Department of Planning and Environment

Abating the threat of exotic perennial grasses in native grassy communities in eastern NSW

Section 1: Overview

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Cover photo: *Holcus lanatus* and *Poa species* flowering post fire at Kosciuszko National Park. Julia Rayment/UOW

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This report is in 5 sections. Each is available as a separate document for download:

1. **Overview (this document)**
2. NSW North Coast
3. NSW Northern Tablelands and Slopes
4. NSW Southern Tablelands and Slopes
5. NSW South Coast.

Executive summary

Exotic perennial grasses, or EPGs, have negative impacts and pose significant risks to native species and ecosystems. Native grasslands and open woodland communities are particularly susceptible to invasion, with native grasses at risk of being displaced by EPGs. With the impact of EPGs more frequently investigated in an agricultural context, this report (in 5 parts), focuses on the **impacts and management needs for native communities of conservation importance in eastern New South Wales.**

This report provides a **risk assessment tool** for land managers to help prioritise EPGs of concern in native areas. Based on published research, and available as an online resource, this is one of the tools land managers can use to identify which EPGs are of most concern in the land they manage. The tool ranks species in terms of characteristics that facilitate invasion into native areas.

The risk assessment tool identifies significant knowledge gaps in our understanding of how some highly ranked species invade native areas, lacking information about seed input and survival, competition with native grasses and their impacts on ecosystem processes. There is a **research priority** to fill these gaps; these are discussed.

This report provides significant new knowledge on levels of invasion by EPGs in ecological communities of conservation importance. **Field surveys of 9 threatened ecological communities** (TECs) (Table 9) that are grasslands or grassy woodlands in eastern New South Wales provide important baseline information on significant invaders. All TECs had significant invasions of EPGs leading to degradation of these conservation areas. Regional differences in the suite of invaders were identified, indicating that regional approaches will be needed to combat the more invasive species. However, the 9 TECs mostly differed in the species that were important invaders, suggesting managers will also need to consider management at the community level.

Trade-off species (pasture grasses), deliberately planted and used in agricultural or urban settings, were significant invaders of threatened native grassy communities and will need to be a focus of management in the future. The report identifies the importance of a range of species that have not been considered as significant invaders of native communities, indicating a need to focus on control and to develop appropriate management tools.

A **land manager survey** identifies that while most managers have the capability to manage the EPGs in their native communities, there are some skills and technical information that will help inform their management. This includes grass identification skills, monitoring skills and information on best practice management.

A 4-step management process is presented as a method to prioritise which species are critical to control in the native communities in which managers are operating:

- **'Identify'** suggests an initial survey of sites to quantify which EPGs are most prevalent; this requires significant knowledge in grass identification.
- **'Prioritise'** uses the risk assessment tool plus the field survey and other local knowledge to prioritise the species that need control.
- **'Control'** involves preparing a management plan and implementing the best control methods to maintain biodiversity values. Suggestions are provided based on our knowledge of different EPG biology.
- **'Monitoring'** before and after control is critical to enhance our knowledge of best practice management and ensure we reduce the impacts of EPGs on grassy communities of conservation significance.

1. Introduction

1.1 What are exotic perennial grasses?

Perennial grasses have a life span of more than one growing season. Non-native, exotic perennial grasses have been accidentally and deliberately introduced into Australia since colonisation (Lonsdale 1994; Cook and Dias 2006). EPGs have, on many occasions, been shown to have negative impacts and pose significant risks to native species and ecosystems (Butler and Fairfax 2003; Jackson 2005; De la Barrera 2008; Eilts and Huxman 2013). In New South Wales, EPGs are legislated as a key threatening process (KTP) under the NSW *Biodiversity Conservation Act 2016*, posing a significant risk to the conservation and ongoing management of threatened biodiversity. The EPGs listed in the NSW Threatened Species Scientific Committee final determination (DPIE 2019) is not an exhaustive list; the EPGs included in Table 1 were informed by the draft and final determination and by discussion with experts in the area. Over 100 EPGs are currently present in New South Wales, many with the potential to adversely affect native plant communities and species. This document outlines the results of surveys to provide an understanding of which of these grass species (and others) are key invaders of native grassy communities in New South Wales.

Figure 1 ***Chloris gayana*** **displacing** ***Themeda triandra*** **in the threatened community Illawarra Lowlands Grassy Woodland. Photo: Julia Rayment/UOW**

1.2 Why are exotic perennial grasses a threat to native biodiversity?

Exotic perennial grasses often have vigorous growth, prolific seed production and highly effective seed dispersal mechanisms, enabling them to compete strongly with native vegetation (D'Antonio and Vitousek 1992; Low 1997). Disturbances, spread by machinery and stock, and deliberate use in agricultural systems improve their likelihood of invading native areas as they increase the supply of seeds (Godfree et al. 2017). Native grasslands and open woodland communities are particularly susceptible to invasion, with native grasses at risk of being displaced by EPGs. EPGs can change the structure, composition and fuel loads of plant communities (D'Antonio and Vitousek 1992; van Klinken and Friedel 2017; Linder et al. 2018). EPGs listed in the KTP determination are known to aggressively invade many open and semi-open habitats in New South Wales (Table 1).

Table 1 EPGs listed by the NSW Threatened Species Scientific Committee (draft and final determinations)

Scientific name	Common name
Agrostis capillaris	Browntop bent
Amelichloa spp	Espartillo (broad or narrow spp)
Andropogon virginicus	Whisky grass
Cenchrus ciliaris	Buffel grass
Cenchrus clandestinus	Kikuyu grass
Cenchrus spinifex	Spiny burrgrass
Chloris gayana	Rhodes grass
Cortaderia spp	Pampas grasses
Ehrharta erecta	Panic veldtgrass
Eragrostis curvula	African lovegrass
Hyparrhenia hirta	Coolatai grass
Melinis minutiflora	Molasses grass
Nassella neesiana	Chilean needle grass
Nassella trichotoma	Serrated tussock
Panicum repens	Torpedo grass
Paspalum urvillei	Vasey grass
Phalaris aquatica	Phalaris
Setaria sphacelata	South African pigeon grass
Sorghum halepense	Johnson grass
Sporobolus spp	Parramatta and rat's tail grasses
Urochloa mutica	Para grass

1.3 What biodiversity do they threaten?

Exotic perennial grasses invade native ecosystems, TECs, roadsides and urban areas, and areas of primary production. In south-east Australia, native grasslands are highly threatened ecosystems (DPE no date b), as they are highly fragmented and have frequently been transformed into exotic pasture. Grassy ecosystems throughout New South Wales provide habitat to threatened flora and fauna not found in other habitats. Grassy ecosystems are particularly under threat from EPG invasion due to the similarity in habitats, known as the 'Habitat Matching Hypothesis' where exotic species invade ecosystems that resemble those in their places of origin (Stohlgren et al. 2005). When Godfree et al. (2017) investigated non-native grasses and their threat to multifunctional rural landscapes, they found low palatability species, like African lovegrass (*Eragrostis curvula*), drive degradation in the landscape in both conservation and agricultural landscapes.

TECs are native communities at risk of extinction due to habitat loss, changes in community structure, disruption of ecological processes, invasion by exotic species, and fragmentation (DPE 2022). Over 100 TECs are listed in New South Wales, several of which are at threat from the invasion of EPGs (OEH 2017a, DPE 2022). TECs with grassy understories such as Natural Temperate Grasslands in South East Australia*,* are often at threat from EPGs. EPGs threaten to permanently damage the limited number of healthy, intact fragments of threatened grassland communities that remain.

Some EPGs are well-documented as species that negatively impact ecosystems. For example, buffel grass (*Cenchrus ciliaris*) creates positive feedback cycles in the fire regime with increased fuel loads that lead to hotter, more intense fires, limiting native regeneration and promoting reinvasion of EPGs (D'Antonio and Vitousek 1992; Miller et al. 2010; Schlesinger et al. 2013). Some EPGs can effectively compete for limited resources against natives, increasing their ability to survive and take up more space in the invaded community (van Klinken and Friedel 2017; Linder et al. 2018). Some EPGs can spread vegetatively, allowing them to form monocultures that smother native ground cover. In Australia, Kikuyu (*Cenchrus clandestinus*) was shown to spread extensively and cover breeding nests of little penguins (*Eudyptula minor*) on Montague Island (Fullagar and Heyligers 2006). However, knowledge about the impact of the vast majority of EPGs is largely missing or in divergent sources.

Figure 2 *Cenchrus ciliaris* invasion. Photo: Forest and Kim Starr/Starr Environmental

1.4 The importance of focusing on conservation land

Figure 3 ***Themeda triandra*. Photo: Julia Rayment/UOW**

Determining the impacts of exotic perennial grass invasion in native ecosystems is hard to quantify compared to economic losses in primary production (Dawson 2005), with research into impact in agricultural systems and production-based control techniques more prominent (Table 2). As a result, our understanding of high-impact grasses is skewed towards those that are economically damaging, such as Weeds of National Significance (WoNS). While some species are impactful in both agricultural systems and native ecosystems there is also a suite of species that may be more problematic in native areas, including contentious agricultural species (see 'Managing trade-off species' below). Similarly, while some aspects of control are relevant across both systems, the applicability and considerations for control in native ecosystems are quite different. Grazing practices in native ecosystems are not possible and require different methods and practices to limit spread and off-target damage.

A number of resources have been developed for the control of exotic perennial grasses in agricultural land, including for serrated tussock, Chilean needle grass, African lovegrass, and weedy *Sporobolus* grasses. Critical to conservation of native environments is an understanding of the differences in EPG invasion across native and agricultural systems, recognition of targeted control strategies in native environments (which may include native pastures), and ongoing research to understand the biology and impact of EPGs in native communities.

Managing trade-off species

Some EPGs were intentionally introduced for use in pasture and garden plantings. Several species are still frequently used in agriculture today and are often referred to as 'trade-off' or contentious species. These species provide economic benefit but are detrimental in native communities and cause environmental losses. Issues arise in the management of these grasses as they may spread into areas of conservation more easily, and may be modified for improved use in pasture, which also improves their invasive ability. High propagule pressure and differences in the management of economically useful grass species greatly increases the likelihood of spread into native areas.

For example, there are breeding programs for Kikuyu for shade and drought tolerance despite its risk to at least 16 threatened species in New South Wales (Coutts-Smith and Downey 2006; Morris 2009; Lowe et al. 2010). Grassy communities are often surrounded by areas of land where trade-off species are planted, and, in the case of native pastures and travelling stock reserves, can experience stock movement and grazing pressure.

Table 2 Literature on exotic perennial grasses that are currently commercially available for use in pastures in New South Wales

Trade-off species	Studies on agricultural land	Studies in native communities
African lovegrass (var. Consol)	19	38
Buffel grass	229	81
Cocksfoot	530	30
Kikuyu	282	10
Mollasses grass	29	23
Paspalum	119	7
Perennial rye grass	1571	51
Phalaris	235	24
Rhodes grass	151	11
South African pigeon grass	80	6
Tall fescue	677	70

Source: DPI (no date b). Literature searches were undertaken using the 'Scopus' search engine.

1.5 A knowledge gap in native communities

Weed control is extremely costly. In New South Wales, weeds account for $1.8 billion a year in lost production and control costs (NRC 2014). CRC Weed Management (2003) estimates that in New South Wales, serrated tussock (*Nassella trichotoma*) has resulted in a loss of more than $40 million in production, with infestations offering no grazing value (Vere and Campbell 1984). In agricultural systems, invasive grasses are avoided by stock, allowing them to spread further or forcing stock to feed on low-quality, sometimes indigestible plant material (Vere and Campbell 1984; Laffan 2006; Bray and Officer 2007; Yobo et al. 2009).

Exotic perennial grasses can also cause damage to native animals and livestock. The seeds of spiny burrgrass (*Cenchrus spinifex*) and Chilean needle grass *(Nassella neesiana)* can pierce animal skin and injure livestock (Anderson et al. 2010; Bourdôt et al. 2010; DPI 2012).

Currently, we lack a good understanding of the specific impact of EPGs on biodiversity values across a range of grassland communities in which they occur. Some EPGs are likely to be more damaging in native communities, and it is the most impactful that require intensive management to reduce their impact in areas of environmental significance. Determining which species to prioritise requires a twofold approach: assess their abundance in the landscape and understand their capacity to degrade native communities.

To gain a better understanding of EPGs in native communities, a 3-year project was undertaken focusing on native grassland and grassy woodlands communities. This set of documents outlines the results and conclusions from the project. We present an overview of the risk assessment tool, field survey and land manager survey results with some broad concepts of management, and then provide regional analyses of important EPGs in 4 separate documents.

Aims of the study

Our aim was to assess current knowledge of EPGs and the risks they pose to native ecological communities. This was achieved through:

1. Developing a risk assessment tool using published information on plant characteristics that might be important to invasion in native communities. This process ranks species based on key characteristics that improve their invasive ability in natural habitats.
2. Surveying 9 focal TECs in the field and using online surveys with TEC managers to identify the most abundant EPGs.
3. Interpreting survey results to identify which EPGs pose the greatest threat to 4 regions in eastern New South Wales to enable strategic threat abatement.
4. Presenting key points for, and links to, key resources for management of these important EPGs in these regions.

The core principles identified here are published in Rayment and French (2021). The analysis of survey results is published in Rayment et al. (2022).

2. The risk assessment tool

This project developed a risk assessment tool specifically aimed at investigating the invasive characteristics of EPGs to rank their risk in damaging native communities. This provides the opportunity to prioritise management of the most damaging EPGs for grasslands and grassy woodlands which are at high risk of invasion by EPGs (McIntyre and Martin 2002; McIntyre et al. 2006). This ranking process was informed by 2 broad risk assessments for non-native plants in Australia: the NSW Weed Risk Management (WRM) System (DPI no date b) and the Victorian Invasive Plant Risk Assessment (Agriculture Victoria 2008).

We identified 5 life-history characteristics that contribute to the invasive success of EPGs (Table 3): dispersal ability, establishment ability, mechanisms to persist, mechanisms to modify habitat and reduce competitors, and the current and future distribution in New South Wales under climate change (D'Antonio and Vitousek 1992; Linder et al. 2018; Rayment and French 2021).

How to use the risk assessment tool

The risk assessment tool is a powerful resource available for land managers online. It contains an Excel spreadsheet, with instructions and examples.

The tool allows you to compare functionally similar exotic perennial grasses to help you prioritise management at your site. This risk assessment is most relevant to grassy ecosystems but may have broader applications for communities across New South Wales. For your site of concern:

- Use this as an early detection system to employ preventative control for high-risk EPG species that may arrive in your area of management.
- Familiarise yourself with the identification of EPGs. If in doubt, seek identification help from local weed officers, ecologists, and trained botanists.
- Identify the EPGs invading your area of concern. First compare the risk scores of each EPG. Secondly, identify any characteristics of consideration, e.g. if an EPG is in low abundance at your site you may want to see its capability to establish at a site to determine if it is likely to increase its presence quickly.
- Use this to determine the risk ranking of species to prioritise your management. High-risk scores identify species that might be prioritised.
- Take note of characteristics that will influence the management strategies you choose. For example, species that possess vegetative reproduction will require whole plant removal and safe disposal if employing manual control.

For researchers, this can help identify where knowledge is missing and where research should focus to improve this risk assessment tool.

2.1 Methods

We assessed the 21 EPG species listed in Table 1 (see details in Rayment and French 2021). Eight additional EPG species, that were identified as significant invaders during field surveys, were also assessed (Rayment et al. 2022). We used field survey data (See Section 3 of this overview) to ensure this risk assessment tool was accurate in ranking species that are most problematic in native grassy communities (Rayment et al. 2022).

For each of the species, literature was searched for information on 10 characteristics within 5 life-history categories that are important in invasion (Table 3). For a given species, a score was assigned for each characteristic, with higher scores indicating a higher risk of invasion. As the amount of published knowledge differed for each species and for each characteristic for a species, we developed a scale of uncertainty for each characteristic and for the species as a whole. Species with a high uncertainty score had limited information available on which to base the ranking. This identifies areas in need of research.

Table 3 The 5 invasive categories and 10 invasive characteristics scored in this ranking

This includes a brief description and the available risk score. For a full justification of characteristics and their scores see Rayment and French (2021).

Category	Characteristic	Description	Available score
Arrival	Trade-off species	EPGs with economic value are more likely to invade nearby areas with characteristics desirable for use in pasture often analogous to invasive characteristics. Any species available for commercial use in the past 10 years was considered a trade-off species; this allows for lag times between introduction and invasion.	Yes = 4 No = 0 Do not know = 2
		Total	**/ 4**
Establishment	Seed output	Increased propagule pressure improves probability of successful establishment (Holle and Simberloff 2005; Lockwood et al. 2005). Seed output was compared against species only when the units were the same.	High = 3 Medium = 2 Low = 1 Do not know = 1.5
	Environmental tolerance	Environmental flexibility, particularly in a new habitat, allows a species to spread and persist in a variety of habitats and influences competitive dominance (Baker 1965; Higgins and Richardson 2014; Linder et al. 2018).	High = 3 Medium = 1.5 Low = 0 Do not know = 1.5
		Total	**/ 6**
Persistence	Vegetative reproduction	Vegetative growth allows local spread regardless of issues that may arise in sexual reproduction in novel habitats, such as lack of pollinators or unfavourable abiotic conditions for production of inflorescences (Cadotte et al. 2006; Liu et al. 2006; Pertierra et al. 2016). Vegetative reproduction can be achieved through rhizomatous spread or tiller production where new growths can act independently of the parent plant.	Yes = 5 No = 0 Do not know = 2.5
	Seed bank persistence	Soil seed banks provide a reserve source of propagules that can increase persistence in an ecosystem and may assist in primary and secondary invasion in response to disturbance (Gioria et al. 2012). Seed banks may be transient (< 1 year), short-term persistent (1–5 years) or persistent (> 5 years) (Gioria et al. 2012).	Persistent = 4 Short-term persistent = 2 Transient = 0 Do not know = 2
		Total	**/ 9**

Category	Characteristic	Description	Available score
Impact	Resource competition	Plants compete for resources including space, nutrients and water. Species may capture resources in response to disturbance, preventing native recovery, or compete with native species directly in an ecosystem.	High = 3 Medium = 2 Low = 1 Do not know = 1.5
	Allelopathy	Interference competition through the release of chemicals from plant parts can be an effective competitive strategy (Putnam and Duke 1985).	Yes = 2 No = 0 Do not know = 1
	Changes to ecosystem	EPGs capable of altering ecosystems through interactions, such as positive feedback cycles with fire, have serious and negative flow-on effects (D'Antonio and Vitousek 1992).	Major negative effect = 3 Minor negative effect = 1 No negative effect = 0 Do not know = 1.5
		Total	**/ 8**
Distribution	Current	Using data from PlantNet, EPGs were scored for the number of subdivisions in New South Wales they were present in. While some EPGs can have large, localised populations the scope of this study focuses on risk at a statewide scale.	1–3 subdivisions = 0 4–6 subdivisions = 1 7–9 subdivisions = 2 10–12 subdivisions = 3
	Future	Species were scored according to whether climate modelling predicts their future suitable habitat will increase, decrease, or stay the same in New South Wales.	Expand = 2 Similar = 1 Retract = 0 Do not know = 1
		Total	**/ 5**
Risk score			**/32**

2.2 Results

Total risk scores for the EPGs ranged from 9.5 – 28/32 (Table 4). African lovegrass is the highest ranked species with a risk assessment score of 28/32. The top 6 species were considered trade-off species at some point over the past 10 years, indicating intentional introduction is a key characteristic of high-risk species. This risk assessment can be used in conjunction with field surveys of land manager surveys to prioritise high risk, high occurrence, or emerging weeds for control.

2.3 Research priorities and recommendations for future research

In collating available knowledge to assess risk and assessing the confidence of the source of the information, we can use the risk assessment tool to identify areas where research is missing or is from less-reliable sources. Effective weed management requires knowledge of key aspects of invasive ability and impact potential, therefore more research should be done to understand the impact of these EPGs on the ecosystems they invade. We identify 3 areas to prioritise: EPG characteristics, specific species, scope of research.

Characteristics of EPGs

Uncertainty of information was highest for information on long-term seed viability (57%), followed by information on the ability of species to compete with native species for resources (53%) and change the invaded native ecosystem (50%). Research focusing on long-term seed viability of EPG species can provide important information for management plans. Species with long-term seed bank viability will require longer management plans to monitor and control re-invasions, while those with shorter viability can be depleted from the seed bank more quickly. Research on seed output often uses qualitative language rather than numbers, with little consistency between seed output units; for the purpose of understanding propagule pressure this could be improved through research. Use of ambiguous terms such as ‘high seed output’ or ‘prolific seed production’ provides little actual detail and does not allow comparisons between species. Similarly, seed yields, often given for trade-off species, have limited applicability in on-ground seed production outside pasture production.

Understanding the impact of an EPG once present in a landscape is vital. This covers both measures of likely competitive success and impact on the invaded community. Competitive dominance may be achieved through improved competition for space, light, water or nutrients. For example, Kikuyu develops deep root systems allowing it to compete effectively for water (Fraser et al. 2017). In comparison, species such as cocksfoot *(Dactylis glomerata)* have only anecdotal evidence to suggest competitive mechanisms (Popay 2015). Only 10 of the 29 species assessed had high confidence in the information available on their ability to change invaded communities. As previously discussed, there is often a focus on impact in agricultural land, negating the importance of native community health and structure. The lack of studies focusing on impact in native communities has been identified previously (Williams et al. 2008). This should be a major focus to determine above- and below-ground interactions of EPGs with native counterparts. We strongly advise changes to ecosystem as a research priority.

Data-deficient species

The risk assessment also revealed several species with insufficient knowledge, so the threat from these species may not be fully recognised. Lack of information (and high uncertainty) is more common in species with a lower rank. Species with little information available that would benefit from further research include espartillo, slender pigeon grass and South African pigeon grass, spiny burrgrass, carpet grass, broadleaf paspalum and phalaris. For these data-deficient species we recommend gathering baseline data such as seed output, growth patterns, and aspects of ecology including environmental tolerance, competitive ability and potential negative impact. We advise referring to the risk assessment for data-deficient species and characteristics of these species that require attention. Within each region we identify research priorities for the most concerning EPG species.

Scope of research

With so many EPGs invading, there is an inherent gap with the sheer number of unassessed species. While it may not be feasible, or useful, to assess the risk of every EPG species, determinations of which species to assess will become clearer through personal field surveys. Lack of research should not limit assessment but should be a push to move forward with assessment and improving understanding. Many risk assessments do not assess species with lack of information. We believe lack of information is a clear signal to assess what knowledge is available, and to highlight and fill gaps to provide the information needed to accurately assess risk (Downey et al. 2011; Hamilton et al. 2014; McGeoch et al. 2016).

Trade-off species were not generally lacking information. However, we recommend research to understand their ability to invade and degrade native communities will improve management and control.

The most reliable research contains quantitative data and may be found in scientific research as well as government publications. Landholders and managers often communicate knowledge in less formal ways. This local ecological knowledge can form the foundations of research and management priorities (Brook and McLachlan 2008; Firn et al. 2018). We propose a greater and continued emphasis on collating and confirming this knowledge for wider benefits.

Table 4 Risk assessment using available knowledge of EPGs, based on Rayment and French 2021 and Rayment et al. 2022

Species are ranked first by total score then by uncertainty score where EPGs with higher confidence (i.e. lower uncertainty scores) are ranked higher. Colours indicate certainty of information: green = high, yellow = medium, red = low, grey = uncertain/ do not know. Uncertainty, or confidence in answers was also calculated and is shown as a percentage for each species and characteristic. (For full methods see Rayment and French 2021.)

	Arrival	Establishment		Persistence		Impact			Distribution			
Species name	**Trade-off species**	**Seed output**	**Environmental tolerance**	**Vegetative reproduction**	**Long-term seed viability**	**Resource competition**	**Allelopathy**	**Changes to ecosystem**	**Current distribution**	**Future distribution**	**Total /32**	**Uncertainty score**
Eragrostis curvula	4	2	3	5	2	3	2	3	3	1	28	15
Cenchrus ciliaris	4	3	3	5	2	3	2	3	2	0	27	12.5
Chloris gayana	4	3	3	5	2	3	0	3	3	0	26	32.5
Cenchrus clandestinus	4	1	3	5	4	2	0	3	3	0	25	15
Melinis minutiflora	4	3	0	5	4	3	0	3	0	2	24	20
Paspalum dilatatum	4	3	1.5	5	2	2	2	1	3	0	23.5	22.5
Sorghum halepense	0	2	1.5	5	4	2	2	3	3	0	22.5	10
Holcus lanatus	0	3	3	5	2	3	2	1	3	0	22	5
Nassella neesiana	0	2	3	5	4	2	0	3	2	0	21	15
Dactylis glomerata	4	3	1.5	5	2	2	0	1	2	0	20.5	22.5
Anthoxanthum odoratum	0	1	3	5	2	2	2	3	2	0	20	15
Phalaris aquatica	4	2	1.5	5	2	1	0	1	3	0	19.5	45
Ehrharta erecta	0	2	3	5	2	3	0	1	3	0	19	10

	Arrival	Establishment		Persistence		Impact			Distribution			
Species name	**Trade-off species**	**Seed output**	**Environmental tolerance**	**Vegetative reproduction**	**Long-term seed viability**	**Resource competition**	**Allelopathy**	**Changes to ecosystem**	**Current distribution**	**Future distribution**	**Total /32**	**Uncertainty score**
Paspalum urvillei	0	3	1.5	5	0	2	2	1	3	0	17.5	35
Agrostis capillaris	0	3	1.5	5	2	2	0	1.5	2	0	17	22.5
Nassella trichotoma	0	3	3	0	4	2	0	3	2	0	17	25
Setaria sphacelata	4	1	1.5	5	0	2	0	1.5	1	0	16	47.5
Sporobolus spp.	0	3	3	0	4	2	0	1	2	0	15	27.5
Paspalum mandiocanum	0	2	0	5	1	2	0	3	0	2	15	40
Setaria parviflora	0	1.5	3	5	0	1	0	1	3	0	14.5	52.5
Cortaderia spp.	0	3	1.5	5	0	1	0	3	0	0	13.5	15
Axonopus fissifolius	0	1.5	1.5	5	1	1.5	0	1	2	0	13.5	42.5
Hyparrhenia hirta	0	1	3	0	0	2	2	3	2	0	13	10
Panicum repens	0	1	0	5	0	1.5	0	3	1	0	11.5	15
Urochloa mutica	0	1	0	5	0	2	0	3	0	0	11	22.5
Andropogon virginicus	0	1	3	0	0	2	2	1	2	0	11	30
Amelichloa spp.	0	1.5	1.5	0	2	1.5	0	1.5	0	2	10	55
Bromus catharticus	0	1	1.5	0	1	2	0	1	3	0	9.5	35
Cenchrus spinifex	0	1	1.5	0	2	1.5	0	1.5	2	0	9.5	40
Confidence (%)	**7**	**39**	**33**	**16**	**57**	**53**	**7**	**50**	**0**	**12**		

3. Field surveys in 9 threatened ecological communities

3.1 Aims and methods

To gain a better understanding of the impact of EPG invasion, we surveyed 9 focal grassy TECs. In eastern New South Wales, favourable climatic conditions increase invasion of TECs, with increased fragmentation and habitat destruction being major threats. Therefore, the focal TECs surveyed occurred along the coast and tablelands of New South Wales. Extreme drought hampered our ability to survey further inland. Field surveys provided an opportunity to understand the role of regional and site-level differences in climate and land use in influencing EPG invasion. We also recognise that drought and rainfall events will causes changes in levels of invasion of particular species. Surveys of areas under management will enable managers to prioritise their issues.

The aim of the surveys was to determine:

1. what EPGs were invading threatened ecological communities
2. whether invasion by EPGs differed between TECs
3. whether EPG invasion was influenced by differences between regions.

Across 9 TECs (Table 5), 139 sites were surveyed between 2018 and 2020 (Figure 4). At each site we assessed the presence of native and exotic grass species in quadrats. This information has been detailed and analysed in Rayment et al. (2022). We present a summary of this information here.

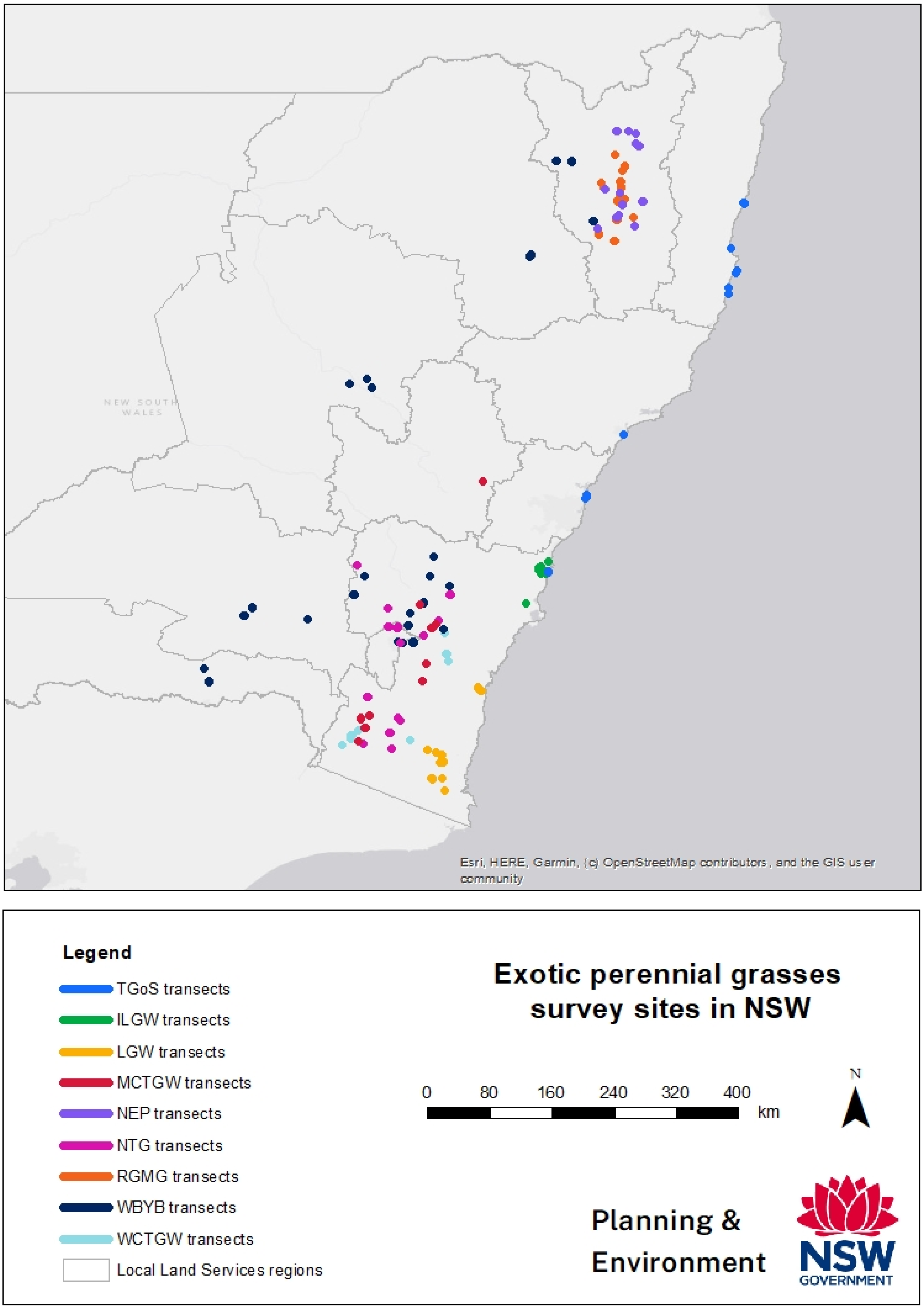


Figure 4 Map of survey sites by ecological community

See Table 5 for abbreviations of TECs.

Table 5 Threatened ecological communities where field surveys were undertaken

Surveys were undertaken in 9 TECs. Table 5 shows NSW conservation status under the *Biodiversity Conservation Act 2016* and Commonwealth conservation status under the *Environment Protection and Biodiversity Conservation Act 1999*. TEC abbreviations are in brackets.

Threatened ecological community (TEC)	Short name and abbreviation	NSW status	Commonwealth status
Illawarra Lowlands Grassy Woodland in the Sydney Basin Bioregion	Illawarra Lowlands Grassy Woodland (ILGW)	Endangered	Critically endangered
Lowland Grassy Woodland in the South East Corner Bioregion	Lowland Grassy Woodland (LGW)	Endangered	Critically endangered
Themeda Grassland on Seacliffs and Coastal Headlands in the NSW North Coast, Sydney Basin and South East Corner Bioregions	Themeda Grassland (TGoS)	Endangered	Not listed
New England Peppermint (*Eucalyptus nova-anglica*) Woodland on Basalts and Sediments in the New England Tableland Bioregion	New England Peppermint Woodland (NEP)	Critically endangered	Critically endangered
Ribbon Gum – Mountain Gum – Snow Gum Grassy Forest/Woodland of the New England Tableland Bioregion	Ribbon – Mountain – Snow Gum Grassy Woodland (RGMG)	Endangered	Not listed
Monaro Tableland Cool Temperate Grassy Woodland in the South Eastern Highlands Bioregion	Monaro Grassy Woodland (MCTGW)	Critically endangered	Not listed
Werriwa Tablelands Cool Temperate Grassy Woodland in the South Eastern Highlands and South East Corner Bioregions	Werriwa Grassy Woodland (WCTGW)	Critically endangered	Not listed
Natural Temperate Grassland of the South Eastern Highlands	Natural Temperate Grassland (NTG)	Not listed	Critically endangered

Threatened ecological community (TEC)	Short name and abbreviation	NSW status	Commonwealth status
White Box – Yellow Box – Blakely's Red Gum Grassy Woodland and Derived Native Grassland in the NSW North Coast, New England Tableland, Nandewar, Brigalow Belt South, Sydney Basin, South Eastern Highlands, NSW South Western Slopes, South East Corner and Riverina Bioregions	White Box –Yellow Box (WBYB)	Critically endangered	Critically endangered

Results

A total of 31 EPGs were recorded across the 9 TECs (Appendix A). Only 15 sites (11%) were not invaded by an EPG. The most abundant genus was *Paspalum* with common paspalum (*Paspalum dilatatum)* the most common and widespread (Table 6). Four other species were widespread: weedy *Sporobolus* grasses (including Parramatta grass*),* cocksfoot (*Dactylis glomerata),* Yorkshire fog *(Holcus lanatus)* and prairie grass (*Bromus catharticus)*. Parramatta grass (*S. africanus)* is one of several exotic *Sporobolus* species in Australia. Due to its genetic and morphological similarity to the other *Sporobolus* species and their ability to hybridise readily, they are collectively referred as the weedy *Sporobolus* grasses. The assemblage of EPGs invading differed amongst TECs. New England Peppermint Woodland, Ribbon – Mountain – Snow Gum Grassy Woodland and Lowland Grassy Woodland had a similar set of invading EPGs. EPGs invading Werriwa Grassy Woodland and Monaro Grassy Woodland were also similar.

Irrespective of the distinction of the species assemblages in TECs, the composition of EPGs also differed among regions and has led to the following chapters being based on regionally specific analyses. Our results support a regional approach to the control and prioritisation of many EPGs (Rayment et al. 2022). However, there are some distinct sets of EPG species invading particular TECs, indicating a need to plan priorities at the TEC level also, where they differ from regional approaches. Rayment et al. (2022) identifies a set of widespread species that are commonly encountered across most regions. These are:

1. common paspalum (*Paspalum dilatatum*)
2. *Sporobolus* grasses (including Parramatta grass)
3. African lovegrass (*Eragrostis curvula*)
4. cocksfoot (Dactylis glomerata)
5. phalaris (Phalaris aquatica).

Common paspalum. Photo: Julia Rayment/UOW

***Sporobolus.* Photo: Vicflora bank Clarke 2021 Royal Botanic Gardens Board**

African lovegrass. Photo: USDA NRCS Tucson PMC

Cocksfoot. Photo: Javier Martin

Phalaris. Photo: NRCS plant material centre

Figure 5 Five EPGs identified as widespread through field surveys of native communities across eastern NSW

These species include 4 trade-off species, and all are causing significant degradation of native communities. Widespread approaches to managing these species is a high priority. Other species were also invading communities in each region.

Only one plant community was surveyed in the North Coast with significant invasions of 3 paspalum species: common paspalum, broadleaf paspalum (*Paspalum mandiocanum*) and vasey grass (*Paspalum urvillei*) as well as weedy *Sporobolus* grasses. Invasion of Themeda

Grassland sites was different between North Coast and South Coast regions, again suggesting a regional approach to management is most relevant.

The Northern Tablelands and Slopes region recorded 16 EPGs. Coolatai grass (*Hyparrhenia hirta*) invaded every White Box – Yellow Box site. The other grassy communities, Ribbon – Mountain – Snow Gum Grassy Woodland and New England Peppermint Woodland, had significant invasions of the widespread species.

The Southern Tablelands and Slopes region recorded the greatest diversity of EPGs, with 21 EPGs recorded across 4 communities. Interestingly, it also contained the 2 communities with the lowest percentage of sites invaded by EPGs: Werriwa Grassy Woodland and Monaro Grassy Woodland. Regionally characteristic EPGs included sweet vernal grass (*Anthoxanthum odoratum*) and serrated tussock (*Nassella trichotoma*).

The highest levels of invasion occurred in the South Coast region with 18 EPGs recorded in Illawarra Lowlands Grassy Woodland. The South Coast region had significant invasions of the widespread species but also had areas heavily invaded by Kikuyu (*Cenchrus clandestinus),* Rhodes grass (*Chloris gayana),* slender pigeon grass *(Setaria parviflora)* and panic veldtgrass (*Ehrharta erecta).*

Table 6 Top 15 EPGs across the 9 TECs surveyed

EPGs are ordered from highest to lowest based on the number of sites present. Common and Latin name are provided, the number of sites each species was recorded in and the number of communities it occurred in is listed. The top 10 are in bold font. For all 31 EPGs see Appendix A.

Common name	EPG	# sites present (/139)	# of TECs (/9)
Common paspalum	***Paspalum dilatatum***	**55**	**8**
Parramatta grass	***Sporobolus africanus***	**39**	**7**
African lovegrass	***Eragrostis curvula***	**36**	**6**
Cocksfoot	***Dactylis glomerata***	**26**	**7**
Phalaris	***Phalaris aquatica***	**26**	**6**
Kikuyu	***Cenchrus clandestinus***	**24**	**5**
Pigeon grass	***Setaria parviflora***	**23**	**6**
Sweet vernal grass	***Anthoxanthum odoratum***	**23**	**6**
Yorkshire fog	***Holcus lanatus***	**18**	**7**
Serrated tussock	***Nassella trichotoma***	**16**	**4**
Carpet grass	*Axonopus fissifolius*	14	5
Rhodes grass	*Chloris gayana*	14	3
Prairie grass	*Bromus catharticus*	12	7
Panic veldtgrass	*Ehrharta erecta*	12	3
Coolatai grass	*Hyparrhenia hirta*	10	4

4. Land manager surveys

Land managers working in natural environments often communicate knowledge in less formal ways than researchers. Land managers are often the first to implement control methods, find new invasions, and see the firsthand impact of EPGs on the environment they manage. It is this knowledge which influences weed control at all levels and can create strong foundations for the management of weeds (Reid et al. 2009; Coutts et al. 2013). Collating information on personal experiences can enhance effective conservation and management strategies (Jordan et al. 2016; Graham 2019).

To gain insight into the current perceptions of EPG species we surveyed people involved with EPG control in native and threatened ecosystems in New South Wales. Our aim was to see how landholder and land manager perceptions align with the findings of the field survey, with the intention of identifying similarities and disparities between them. Through this, we can draw attention to those EPG species that may require more attention or concern from land managers, and identify which species are a high priority for management. The land manager survey helped us identify the information to be provided in this report and provided insight into current control techniques.

4.1 Methods

A range of participants with experience in managing native communities and weed incursions were contacted to complete an online survey conducted by the University of Wollongong. The purpose of the research was to investigate the impact of EPGs to threatened and non-threatened native communities in New South Wales, and to investigate best practice management of these invasive grasses.

4.2 Results

Between February and April 2021, 62 respondents participated in the online survey. Some respondents did not answer every question and some questions allowed multiple responses; as such, the total count varies with questions.

Characteristics of participants

Most participants (40%) were from the South East Local Land Services (LLS) region and worked as a project officer or government land manager (46%; Table 7). Most participants (88%) had been involved in invasive plant management for 5 or more years, with 68% of respondents stating their experience in invasive plant management is above average (Table 7). Respondents worked on a variety of land types across public and private land.

Table 7 Characteristics of participants in the land manager survey

Showing (from top left): a) LLS region of respondents, b) area of involvement with invasive plants, c) level of experience with invasive plant management, d) time involved with invasive plant management. As there were different levels of response to these questions, we also provide percentages of the respondents at different levels.

a) LLS region	Count (/59)	%
South East	24	40.7
Greater Sydney	7	11.9
ACT	7	11.9
North Coast	7	11.9
Northern Tablelands	5	8.5
Central Tablelands	3	5.1
Hunter	3	5.1
Riverina	2	3.4
Central West	1	1.7

b) Type of involvement	Count (/60)	%
Project officer/ govt land manager	28	46.7
Researcher	7	11.7
Bush regeneration	5	8.3
Volunteer	5	8.3
Primary producer (ag.)	4	6.7
Own land for conservation	4	6.7
Hobby farm	3	5.0
Landcare	2	3.3
Peri-urban landowner (>10 ha)	1	1.7
Other	1	1.7

c) Experience	Count (/61)	%
Above average	42	68.9
Average	17	27.9
Below average	2	3.3

d) Time involved	Count (/60)	%
<1 year	1	1.67
1–5 years	6	10
>5 years	53	88.3

Table 8 Land types managed by different participants expressed as a count and percentage of people

Land type	Count (/58)	%
Public land gazetted for conservation purposes	19	33.3
Private land	17	28.3
All land types	6	11.7
Private and public	5	8.3
Private land with conservation covenant	4	6.7
Public land not gazetted for conservation purposes	4	6.7
Other	3	5.0

When asked to rank important threats to TECs, respondents ranked ‘clearing of native vegetation’ or ‘general weed invasion’ as the biggest threat. Invasion by EPGs was most frequently ranked second. Clearing of native vegetation increases disturbance, reduces fragment size and increases exposure to other land types (including cleared land), which provides opportunities for invasion by non-native plants (Auld and Tozer 2004; OEH 2017b; DPE 2022).

Figure 6 White Box – Yellow Box TEC. Photo: Steve Lewer/DPE

TEC selection

Participants were asked to select up to 3 TECs, or native communities, in which they work. One TEC was selected by 27% participants, 38% selected 2 TECs and 34% selected 3 or more TECs. For those that selected more than 3 TECs only the first 3 selections were included for analysis. In total, 33 TECs were selected, with 10 ‘other’ or native communities for those who did not work on TECs (Table 9).

Table 9 Top 15 TECs that participants are involved with (n=70)

For a full list of threatened and native communities (total n = 98) see Appendix B.

Community	Abbreviation	Count
White Box – Yellow Box – Blakely's Red Gum Grassy Woodland and Derived Native Grassland in the NSW North Coast, New England Tableland, Nandewar, Brigalow Belt South, Sydney Basin, South Eastern Highlands, NSW South Western Slopes, South East Corner and Riverina Bioregions	WBYB	20
Montane Peatlands and Swamps of the New England Tableland, NSW North Coast, Sydney Basin, South East Corner, South Eastern Highlands and Australian Alps Bioregions	MPS	7
Monaro Tableland Cool Temperate Grassy Woodland in the South Eastern Highlands Bioregion	MCTGW	6
Natural Temperate Grassland of the South Eastern Highlands	NTG	6
Lowland Grassy Woodland in the South East Corner Bioregion	LGW	4
Themeda Grassland on Seacliffs and Coastal Headlands in the NSW North Coast, Sydney Basin, and South East Corner Bioregions	TGoS	4
Hunter Lowland Redgum Forest in the Sydney Basin and NSW_North Coast Bioregions	HLRF	3
Illawarra Lowlands Grassy Woodland in the Sydney Basin Bioregion	ILGW	3
River-flat Eucalypt Forest on Coastal Floodplains of the NSW North Coast, Sydney Basin and South East Corner Bioregions	RFEF	3
Ribbon Gum – Mountain Gum – Snow Gum Grassy Forest/Woodland of the New England Tableland Bioregion	RGMGSG	3
Werriwa Tablelands Cool Temperate Grassy Woodland in the South Eastern Highlands and South East Corner Bioregions	WCTGW	3
Dry Rainforest of the South East Forests in the South East Corner Bioregion	DR	2
Inland Grey Box Woodland in the Riverina, NSW South Western Slopes, Cobar Peneplain, Nandewar and Brigalow Belt South Bioregions	IGB	2
McKies Stringybark/Blackbutt Open Forest in the Nandewar and New England Tableland Bioregions	MSBOF	2
New England Peppermint (*Eucalyptus nova-anglica*) Woodland on Basalts and Sediments in the New England Tableland Bioregion	NEP	2
	Total	**70**

Perceptions on EPGs

About half the participants used scientific studies (33 people), while 30 people used government sources to inform their management practice. Fewer used 'word of mouth' (18 people) or 'local councils' (16 people). Personal learning was a significant source of information (28 counts). Participants are clearly self-motivated to manage the threat of EPGs and show trust in evidence-based research and information provided by government organisations.

Participants overwhelmingly agreed they were concerned about the threat of EPGs to their communities (89%) and considered a number of characteristics were important in invasion.

Just about all participants (94%) believed soil disturbance increased the spread of EPGs. While 72% felt that impact of grazing increased EPG spread, most participants perceived a decrease in the spread of EPGs in response to canopy cover (68%) and native grass presence (68%). These results support our understanding that a healthy native community may have the ability to resist invasion (Mcglone et al. 2012; van Klinken and Friedel 2017), and increased disturbances are likely to be detrimental to native grass communities (Mack and D'Antonio 1998; Foster et al. 2002; Cilliers et al. 2008). Interestingly, there were mixed reports on the influence of low soil fertility, with 34% believing it had no impact, 28% thought it increased EPG spread, and 22% thought it decreased EPG spread. This suggests that EPGs might vary in their response to fertility which suggests an important area for further research.

As participants were more common in some regions, the identification of EPGs of concern is left for the regional analysis. However, overall, participants recorded 36 EPGs they were concerned about (Table 10). What is interesting about this list is that it is heavily skewed towards the well-known invasive EPGs such as African lovegrass and serrated tussock but misses a range of species that occurred across many TECs and were in high abundance (See field surveys in Section 3 of this overview). This project has therefore identified a suite of species that should be considered in each region. Species such as serrated tussock and Chilean needle grass, which are WoNS, were comparatively rare in the field survey. This could mean 2 things: these species could be well-managed in agricultural lands and their spread into native communities has been reduced, or these species are EPGs of agricultural areas, and not particularly important in many native communities.

Table 10 EPGs chosen by survey participants as 'highly damaging' on their land

Table 10 shows the EPGs and the number of participants (count). As some participants worked on multiple communities and could pick up to 3 grasses for each community, total count is higher than the number of survey participants.

Common name	Count
African lovegrass	44
Serrated tussock	27
Chilean needle grass	23
Coolatai	21
Phalaris	12
Sporobolus species	10
Kikuyu	10
Panic veldtgrass	8
Sweet vernal grass	6
Rhodes grass	6
Whisky grass	5
Common paspalum	5
Broadleaf paspalum	4
South African pigeon grass	4
Yorkshire fog	3
Pampas grass	3
Mexican feather grass	2
Buffalo grass	2
Carpet grass	2
Timothy	1
False oatgrass	1
Queensland blue couch	1
Buffel grass	1
Red fescue	1
Tall fescue	1
Common couch	1
Torpedo grass	1
Barley grass	1
Cane needle grass	1
Molasses grass	1
Johnson grass	1
Total sum	**212**

5. Four-step approach to managing EPGs in native communities

The results indicate that management practices need to be coordinated at different scales. Widespread EPGs of concern should have statewide or at least regional management plans, while regionally important EPGs and some community-specific EPGs of concern may need plans at smaller scales. Prioritisation needs to occur at the TEC level, considering both the risk assessment and the occurrence of each species at sites. However, TEC priorities will need to dovetail with regional approaches as these will be most economic and effective in effort.

While this document is centred around grassy communities of conservation importance, the role of management in controlling weeds on native pastures would benefit from this information. Effective management requires input from groups at various levels within any region, and communication of knowledge, research, concerns, resources, and expected roles and responsibilities is key to the effectiveness of controlling EPGs in the regions. Most participants felt EPGs were having ‘major negative effects’ (134/191) on the areas they were managing, and there was a heavy reliance on herbicides for control (47%) despite the issues of herbicide resistance.

In this chapter, we set up a 4-step approach to management: **Identify, Prioritise, Control and Monitor** (Figure 7). We include many of the ideas the land managers in our surveys are using already. Most participants (71%) have noticed a reduction in the abundance of the target weed using their current techniques. Some participants (48%) found control also led to an increase in native ground cover. A resources page can be found at the end of this document with links to useful documents and websites for control strategies.

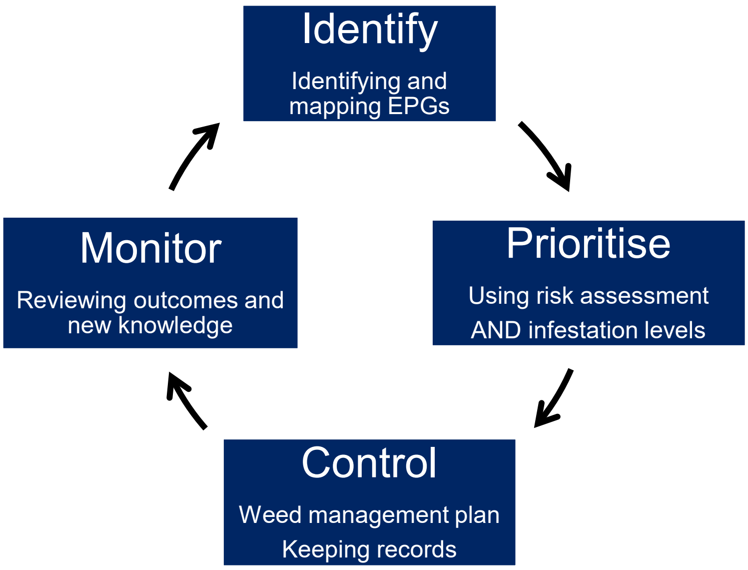


Figure 7 Example of the weed control cycle

As the cycle repeats over time, each step may alter slightly based on goals, control needed, influences from climate, improved knowledge, etc.

5.1 Identify

Critical to management of native communities is a quantitative survey of the area to identify and map the EPGs in the sites and their levels of invasion. The *Monitoring Manual for Invasive and Native Flora* (Watson et al. 2021) outlines methods to do this in a rigorous manner, but other grass surveys in the literature can also provide good methods in different communities. Grass identification can be a difficult skill to learn, with hundreds of grasses and similarity among and between genera. Confident grass ID is an important line of defence in weed management. Grass ID is an invaluable skill to learn: the more confident you are with grass ID the quicker you can respond to invasion, perhaps even before seed sets, and the more you can minimise off-target damage by upskilling yourself and those contracted to manage the grasses. Almost all respondents somewhat (40%) or strongly (56%) agreed they could identify EPGs, suggesting there is some value in the provision of training in grass ID. Tocal College has developed 3 regionally relevant field guides for grass identification available for purchase. Many organisations, including Landcare and the NSW Department of Primary Industries (DPI) have previously run identification workshops. We recommend getting in touch with your local weed officers, organisations, and Landcare facilitators to generate interest in running courses.

Native *Austrostipa* sp.
Photo: Harry Rose

Exotic *Nassella neesiana*
Photo: Harry Rose

Figure 8 Many native and exotic grasses look similar and can be misidentified

5.2 Prioritise

A combination of field surveys (Section 5.1 above) coupled with the risk assessment tool (Section 2 in this overview) should be used to identify the species which are of most concern within the native community. Land managers should also use other available resources and regional priorities to help prioritise the species of greatest concern. Regional priorities from 2 sources should be considered. Firstly, we provide documents for each of 4 broad regions in eastern New South Wales and list the EPGs that are considered the greatest threat. Secondly, regional groups may be undertaking a coordinated management of some species which may increase prioritisation of a less invasive species in the sites to gain regional reductions in that species. Furthermore, some species might be rare in your community but have a high-risk score, leading to the need to prioritise the removal of the species from sites and an increase in the prioritisation level.

While this document focuses on prioritising between EPGs, land managers often have to prioritise invasive species of all life forms. Members of Port Stephens Council developed a resource to assist with invasive species prioritisation (Skinner and Porter 2019). The tool determines how available time (or money) should be partitioned for management using scores from the NSW Weed Risk Assessment (Skinner and Porter 2019). Contact information is available in the resources section.

A case study for prioritisation – EPG invasion in Illawarra Lowlands Grassy Woodland

The following example, taken from surveys in Illawarra, illustrates how to use the risk assessment tool with on-ground surveys to prioritise EPGs for control (Note: this is a subset of the total 18 EPG species present in this community). In Table 11 several species have the same level of occurrence but very different risk scores, and some EPG species with lower presence (e.g. Rhodes grass), score high on the risk assessment. Prioritisation combines the 2 so that the highest priority grasses are those with: a) high occurrence and high risk (e.g. paspalum) likely to exert the most impact in the community, and b) lower occurrence but high risk (e.g. Rhodes grass), to mitigate high threats.

To further strengthen our confidence in prioritisation we would consider separate characteristics that may improve spread or invasiveness. For example, although *Sporobolus* has a lower risk score of 15 it is known to have high seed output, germination success, and longevity that vastly improve invasive success, leading it to higher prioritisation than Kikuyu. Conversely, slender pigeon grass has a high degree of uncertainty in the risk assessment so our priority would be to gather data to improve our understanding and, in turn, management.

For these species, the risk assessment has already been completed (Table 4). For grasses not assessed you can use the Excel risk assessment tool provided online (on the Environment and Heritage website) to complete your own assessment.

Table 11 Invasion profiles of 6 EPGs into Illawarra Lowlands Grassy Woodland

Table 11 shows the percentage of sites present (n = 8), their risk assessment score and level of uncertainty (%) and their priority for management.

EPG	% sites present	Risk score	Uncertainty	Priority
Paspalum	88	23.5	22.5	1
Rhodes grass	63	26	15	2
Sporobolus	88	15	27.5	3
Kikuyu	75	25	32.5	4
Slender pigeon grass	88	14.5	52.5	5
Carpet grass	63	13.5	42.5	6

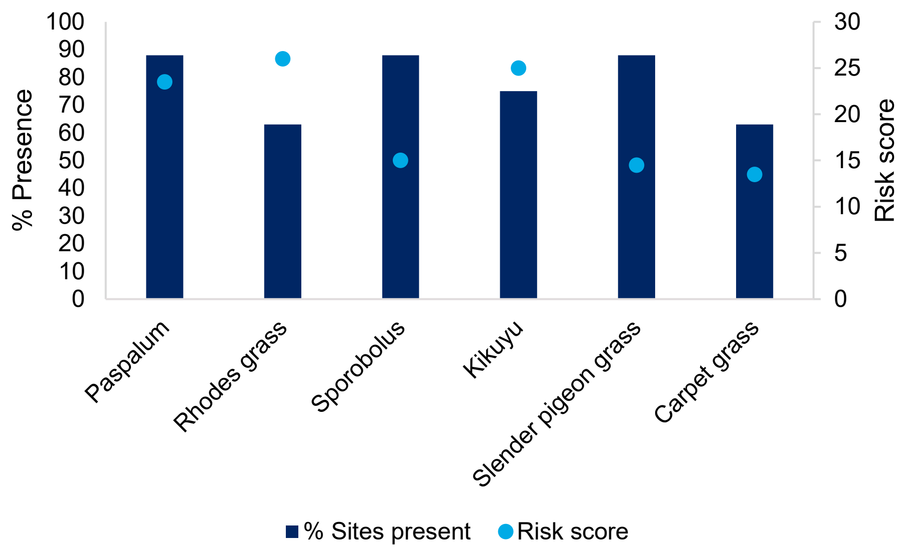


Figure 9 Invasion of 6 EPGs into Illawarra Lowlands Grassy Woodland and their risk score in the risk assessment

5.3 Control

Preventative weed control

Prevention focuses on keeping weeds out of uninvaded areas through spread reduction practices such as footwear and machinery cleaning and other hygiene, minimising inputs of weed seeds and maintaining a healthy, competitive native community. Roadsides can act as a reservoir for weeds, and improper management, including slashing and mowing, can greatly improve the spread of EPGs and improve their long-distance dispersal mechanisms. Coupled with the fact the roadsides are often near, or themselves are, significant environmental areas, appropriate roadside grass control can greatly affect preventative weed control (Eco Logical 2020; CSIRO 2021). An example of this is the Red Guide Post program in New South Wales which identifies areas of infestations to ensure no work is done without proper permission (Federation Council 2021). Weed hygiene is a simple and important way to limit the spread of EPGs. Examples include staying on designated tracks; cleaning machinery, vehicles and clothing before and after leaving a site; working from least-infested to most-infested sites and managing stock movement to limit spread of weeds. Research found implementation of weed hygiene was low compared to its perceived importance (Graham et al. 2016). Investing in weed hygiene assists in prevention of spread and has the highest cost: benefit ratio as per the generalised species invasion curve.

Cleaning machinery. Photo: DAF QLD

Hygiene in parks and reserves. Photo: Julia Rayment/UOW

Farm biosecurity. Photo: farmbiosecurity.com.au

Figure 10 Examples of preventative weed control practices

The NSW Department of Planning and Environment has developed hygiene guidelines to reduce the risks of introducing pathogens and invasive plants into areas of New South Wales, especially those with susceptible threatened species, ecological communities and outstanding biodiversity values. Some weed hygiene practices are less costly or more accessible than others, for example, staying on designated tracks, or employing farm biosecurity, which has multifaceted benefits (Graham et al. 2016). Implementing other weed hygiene practices might be initially costly in time and money, e.g. wash-down stations, and this can be a barrier for some to alleviating future costs (Gill et al. 2018). Social acceptance of weed hygiene, through training and inclusion in contracts, may also improve implementation of these important preventative measures (Graham et al. 2016).

Management options

Table 12 sets out considerations necessary for the control of particular EPGs, and provides a broad overview of effective management strategies that might be used on EPGs, including advantages and disadvantages of different options. Understanding the biology of target species allows us to predict how they will respond to certain control techniques. The risk assessment tool can also provide further information.

Control through grazing practices

Several resources are available for weed control in areas of primary productivity (e.g. GRDC Integrated Weed Management Manual). Weed hygiene to limit spread of all pasture species, particularly trade-off species that are highly impactful in native ecosystems, is important in grazing areas. Pasture plantings, particularly in areas of high environmental value, should consider the invasive potential of the pasture plant. Use of grazing should be reserved for native grasslands where grazing is allowed, i.e. native pastures or travelling stock reserves (TSRs). For important areas of intermittent grazing, such as TSRs, grazing should be avoided for as long as possible, with a focus on maximising native ground cover to build resilience to grazing, and resilience to times of high environmental stress when they may be used (Prober and Thiele 1995; Davidson et al. 2005; Spooner and Morris 2012; Vella et al. 2020).

Table 12 Outline of main control types

Table 12 includes the advantages and disadvantages of each, and infestation size where use is most suitable.

Control	Examples	Advantages	Disadvantages	Infestation size
Preventative	Weed hygiene, sourcing uncontaminated seed	Prevents weed infestations from spreading	Success can be influenced by hygiene practices of those around you, e.g. other land managers, hikers, campers, contractors, etc.	All situations – important basic weed control
Manual	Hand pulling, grubbing, chipping	Low cost, immediate removal of weed, no training required	Several EPG species can regenerate from rhizomes or stolons, e.g. Kikuyu, Rhodes grass, torpedo grass; removal of seed heads is critical	Light infestations, untrained volunteers
Mechanical	Slashing, mowing, mulching, steaming	Reduced biomass of large areas, can limit seed set	Machinery can act as a vector for spread without weed hygiene; many grasses re-establish from buds, roots or seed banks after disturbance	Large infestations, reducing biomass before seed set
Fire	Cool season burn, cultural burn	Reduces biomass, can reduce seed bank, can promote native regeneration	Some EPGs are adapted to fire regimes (e.g. buffel grass)	Integrated weed management, medium to large infestations
Chemical	Wick wipe, broadacre, spot spray; selective (flupropionate) or general (glyphosate)	Generally effective, easy to administer; most grasses susceptible	Potential for herbicide resistance (e.g. African lovegrass, Coolatai), costly, dependent on weather, requires training, off-target damage possible	Infestations of all size, using IWM to reduce likelihood of resistance; use NSW Weed Control Handbook
Biocontrol	Research underway for several grasses	Highly effective at controlling populations, low effort, environmentally friendly	Research takes several years before entering general market	See Biological control of weeds manual for more information
Integrated weed management	Simple (weed hygiene and one other control) or complex (multiple control techniques)	High efficacy, avoids resistance to singular control method, useful for multiple EPGs	Requires planning and monitoring for best outcome, can be resource intensive	All infestations, transdisciplinary weed management

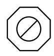
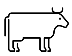
Table 13 Infographic of management techniques for EPG control in native communities

'Traffic light' symbols indicate applicability of control technique. See Table 14 for icon legend.

EPG species	Preventative	Manual	Mechanical	Fire	Chemical	Biocontrol	Grazing
African lovegrass	✓ ⊘	✓ 🤲	❚❚ 💧	❚❚ 🔥	❚❚ 🧴	❚❚ 🔍	❚❚ 🐄
Rhodes grass	✓ ⊘	❚❚ 💧	❚❚ 💧	❚❚ 🔥	✓ 🧴	✗	✓ 🐄
Kikuyu	✓ ⊘	✗ 💧	❚❚ 💧	❚❚ 🔥	✓ 🧴	✗	❚❚ 🐄
Common paspalum	✓ ⊘	✓ 🤲	❚❚ 💧	❚❚ 🔥	❚❚ 🧴	✗	❚❚ 🐄
Chilean needle grass	✓ ⊘	✓ 🤲 ❚❚ 💧	✓ 🚜	✓ 🔥	✓ 🧴	❚❚ 🔍	❚❚ 🐄
Cocksfoot	✓ ⊘	❚❚ 💧	✓ 🚜	📖	❚❚ 🧴	✗	✓ 🐄
Yorkshire fog	✓ ⊘	✓ 🤲	❚❚ 🚜 📖	❚❚ 🔥 📖	✓ 🧴	✗	✓ 🐄
Sweet vernal grass	✓ ⊘	✓ 🤲 ❚❚ 💧	❚❚ 💧	❚❚ 🔥 📖	❚❚ 🧴 📖	✗	❚❚ 🐄 📖
Phalaris	✓ ⊘	❚❚ 💧	✓ 🚜	❚❚ 🔥	❚❚ 🧴 📖	✗	✓ 🐄
Panic veldtgrass	✓ ⊘	✓ 🤲	✓ 🚜	❚❚ 🔥	✓ 🧴	✗	✓ 🐄
Serrated tussock	✓ ⊘	✓ 🤲	✓ 🚜	✓ 🔥	❚❚ 🧴	❚❚ 🔍	✓ 🐄
Sporobolus	✓ ⊘	✓ 🤲	❚❚ 🚜	✓ 🔥	✓ 🧴	❚❚ 🔍	❚❚ 🐄
Coolatai	✓ ⊘	✓ 🤲	✓ 🚜	❚❚ 🔥	✗ 🧴	✗	❚❚ 🐄

EPG list is a subset of species important across New South Wales based on scientific listing, field survey results, and risk assessment ranking. Note: grazing should be considered as a control strategy for conservation land only where it occurs on native pasture.

Table 14 Explanation of the icons in Table 13

Icon	Explanation	Icon	Explanation
	Provides good control		Fire can provide control
	Not suggested as good control or not available		Adapted to fire regime; resprouts or promotes seed production
	Considerations required before undertaking control		Chemical control
	Small infestations		Potential or known herbicide resistance
	Capacity for regrowth		More research needed
	Mechanical control		Preventative weed control (e.g. cleaning stations, biosecurity, purchase weed-free seed and hay, etc.)
	Grazing control (see resources for more information)		Biocontrol available
	Grazing may promote spread or is only palatable under certain conditions and timing		Biocontrol under review

Best practice management – integrated weed management

Improving EPG management relies on large-scale integrated weed management. That is, not only integration of multiple control techniques, but integration across disciplines for better access to research, better problem solving, greater understanding of risk and improved relationships.

Restoration of communities through management of EPGs will differ between agricultural land and conservation land, as goals in terms of biodiversity and ecosystem services differ. Although the agricultural land may also be managing threats to conservation land, the resources available, end goals, and drivers of invasion are different. Grazing pressure, land management, and pasture planting can act as both management tools and pathways for invasion. Differences in management also results from the different impacts of the weeds in the system i.e. lost productivity compared with reduced biodiversity and ecosystem function (Neve et al. 2018). Both agricultural and conservation land management aim to design systems that have greater resilience to weeds (Neve et al. 2018).

At its core, integrated weed management (IWM) involves using more than one of the above control methods to increase the chances of successful control (DPI no date). IWM is particularly useful to avoid plants adapting or improving their resilience to any single control method, such as herbicide spray. IWM should consider the biology and ecology of the target EPGs to combine appropriate techniques. IWM may vary in its complexity based on available resources and the target EPG. Basic IWM may incorporate weed hygiene with one or 2 control aspects, while more complex IWM may involve multiple techniques. Native recovery should also be considered, with a focus on the restoration of a resilient native plant community in line with the community scientific determination.

Graham (2019) identifies 3 main strategies for plant management which grade from individual effort to a coordinated effort:

- highly individualised widespread participation, with many parties controlling a weed but not necessarily for the same reason or in the same way
- linking efforts, where the efforts of weed control are coordinated across properties and local government areas
- collaboration, with a pooling of resources aiming to control a common area of land or common plant and including education and outreach.

Research shows higher levels of collaboration lead to more effective weed management. Integrating different kinds of knowledge and social bonding allows dynamic invasive plant management coordination (Graham 2019). This is demonstrated through the creation of Landcare, which began with the collaboration of farmers and conservationists with the intention of protecting the landscape. Interviewing 3 Landcare groups independently managing serrated tussock across New South Wales and Victoria, Graham and Rogers (2017) found the groups addressed the common nature of the problem and shared information and resources in order to address the problem. This reduced stigma, encouraged collective learning and developed strong social relationships (Graham and Rogers 2017). Access to resources and support influences confidence, interest in, and ability to control problem weeds (Graham 2013). Grants and funding available through NSW Department of Planning and Environment (DPE no date a), NSW Local Land Services (LLS no date) and DPI (DPI 2019) aim to encourage management by providing aid and financial resources. Effective weed management allows benefits to extend wider than just those directly involved in the management (Jordan et al. 2016; Bagavathiannan et al. 2019). Multistakeholder collaboration requires determining the roles and expectations at different levels, e.g. individual, local organisation, state (Bagavathiannan et al. 2019).

Weed control is rarely short term: native regeneration is often slow, and EPG control can seem like a never-ending battle with reinfestations and long-lived seed banks. Long-term control involves ensuring native communities have natural resilience to future disturbances and reinvasion (D'Antonio et al. 2009). Transdisciplinary involvement can improve long-term management through wide-scale research into management efficacy, more efficient transfer of knowledge between stakeholders, improved relationships, and an ongoing sense of shared commitment.

Examples of integrated, transdisciplinary management of EPGs can be seen in the establishment of the National Strategy for Serrated Tussock (ARMCANZ 2000, in Klepeis et al. 2009) and transdisciplinary community-led control of weeds in the Bega Valley, including pampas grass (Herbert et al. 2013). Research continues to improve our understanding of African lovegrass invasion (CRC Weed Management 2007; Marshall et al. 2011; Firn et al. 2018), and organisations have been developed to protect the grassy communities at threat, including the Grassy Box Woodland Conservation Management Network (GBWCMN 2010) and the Kosciusko 2 Coast (K2C) program (K2C 2017). There remains a need to amplify the importance of participation by multiple stakeholders, and to continue to develop ways to share findings and implement practices that facilitate stakeholders' efforts (Neve et al. 2018).

Preparing a management plan

Preparation of a management plan is an important exercise in the 4-step approach to managing EPGs, particularly when planning control within areas with biodiversity value.

A site-managed plan should include the following information:

1. Site location and description, including:
    - information that will help identify which species may be present or able to invade, and factors influencing invasion success, e.g., current and previous site use, disturbance history, management history, prevailing winds, slopes, climate etc.
    - information on native community composition including threatened species, ecological communities or non-threatened biodiversity of importance, to determine priority areas for management and considerations.
2. Weed locations and extent of infestations:
    - Identify and map all EPGs and other weeds present, and levels of infestation.
3. Priorities:
    - Use the risk assessment and advice in Sections 1 and 2 of this overview to research and assess risk of all EPGs; include control of other weeds on site.
    - What are your goals and priorities for weed control? Do you have threatened flora and fauna you need to protect? Are you containing a spread?
    - What needs to be controlled? When does it need to be controlled? Where does it need to be controlled? How can it be controlled? Who should control it? (You? Contractors?)
4. The approach you will use:
    - Determine the best approach based on the infection level and available resources.
5. Implementation:
    - Conduct the control. Be sure to monitor your processes.
6. Monitoring and review:
    - Determine the outcome and any successes and challenges. Review and revise your plan accordingly, and repeat.

See Section 6 'Resources' for information on developing an effective weed management plan.

5.4 Monitor

Monitoring is critical to assess the success of control, identify new emerging threats, and will improve our understanding of management efficacy and native recovery. It also provides the opportunity to alter control strategies for long-term success. Of the 46 participants who answered questions about record keeping, only half (56%) kept records on the cost or response of the target EPG to control. Of this 56%, most records (54%) were necessary for the use of herbicides (Table 15). Only 17% conducted biodiversity assessments to determine impact on native regeneration and weed cover, and only 12% conducted monitoring, including both general and long-term monitoring. Monitoring is often neglected due to lack of time, money, or knowledge of how to monitor control programs (Downey et al. 2009.

Monitoring has also previously been highly decentralised, with different outcomes influencing methods, and monitoring influenced by level of resources (Downey et al. 2009). Despite this, monitoring is an essential component, and is the cornerstone of our ability to understand invasion, mitigate negative impact to biodiversity, and to learn from our successes and failures (Downey et al. 2009). Monitoring provides a clear indication of the efficacy of control programs on target weeds and surrounding biodiversity, allowing management strategies to improve or change in response. Implementation of standard monitoring ensures data is consistent and improves transdisciplinary communication and integration.

We recommend using the *Monitoring Manual for Invasive and Native Flora* (Watson et al. 2021) and implementing monitoring as a key requirement of EPG management.

Table 15 Record keeping of EPG control and response by participants in the land manager survey

Note: some participants used more than one method of record keeping.

Record keeping	Count	%
Recording herbicide usage (place, time, cost, etc.)	19	54.3
Biodiversity assessments (i.e. impact on native regen. and weed cover)	6	17.1
Maps	3	8.6
Long-term monitoring	2	5.7
Monitoring general	2	5.7
Risk assessments	1	2.9
Photographs	1	2.9
Grazing records	1	2.9
Total	**35**	

5.5 Conclusion

The research presented above has created a strong foundation for reassessing and prioritising EPG management to abate this key threatening process and improve biodiversity outcomes. We assessed our current knowledge and risk of EPGs in eastern NSW and determined which EPGs were invading priority threatened native communities. We identified differences in widespread, regional, and community-level invasions. Lastly, we sought to understand the current focus for those directly involved with EPG and native ecosystem management and gained insights into their approaches, opinions, and perceptions of EPG management. The combination of the land manager surveys and the field surveys reveal in which communities and regions EPGs are having greater effects and which emerging EPGs may need more attention. With major findings identifying regional differences influencing EPG invasion prioritisation, management can be separated into regional foci for more efficient and tailored management. As a result, the findings are discussed at a regional level in 4 separate documents covering the North Coast, Northern Tablelands and Slopes, Southern Tablelands and Slopes, and South Coast. Within each region the highest risk and most invasive or characteristic EPGs of the region are discussed, with a focus on biology and ecology that drives their invasion. Information on best practice management for each species is discussed with the aim to improve the management of EPGs. By identifying gaps in research, areas for concern, and management strategies, these chapters can be used as a tool to facilitate improved transdisciplinary weed management with the aim of abating the threat of EPGs and improving native ecosystem function and health.

Figure 11 Countryside grasses. Photo: Peter Robey/DPE

6. Resources

6.1 General

NSW Weed Control Handbook – DPI

NSW WeedWise – DPI

No Space For Weeeeeds – DPI

Saving our Species Hygiene guidelines – DPIE

Arrive Clean, Leave Clean – Australian Government Department of Agriculture, Water and the Environment

About weed biological control – DPI

Weed management guides – DPI

Australian Weeds Strategy 2017–2027 – Invasive Plants and Animals Committee, Australian Government Department of Agriculture and Water Resources

Machinery hygiene course – Tocal College

6.2 Agricultural resources

Developing whole farm Integrated Management programs for Unpalatable grasses (incl. Chilean needle grass and serrated tussock) – DPI Victoria

Weed Detection and Control on Small Farms – B Sindel and M Colemen, UNE

Hotspots Fire Project: Managing fire on your property, The interaction between fire and weeds – Nature Conservation Council and NSW Rural Fire Service

Integrated Weed Management Manual – Australian Government Grains Research and Development Corporation

6.3 Grants and funding

Apply for grants and funding – LLS

Grants – DPE

6.4 Grass identification

Grasses of New South Wales – Friends of Grasslands

Identify grasses – Tocal College short course

Grasses of the NSW tablelands – Tocal College field guide

Grasses of coastal NSW – Tocal College field guide

Grasses of the NSW slopes and adjacent plains – Tocal College field guide

6.5 Weed management plans

A Field Manual for Surveying Nationally Significant Weeds – Australian Government Bureau of Rural Sciences

Developing a Weed Management Plan – Land for Wildlife Queensland

Threat abatement plan to reduce the impacts on northern Australia's biodiversity by the five listed grasses – Australian Government Department of Sustainability, Environment, Water, Population and Communities

Preparing a Whole of Property Weed Management Plan: A land managers guide – South East LLS

6.6 Monitoring

Monitoring Manual for Invasive and Native Flora – Watson et al./DPIE

20th Weeds NSW Conference Proceedings, Weed Society of NSW – see page 12: *Operationalising the NSW Weed Risk Management System – A Resource Prioritisation and Allocation Model*, J Skinner and S Porter

6.7 Species specific

Sporobolus

Nigrospoa crown rot for biocontrol of giant Parramatta grass – DPI fact sheet

NSW WeedWise: Giant rat's tail grass (Sporobolus pyramidalis) – DPI

NSW WeedWise: Giant Parramatta grass (Sporobolus fertilis) – DPI

Strategic management of weedy Sporobolus grasses – Meat & Livestock Australia (MLA)

Weed Management Guide – Weedy Sporobolus Grasses, Technical Report 2011 – Australian Government Department of Agriculture and Fisheries

Weedy Sporobolus grasses: Best practice manual – Queensland Department of Primary Industries and Fisheries

African Lovegrass

NSW WeedWise: African lovegrass (*Eragrostis curvula*) – DPI

African lovegrass fact sheet – GLENRAC

Molonglo Catchment Group Weed Fact Sheet: African lovegrass– Molonglo Catchment Group

African lovegrass management – DPI fact sheet

African lovegrass – 3D weed management

Using fire to manage priority weeds in Cumberland plain vegetation: African lovegrass – Nature Conservation Council

6.8 Weeds of National Significance

Chilean needle grass

Chilean needle grass – 3D weed management

Integrated control of Chilean Needle Grass – MLA

Chilean Needle Grass Case Studies (Farmers managing Chilean needle grass in grazing systems) – 3D weed management

Nassella neesiana (Trin. & Rupr.), Chilean needle grass – Weeds Australia – Profiles

Weed Management Guide: Chilean needle grass – Natural Heritage Trust

Serrated tussock

NSW WeedWise: Serrated tussock (*Nassella trichotoma*) – DPI

Serrated Tussock Management and Control in NSW and ACT – DPI

National Best Practice Management Manual: Serrated Tussock – National Serrated Tussock Management Group

Regional Local Weed Management Plan: Serrated tussock – Central Tablelands and Central West LLS

Serrated tussock – 3D weed management

Integrated Management Strategies for the Control of Serrated Tussock in Inaccessible Native Pastures – MLA

7. More information

- African lovegrass
- Biological control of weeds manual
- Chilean needle grass
- GRDC Integrated Weed Management Manual
- Hygiene guidelines
- Illawarra Lowlands Grassy Woodland in the Sydney Basin Bioregion
- Lowland Grassy Woodland in the South East Corner Bioregion
- Monaro Tableland Cool Temperate Grassy Woodland in the South Eastern Highlands Bioregion
- Natural Temperate Grassland of the South Eastern Highlands
- New England Peppermint (*Eucalyptus nova-anglica*) Woodland on Basalts and Sediments in the New England Tableland Bioregion
- NSW Weed Control Handbook
- Ribbon Gum – Mountain Gum – Snow Gum Grassy Forest/Woodland of the New England Tableland Bioregion
- Serrated tussock
- Themeda Grassland on Seacliffs and Coastal Headlands in the NSW North Coast, Sydney Basin and South East Corner Bioregions
- Tocal College: grasses
- Weedy Sporobolus grasses
- Werriwa Tablelands Cool Temperate Grassy Woodland in the South Eastern Highlands and South East Corner Bioregions
- White Box – Yellow Box – Blakely's Red Gum Grassy Woodland and Derived Native Grassland in the NSW North Coast, New England Tableland, Nandewar, Brigalow Belt South, Sydney Basin, South Eastern Highlands, NSW South Western Slopes, South East Corner and Riverina Bioregions

8. References

Agriculture Victoria (2008), Victorian Weed Risk Assessment (WRA) Method, Victorian Resources Online, https://vro.agriculture.vic.gov.au/dpi/vro/vrosite.nsf/pages/weeds_listing_docs/$FILE/vic_weed_risk_ass_method.pdf.

ARMCANZ (2000), *Weeds of National Significance Serrated Tussock* (Nassella trichotoma) *Strategic Plan*, Agriculture and Resource Management Council of Australia and New Zealand, Australian & New Zealand Environment & Conservation Council and Forestry Ministers.

Anderson FE, Barton J and McLaren D (2010), 'Studies to assess the suitability of Uromyces pencanus as a biological control agent for Nassella neesiana (Poaceae) in Australia and New Zealand', *Australasian Plant Pathology* 39(1): 69–78.

Auld TD and Tozer M (2004), 'Endangered ecological communities and landscape conservation in NSW: successes and failures in the Sydney Basin', in Royal Zoological Society of NSW *Threatened species legislation: is it just an Act*: 94–101.

Bagavathiannan M V et al. (2019), 'Considering weed management as a social dilemma bridges individual and collective interests', *Nature Plants* 5(4) 343–351.

Baker HG (1965), 'Characteristics and modes of origin of weeds', *Genetics of colonizing species*: 147–172, Academic Press, New York.

Bourdôt GW et al. (2010), 'Current and potential distributions of *Nassella neesiana* (Chilean needle grass) in Australia and New Zealand', in *17th Australasian Weeds Conference: New frontiers in New Zealand: together we can beat the weeds*: 424–427, Plant Protection Society, Hastings, New Zealand.

Bray S and Officer D (2007), *Weedy Sporobolus grasses: best practice manual*, 3rd edn, Queensland Department of Primary Industries and Fisheries, https://futurebeef.com.au/wp-content/uploads/2011/09/Weedy_sporobolus_manual.pdf.

Brook RK and McLachlan SM (2008), 'Trends and prospects for local knowledge in ecological and conservation research and monitoring', *Biodiversity and Conservation* 17(14): 3501–3512.

Butler DW and Fairfax RJ (2003), 'Buffel Grass and fire in a Gidgee and Brigalow woodland: A case study from central Queensland', *Ecological Management and Restoration* 4(2): 120–125.

Cadotte MW, Murray BR and Lovett-Doust J (2006), 'Ecological patterns and biological invasions: using regional species inventories in macroecology', *Biological Invasions*, 8(4): 809–821.

Cilliers SS, Williams NSG and Barnard FJ (2008) 'Patterns of exotic plant invasions in fragmented urban and rural grasslands across continents', *Landscape Ecology* 23(10): 1243–1256.

Cook GD and Dias L (2006), 'It was no accident: deliberate plant introductions by Australian government agencies during the 20th century', *Australian Journal of Botany* 54(7): 601–625.

Coutts-Smith A and Downey PO (2006), *Impact of weeds on threatened biodiversity in New South Wales*, CRC for Australian Weed Management, Adelaide.

Coutts SR, Yokomizo H and Buckley YM (2013), 'The behavior of multiple independent managers and ecological traits interact to determine prevalence of weeds', *Ecological Applications* 23(3): 523–536.

CRC Weed Management (2003), *Weed Management Guide: Serrated tussock (Nassella trichotoma*), http://serratedtussock.com/wp-content/uploads/files/CRC-Weed-Management-Guide-Serrated-Tussock.pdf

CRC Weed Management (2007), *Weed Management Guide: Coolatai grass (Hyparrhenia hrita),* https://archive.dpi.nsw.gov.au/__data/assets/pdf_file/0007/347155/coolatai-grass-weed-management-guide.pdf. Accessed: 3 September 2019.

CSIRO (2021), *The responsibility and management of weeds along Australian roadsides. Australia* p. 8, https://research.csiro.au/weed-awm/wp-content/uploads/sites/381/2021/07/roadside-management-fact-sheet-general-MAY-2021.pdf.

D'Antonio CM et al. (2009), 'Applying ecological concepts to the management of widespread grass invasions', in *Management of invasive weeds* 123–149, Springer.

D'Antonio CM and Vitousek PM (1992), 'Biological Invasions by Exotic Grasses, the Grass/Fire Cycle, and Global Change', *Annual Review of Ecology, Evolution, and Systematics* 23(1): 63–87.

Davidson I et al. (2005), 'Travelling stock reserves: refuges for stock and biodiversity?', *Ecological Management & Restoration* 6(1): 5–15, Wiley Online Library.

Dawson N (2005), *Review of Progress on Invasive Species*, *Final Report to Department of Environment and Heritage*, Commonwealth Department of the Environment and Heritage, https://www.environment.gov.au/system/files/resources/b3fc09c0-6969-41dc-ab47-29373d6f267f/files/review-full.pdf.

De la Barrera E (2008), 'Recent invasion of buffel grass (*Cenchrus ciliaris*) of a natural protected area from the southern Sonoran Desert', *Revista mexicana de biodiversidad* 79(2): 385–392.

Downey PO et al. (2009), 'Weeds and biodiversity conservation: a review of managing weeds under the New South Wales Threatened Species Conservation Act 1995', *Ecological Management & Restoration* 10: S53–S58, Wiley Online Library.

Downey PO et al. (2011), 'Assessing risk across the spectrum of weed management', *Plant Sciences Reviews 2010*, CABI, 203.

DPE (no date a), *Grants*, Environment and Heritage website, NSW Department of Planning and Environment, https://www.environment.nsw.gov.au/funding-and-support/grants. Accessed: 8 May 2021.

DPE (no date b), *Grasslands*, Environment and Heritage website, NSW Department of Planning and Environment, https://www.environment.nsw.gov.au/threatenedSpeciesApp/VegFormation.aspx?formationName=Grasslands. Accessed 15 October 2020.

DPE 2022, *Threatened ecological communities*, Environment and Heritage website, NSW Department of Planning and Environment, https://www.environment.nsw.gov.au/topics/animals-and-plants/threatened-species/about-threatened-species/threatened-ecological-communities. Accessed: 13 August 2019.

DPI (no date a), *Integrated weed management*, NSW Department of Primary Industries website, https://www.dpi.nsw.gov.au/biosecurity/weeds/weed-control/general-management/integrated-weed-management. Accessed: 9 May 2021.

DPI (no date b), *Pasture species and varieties,* NSW Department of Primary Industries website, https://www.dpi.nsw.gov.au/agriculture/pastures-and-rangelands/species-varieties

DPI (no date c), *Weeds strategy and policy*, *NSW Weed Risk Management System*, NSW Department of Primary Industries website, https://www.dpi.nsw.gov.au/biosecurity/weeds/strategy.

DPI (2012), *Spiny burrgrass*, NSW Department of Primary Industries fact sheet, https://www.murrumbidgee.nsw.gov.au/files/ENVIRONMENT/Spiny-burrgrass-Primefact-799-Press-Quality-PDF.pdf. Accessed: 6 June 2019.

DPI (2019), New South Wales Weeds Action Program Guidelines 2020–2025, NSW Department of Primary Industries.

DPIE (2019), Invasion of native plant communities by exotic perennial grasses – key threatening process listing, NSW Scientific Committee – final determination, Environment, Energy and Science website, NSW Department of Planning, Industry and Environment, https://www.environment.nsw.gov.au/topics/animals-and-plants/threatened-species/nsw-threatened-species-scientific-committee/determinations/final-determinations/2000-2003/invasion-of-native-plant-communities-by-exotic-perennial-grasses-key-threatening-process-listing.

Eco Logical (2020), *Council Roadside Environmental Management Framework*, Local Government NSW, https://www.lgnsw.org.au/common/Uploaded files/REM_files/CREMF.pdf. Accessed: 29 September 2021.

Eilts J and Huxman T (2013), 'Invasion by an exotic, perennial grass alters responses of a native woody species in an arid system', *Journal of Arid Environments* 88: 206–212.

Federation Council (2021), *Red Guide Post Program*, Federation Council, https://www.federationcouncil.nsw.gov.au/Environment-Waste/Animals-Plants/Noxious-Weeds/Red-Guide-Post-Program. Accessed: 29 September 2021.

Firn J, Ladouceur E and Dorrough J (2018), 'Integrating local knowledge and research to refine the management of an invasive non-native grass in critically endangered grassy woodlands', *Journal of Applied Ecology* 55(1): 321–330.

Foster BL et al. (2002), 'Invasibility and compositional stability in a grassland community: relationships to diversity and extrinsic factors', *Oikos* 99(2): 300–307, doi: 10.1034/j.1600-0706.2002.990210.x.

Fraser D et al. (2017), 'Abiotic stress tolerance of kikuyu (*Cenchrus clandestinus*) and some related grasses and potential of kikuyu for agricultural and urban environments', *Crop and Pasture Science* 68(3): 285–296, CSIRO Publishing, doi: 10.1071/CP15380.

Fullagar P and Heyligers P (2006), 'Shearwater colonies on Montague Island; are they being affected by encroaching Kikuyu Grass?' *Aust. Zool.* 33(4): 476–479, doi: 10.7882/az.2006.020.

GBWCMN (2010), *Grassy Ecosystems Conservation Management Networks*, Grassy Box Woodlands Conservation Management Network website, https://www.gbwcmn.net.au/about. Accessed: 20 September 2021.

Gill N et al. (2018), 'Weed hygiene practices in rural industries and public land management: variable knowledge, patchy implementation, inconsistent coordination', *Journal of Environmental Management* 223: 140–149, Elsevier.

Gioria M, Pyšek P and Moravcova L (2012), 'Soil seed banks in plant invasions: promoting species invasiveness and long-term impact on plant community dynamics', *Preslia* 84(2): 327–350.

Godfree R et al. (2017), 'Why non-native grasses pose a critical emerging threat to biodiversity conservation, habitat connectivity and agricultural production in multifunctional rural landscapes', *Landscape Ecology* 32(6): 1219–1242.

Graham S (2013), 'Three cooperative pathways to solving a collective weed management problem', *Australasian Journal of Environmental Management* 20(2): 116–129, Taylor & Francis.

Graham S et al. (2016), 'Weed hygiene practices in NSW: Knowledge and practices of landholders, public land managers, weed contractors and agricultural transport operators', *Faculty of Social Sciences – Papers*, University of Wollongong.

Graham S (2019), 'Coordinating invasive plant management among conservation and rural stakeholders', *Land Use Policy* 81: 247–255, Elsevier.

Graham S and Rogers S (2017), 'How local landholder groups collectively manage weeds in south-eastern Australia', *Environmental Management* 60(3): 396–408, Springer.

Hamilton MA et al. (2014), 'Using Weed Risk Management assessments to inform on-ground action for new and emerging environmental weeds in New South Wales', in Baker M (ed.) *Proceedings of the 19th Australasian Weeds Conference*.

Herbert A, Cameron S and Davies H (2013), 'No Boundaries for NRM on the Far South Coast', in Wu H (ed.) *Weeds have no boundaries*, *17th NSW Weeds Conference*, 9–12 September 2013, Corowa.

Higgins SI and Richardson DM (2014), 'Invasive plants have broader physiological niches', *Proceedings of the National Academy of Sciences* 111(29): 10610–10614.

Holle B Von and Simberloff D (2005), 'Ecological resistance to biological invasion overwhelmed by propagule pressure', *Ecology* 86(12): 3212–3218.

Jackson J (2005), 'Is there a relationship between herbaceous species richness and buffel grass (*Cenchrus ciliaris*)?' *Austral Ecology* 30(5): 505–517.

Jordan N et al. (2016), 'Transdisciplinary weed research: new leverage on challenging weed problems?' *Weed Research* 56(5): 345–358, Wiley Online Library.

Klepeis P, Gill N and Chisholm L (2009), 'Emerging amenity landscapes: Invasive weeds and land subdivision in rural Australia', *Land Use Policy* 26(2): 380–392, doi: 10.1016/j.landusepol.2008.04.006.

van Klinken RD and Friedel MH (2017), 'Unassisted invasions: understanding and responding to Australia's high-impact environmental grass weeds', *Australian Journal of Botany* 65(8): 678–690.

K2C (2017), *Kosciuszko to Coast (K2C)*, NSW Landcare Gateway website, https://landcare.nsw.gov.au/groups/kosciuszko-to-coast/. Accessed: 20 September 2021.

Laffan SW (2006), 'Assessing regional scale weed distributions, with an Australian example using Nassella trichotoma', *Weed Research* 46(3): 194–206, doi: 10.1111/j.1365-3180.2006.00491.x.

Linder HP et al. (2018), 'Global grass (*Poaceae*) success underpinned by traits facilitating colonization, persistence and habitat transformation', *Biological Reviews* 93(2): 1125–1144.

Liu J et al. (2006), 'Invasive alien plants in China: role of clonality and geographical origin', *Biological Invasions* 8(7): 1461–1470.

LLS (no date), *Apply for Grants & Funding*, NSW Local Land Services website, https://www.lls.nsw.gov.au/i-want-to/apply-for-grants-and-funding.

Lockwood JL, Cassey P and Blackburn T (2005), 'The role of propagule pressure in explaining species invasions', *Trends in Ecology & Evolution* 20(5): 223–228.

Lonsdale WM (1994), 'Inviting trouble: Introduced pasture species in northern Australia', *Australian Journal of Ecology* 19(3): 345–354, doi: doi:10.1111/j.1442-9993.1994.tb00498.x.

Low T (1997), 'Tropical pasture plants as weeds', *Tropical Grasslands* 31(4): 337–343, https://www.scopus.com/inward/record.uri?eid=2-s2.0-0000895601&partnerID=40&md5=5ac34fda92a0ca044e533512ceaa4f53.

Lowe KF, Bowdler TM, Holton TA and Skabo SJ (2010), 'Phenotypic and genotypic variation within populations of kikuyu (*Pennisetum clandestinum*) in Australia', *Tropical Grasslands* 44: 84–94.

Mack MC and D'Antonio CM (1998), 'Impacts of biological invasions on disturbance regimes', *Trends in Ecology & Evolution* 13(5): 195–198.

Marshall NA *et al.* (2011), 'Considering the social dimension of invasive species: The case of buffel grass', *Environmental Science and Policy* 14(3): 327–338.

McGeoch MA et al. (2016), 'Prioritizing species, pathways, and sites to achieve conservation targets for biological invasion', *Biol. Invasions* 18(2): 299–314, doi: 10.1007/s10530-015-1013-1.

Mcglone CM et al. (2012), 'Established native perennial grasses out-compete an invasive annual grass regardless of soil water and nutrient availability', *Plant Ecology* 213(3): 445–457, doi: http://dx.doi.org/10.1007/s11258-011-9992-1.

McIntyre S et al. (2006), 'Plant traits predict impact of invading species: an analysis of herbaceous vegetation in the subtropics', *Australian Journal of Botany* 53(8): 757–770.

McIntyre S and Martin TG (2002), 'Managing intensive and extensive land uses to conserve grassland plants in sub-tropical eucalypt woodlands', *Biological Conservation* 107(2): 241–252.

Miller G et al. (2010), 'Ecological impacts of buffel grass (*Cenchrus ciliaris* L.) invasion in central Australia – does field evidence support a fire-invasion feedback?' *The Rangeland Journal* 32(4): 353–365, CSIRO Publishing.

Morris B (2009), 'Variation and breeding of kikuyu grass (*Pennisetum clandestinum*)', Doctor of Philosophy thesis, University of Sydney, Sydney.

Neve P et al. (2018), 'Reviewing research priorities in weed ecology, evolution and management: a horizon scan', *Weed Research* 58(4): 250–258, Wiley Online Library.

NRC (2014), *Weeds – Time to Get Serious: Review of Weed Management in NSW*, Draft Report, Natural Resources Commission, Sydney, NSW.

OEH (2017a), *Invasion of native plant communities by exotic perennial grasses – profile*, Office of Environment and Heritage website, NSW Government, https://www.environment.nsw.gov.au/threatenedspeciesapp/profile.aspx?id=20018. Accessed: 15 September 2019.

OEH (2017b), *Key threatening processes*, Office of Environment and Heritage website, NSW Government, https://www.environment.nsw.gov.au/topics/animals-and-plants/threatened-species/about-threatened-species/key-threatening-processes. Accessed: 8 May 2018.

Pertierra LR et al. (2016), 'Assessing the invasive risk of two non-native Agrostis species on sub-Antarctic Macquarie Island', *Polar Biology* 39(12): 2361–2371.

Popay I (2015), *Dactylis glomerata (cocksfoot),* CABI Invasive Species Compendium website, https://www.cabi.org/isc/datasheet/17618#topreventionAndControl. Accessed: 10 September 2020.

Prober SM and Thiele KR (1995), 'Conservation of the grassy white box woodlands: relative contributions of size and disturbance to floristic composition and diversity of remnants', *Australian Journal of Botany* 43(4): 349–366, CSIRO Publishing.

Putnam AR and Duke SO (1985), 'Weed allelopathy', *Weed physiology Vol. I. Reproduction and ecophysiology*: 131–155.

Rayment JT and French K (2021), 'Uncertainty in research about key invasion characteristics limits the evaluation of exotic perennial grasses in natural systems in New South Wales, Australia', *Ecological Management & Restoration*, Wiley Online Library.

Rayment J, French K and Bedward M (2022), 'Understanding patterns and pathways of exotic perennial grass invasion in South-eastern Australian grassy communities', *Diversity and Distributions* 28.5 (2022): 1136–1150.

Reid AM et al. (2009), 'Does invasive plant management aid the restoration of natural ecosystems?', *Biological Conservation* 142(10): 2342–2349.

Schlesinger C, White S and Muldoon S (2013), 'Spatial pattern and severity of fire in areas with and without buffel grass (*Cenchrus ciliaris*) and effects on native vegetation in central Australia', *Austral Ecology* 38(7): 831–840, doi: 10.1111/aec.12039.

Skinner J and Porter S (2019), 'Operationalising the NSW Weed Risk Management system: A Resource Prioritisation & Allocation model', in Hignell K, Wu H and Walsh M (eds) *20th Biennial Weeds Conference*, Weeds Society of New South Wales, Newcastle, NSW.

Spooner PG and Morris MC (2012), 'Long-term stock grazing management in Travelling Stock Reserves and influence on conservation values', *Ecological Management & Restoration* 13(3): 309–311, Wiley Online Library.

Stohlgren TJ et al. (2005), 'Life-history Habitat Matching in Invading Non-native Plant Species', *Plant and Soil* 277(1): 7–18, doi: 10.1007/s11104-005-4893-5.

Vella B, Gonzalez P and Spooner PG (2020), 'The New South Wales Travelling Stock Route and Reserve (TSR) network: historical extent, spatial distribution and drivers of loss 1884–2017', *Australian Geographer* 51(1): 87–103, Taylor & Francis.

Vere DT and Campbell MH (1984), 'Economics of Controlling Serrated Tussock in the Southeastern Australian Rangelands', *Journal of Range Management* 37(1): 87, doi: 10.2307/3898832.

Watson GM, French KO, Burley AL, Brading MB and Hamilton MA (2021), *Monitoring Manual for Invasive and Native Flora: Guidance for field monitoring and reporting*, NSW Department of Planning, Industry and Environment, Sydney.

Williams MC et al. (2008), 'Prioritising weed management for biodiversity conservation at the NRM level', in *Proceedings of the 16th Australian Weeds Conference, Cairns, Queensland:* 408–410, Queensland Weeds Society.

Yobo KS et al. (2009), 'Evaluation of Ustilagosporoboli-indici as a classical biological control agent for invasive Sporobolus grasses in Australia', *Biological Control* 50(1): 7–12, doi: 10.1016/j.biocontrol.2009.01.006.

Appendix A

Table 16 EPGs found in the 9 TECs surveyed

Table 16 shows EPG common and scientific names, the total number of sites they were found in, and the number of TECs they were present in. The top 10 are in bold font.

Common name	EPG	Total # of sites present (/124)	#of TECs (/9)
Common paspalum	***Paspalum dilatatum***	**55**	**8**
Parramatta grass	***Sporobolus africanus***	**39**	**7**
African lovegrass	***Eragrostis curvula***	**36**	**6**
Cocksfoot	***Dactylis glomerata***	**26**	**7**
Phalaris	***Phalaris aquatica***	**26**	**6**
Kikuyu	***Cenchrus clandestinus***	**24**	**5**
Pigeon grass	***Setaria parviflora***	**23**	**6**
Sweet vernal grass	***Anthoxanthum odoratum***	**23**	**6**
Yorkshire fog	***Holcus lanatus***	**18**	**7**
Serrated tussock	***Nassella trichotoma***	**16**	**4**
Carpet grass	*Axonopus fissifolius*	14	5
Rhodes grass	*Chloris gayana*	14	3
Prairie grass	*Bromus catharticus*	12	7
Panic veldtgrass	*Ehrharta erecta*	12	3
Coolatai grass	*Hyparrhenia hirta*	10	4
Whisky grass	*Andropogon virginicus*	8	4
Buffalo grass	*Stenotaphrum secundatum*	7	3
Chilean needle grass	*Nassella neesiana*	7	1
Elastic grass	*Eragrostis tenuifolia*	6	2
Quaking grasses	*Briza subaristata*	6	2
Broadleaf paspalum	*Paspalum mandiocanum*	6	2
Kentucky bluegrass	*Poa pratensis*	5	2
Vasey grass	*Paspalum urvillei*	5	1
Giant Parramatta grass	*Sporobolus fertilis*	3	2
Meadow fescue	*Festuca pratensis*	2	2
Feathertop Rhodes grass	*Chloris virgata*	2	2
Tussock paspalum	*Paspalum quadrifarium*	1	1
Perennial ryegrass	*Lolium perenne*	1	1
Bahia grass	*Paspalum notatum*	1	1
Timothy	*Phleum pratense*	1	1
Stinkgrass	*Eragrostis cilianensis*	1	1

Appendix B

Table 17 Full list of TECs chosen by participants in the land manager survey

Table 17 includes the abbreviation and count of participants involved with that community

Community	Abbreviation	COUNT
White Box –- Yellow Box – Blakely's Red Gum Grassy Woodland and Derived Native Grassland in the NSW North Coast, New England Tableland, Nandewar, Brigalow Belt South, Sydney Basin, South Eastern Highlands, NSW South Western Slopes, South East Corner and Riverina Bioregions	WBYB	20
Montane Peatlands and Swamps of the New England Tableland, NSW North Coast, Sydney Basin, South East Corner, South Eastern Highlands and Australian Alps Bioregions	MPS	7
Monaro Tableland Cool Temperate Grassy Woodland in the South Eastern Highlands Bioregion	MCTGW	6
Natural Temperate Grassland of the South Eastern Highlands	NTG	6
Lowland Grassy Woodland in the South East Corner Bioregion	LGW	4
Themeda Grassland on Seacliffs and Coastal Headlands in the NSW North Coast, Sydney Basin and South East Corner Bioregions	TGOS	4
Hunter Lowland Redgum Forest in the Sydney Basin and NSW North Coast Bioregions	HLRF	3
Illawarra Lowlands Grassy Woodland in the Sydney Basin Bioregion	ILGW	3
River-flat Eucalypt Forest on Coastal Floodplains of the NSW North Coast, Sydney Basin and South East Corner Bioregions	RFEF	3
Ribbon Gum – Mountain Gum – Snow Gum Grassy Forest/Woodland of the New England Tableland Bioregion	RGMGSG	3
Werriwa Tablelands Cool Temperate Grassy Woodland in the South Eastern Highlands and South East Corner Bioregions	WCTGW	3
Subtropical Coastal Floodplain Forest of the NSW North Coast Bioregion	SCFF	3
Dry Rainforest of the South East Forests in the South East Corner Bioregion	DR	2
Inland Grey Box Woodland in the Riverina, NSW South Western Slopes, Cobar Peneplain, Nandewar and Brigalow Belt South Bioregions	IGB	2
McKies Stringybark/Blackbutt Open Forest in the Nandewar and New England Tableland Bioregions	MSBOF	2
New England Peppermint (*Eucalyptus nova-anglica*) Woodland on Basalts and Sediments in the New England Tableland Bioregion	NEP	2
Other (blank)	OTHER	2
Farmland in New South Wales	FARMLAND	2
Brogo Wet Vine Forest in the South East Corner Bioregion	BWVF	1
Blue Mountains Shale Cap Forest in the Sydney Basin Bioregion	BMSC	2
Central Hunter Grey Box – Ironbark Woodland in the NSW North Coast and Sydney Basin Bioregions	CHGB	1

Community	Abbreviation	COUNT
Cumberland Plain Woodland in the Sydney Basin Bioregion	CPW	1
Duffys Forest Ecological Community in the Sydney Basin Bioregion	DF	1
Eastern Suburbs Banksia Scrub in the Sydney Basin Bioregion	ESBS	1
Fuzzy Box Woodland on Alluvial Soils of the South Western Slopes, Darling Riverine Plains and Brigalow Belt South Bioregions	FBW	1
Howell Shrublands in the New England Tableland and Nandewar Bioregions	HS	1
Melaleuca armillaris Tall Shrubland in the Sydney Basin Bioregion	MTS	1
Semi-evergreen Vine Thicket in the Brigalow Belt South and Nandewar Bioregions	SEVT	1
Coastal Cypress Pine Forest in the NSW North Coast Bioregion	CCPF	1
Coastal Saltmarsh in the NSW North Coast, Sydney Basin and South East Corner Bioregions	CS	1
Shale Gravel Transition Forest in the Sydney Basin Bioregion	SGTF	1
Illawarra Subtropical Rainforest in the Sydney Basin Bioregion	ISTRF	1
Lowland Rainforest in the NSW North Coast and Sydney Basin Bioregions	LRSTA	1
Bangalay Sand Forest of the Sydney Basin and South East Corner Bioregions	BSF	1
Natural Grasslands on Basalt and Fine-textured Alluvial Plains of Northern NSW and Southern Queensland	NG	1
Swamp Sclerophyll Forest on Coastal Floodplains & Swamp Oak Floodplain Forest TECs	SSF	1
Wetland	WETLAND	1
South East NSW	SE NSW	1
Hobby Garden	HOBBY GARDEN	1
Cooleman Ridge ACT which includes patches of Yellow Box Red Gum Blakely's Grassy Woodland	GRASSY WOODLAND ACT	1
Broad-leaved Paperbark – Swamp Oak on Estuarine Sediments	BLPSO	1
Northern Tablelands NSW	NORTHERN TABLELANDS	1
	Total sum	**102**