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Authors: Pickering, Catherine, and Hill, Wendy

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*Catherine Pickering and Wendy Hill*

# Roadside Weeds of the Snowy Mountains, Australia





*Weeds are an increasing threat to the biodiversity of mountain regions worldwide, including in Australia. We reviewed 18 surveys of 401 sites conducted between 1986 and 2004 and examined the distribution and characteristics of common weeds on roadsides in the Snowy Mountains, Australia, to determine the range of natural habitats these weeds are found in, whether they are limited to disturbed sites, whether they are also common in other mountain regions including the Australian Alps, and whether they have invasive traits. There are only 8 common weeds in the Snowy Mountains:* Acetosella vulgaris *(also known as* Rumex acetosella*),* Hypochaeris radicata, Trifolium repens, Taraxacum officinale, Agrostis capillaris, Dactylis glomerata, Anthoxanthum odoratum, *and* Achillea millefolium. *They occur in areas disturbed by humans, such as along roadsides and around buildings and tracks, from the low-altitude montane zone to the high-altitude high subalpine/alpine zone. They also occur to varying extents in undisturbed native vegetation, reflecting their invasive capacity. These species are all perennial, with high vegetative and/or sexual reproduction, native to Europe, and are found growing on roadsides and in native vegetation in mountains in Europe, North America, South America, and New Zealand. Therefore, it appears that these plants are the usual suspects: common mountain weeds, which may be found worldwide at high altitude.*

***Keywords:*** *Weeds; exotics; impacts of tourism; disturbance; Snowy Mountains; Australia.*

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## Introduction

Mountain regions worldwide are important reservoirs of vegetal biodiversity, accounting for 4% of all known vascular plants (Körner 1999). However, increasingly important components of mountain flora are exotic species that have been deliberately or accidentally introduced by humans (Körner 1999; Jesson et al 2002; Carbutt and Edwards 2004; Daehler 2005). They can be found growing along roads, tracks, and around ski slopes and buildings, as weeds generally benefit from human disturbance (Tyser and Worley 1992; Johnston and Pickering 2001; Jesson et al 2002; Tsuyuzaki 2002; Pauchard and Alaback 2004; Arévalo et al 2005). For example, many of the 274 exotic plants in the Australian Alps are disturbance-oriented, ie they are largely limited to areas where native vegetation has been damaged and there are areas of bare ground. However, some have spread from disturbed sites into natural vegetation, with a few becoming important environmental weeds (Johnston and Pickering 2001; Godfree et al 2004; Bear et al 2006). Weeds that are able to establish and spread in mountain regions tend to have similar traits. They tend to be polycarpic, perennial, with vegetative reproduction, wide climatic tolerance, benefit from disturbance, and have high seed output that is often wind pollinated (Godfree et al 2004; Alaska Natural Heritage Program 2005).

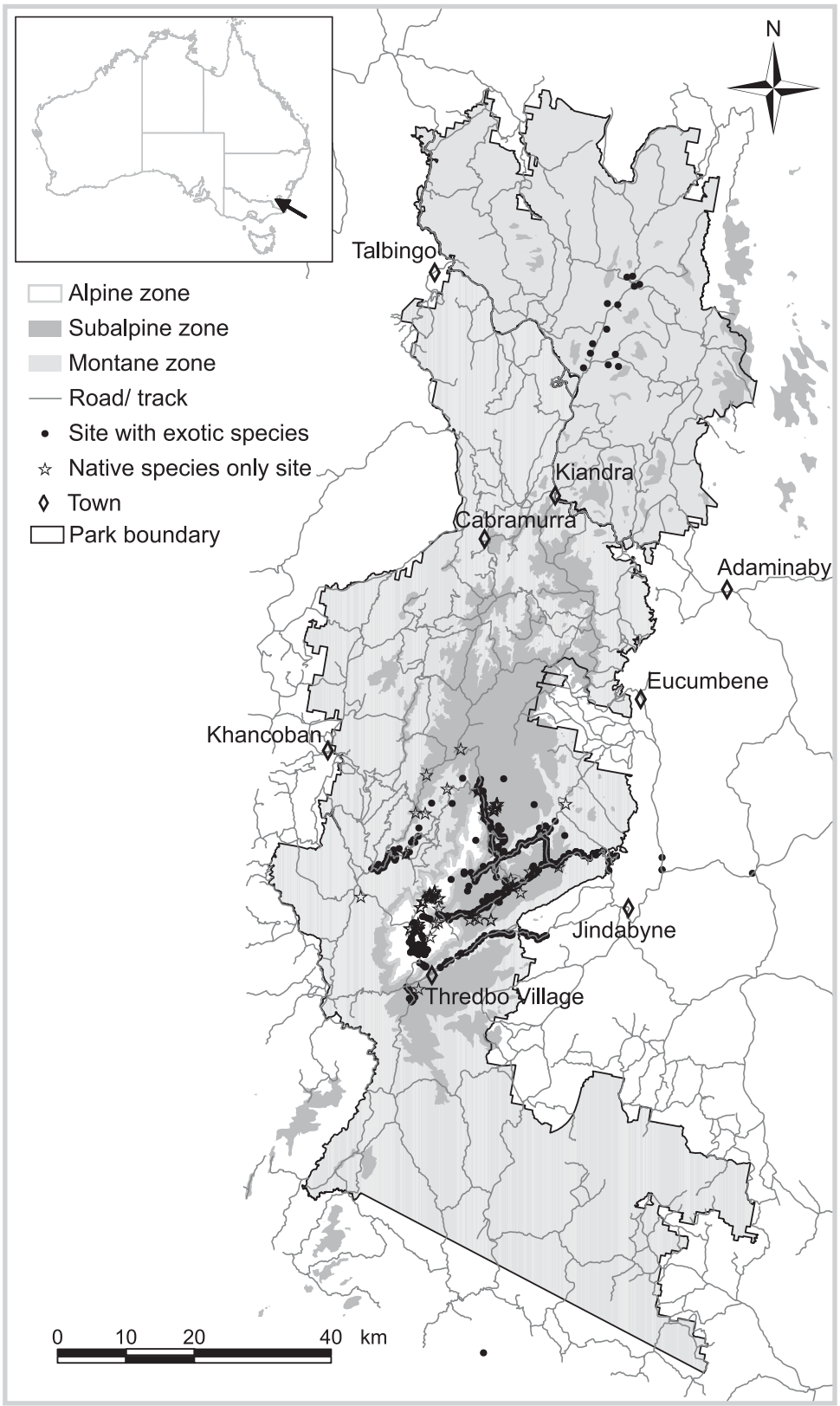
We examined the distribution of exotic plants in the Snowy Mountains in the Australian Alps to determine: (1) which are the most common exotics; (2) what types of habitats they are found in; (3) whether they are limited to disturbed sites or also occur in natural vegetation; (4) whether they are also common in the rest of the Australian Alps; (5) whether they are found in mountains elsewhere in the world; and (6) whether they have traits that make them a high risk for invasion.

## Methods

The Snowy Mountains, which include continental Australia's highest mountain, Mount Kosciuszko (2228 m), are part of the Australian Alps in southeastern Australia (Figure 1). There are 3 main floristic zones in the Snowy Mountains: montane, subalpine, and alpine, with the zones strongly correlating with altitudinal/climatic gradients.

The montane zone occurs between ~500 m and ~1500 m (Good 1992) and is dominated by *Eucalyptus pauciflora* alliance woodlands in association with other eucalypt species (Good 1992). The subalpine zone occurs between the lower winter snow line at ~1500 m and the climatic limit of tree growth at ~1850 m (Costin 1954). Winter temperatures average 0°C with continuous snow cover for at least one month per year (Green and Osborne 1994). The dominant vegetation type is *Eucalyptus niphophila* woodland interspersed with areas of bog, fen, heath, and subalpine grasslands (Costin et al 2000). The alpine zone in the Snowy Mountains occurs at lower elevations than in many other mountain regions; it extends from the climatic treeline at approximately 1850 m to the top of Mt Kosciuszko, at 2228 m, and covers an area of approximately 250 $km^2$ (Costin et al 2000). Annual precipitation ranges from 1800 mm to 3100 mm, about 60% of which falls as snow in winter, persisting for more than 4 months in some areas (Green and Osborne 1994). Low-growing shrubs, grasses, and herbs characterize the alpine zone and occur in a number of different communities according to the biotic and abiotic characteristics of a site.

**FIGURE 1** Location of the 401 sites surveyed from 1986–2004 in 18 vegetation surveys in the Snowy Mountains. Sites with exotic taxa and those with only native species are marked. (Map generated by the authors in ArcGIS, using spatial layers provided by New South Wales National Parks and Wildlife Service)



### The most common weeds in the Snowy Mountains

We identified the most common weeds using a database of exotic taxa recorded in vegetation surveys undertaken from 1986 to 2004 in the Snowy Mountains. These surveys were published in research papers, PhD and Honors theses, and management agency reports (New South Wales National Parks and Wildlife Service), or were data from unpublished research by the authors and other members of the School of Environmental and Applied Sciences at Griffith University (Table 1). For each of the 401 sites for which there were detailed site data, the presence/absence of all exotics was recorded, as well as the spatial coordinates, vegetation zone, altitude, and native vegetation community or anthropogenic disturbance type of the site. From these data it was possible to identify the most common exotics (defined as occurring in more than 5% of sites), which habitats they occurred in, at what frequencies, their altitudinal ranges, and whether there were differences in their distribution between disturbed and natural sites.

We reviewed other vegetation surveys to determine whether these exotics were also common in the rest of the Australian Alps, and whether they were found in mountains elsewhere in the world. We also examined the invasive risk of the species, using information on the species' biological traits, distribution, and potential to be controlled (Alaska Natural Heritage Program 2005).

## Results

Of the 156 exotic taxa recorded in the 401 sites surveyed in the Snowy Mountains (Bear et al 2006), there were only 8 weeds that occurred in more than 5% of the sites, and hence could be considered "common:" *Acetosella vulgaris* (also known as *Rumex acetosella*), *Hypochaeris radicata, Trifolium repens, Taraxacum officinale, Agrostis capillaris, Dactylis glomerata, Anthoxanthum odoratum, Achillea millefolium*, and *Cerastium* spp. (Table 2).

Sheep sorrel (*Acetosella vulgaris* in flora of New South Wales, *Rumex acetosella* in many European floras) is by far the most common species, recorded in 46% of all sites, including 43% of all natural sites (Table 2). It has a broad altitudinal range in the Snowy Mountains, extending from the lowest surveys to just below continental Australia's highest mountain (Mt Kosciuszko at 2228 m) along the Main Ridge of the Snowy Mountains at 2129 m. It was found on road and track verges, in ski resorts, and in disturbed subalpine grassland. It was also common in natural subalpine grasslands, woodlands, heaths, and tall alpine herbfields (Tables 2 and 3). It was found in other vegetation surveys or general listings of the flora for areas within the Australian Alps, indicating that it is ubiquitous in this region. Recorded in the earliest surveys of the high-altitude areas of the Snowy Mountains (Maiden 1898), this forb is a primary colonizer of bare ground.

Sheep sorrel is also found in mountain regions in South America, New Zealand, and North America, and on some islands (Table 4). In New Zealand it is one of the most abundant weeds, and is often the only naturalized weed species present at higher altitudes (Ullman et al 1995; Jesson et al 2002; Rose et al 2004). It is considered an environmental weed in some regions of the world, and can invade grass and heath, freshwater wetlands, costal beaches, and rock outcrops (Weber 2003). It has a range of traits that make it highly invasive (extensive vegetative spread, many seeds that are easily spread by human activities; Table 5). Although extensively naturalized, it is not considered an important environmental weed in the Australian Alps as it tends to be out-competed by native species in the absence of continued disturbance (Pickering et al 2003). Control of the species would be expensive and difficult, and does not appear warranted (Table 5).

Catsears (*Hypochaeris radicata* or *Hypochoeris radicata*) is also a common forb (26% of all sites), both in disturbed sites (45%) and in natural vegetation (18%) in the Snowy Mountains (Table 2). It was found on road verges, tracks in ski resorts including gardens, in disturbed and natural subalpine grasslands, woodlands, tall alpine herbfields, and heaths (Table 3). It was recorded in the first surveys of the region (Maiden 1898) and is regularly recorded in vegetation surveys and general records of the flora of the Australian Alps, including in the alpine zone (Table 2). It is also commonly recorded in vegetation surveys in mountains, along roads, and in natural vegetation in South America, New Zealand, on roadsides of North America, and in natural vegetation of the Hawaiian Islands (Table 4). It is an environmental weed in many parts of the world, including Australia (Table 4, Weber 2003). In addition to disturbed habitats, it can be found colonizing grassland, riparian, seasonal freshwater wetlands and coastal beaches (Weber 2003). This perennial herb can spread vegetatively using perinating buds, and has high seed output that is wind dispersed (Table 5). It has moderate competitive ability, including in the Snowy Mountains, and would be difficult to control due to the high seed output and innate potential for long-distance dispersal (Table 5).

The third most common species, yarrow (*Achillea millefolium*), is found along roadsides in the subalpine and montane zones where it can spread into adjacent grasslands in wet areas. Once established it appears to be able to out-compete natives and is difficult to remove (Tables 2 and 3, Johnston 2005). Away from roads, however, it is not common (Table 3, McDougall and Walsh 2007) and is not considered as much of a problem in other parts of the Australian Alps (Johnston 2005; McDougall and Walsh 2007). It has been recorded on mountain roadsides, including in New Zealand, North America, and Hawaii (Table 4). It can reproduce

**TABLE 1** Details of the 18 vegetation surveys (1986–2004) analyzed in this study, covering a total of 401 sites in the Snowy Mountains. NB: this excludes 98 additional sites used in Bear et al 2006, as detailed information about the sites was not available.

| # | Source | Survey location | Sampling unit |
|---|---|---|---|
| 1 | ***Hill W, Pickering CM.*** 2004. Effect of drought and fire on alpine and subalpine vegetation in Kosciuszko National Park: Severity of initial impact and predictions for recovery. Unpublished data. Available from the authors of this article. | 1. Tall alpine herbfield, grassland, heath and feldmark vegetation<br>2. Alpine and subalpine<br>3. Natural vegetation | 30×20-m sites<br>200 point quadrats each site |
| 2 | ***Pickering CM, Growcock A, Hill W, Banks J, Field J.*** 2003. Long Plain disturbed. Unpublished data. Available from the authors of this article. | 1. Grassland vegetation<br>2. Montane zone<br>3. Natural and disturbed vegetation | 6×1-m quadrats |
| 3 | ***Pickering CM, Growcock A, Hill W, Banks J, Field J.*** 2003. Long Plain natural. Unpublished data. Available from the authors of this article. | 1. Grassland vegetation<br>2. Montane zone<br>3. Natural only | 6×1-m quadrats |
| 4 | ***Pickering C, Appleby M, Good R, Hill W, McDougall K, Wimbush D, Woods D.*** 2002. Plant diversity in subalpine and alpine vegetation recorded in the Thredbo 2002 Biodiversity Blitz. *In:* Green K, editor. Biodiversity in the Snowy Mountains. Jindabyne, Australia: Australian Institute of Alpine Studies, pp 27–46. | 1. Range of vegetation types<br>2. Alpine and subalpine<br>3. Natural and disturbed vegetation | Very large to large sites |
| 5 | ***Pickering CM, Growcock A, Hill W, Banks J, Field J.*** 2003. Long Plain transgrid. Unpublished data available from the authors of this article. | 1. Grassland vegetation<br>2. Montane zone<br>3. Disturbed vegetation | 6×1-m quadrats |
| 6 | ***Hill W, Pickering CM.*** 2006. Vegetation associated with different walking track types in the Kosciuszko alpine area, Australia. *Journal of Environmental Management* 78:24–34. | 1. Tall alpine herbfield and heath vegetation<br>2. Alpine<br>3. Disturbed and adjacent natural vegetation | 1.5×0.5-m quadrats |
| 7 | ***Mallen-Cooper J.*** 1990. *Exotic Plants in the High Altitude Environments of Kosciuszko National Park, Southeast Australia* [PhD thesis]. Canberra, Australia: Department of Biogeography and Geomorphology, Research School of Pacific Studies, Australian National University. | 1. Range of vegetation<br>2. Alpine to montane<br>3. Disturbed road verges and nearby natural areas | 20×6-m sites |
| 8 | ***Global Research Initiative in Alpine Environments GLORIA*** (2004 sampling). Available at http://www.gloria.ac.at/?a=14; accessed on 13 February 2007. | 1. Grassland vegetation<br>2. Alpine<br>3. Natural only | Large (> 50×50 m) sites<br>At each site 16 x 1×1-m quadrats intensively sampled |
| 9 | ***Bear R.*** 2004. *Comparing Unburnt and Burnt Subalpine Grasslands One Year after Wildfire* [Honors thesis]. Gold Coast, Australia: School of Environmental and Applied Sciences, Griffith University.<br>***Bear R, Pickering CM.*** 2006. Recovery of subalpine grassland from bushfire. *Australian Journal of Botany* 54(5):451–458. | 1. Grassland vegetation<br>2. Subalpine<br>3. Natural vegetation | 20×6-m paired plots<br>5 line transects 1.5 m apart with point quadrats every 50 cm |
| 10 | ***Campbell M.*** 2004. *Vegetation Associated with the Latest Lying Snowbanks in Australia* [Honors thesis]. Gold Coast, Australia: School of Environmental and Applied Sciences, Griffith University. | 1. Tall alpine herbfield, short alpine herbfield, and windswept feldmark vegetation<br>2. Alpine zone<br>3. Natural vegetation | One linear transect sampled using 68 x 0.3×0.5-m photoquadrats<br>Other sites: 30 x 0.3×0.5-m photoquadrats = 4.5 $m^2$<br>40 point quadrats for each photoquadrat |
| 11 | ***Scherrer P.*** 2003. *Monitoring Vegetation Change in the Kosciuszko Alpine Zone, Australia* [PhD thesis]. Gold Coast, Australia: School of Environmental and Applied Sciences, Griffith University. | 1. Tall alpine herbfield vegetation<br>2. Alpine zone only<br>3. Natural areas only | One line transect 12×15.25-m sections<br>200 point quadrats per section |
| 12 | ***Scherrer P, Wimbush D, Wright G.*** 2004. *The Assessment of pre and post 2003 Wildfire Data Collected from Subalpine Transects in Kosciuszko National Park.* Report 35. Queanbeyan, Australia: Department of Environment and Conservation, National Parks and Wildlife Service Division. | 1. Grassland and heath vegetation<br>2. Subalpine only<br>3. Natural areas only | 2 line transects:<br>320 m (2100 points) and<br>503 m (3300 points) |
| 13 | ***Growcock A.*** 2005. *Impacts of Camping and Trampling on Australian Alpine and Subalpine Vegetation and Soils* [PhD thesis]. Gold Coast, Australia: School of Environmental and Applied Sciences, Griffith University. Available at http://www4.gu.edu.au:8080/adt-root/public/adt-QGU20060818.164033/index.html; accessed on 31 October 2007. | 1. Tall alpine herbfield and grassland vegetation<br>2. Alpine and subalpine<br>3. Natural vegetation | 2.2-$m^2$ quadrats |
| 14 | ***Scherrer P, Pickering CM.*** 2005. Recovery of alpine vegetation from grazing and drought: Data from long term photoquadrats in Kosciuszko National Park, Australia. *Arctic, Antarctic and Alpine Research* 37:574–584. | 1. Tall alpine herbfield vegetation<br>2. Alpine zone<br>3. Natural vegetation | Linear transects sampled by 30 x 0.7×0.9-m photoquadrats |
| 15 | ***Scherrer P, Pickering CM.*** 2006. Recovery of alpine herbfield on a closed walking track in the Kosciuszko Alpine Zone, Australia. *Arctic, Antarctic and Alpine Research* 38:239–248. | 1. Tall alpine herbfield vegetation<br>2. Alpine<br>3. Disturbed and adjacent natural vegetation | 1×1-m quadrats |

**TABLE 1** Continued.

| # | Source | Survey location | Sampling unit |
|---|---|---|---|
| **16** | ***Johnston F.*** 2005. *Exotic Plants in the Australian Alps Including a Case Study of the Ecology of* Achillea millefolium *in Kosciuszko National Park* [PhD thesis]. Gold Coast, Australia: School of Environmental and Applied Sciences, Griffith University. | 1. Grassland vegetation<br>2. Subalpine<br>3. Disturbed adjacent and nearby natural vegetation | 0.5×1-m quadrats |
| **17** | ***Bear R, Pickering CM.*** 2004. Impacts of fire on road verges and adjacent natural areas. Unpublished data. Available from the authors of this article. | 1. Grassland vegetation<br>2. Subalpine zone<br>3. Disturbed road verge and adjacent natural vegetation | 3 x 5×20-m line transects with 40 point quadrats sampled every 50 cm |
| **18** | ***Johnston F, Johnston S.*** 2004. Impacts of road disturbance on soil properties and on exotic plant occurrence in subalpine areas of the Australian Alps. *Arctic, Antarctic and Alpine Research* 36:201–207. | 1. Grassland vegetation<br>2. Subalpine<br>3. Disturbed road verge and adjacent natural areas | 1×1-m quadrats |

**TABLE 2** Frequency of occurrence of the 8 most common weeds in the Snowy Mountains between 1986 and 2004, based on analysis of 18 general vegetation surveys of 401 sites (1004 records of exotics); for comparison, frequency of these species in 1222 floristic quadrats in treeless vegetation sampled across Australian Alps (McDougall and Walsh 2007).

| | Disturbed | | | | Natural | | | | | | McDougall & Walsh |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species** | **Alpine** | **Subalpine** | **Montane** | **Total** | **Alpine** | **Subalpine** | **Montane** | **Total** | **Total all sites** | **% of all sites** | **Treeless vegetation** |
| ***Acetosella vulgaris*** | 27 | 25 | 15 | *66* | 51 | 41 | 27 | *120* | 186 | **46.4** | 42.9% |
| ***Hypochaeris radicata*** | 8 | 31 | 17 | *56* | 5 | 15 | 30 | *50* | 106 | **26.4** | 26.5% |
| ***Achillea millefolium*** | 1 | 26 | 14 | *41* | | 10 | 18 | *38* | 69 | **17.2** | > 1% |
| ***Trifolium repens*** | 7 | 26 | 21 | *54* | | 5 | 4 | *9* | 63 | **15.7** | 14.9% |
| ***Anthoxanthum odoratum*** | | 23 | 13 | *36* | | 16 | 3 | *14* | 55 | **13.7** | 1.4% |
| ***Taraxacum officinale*** | 9 | 17 | 5 | *31* | 2 | 15 | 4 | *21* | 52 | **13.0** | 8.7% |
| ***Dactylis glomerata*** | | 22 | 3 | *25* | | 3 | 5 | *7* | 32 | **8.0** | > 1% |
| ***Agrostis capillaris*** | 2 | 17 | 2 | *21* | 1 | 5 | | *6* | 27 | **6.7** | 1.0% |
| **Number of sites with exotics** | **33** | **54** | **25** | ***112*** | **37** | **109** | **17** | ***163*** | | | |
| **Number of sites sampled** | 45 | 54 | 25 | ***124*** | 139 | 121 | 17 | ***277*** | | | ***1222*** |

**TABLE 3** Ecological distribution of the 8 most common weeds on 401 sites surveyed in 18 general vegetation surveys in the Snowy Mountains between 1986 and 2004.

| Species (highest occurrence) | Road verge | Track verge | Ski resort | Garden | Disturbed subalpine grassland | Natural subalpine grassland | Woodland | Tall alpine herbfield | Heath |
|---|---|---|---|---|---|---|---|---|---|
| ***Acetosella vulgaris*** **(2129 m)** | 28 | 20 | 4 | | 11 | 51 | 15 | 47 | 3 |
| ***Hypochaeris radicata*** **(2070 m)** | 30 | 3 | 9 | 1 | 11 | 20 | 15 | 4 | 3 |
| ***Achillea millefolium*** **(1948 m)** | 37 | | 4 | | | 29 | | | |
| ***Trifolium repens*** **(2019 m)** | 29 | 6 | 9 | | 11 | 4 | 4 | | 1 |
| ***Anthoxanthum odoratum*** **(1845 m)** | 32 | | 3 | | | 19 | 1 | | |
| ***Taraxacum officinale*** **(2028 m)** | 14 | 6 | 6 | | 1 | 13 | 4 | 2 | 2 |
| ***Dactylis glomerata*** **(1845 m)** | 14 | | 6 | | | 2 | 4 | | 1 |
| ***Agrostis capillaris*** **(2106 m)** | 18 | | 2 | | | 5 | | 1 | |
| **Number of sites with exotics = 270** | **52** | **26** | **22** | **1** | **15** | **78** | **25** | **47** | **4** |
| **Number of sites sampled = 401** | 52 | 26 | 22 | 1 | 15 | 91 | 25 | 133 | 31 |

| Country / continent | New Zealand | | | South America | | | AF | Sub-antarctic islands | | | North America | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Source | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| Species | R | N | S | R | S | S | N | N | S | G | R | R | R | R | S | N |
| *Acetosella vulgaris* | x | x | x | x | x | x | | x | | x | x | | | x | x | x |
| *Hypochaeris radicata* | x | x | x | x | x | | ? | | | x | x | | | | | |
| *Achillea millefolium* | x | | | | | | ? | | | x | | x | x | x | x | |
| *Trifolium repens* | x | x | x | | x | | | | | x | x | | x | x | ? | |
| *Anthoxanthum odoratum* | x | x | x | | | | | x | | x | | | | | | |
| *Taraxacum officinale* | x | x | | | x | | ? | | x | x | x | | x | x | ? | |
| *Dactylis glomerata* | x | x | | x | x | | ? | | | x | x | x | | x | x | |
| *Agrostis capillaris* | x | x | x | x | x | | | x | | x | | | | | | |

| | *Acetosella vulgaris* | *Hypochaeris radicata* | *Achillea millefolium* | *Trifolium repens* |
|---|---|---|---|---|
| **Biological traits** | | | | |
| **Mode of reproduction** | Highly aggressive | Highly aggressive | Highly aggressive | Highly aggressive |
| **Innate potential for long distance dispersal** | Mod. to low | High | Mod. to low | Mod. to low |
| **Spreading by human activities** | High | High | Moderate | High |
| **Competitive ability** | Poor | Moderate | Moderate | Moderate |
| **Germination requirements** | Requires disturbance | | Requires disturbance | Requires disturbance |
| **Benefits from disturbance** | Yes | Yes | Yes | Yes |
| **Distribution** | | | | |
| **Origin** | Europe, Mediterranean | Europe | Europe | Europe |
| **Already invasive in Australia** | Yes | Yes | Yes | Yes |
| **Occurs in other mountain regions in Australia** | Yes | Yes | Yes | Yes |
| **Occurs in other mountain regions overseas** | Yes | Yes | Yes | Yes |
| **Impact** | | | | |
| **In natural areas, general** | Moderate | Moderate | Moderate | Moderate to high |
| **In natural areas, Snowy Mountains** | Low | Moderate | Moderate | Moderate to high |
| **Spreading in natural areas in Snowy Mountains** | Extensive | Moderate | Localized but extensive | Limited |
| **Control** | | | | |
| **Feasibility of control of seedbanks** | Low | Low | Low | Low |
| **Feasibility of control of vegetative regeneration** | Moderate | None | Moderate | Moderate |
| **Level of effort required for control** | Mod. to low | Mod. to high | High | Mod. to high |
| **Sources (see caption)** | 1, 2, 3, 4, 6, 7 | 2, 3, 4, 6, 7 | 1, 2, 3, 5, 6, 7 | 1, 2, 3, 4, 6, 7 |

vegetatively from small stolons and is a prolific flowerer that produces many seeds, giving it a highly aggressive mode of reproduction (Table 5, Johnston 2005). Although it can be spread by human activities, it has limited innate potential for long-distance dispersal, with most seed falling within a few meters of adult plants. However, once established, it is highly competitive, able to exclude other species, and difficult to control due to the large seedbank and potential for vegetative reproduction (Table 5, Johnston 2005).

White clover (*Trifolium repens*) is a forb that was deliberately introduced into the Australian Alps, as a species used to revegetate areas damaged by cattle and sheep grazing, and also in ski resorts (Johnston and Pickering

| Europe | | | | | | | Japan | Island Tenerife | Island Hawaii | |
|---|---|---|---|---|---|---|---|---|---|---|
| 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 |
| R | R | R | Car | N | N | S | SS | R | N | S |
| | x | | | x | | x | x | x | x | |
| | | | | | | | x | | x | x |
| | | x | | x | | x | | | x | |
| x | x | x | x | | | x | x | | x | |
| | | | | | x | x | | | x | x |
| x | | | | | | | x | x | x | |
| | | | x | | x | | x | | x | |
| | | x | | x | x | x | | | x | |

**TABLE 4** Occurrence in other mountain regions of the world of the 8 most common exotics found in the Snowy Mountains, according to published vegetation surveys of roadside and natural vegetation. AF = Africa; R = Road, N = Natural vegetation, S = semi-natural vegetation, SS = Ski slope, G = General species list for region. Sources: (1) Ullmann et al 1995, (2) Jesson et al 2002, (3) Rose et al 2004, (4) Pauchard and Alaback 2004, (5) Finckh and Thomas (1997) cited in Pauchard and Alaback 2004, (6) Sarmiento et al 2003, (7) Carbutt and Edwards 2004, (8) Meurk et al 1994, (9) Chapuis et al 2004, (10) Frenot et al 2005, (11) Parendes and Jones 2000, (12) Rentch et al 2005, (13) Tyser and Worley 1992, (14) Lausi and Nimis 1985, (15) Leege et al 1981, (16) Wiser et al 1996, (17) Godefroid and Koedam 2004, (18) Acar 2003, (19) Berge and Hestmark 1997, (20) Schmidt 1989, (21) Austrheim 2002, (22) Odland and Birks 1999, (23) Vandvik and Birks 2004, (24) Tsuyuzaki 2002, (25) Arévalo et al 2005, (26) Daehler 2005, (27) D'Antonio et al 2000.

| *Anthoxanthum odoratum* | *Taraxacum officinale* | *Dactylis glomerata* | *Agrostis capillaris* |
|---|---|---|---|
| | | | |
| Moderate | Highly aggressive | Low to moderate | Highly aggressive |
| Moderate | High | Mod. to low | Limited |
| High | High | High | High |
| Moderate | Moderate | Moderate | High |
| | Requires disturbance | Does not require disturbance | N/A |
| Yes | Yes | Yes | Yes |
| | | | |
| Europe, temp. Asia | Europe | Mediterranean, temp. Asia | Europe, North Africa, temp. Asia |
| Yes | Yes | Yes | No |
| Yes | Yes | Yes | Yes |
| Yes | Yes | Yes | Some |
| | | | |
| High | Moderate | Moderate | Moderate |
| Moderate | Moderate | Moderate | Low |
| Moderate | Localized | Limited | Limited |
| | | | |
| Low | Low | High | N/A |
| Low to mod. | Moderate | Moderate | Low |
| Mod. to high | Mod. to high | Mod. to high | Moderate |
| 3, 4, 6, 7 | 1, 2, 3, 7 | 1, 2, 3, 4, 7 | 3, 4, 7, 8 |

**TABLE 5** Biological traits, distribution, impact, and control of the 8 most common weeds in the Snowy Mountains, Australia. Categories based on weed risk assessment methodology used in Alaska (1). Sources: (1) Alaska Natural Heritage Program 2005, (2) Lamp and Collet 1999, (3) Tables 2, 3, and 4 in this paper, (4) Weber 2003, (5) Johnston 2005, (6) Blood 2001, (7) Harden 1990, (8) Lamp et al 2001.

2001). As a result, it was common in disturbed sites (44%) including road and track verges, ski resorts, and disturbed subalpine grasslands. In contrast it was uncommon in natural sites (3%), only occurring in a few subalpine/montane woodland and grassland sites (Tables 2 and 3).

At lower altitudes it is considered invasive of natural areas in Australia (Weber 2003). Recorded in mountains in South America, North America, New Zealand, Japan, and the Hawaiian Islands, it is considered a high weed risk in Alaska (Table 4). It does have many weed traits, including high reproductive and vegetative output and moderate competitive ability. It is difficult to control due to the large seedbank and its capacity for vegetative spread (Table 5).

Sweet vernal grass (*Anthoxanthum odoratum*) occurs in disturbed (29%) and natural sites (5%) in the montane and subalpine areas in the Snowy Mountains, mostly on road verges and natural subalpine grasslands (Table 2). It was not found in any of the 184 alpine sites sampled here, although other studies have found it at high altitudes (Table 3, Costin et al 2000). Although it has been found in most of the Australian Alps, it is less common than the 7 other species, in these and other mountain regions of the world (Table 4). It has been introduced into Africa, temperate Asia, New Zealand, western USA, and South America, and is considered invasive in Australia, Chile and Argentina, and the islands of Mascarenes, Micronesia, and Hawaii (Weber 2003). It does well on nutrient-poor soils, and can be highly competitive with other grass species (Weber 2003). Although it has high seed output, it does not reproduce vegetatively, unlike many other invasive exotics in mountains (Table 5, Godfree et al 2004).

Dandelion (*Taraxacum officinale*) is a moderately common forb in alpine, subalpine and montane natural (8%) and disturbed (25%) sites in the Snowy Mountains (Table 2). It was found in most habitats including road and track verges, ski resort gardens, natural subalpine grasslands, woodlands, tall alpine herbfields, and heaths (Table 3). Recorded in the earliest surveys of the mountains, it is commonly found in vegetation surveys and general reviews of the flora of the Australian Alps (Table 2). Although it is not always considered an important weed internationally (Weber 2003) and in Australia (Parsons and Cuthbertson 2001), it occurs in vegetation surveys in mountains in North America, South America, New Zealand, Hawaii, Tenerife/Canary Islands and on at least one subantarctic island (Table 4). It is also ranked as a highly invasive species in Alaska. Although it does not reproduce vegetatively, it produces large numbers of wind-dispersed seed, and has moderate competitive ability once established (Table 5). Control can be difficult because of the seedbank and capacity for long-distance dispersal (Table 5).

Cocksfoot (*Dactylis glomerata*) can be found in disturbed (20%) and a few (2.5%) natural montane and subalpine sites, but is not very common even at these lower altitudes (< 1% of treeless vegetation, Table 2). It was found on road verges and in ski resort gardens, and in a few sites in natural subalpine grasslands, woodlands, and a heath site (Table 3). Although recorded in general vegetation surveys of the Australian Alps, predominantly in disturbed sites, it is often not found in specific field surveys. It has been introduced into Southern Africa, New Zealand, some parts of the USA, and South America, and is considered invasive in Australia and Hawaii (Weber 2003). It has been recorded in natural and roadside vegetation surveys in South America, New Zealand, on roadsides in North America, ski slopes in Japan, and in natural vegetation in Hawaii (Table 4). It can reproduce vegetatively and has prolific wind-, water-, and animal-dispersed seed, making it difficult to control (Table 5).

Brown top bent (*Agrostis capillaris*) was deliberately introduced into the Australian Alps for revegetation (Johnston and Pickering 2001). It is less common than the other species (6.7% of the sites), and is mainly restricted to disturbed sites (17%) such as roadsides and around buildings, with few records on natural sites (2%) (Table 3). It has been recorded in general vegetation surveys on roadsides and in natural areas in mountains of South America and New Zealand, but appears uncommon in North American roadside vegetation surveys (Table 4). It has been introduced to Southern Africa, tropical Asia, New Zealand, North America, South America, and Hawaii, and is considered invasive in Australia and New Zealand, where it can be found in grasslands, shrublands, pastures, and other disturbed sites (Weber 2003). This species is a major weed in pastures, but unlike the other common weeds, it is not considered generally invasive in Australia, nor is it as difficult to control as other species (Table 5).

## Discussion

The most common exotics in the Snowy Mountains are native to Europe, but are currently found in many mountain regions worldwide where they are associated with human disturbances such as roads and ski slopes. They are all naturalized in Australia, and 5 of them (sheep sorrel, catsears, yarrow, white clover and dandelions) can be found spreading into native vegetation adjacent to roads and tracks in the Snowy Mountains (Table 3). They show many general weed traits, including high seed output and/or vegetative spread, and wide climatic tolerance—including of temperate regions (Lamp et al 2001; Godfree et al 2004; Alaska Natural Heritage Program 2005). They are all relatively hard to remove, either mechanically or through spraying, due to their large seed output that can be spread by wind and/or animals, and their capacity to spread vegetatively (Csurhes and Edwards 1998; Blood 2001; Lamp et al 2001; Weber 2003; Alaska Natural Heritage Program 2005).

It is also clear that human disturbance in mountain regions, such as the construction and use of roads and tracks, provides the opportunity for the establishment of these and other weeds that can then spread into adjacent native vegetation, with some species becoming naturalized and competing with native taxa (Mallen 1986; Godfree et al 2004; Johnston 2005; McDougall and Walsh 2007). These results highlight that despite the many differences in the diversity and ecology of mountain regions, they appear to be similarly susceptible to invasion by a common group of alien plants that share many of the same traits, making them the usual suspects.

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## AUTHORS

***Catherine Pickering and Wendy Hill***
School of Environment, Griffith University, PMB 50, Gold Coast Mail Centre, Gold Coast, QLD 9726, Australia.
c.pickering@griffith.edu.au; wendy.hill@griffith.edu.au

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