Establishing weed management priorities in a changing climate: NSW ski resorts

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Summary As a result of land use changes in the last century the diversity of weed species in the Australian Alps has increased. The infrastructure associated with ski resort development removes the barrier for weeds to reach higher altitudes. The potential for weed expansion from disturbed areas into surrounding natural mountain ecosystems is high. Future climate change predictions may provide conditions more conducive for weed establishment highlighting the need to have a greater understanding of their distribution and abundance. Identifying the location of known environmental weeds using geographic information systems provides baseline information to define priorities and implement management programs.

Keywords Australian Alps, dispersal, disturbance, distribution, abundance, climate change, management strategies, monitoring, geographic information system.

INTRODUCTION

In recent decades the invasion of mountain ecosystems by exotic species on a worldwide scale has increased as these landscapes become more accessible through increased human-induced activities and climate change weakening biotic resistance (Pauchard *et al.* 2009). The infrastructure associated with the ski resorts provides mechanisms for weed dispersal through the transport of propagates on machinery or vehicles, the use of introduced species in soil stabilisation projects and from historic plantings in domestic gardens (Pickering *et al.* 2002, McDougall *et al.* 2005). Some weed species pose a significant threat to biodiversity within and outside of the ski resorts.

The alpine and sub alpine areas of Kosciuszko National Park (KNP) support a unique range of endemic plants and animals. The alpine areas have one of the world's highest proportions of endemic flora and represent only a small percentage (0.02%) of vegetation on the Australian mainland (Costin *et al.* 2000). The cold temperatures and snow cover for up to 4 months of the year at higher altitudes has acted as a barrier to many introduced species preventing their establishment.

Since the 1950s there has been an increase in weed species recorded in alpine and sub-alpine areas. Six species were recorded in 1954 (Costin *et al.* 2000) and 68 in 1986 (Mallen-Cooper 1990). In 2005 an exotic plants inventory was completed and this identified 175 species of weeds, 100 of which were located in and around resorts, with many being found in lodge gardens (Johnston 2005).

The potential for weed expansion into surrounding less disturbed National Park areas is high. With climate change predictions, leading to increased temperatures, a reduction in the snow duration and a rise in the snow line (Hennessey *et al.* 2003), conditions may become more suited for increased dispersal of existing weeds or new species to establish (Pickering *et al.* 2004). These predictions highlight the importance of greater understanding of current threats from weeds to ensure management strategies are in place to reduce their impacts on key values (Steffen *et al.* 2009).

Study site The Perisher Ski Resort (1598 ha, 1700–2050 m altitude) is one of four resorts located within KNP in the Australian Alps, south eastern NSW. The resort contains areas of disturbance associated with ski infrastructure interspersed with both nationally significant sub-alpine and alpine vegetation communities including threatened ecological communities and species (White and McMahon 2000).

Weed control programs for selected species have been undertaken for the past decade, resulting in reduced populations of larger woody weeds, such as pine (*Pinus* spp.), willow (*Salix* spp.) and apple (*Malus domestica* Borkh.), and various perennial forbs, such as lupins (*Lupins polyphyllus* (Lindl.) Anderson), millfoil (*Achillea millefolium* L.) and barbarea (*Barbarea verna* (Mill.) Asch.). No systematic record of weed treatment or distribution and density has been undertaken. Given this information was unavailable, monitoring the success of control programs relied on visual observations. Setting priorities and directing weed control works is more difficult in the absence of reliable locality data.

MATERIALS AND METHODS

Distribution and density weed mapping was undertaken at the peak of the flowering season in January and February 2009.

The objectives of the mapping project included:

1. Collect accurate point locality information of less common weed incursions or weeds that are known to cause impacts in natural systems,
2. Map the density of weed infestations, and
3. Establish a geographic baseline data set to measure the effectiveness of weed control management programs over time.

Although the number of introduced species in the Perisher Range exceeds 100, 28 were targeted as part of recording point locality. These species were chosen based on whether they are new incursions of limited distribution and/or are known to be invasive in other high altitude areas. Weeds such as sorrel (*Acetosella vulgaris* Fourr.), cats ear (*Hypochaeris radicata* L.) and clover (*Trifolium* spp.) are widely distributed and are considered to have only a minor impact on the diversity and function of vegetation communities (Godfree *et al*. 2004, McDougall *et al*. 2005) and hence were not included. Due to the widespread nature of introduced grass species, information on their locality was captured through the density mapping with the exclusion of new occurrences of some grass species, i.e. creeping fog (*Holcus mollis* L.) and creeping canary grass (*Phalaris arundinacea* L.).

To guide field data collection, digital aerial photographs of the resort were used to identify areas of disturbance or where vegetation colour varied from native vegetation communities, e.g. introduced grasses on ski slopes. Data were collected from the field using a handheld personal digital assistant (PDA) downloaded with a mobile mapping and geographic information system (ArcPAD™). This system allows for multi layered information to be collected in the field, capturing both point and area spatial data. The location for individual or groups of species was recorded along with a description of their location and the number of plants within 10 m^2. Density information was collected using six classes:

i. Disturbed – severely altered sites with greater than 60% cover of weeds,
ii. High – greater than 40% weed infestations unlikely to regenerate unassisted,
iii. High (native) – greater than 40% weed infestations although containing a high proportion of native species capable of regeneration,
iv. Medium – 20 to 39% weed infestations and native species,
v. Low – less than 20%, and
vi. Scattered – less than 5%.

These data were then downloaded into the geographic information system desktop program ArcMAP™.

RESULTS

In total 176 ha (11%) of the 1598 ha of the Perisher Range has a higher level of weed infestation than surrounding natural areas. Of the 176 ha, 107 ha (61%) were mapped as severely disturbed to the point where natural regeneration is unlikely. A further 19 ha (11%) was mapped as high but a significant level of native vegetation also occurred at these sites. Areas mapped as medium (16 ha, 9%), low and scattered often occurred in proximity to ski lodges or ski runs where past disturbance would have involved the removal of vegetation, which is now regenerating.

Of the 422 point locality records, tree species such as apple, willow, silver birch (*Betula* sp.) and *Pinus* species made up 13%; forbs, such as millfoil and vipers bugloss (*Echium vulgare* L.), made up the greatest number of records at 57%. Species that prefer wet soils, such as juncus (*Juncus acutus* L.), lotus (*Lotus corniculatus* L.) and willow herb (*Epilobium ciliatum* Raf.), made up 24%. The survey also identified a number of species recorded at their highest known altitude in NSW, hairy mullein (*Verbascum thapsus* L.), goats beard (*Tragopogopogon dubius* Scop.) and potentilla (*Potentilla recta* L.).

The collection of weed distribution data indicated most infestations were in proximity to areas of soil disturbance. This included roadways, ski slopes around buildings, etc.

The locality data indicated that some species were able to establish in intact vegetation communities, such as juncus, sweet vernal grass (*Anthoxanthum odoratum* L.) and millfoil.

Given this is the first time mapping of this type has been undertaken it is currently unknown whether weed species are spreading into less disturbed areas. Many of the introduced grasses, such as cocksfoot (*Dactylis glomerata* L.), browntop Bent (*Agrostis capillaris* L.) and Chewings fescue (*Festuca nigrescens* Lam.) whilst persistent on a disturbed site are not considered invasive in the absence of disturbance.

Based on the data collected weed species were placed into one of three categories:

1. Species considered too widespread to control but not considered to have major impacts on ecological function,
2. Species largely confined to disturbed sites or used in revegetation projects, and
3. Species capable of invading native vegetation communities and are known to alter ecological function or an isolated occurrence

Weeds that meet the later category were prioritised for control.

CONCLUSION

Weed distribution and density within the Perisher Range is largely associated with past or present disturbance. Due to alterations in available resources often through soil disturbance these locations are where most weeds find conditions more favourable for recruitment.

Alpine environments are recognised as ecological systems vulnerable to climate change therefore the need to understand weed diversity and distribution when developing management control programs is critical. Recent studies in KNP indicate that weed species diversity is increasing at higher altitudes, this study located new altitudinal records for a number of species.

Successful weed control relies on identifying those species that have the greatest potential to impact (D'Antonio and Chambers 2006). This study has located environmental weeds on a geographic information system allowing for the preparation of maps and the establishment of priorities and the implementation of strategic management programs. These programs also incorporate community education, preventing seed dispersal through machinery cleaning, use of endemic plant species in restoration and vertebrate pest control.

The effectiveness of weed management programs can be evaluated by repeating this study every 5 years. The effects of ongoing land use and climate change resulting in new weed incursions can also be monitored.

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