Initial identification and prioritisation of weeds of conservation management areas in the Kosciuszko to Coast (K2C) corridor of New South Wales, Australia

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Summary

Weed management remains a central problem for landscape-scale conservation projects in Australia and globally. However, little is known about the invasive species that will be favoured by new land use regimes intended to protect and enhance native biodiversity, and whether these species have the greatest impact on broad-scale conservation goals. In this paper we use survey data collected from landholders and regional land managers to provide an initial identification and prioritisation of the weed species that have the greatest potential to degrade conservation management areas in the Kosciusko to Coast (K2C) Partnership corridor area of south-eastern New South Wales. We show that the control of invasive weeds remains a significant problem for virtually all landholders and managers in the region, and that consistent with expectation, *Hypericum perforatum* L. (St. John's wort), *Rubus fruticosus* L. (blackberry) and a range of annual and biennial herbs tend to increase under management regimes designed to benefit native biodiversity. However, the most serious invaders were invasive grasses species like *Eragrostis curvula* (Schrad.) Nees, (African lovegrass), *Nassella neesiana* (Trin. & Rupr.) Barkworth (Chilean needle grass) and *Nassella trichotoma* (Nees) Hack. ex Arechav. (serrated tussock), which degrade both agricultural and conservation land use types and drive reorganisation of recipient socio-ecological systems. Infestations of *E. curvula* in particular appear to be expanding in most areas, and this largely intractable species must now be considered the primary weed threat to biodiversity conservation and agricultural production across the K2C region. There is a strong need for further research into the impacts of invasive weeds on functional landscape connectivity and the development of integrated weed management strategies for the most damaging species, especially *E. curvula*.

Introduction

Increasingly, conservation initiatives in Australia and globally are adopting landscape-level planning to encourage the conservation of native biodiversity alongside other human land uses (Doerr *et al.* 2011). At this scale, management of the composition and proportion of different land use types, and their level of connectivity, is aimed at facilitating animal and plant dispersal (Hilty *et al.* 2006), thus facilitating the persistence of viable metapopulations in otherwise fragmented habitats. Landscape-level conservation initiatives often involve protection of high conservation value areas, rebalancing human and conservation needs in agricultural areas, and enhancing structural connectivity among remnant patches by revegetating and restoring degraded areas. In this way, the long-term sustainability of the entire socio-ecological system is potentially improved.

Weed control is often a central focus of management in conservation initiatives, since they hinder the establishment of newly planted tubestock (Cole and Lunt 2005), compete with native plant communities (Snell *at al.* 2007), or harbor feral animals (White *et al.* 2006). However, very little is known about which species are viewed by landholders and land managers as being most detrimental to these projects. There also exists very little information on weed responses to management strategies put in place to preserve or enhance native vegetation: for example, the restriction or removal of livestock grazing or establishment of tree plantings. While we might expect animal-dispersed weeds to benefit from such changes, other species capable of invading both agricultural and conservation areas largely independent of land use, like some invasive grasses, for example Snell *et al.* (2007), Osmond and Verbeek (2008), may pose an even greater threat to landscape conservation.

In this paper we report the results of a small study aimed at providing a preliminary identification and prioritisation of weed species that have the greatest perceived impact in conservation management areas (CMAs; here defined as private or public areas with defined management strategies to increase functional landscape connectivity for flora and fauna or to protect or enhance existing remnant vegetation) in the southern and central Kosciusko to Coast (K2C) Partnership corridor area of south-eastern New South Wales. The objective of the K2C Partnership is to conserve and restore native flora and fauna in the region, and to increase connectivity between forested areas of the Snowy Mountains and the coastal escarpment, the latter as part of the broader objective of the Great Eastern Ranges corridor initiative (Pulsford *et al.* 2013). Since little is known about the problems posed by weeds to those implementing conservation-related projects in the K2C corridor region, our goal was to sample a small number of properties and land managers and provide an initial identification of the main weed species in revegetation areas and other significant landscape connectivity features. We also sought to identify significant knowledge gaps to guide future research.

Materials and Methods

Data on weed prevalence, severity and control (defined below) were collected during a series of in-person interviews of fifteen landholders and a small number of regional land managers from southern and central parts of the K2C Partnership area. Potential survey candidates were identified by contacting local public land management bodies and K2C Partnership Facilitators. Landholders were concentrated in the Monaro region of the Southern Tablelands (12), with a further two in the eastern Australian Capital Territory and one in the Shoalhaven Region of the north-eastern K2C (Figure 1). These covered a total of 15 316 hectares of private land. One survey participant provided two surveys; one for a small section of the Murrumbidgee River corridor that ran through their property, and the other for the rest of the property, including dry sclerophyll forest.

An additional survey of seven regional land managers was conducted (Figure 1). Two of these covered the whole of the Cooma Shire (c. 518 000 ha), one covered the Bredbo region of the northern Monaro Tablelands (c. 26 000 ha), one covered the entire K2C region (c. 3 300 000 ha), and three covered the northern Australian Capital Territory (c. 100,000 ha). The first four surveys were completed by public land managers responsible for weed control or conservation work over a broad range of land tenure types, including landscape connectivity initiatives (but excluding National Parks), and provide a perspective on both private and public land on a regional scale. The latter three surveys were completed by a single manager of public land in the Australian Capital Territory and mainly covered wet sclerophyll forest, riparian and box gum grassy woodland (BGGW) communities, urban lowland grassland, and BGGW of the north-east of the Territory, including some on private land. These communities varied in disturbance level but retained significant biodiversity value.

Surveys usually lasted between 30 mins and one hour in duration. Questions covered basic property information (size, property type, farming methods and types of conservation management strategies) and weed severity. We defined perceived weed severity (PWS) as the perceived potential to seriously impact management operations, either at the property (landholder) or regional (manager) scales. Importantly, we distinguished between *general weeds*, with impacts at the whole-farm or regional scale, and *CMA weeds*, with impacts specifically in CMAs with direct conservation and connectivity objectives. Five landholders, along with the Australian Capital Territory regional manager (3 surveys), provided data only for CMA weeds, since land in their tenure was currently managed only for conservation purposes. Thus, we obtained general weed lists from 11 landholders and 4 regional managers, but CMA weed lists from all surveys (16 and 7 respectively).

Survey participants were asked to list the top five general and CMA weeds in order of perceived severity, which were then assigned scores of between 6 and 2 in descending order. Any other significant species were each given a score of 1. Survey participants were not provided a list of species or taxa to choose from prior to questioning, and the ranking provided was purely based on the landholder or manager's opinion based on their experience in dealing with each weed taxa. They were then asked to identify any important species within CMAs that had specifically required control or management, and to rank the perceived success of these efforts (PCS) according to the following scale: 0 = completely unsuccessful; 1 = mostly unsuccessful; 2 = moderately successful; 3 = very successful; and 4 = complete success. Again, PCS was based purely on landholder or regional manager opinion. Finally, participants were asked which if any CMA weed taxa had become notably more severe or abundant during the course of their conservation project or management activities.

Survey participants usually identified weeds to the species level, but occasionally only to the generic level. For simplicity, we refer to all as 'taxa' throughout this paper, acknowledging that some taxa therefore likely contained multiple species, for example the *Salix* spp. Survey participants also specifically identified two additional functional groups: 'exotic annual grasses' and 'thistles'. To provide an indication of the overall importance of these groups we lumped data across all species within each group, with the highest PWS and PCS for any individual species within a survey assigned to the combined group as a whole. We also generated a separate *Echium* group (*Echium* spp. combined) which contained the common species *Echium vulgare* L. and *Echium plantagineum* L., and any weeds only identified as '*Echium*' spp. For each general and CMA weed taxon and group we calculated the frequency of occurrence across properties or regions (Freq), the mean perceived weed severity score (μ_{PWS}; including only surveys in which the weed was recorded), and the mean perceived control success (μ_{PCS}; CMA weeds only). We also recorded the number of times individual weeds were reported as increasing in severity or abundance on properties and across regions.

Results

The fifteen private properties averaged 1 020 ha in area (range <50 ha to 5 000 ha), although since only five properties exceeded 1 000 ha, the median (450 ha) was substantially smaller. Twelve properties were mainly managed either as commercial grazing enterprises or as a mix of lifestyle, conservation and commercial land use types; only three were run solely for non-agricultural purposes. Livestock grazing was the main form of agricultural production on commercial properties, although several properties undertook cropping on limited areas. From a conservation perspective, 10 of the 15 properties contained plantings of native flora to increase native plant

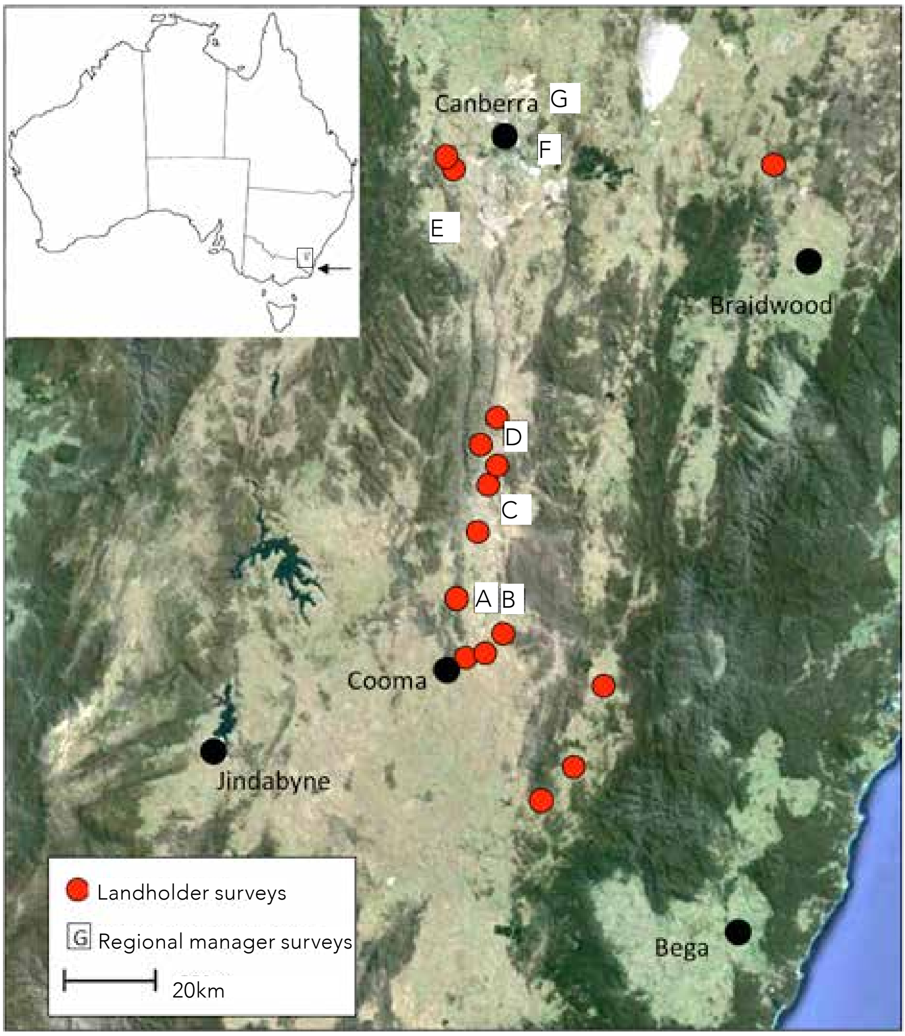

Figure 1. Locations of properties and regions surveyed during the study. White markers indicate the approximate centre of the areas covered under the regional manager survey; A + B = Cooma Shire, C = Bredbo region, D = whole K2C region, E = western Australian Capital Territory (mainly wet sclerophyll forest), F = urban lowland grassland, G = box gum grassy woodland of the north-eastern Australian Capital Territory.

Table 1. General and Conservation Management Area (CMA) weeds identified by landholders (Prop) and regional land managers (Reg) in the K2C Partnership corridor area. Numbers in brackets refer to the number of relevant surveys conducted. Freq = the number of surveys in which a taxon was reported; μ_{SEV} = mean severity score across all surveys in which the species was reported. * = species native to Australia.

Taxon	General weeds				CMA weeds			
	Prop (n = 11)		Reg (n = 4)		Prop (n = 16)		Reg (n = 7)	
	Freq	μ_{PWS}	Freq	μ_{PWS}	Freq	μ_{PWS}	Freq	μ_{PWS}
Eragrostis curvula (African lovegrass)	11	5.45	4	5.75	12	4.75	7	5.57
Thistles (combined)	10	2.40	1	1.00	10	3.50	1	1.00
Carduus nutans (nodding thistle)	3	3.67	1	1.00	3	3.67	1	1.00
Carthamus lanatus (saffron thistle)	6	1.50	1	1.00	3	1.00	-	-
Cirsium vulgare (black thistle)	1	2.00	-	-	1	2.00	-	-
Onopordum acanthium (Scotch thistle)	3	1.33	1	1.00	2	4.00	-	-
Silybum marianum (variegated thistle)	-	-	1	1.00	-	-	-	-
Hypericum perforatum (St. John's wort)	10	3.70	4	3.25	9	3.44	7	3.43
Nassella trichotoma (serrated tussock)	8	5.13	4	5.25	11	5.18	5	4.00
Echium spp. (combined)	8	2.13	2	1.00	5	1.60	2	1.00
Echium vulgare (Viper's bugloss)	5	1.60	1	1.00	3	1.00	-	-
Echium plantagineum (Paterson's curse)	2	1.50	1	1.00	3	1.67	2	1.00
Rosa rubiginosa (sweet briar)	7	2.43	3	2.33	6	3.00	3	1.00
Verbascum spp. (*V. thapsus*) (Aaron's rod)	5	1.80	1	1.00	6	2.67	3	1.00
Rubus fruticosus spp. agg (blackberry)	3	4.67	3	2.33	8	3.75	5	2.80
Exotic annual grasses (combined)	3	1.00	-	-	2	3.00	1	1.00
Avena barbata/ A. fatua (oat)	1	1.00	-	-	1	5.00	1	1.00
Hordeum spp. (barley grass)	1	1.00	-	-	-	-	-	-
Bromus spp. (brome)	-	-	-	-	-	-	1	1.00
Conyza spp. (fleabane)	2	1.00	1	1.00	4	1.00	-	-
Salix spp. (willow)	2	1.00	1	5.00	4	3.00	1	4.00
Marrubium vulgare (horehound)	1	3.00	1	2.00	3	3.00	-	-
Senecio madagascariensis (Madagascan fireweed)	1	3.00	1	3.00	2	3.00	1	3.00
Ulex europaeus (gorse)	1	2.00	-	-	-	-	-	-
Chondrilla juncea (skeleton weed)	1	1.00	-	-	-	-	-	-
Cytisus spp. (broom)	1	1.00	2	1.00	1	1.00	2	2.00
Amaranthus spp. (amaranth)	1	1.00	-	-	-	-	-	-
Pteridium esculentum (bracken)*	1	1.00	-	-	1	1.00	-	-
Hypochaeris glabra + *H. radicata* (flatweed)	1	1.00	-	-	-	-	-	-
Nassella neesiana (Chilean needle grass)	-	-	2	3.5	1	1.00	4	4.25
Salvia reflexa (mintweed)	-	-	1	1.00	-	-	-	-
Conium maculatum (hemlock)	-	-	1	1.00	-	-	-	-
Crataegus monogyna (hawthorn)	-	-	1	1.00	-	-	2	1.00
Cotoneaster glaucophyllus (cotoneaster)	-	-	1	1.00	-	-	2	1.00
Grevillea juniperina x *G. rosmarinifolia* hybrid 'Canberra Gem'*	-	-	-	-	1	5.00	-	-
Holcus lanatus (Yorkshire fog)	-	-	-	-	1	2.00	-	-

Taxon	General weeds				CMA weeds			
	Prop (n = 11)		Reg (n = 4)		Prop (n = 16)		Reg (n = 7)	
	Freq	μ_{PWS}	Freq	μ_{PWS}	Freq	μ_{PWS}	Freq	μ_{PWS}
Kunzea spp.* (kunzea)	-	-	-	-	1	2.00	-	-
Phalaris aquatica (Phalaris)	-	-	-	-	2	3.50	1	1.00
Acacia baileyana (Cootamundra wattle)*	-	-	-	-	-	-	1	1.00
Ailanthus altissima (tree of heaven)	-	-	-	-	-	-	1	1.00
Hieracium aurantiacum (hawkweed)	-	-	-	-	-	-	1	1.00
Pyracantha angustifolia (firethorn)	-	-	-	-	-	-	1	1.00

Table 2. Mean (μ_{PCS}), maximum and minimum perceived control success (PCS) scores for selected weeds in conservation management areas (CMAs) provided by landholders and regional land managers in the K2C Partnership corridor area. Control success was scored as 0 = completely unsuccessful, 1 = mostly unsuccessful, 2 = moderately successful, 3 = very successful, and 4 = complete success. Records = the number of times reported by landholders or regional managers.

Taxon	Landholders				Regional managers			
	Records	μ_{PCS}	Max.	Min.	Records	μ_{PCS}	Max.	Min.
Eragrostis curvula (African lovegrass)	12	2.29	3	1	6	1.57	2.5	0
Nassella trichotoma (serrated tussock)	11	2.73	3	2	4	2.38	3	2
Hypericum perforatum (St. John's Wort)	9	2.63	3	2	3	2.00	2.5	1.5
Rosa rubiginosa (sweet briar)	6	3.17	4	3				
Thistles	5	2.80	3	2				
Carduus nutans (nodding thistle)	2	2.00	2	2				
Onopordum acanthium (Scotch thistle)	1	3.00	3	3				
Rubus fruticosus spp. agg (blackberry)	3	2.67	3	2	2	2.50	2	3
Echium plantagineum (Paterson's curse)	3	2.50	3	2				
Salix spp.	2	3.00	3	3	1	2.50		
Verbascum spp. (*V. thapsus*) (Aaron's rod)	2	3.00	3	3				
Marrubium vulgare (horehound)	1	3.00	3	3				
Ulex europaeus (gorse)	1	3.00	3	3				
Senecio madagascariensis (Madagascan fireweed)	2	3.50	3	4				
Exotic annual grasses	1	1.00	1	1				
Avena barbata/*A. fatua* (oat)	1	1.00	1	1				
Nassella neesiana (Chilean needle grass)					3	1.67	2	1
Cytisus spp. (broom)					1	2.00		

and animal biodiversity, with a significant majority also undertaking grazing management to protect existing native vegetation (11), fencing to restrict livestock access to sensitive areas (12), pest animal control (9) and weed control (13) specifically designed to conserve or enhance farm-scale biodiversity. A minority of properties used management techniques such as fire, shelterbelts, soil stabilisation and soil manipulation to control weed species. Work conducted in eight of 15 properties was formally included in a regional corridor (K2C) or connectivity initiative. Key vegetation types targeted for conservation included box gum grassy woodland, dry sclerophyll forest, native and derived grassland and alluvial or riverine systems.

A total of 39 problematic weed taxa (excluding the thistle, exotic annual grass and *Echium* spp. groups) were recorded by property owners and regional managers (Table 1). Among landholders the most frequently reported general weed was *Eragrostis curvula* (Schrad.) Nees (African lovegrass), which was present on 11 properties (100% of the total), followed by the combined thistles group (91%) and *Hypericum perforatum* L. (91%; Table 1). The most important thistle was *Carthamus lanatus* L. (55% of properties). Other widespread general weeds included *Nassella trichotoma* (Nees) Hack. ex Arechav. (serrated tussock; 73%), *Echium* spp. (73%), *Rosa rubiginosa* L. (sweet briar; 64%), and *Verbascum* spp. (mainly *V. thapsus* L.; 45%). The four regional managers, who provided a perspective on similar land use types but on a larger spatial scale, reported a similar suite of general weed taxa (Table 1), the most frequent being *E. curvula*, *H. perforatum*, *N. trichotoma*, *R. rubiginosa* and *Rubus fruticosus* L. spp. agg. (blackberry).

The list of CMA weeds provided by landholders was broadly similar to that of general weeds, with *E. curvula*, *N. trichotoma*, thistles, and *H. perforatum* again being most widespread (Freq ≥ 9 out of 16 properties). Blackberry was also identified on 50% of properties. Regional managers again reported a similar suite of CMA weeds, although they identified fewer annual or biennial forbs and grasses than private landholders, for example, thistles, *Verbascum* spp., *Conyza* spp., (Table 1), and more woody weeds, for example *Crataegus monogyna* Jacq. and *Cotoneaster glaucophyllus* Franch.). The latter tended to be more prevalent around urban areas. Both survey groups reported *R. fruticosus* and *Salix* spp. as being more prevalent in CMAs than across properties and regions generally, and regional managers specifically noted that *Nassella neesiana* (Trin. & Rupr.) Barkworth (Chilean needle grass) was an especially important weed of grassland and woodland CMAs, despite having a restricted distribution.

Landholders and regional managers perceived *E. curvula* to be the most severe general weed of properties and the broader study region (μ_{PWS} = 5.45 and 5.75 respectively; Table 1), ahead of *N. trichotoma* (μ_{PWS} = 5.13 and 5.25). Both grasses were usually ranked as either the worst or second-worst weed when present. Other severe general weeds included *H. perforatum*, *R. fruticosus* and *Carduus nutans* L. , with willows (*Salix* spp.) and garden escapes, for example *Grevillea juniperina* x *Grevillea rosmarinifolia* hybrid 'Canberra Gem' being very significant in restricted locations. Regional managers also rated *Nassella neesiana* as being of high general severity (μ_{PWS} = 3.5) at the regional scale, but by chance this species did not occur on any of the individual properties surveyed.

Within on-farm conservation management areas (Table 1), where 31 weed taxa were recorded (including 24 to the species level), landowners rated *N. trichotoma* as being slightly more severe than *E. curvula* (μ_{PWS} = 5.18 vs 4.75), ahead of other widespread taxa such as *R. fruticosus* (μ_{PWS} = 3.75), thistles (μ_{PWS} = 3.50) and *H. perforatum* (μ_{PWS} = 3.44). However, regional managers again ranked *E. curvula* as easily the most severe CMA weed (μ_{PWS} = 5.57), well ahead of *N. trichotoma* (μ_{PWS} = 4.00), *H. perforatum* (μ_{PWS} = 3.43) and *R. fruticosus* (μ_{PWS} = 2.80). They also considered *N. neesiana* to be a more serious weed (μ_{PWS} = 4.25) of CMAs than all other species except *E. curvula* (Table 1), but again rarely rated thistles and other annual and biennial forbs highly.

Among the more commonly reported species, *E. curvula* was, by a significant margin, the most difficult to manage, with landholders on average rating the perceived success of control as only moderately successful (μ_{PCS} = 2.29; Table 2). Importantly, however, some rated their success in controlling this species as mostly unsuccessful (PCS = 1). The next most difficult taxa to control were *H. perforatum* (μ_{PCS} =2.63), *N. trichotoma* (μ_{PCS} =2.73) and thistles (μ_{PCS} =2.80). However, control of all of these species proved challenging under certain circumstances, with minimum PCS scores of two on individual properties (Table 2). These data were corroborated by regional managers, who rated regional control of *E. curvula* as mostly unsuccessful to moderately successful (μ_{PCS} = 1.57), a similar score to that of *N. neesiana* (μ_{PCS} = 1.67). Interestingly, regional managers consistently rated their success at controlling important weed species lower than did landholders (Table 2).

Finally, *E. curvula* was mentioned by 14 survey participants (74%) as increasing in abundance or range over the duration of their conservation work. However, the proportion of regional managers (100%) observing an increase in *E. curvula* was notably higher than that of landholders (58%). A similar proportion (75%) of regional managers also noted an ongoing increase in *Nassella neesiana*. Other widespread weeds that appeared to be increasing in a substantial proportion of properties and regions included thistles (40%; especially *Carduus nutans*), *N. trichotoma* (38%), *H. perforatum* (31%) and *R. fruticosus* (31%). The most successfully controlled common weed species was *R. rubiginosa*, with none of nine of respondents reporting an increase in abundance.

Discussion

Our data support the view that the control and management of weeds in conservation management areas (CMAs) remains a central problem at both individual property and regional scales across the southern and central Kosciuszko to Coast (K2C) Partnership area. While this is unsurprising, several features of the weed assemblage have important implications for the viability of conservation-related projects both in the K2C corridor and in Australian landscape-scale connectivity initiatives generally.

First, it is clear that although the invasive flora of the K2C region is both floristically diverse and ecologically heterogeneous, only a restricted number of species were present across most properties and land use types surveyed, and even fewer appear were considered by the 22 survey participants to be especially difficult to manage effectively. The most important weeds in the study area that fall into the latter category, according to the surveyed landowners and regional managers, are *E. curvula, N. trichotoma, H. perforatum* and *R. fruticosus*. *Rosa rubiginosa*, a group of annual or biennial species that includes thistles, *Verbascum* spp., and *Echium* spp., and several taxa with restricted distributions such as *Salix* spp. and *Nassella neesiana* are also significant in some settings. Among these species, however, *E. curvula* clearly emerges as the most serious perceived weed threat to regional biodiversity conservation and landscape connectivity in the K2C Partnership area.

Eragrostis curvula is a low-palatability species which tends to form extensive areas of relatively unproductive grassland (Robinson and Whalley 1991) with a greatly impoverished native flora, and clearly has the capacity to invade on-farm conservation areas while at the same time threatening the viability of grazing enterprises (Firn 2009). By generating a large standing body of above-ground biomass, *E. curvula* also alters the intensity and behaviour of fire in infested areas, which may be an example of the grass/fire feedback dynamic associated with other invasive grasses, for example Brooks *et al.* (2010). Such changes have the potential to fundamentally transform entire ecosystems.

Most landholders and regional managers (74%) in the study area report increasing abundance of *E. curvula* over time, with control efforts normally being mostly unsuccessful to only moderately successful. While control appeared to be more successful when infestations were targeted in early stages of the invasion process (cf., Hobbs and Humphries 1995), it is concerning that several landholders failed to stop the spread of *E. curvula* on their properties even when management actions were put in place when the first plants were seen. Anecdotally, controlling *E. curvula* was made much more difficult when large, unmanaged infestations were present on adjacent properties or public land, especially combined with long distance dispersal by native animals. Indeed, several landholders noted that kangaroos favour stands of *E. curvula* (and *N. trichotoma*) as camps, and therefore used kangaroo culling as a strategy for controlling the spread of these weeds. However, the relative importance of native animals compared with other agricultural modes of spread, for example, sheep movement and vehicles is unknown and requires further study.

Several K2C regional managers noted that the ongoing subdivision of large commercial properties reduced their ability to coordinate landscape-level management of *E. curvula* (and also other invasive species). Indeed, across the K2C study area the median property size was only 450 ha, with only five of fifteen surveyed properties exceeding 1 000 ha. Many Australian production landscapes are experiencing an influx of landholders seeking amenity values, often purchasing smaller lifestyle-oriented blocks (Mendham *et al*. 2012). Many of these landholders lack farming backgrounds, are absentees, tend to be less engaged in natural resource management programs and other traditional extension processes (Mendham *et al*. 2012), and according to regional managers, often lack the skills necessary to identify *E. curvula* and other invasive grasses. The properties themselves also tend to experience a high rate of ownership turnover (Mendham and Curtis 2010). Such changes now pose a significant threat to the ability of rural land managers to respond to broad-scale environmental challenges (Klepeis *et al*. 2009) and to coordinate landscape connectivity initiatives.

The apparent intractability of *E. curvula* in the study area appears to differ in some important ways to that of *Nassella trichotoma*, a Weed of National Significance (WoNS, Osmond and Verbeek 2008) that is also highly invasive in the K2C region. Both landholders and regional managers reported higher perceived success in controlling *N. trichotoma* than *E. curvula,* (μ_{PCS} = 2.7 vs 2.3 and μ_{PCS} = 2.4 vs 1.6 respectively) albeit at significant, sustained economic cost. One significant difference noted by landholders was the viability of chemically controlling *N. trichotoma*, an option rarely economical for large infestations of *E. curvula*, and the large amount of information available on integrated management of this species. Another difference is that unlike *N. trichotoma*, *E. curvula* has been promoted as a valuable pasture species, and the tendency of some landholders to manage *E. curvula* to maximise production rather than attempt control is one reason why this and other more palatable pasture grasses are a major source of societal conflict over land use (Grice *et al.* 2012). In the K2C region, however, more palatable forms (Johnston *et al*. 2005) of *E. curvula* seem to be rare or absent, and virtually all landholders view the species negatively - several even regretted not selling their properties before the species arrived. *Nassella neesiana* has many agronomic and ecological characteristics in common with *E. curvula,* and given its severe impacts on both agricultural profitability and biodiversity conservation (Snell *et al*. 2007) is likely to be an increasing problem in the K2C area in the future. There is an urgent need for new integrated management strategies that improve control of both of these species.

As expected, several species appear to directly benefit from management practises conducted in previously agricultural (grazing) areas targeted for conservation. For example, *H. perforatum,* which is a significant invader of native grassland, woodland and restored native vegetation (Buckley *et al*. 2003), often increases in abundance following livestock removal (Campbell *et al*. 1995). It is a therefore a particular problem on ungrazed 'lifestyle' properties in the K2C region. In contrast, several landholders noted that *R. fruticosus* benefits from increased movement of animals through revegetated parts of the landscape. Indeed, foxes, birds, and wombats often move along fencelines or through tree plantings, rapidly spreading seed into conservation areas from adjoining infested (often public) land (cf. Brunner *et al*. 1976). Once established, persistent species such as *H. perforatum* and *R. fruticosus* are difficult to control chemically without damaging revegetation tubestock, and their tendency to grow in inaccessible areas such as creeklines (Aghighi *et al*. 2012) causes significant logistical problems for those using heavy equipment to apply herbicides to infestations. Short-lived grasses and forbs also often temporarily increase following grazing exclusion, but management of these infestations using livestock can be effective, and most tend to decline as native cover increases.

Interestingly, while *R. fruticosus* has long been abundant in moister sclerophyll forests across the western Australian Capital Territory and along the Murrumbidgee River corridor, it has, until recently, been less common in the Monaro. However, a recent trend towards higher summer rainfall is reported by some regional managers to be significantly increasing the invasiveness of *R. fruticosus* in this region, an observation which deserves further study. Indeed, future changes in weed distributions in response to climate change are now a major concern globally (Hellmann *et al*. 2008), and may considerably alter weed assemblages across the K2C region. How such changes will affect the viability of current biological control agents for *R. fruticosus* (Gomez *et al*. 2008) and *H. perforatum* (Parsons and Cuthbertson 2001, Willis *et al*. 2003), which several landholders indicated provide sporadic or partial control of these species, remains to be seen.

Another interesting result was that regional managers tended to report weed control success scores that were considerably lower than those provided by landholders, despite covering similar land use types. These data indicate that while many landholders experience moderate to high levels of success in their individual weed control efforts, at broader spatial scales, most weeds, and especially *E. curvula, N. neesiana* and *H. perforatum*, continue to expand, resulting in an ever-increasing regional propagule pressure (Simberloff 2009). The pattern that emerges is one of a landscape gradually becoming dominated by these species, with only specific, targeted areas remaining relatively weed-free. Over time, such areas might become the exception, rather than the rule. The decision taken by many landowners to simply live with species like *E. curvula* is likely to hasten this process.

While it is clear that many of the weeds identified in this paper can adversely affect native plant communities and broader biodiversity conservation goals, surprisingly little is known about the impact of most weeds on functional landscape connectivity for native flora and fauna. Invasive species can, for instance, have disastrous transformational effects on entire ecosystems (e.g. D'Antonio and Vitousek 1992), and weeds that dominate the ground layer are likely to adversely affect native plant species with short dispersal distances. Yet many, including grasses, can also provide habitat or resources for endangered species (e.g. Richter *et al*. 2013), and even play a role in reducing erosion and other drivers of landscape degradation. Such interactions can greatly complicate weed control in biodiversity conservation initiatives. The degree to which weeds reduce functional connectivity for native plants and animals, and the development of better decision making tools for dealing with ecological transformers such as *Eragrostis curvula* clearly require further study if the benefits of future landscape-scale conservation work in the K2C region and in Australia generally are to be maximised.

Conclusions

The results of our survey indicate that the control of invasive weeds remains a significant problem for virtually all landowners and land managers undertaking projects to enhance biodiversity conservation and landscape connectivity within the Kosciuszko to Coast corridor Partnership. Consistent with expectations, there was strong evidence that *Hypericum perforatum* and a range of annual species increase in abundance following livestock removal, and that *Rubus fruticosus* benefits from increased movement of birds, foxes and wombats along fencelines and through revegetation areas. Future projects will clearly need to anticipate these weed responses to land use change. However, the most serious invader was *Eragrostis curvula*, which degrades both agricultural and conservation land use types and drives broad-scale landscape transformation and socio-ecological reorganisation. Control of this species has been particularly challenging at the regional scale, and *E. curvula* must now be considered a critical threat to the viability of biodiversity conservation and agricultural production across the much of the K2C corridor. There is a strong need for further research into the impacts of invasive weeds on functional landscape connectivity and the development of integrated weed management strategies for the most damaging species.

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