |
| | <i>Aprasia parapulchella</i> |
| | <i>Argyreus hyperbius</i> |
| | <i>Calamanthus fuliginosus</i> |
| | <i>Christinus guentheri</i> |
| | <i>Ctenotus pantherinus ocellifer</i> |
| | <i>Cyclodomorphus melanops elongata</i> |
| | <i>Delma australis</i> |
| | <i>Eulamprus leuraensis</i> |
| | <i>Heleioporus australiacus</i> |
| | <i>Litoria aurea</i> |

| Type ^a | Threatened species ^b |
|----------------------------|---|
| Animal species [continued] | <p><i>Maccullochella ikei</i> <i>Macropus dorsalis</i> <i>Melanodryas cucullata cucullata</i> <i>Meridolum corneovirens</i> <i>Mixophyes fleayi</i> <i>Mixophyes iteratus</i> <i>Monarcha leucotis</i> <i>Nurus atlas</i> <i>Nyctimene robinsoni</i> <i>Petrogale penicillata</i> <i>Pezoporus wallicus</i> <i>Phascolarctos cinereus</i> <i>Phyllodes imperialis southern</i> subsp. of the moth <i>Placostylus bivaricosus</i> <i>Podargus ocellatus</i> <i>Poephila cincta</i> <i>Polytelis anthopeplus</i> <i>Pomatostomus temporalis temporalis</i> <i>Pseudomoia lichenigra</i> <i>Pteropus alecto</i> <i>Ptilinopus magnificus</i> <i>Ptilinopus regina</i> <i>Ptilinopus superbus</i> <i>Pyrrholaemus sagittata</i> <i>Stagonopleura guttata</i> <i>Sterna fuscata</i> <i>Suta flagellum</i> <i>Thersites mitchellae</i> <i>Tympanocryptus pinguicolla</i> <i>Tyto capensis</i> <i>Tyto novaehollandiae</i> <i>Tyto tenebricosa</i> <i>Zosterops lateralis tephropleura</i></p> |
| Plant population | <p><i>Acacia prominens</i> population in the Hurstville and Kogarah Local Government Areas (LGAs) <i>Chorizema parviflorum</i> population in the Wollongong and Shellharbour LGAs <i>Dillwynia tenuifolia</i> population at Kemps Creek <i>Dillwynia tenuifolia</i> population in the Baulkham Hills <i>Eucalyptus seeana</i> population in the Greater Taree LGA <i>Keraudrenia corrolata</i> var. <i>denticulata</i> population in the Hawkesbury LGA <i>Lespedeza juncea</i> subsp. <i>sericea</i> population in the Wollongong LGA <i>Pomaderris prunifolia</i> population in the Parramatta, Auburn, Strathfield and Bankstown LGAs <i>Pultenaea villifera</i> population in the Blue Mountains LGA <i>Wahlenbergia multicaulis</i> population in the Auburn, Bankstown, Baulkham Hills, Canterbury, Hornsby, Parramatta and Strathfield LGAs</p> |
| Ecological community | <p><i>Acacia loderi</i> shrublands Agnes Banks woodland Blue gum high forest Brigalow within the brigalow belt south Nandewar and Darling Riverine Plains Brogro wet vine forest in the south east corner bioregion Byron Bay dwarf graminoid clay heath community Candelo dry grass forest in the south east corner bioregion Castlereagh swamp woodland community</p> |

| Type ^a | Threatened species ^b |
|----------------------------------|--|
| Ecological community [continued] | Castlereagh swamp woodland community Cooks River/Castlereagh ironbark forest in the Sydney basin bioregion Cumberland plain woodland Dry rainforest of the south east forests in the south east corner bioregion Duffy's forest ecological community in the Sydney Basin bioregion Genowlan Point <i>Allocasuarina nana</i> heathland Hygrocybeae community of Lane Cove bushland park Illawarra lowlands grassy woodland in the Sydney Basin bioregion Lagunaria swamp forest on Lord Howe Island Low woodland with heathland on indurated sand (Norah Head) Maroota sands swamp forest McKies stringybark/blackbutt open forest in the Nandewar and New England Tablelands bioregions <i>Melaleuca armillaris</i> tall shrubland Illawarra subtropical rainforest in the Sydney Basin bioregion Milton Ulladulla subtropical rainforest in the Sydney Basin bioregion Moist shale woodland in the Sydney Basin bioregion New England peppermint (<i>Eucalyptus nova-anglica</i>) woodland on basalts and sediments in New England Tableland bioregion Quorrobolong scribbly gum woodland in the Sydney Basin bioregion Robertson basalt tall open-forest in the Sydney Basin bioregion Semi-evergreen vine thicket in the brigalow belt south and Nandewar bioregion Shale gravel transition forest in the Sydney Basin bioregion Shale/sandstone transition forest Sun valley cabbage gum forest in the Sydney Basin bioregion Sydney turpentine-ironbark forest Upland wetlands of the drainage divide of the New England Tablelands bioregion Warkworth sands woodland in the Sydney Basin bioregion White box yellow box Blakely's red gum woodland |

Footnotes as per Table F.





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