Takahe Valley Hut: a focal point for weed invasion in an isolated area of Fiordland National Park, New Zealand.

Kelvin M. Lloyd*, William G. Lee and Susan Walker
Landcare Research, Private Bag 1930, Dunedin.
*Author for correspondence (E-mail: LloydK@LandcareResearch.co.nz)

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Abstract: The role of backcountry huts as focal points for weed establishment and spread into New Zealand's national parks has received little attention. In this study we describe the pattern of weed spread around Takahe Valley Hut, Murchison Mountains, Fiordland National Park. Established in 1948, the hut is located at 900 m a.s.l. at the ecotone between *Nothofagus* forest and valley floor shrubland/grassland. We recorded the distribution of vascular plants in quadrats (110) placed by restricted randomisation around the hut, and measured relative irradiance and distance from the hut. Nine exotic species, mostly grasses, were recorded, the most frequent being *Agrostis capillaris* (34%). The majority of occurrences of exotic plant species were located in the immediate vicinity (less than 5 m) of the hut but two exotic species (*Agrostis capillaris* and *Dactylis glomerata*) ranged more widely. Exotic species were present in well-drained shrubland and grassland but did not extend far into *Nothofagus* forest or onto infertile wetlands. The percentage of exotic species in quadrats declined significantly with distance from the hut. There was no linear relationship between the percentage of exotic species and relative irradiance. When forest quadrats were excluded, the number of native species in quadrats was negatively correlated with the number of exotic species, suggesting competitive displacement of native species by exotics in non-forest habitats. Long-term persistence of most exotic species at this site depends on physical disturbance and nutrient enrichment associated with human activities at the hut site. However the maintenance of this species pool has provided sufficient propagule pressure for some exotic species to disperse into the wider area. Weed accumulation around huts can be reduced by locating huts in vegetation types that are more resistant to invasion, and maintaining facilities to eliminate local weed infestations.

Keywords: invasive plants; grasses; Fiordland; Takahe Valley; hut sites; disturbance.

Introduction

The role of back country recreational facilities as focal points for weed spread has rarely been documented in New Zealand's national parks (Given, 1973; Johnson, 1982; Jesson *et al*., 2000). Backcountry facilities are often located in habitats that are susceptible to weed invasion, such as alluvial grasslands (Walker and Lee 2002), but other habitats, for example forest, are likely to have greater resistance to weeds. Little research has examined the differing resistance to weed invasion of the upland and mountain vegetation types that are most commonly represented in New Zealand national parks, but low stature communities tend to be more vulnerable to weed invasion in lowland areas (Timmins and Williams, 1987).

Research on weeds in New Zealand's protected natural areas has been dominated by studies of small lowland reserves, typically of shrubland or forest, that are mostly surrounded by highly modified landscapes (e.g. Timmins and Williams, 1987; 1988; cf. Jesson *et al.*, 2000), where proximity to urban areas and settlements is the primary determinant of weed numbers (Timmins and Williams, 1988; Sullivan *et al.*, 2005). However, the characteristics of weeds in lowland reserves are likely to be quite different from those in the largely mountainous and more remote national parks, due to differences in dispersal ability, propagule pressure and environment. Greater distance from propagule sources suggests that long distance dispersal syndromes (by wind or attachment) will be over-represented in back country weeds, however propagules may also be dispersed by seed-ingesting animals, and human activities, including past air-drops of supplies which were typically protected by hay. Establishment opportunities are another critical factor for weeds if they are to persist in natural environments. Weeds frequently depend on disturbance for seedling establishment, even though planted ramets will survive (Jesson *et al.*, 2000). Thus back country weeds may be reliant on natural and anthropogenic disturbance for germination of seeds following dispersal, and thus be primarily associated with areas adjacent to roads and dwellings (Hourdequin 2000).

To determine the environmental and vegetation features associated with exotic species establishment in remote areas, we measured the distribution of weeds in the vicinity of Takahe Valley Hut, located in the Murchison Mountains, a specially protected area of Fiordland National Park. The hut is located on the ecotone between *Nothofagus solandri* var. *cliffortiodes* forest and shrubland, and in close proximity to grassland and wetland, allowing a test of the differing vulnerability of these habitats to weed invasion. An earlier account of weeds present at this site (Johnson, 1982) allowed turnover of weed species to be assessed.

Methods

Site description

Takahe Valley lies in southwest New Zealand, west of Lake Te Anau, on the eastern side of the Murchison Mountains in Fiordland National Park. In 1948, a flightless rail, which was presumed to be extinct, the takahe (*Notornis mantellii*), was rediscovered in the valley, signalling the start of intensive conservation management aimed at protecting the takahe (Lee and Jamieson, 2001). Soon after, the Murchison Mountains were declared a special protected area with access restricted to scientific researchers and conservation staff. A hut was built in the valley, near Lake Orbell, in 1948. The hut is located at the ecotone of *Nothofagus* forest and a diverse shrubland dominated by species of *Coprosma*, *Olearia bullata* and *Aristotelia fruticosa*, which slopes down to poorly drained red tussock (*Chionochloa rubra*) grassland and bog. The forest/shrubland ecotone, several metres from the lowest point on the valley floor, appears to be a result of periodic severe frosts which limit forest expansion into the adjoining shrubland and grassland. Unformed foot tracks lead from the hut to a weather station situated some 150 m northwest of the hut, east and west through the forest about 10 m from the forest margin, and to a stream crossing site at the outlet of Lake Orbell.

Climate

Information from the meteorological records taken from near the hut site (45° 17' 52" S; 167° 41' 3" E) over the past three decades (from 1972) indicate that mean annual rainfall is c. 2500 mm, the mean temperature of the warmest month (January) is c. 10 ºC, and the mean temperature of the coldest month (July) is 0 ºC.

Vegetation sampling

The species composition of the vegetation surrounding the hut (c. 4 m × 4 m) was measured by recording the presence of all vascular plant species in 0.5 m × 0.5 m quadrats that were positioned in two ways, reflecting the concentration of exotic species near the hut. First, forty quadrats were placed by restricted randomisation within a 10 m × 5 m area on each side of the hut. Second, two 20-m transects radiating away from the hut were oriented randomly within each 90-degree sector (giving a total of eight transects). Transects started 5 m from the hut, and five quadrats were sampled at random distances along each one. To quantify the distribution of exotic species that extended beyond the end of the 20-m transects in the grassland and shrubland along the northern edge of the hut, a further three 100-m-long transects were placed at random orientations within the northern aspect of the hut, and a quadrat sampled randomly within each 10-m interval, giving 30 additional quadrats, and a total of 110 (Fig. 3).

For all quadrats, the distance to the nearest part of the hut was measured. Measurements of photosynthetically active radiation were taken with a Li-Cor quantum sensor at each quadrat, 0.5 m above ground level, simultaneously with light readings taken in the open. Quadrat irradiance was expressed as a percentage of the irradiance simultaneously recorded in open light conditions.

Data analysis

Ordination was used to describe the vegetation pattern around the hut. Ten quadrats that contained only one species were excluded from vegetation analysis, as were species that occurred only once. The species/quadrat information from the remaining 100 quadrats was analysed by Detrended Correspondence Analysis (DCA), using the Canberra distance measure, excluding double zero matches. The values at quadrats for relative irradiance, and distance from the hut, were correlated against the ordination axes to test for relationships between these factors and the vegetation gradients. Correlations were also used to examine relations between the number of exotic species, relative irradiance, distance from the hut, and native species richness.

Results

The ordination of species (Fig. 1) reflects the gradient from forest through shrubland to wet grassland, with species of forest interiors (*Nothofagus solandri*, *Coprosma pseudocuneata*, *Uncinia nervosa*, *Lagenifera strangulata*, *Polystichum vestitum*) occupying the extreme left, and herbaceous species typical of wet, infertile sites (*Coprosma perpusilla*,

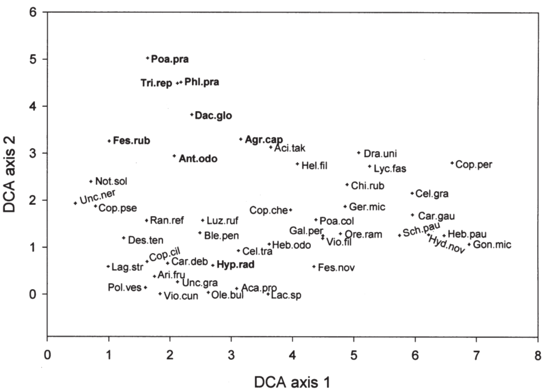

Figure 1. Ordination of species by detrended correspondence analysis. Species are labelled by the first three letters of the genus and specific epithet. Exotic species are indicated by bold font.

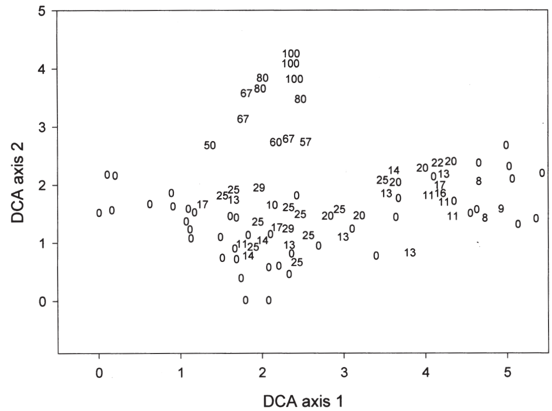

Figure 2. Ordination of quadrats by detrended correspondence analysis, with quadrats labelled by the percentage of exotic species recorded within them.

Carex gaudichaudiana, *Celmisia gracilenta*, *Hebe pauciramosa*, *Hydrocotyle novae-zelandiae*, *Shoenus pauciflorus*) occupying the extreme right, of the ordination diagram. Species of well-drained, fertile shrubland occupy the centre of the ordination. Exotic species are distributed toward the forest/shrubland end of axis 1 and are largely separated from the indigenous taxa along axis 2.

The primary axis of the quadrat ordination (Fig. 2) is also related to the gradient from forest through shrubland to wet grassland. Quadrats at the extreme left of the quadrat ordination occurred beneath the *Nothofagus* forest canopy, had low species richness, and contained no exotic species. Quadrats from shrubland and tussock grassland occupy the centre in the lower half of the ordination diagram. Many of these quadrats contained a low to moderate proportion of exotic species. Quadrats from the wet, infertile habitat occur at the extreme right of the ordination diagram and exotic species were uncommon or absent from these. Quadrats dominated by exotic species occur together at an intermediate position along axis 1, but are differentiated from all other quadrats along axis 2.

Nine exotic species were recorded in quadrats, and 75% of these were grasses. *Agrostis capillaris* (in 38 quadrats) was the most common exotic grass, followed by *Anthoxanthum odoratum* (16), *Dactylis glomerata* (14), *Poa pratensis* (6), *Phleum pratense* (6), and *Festuca rubra* (3). The exotic *Poa annua* was recorded only once. Exotic herbs were infrequent, *Trifolium repens* (4) and *Hypochaeris radicata* (3) the most common. The exotic grass *Holcus lanatus* and sprawling herb *Cerastium fontanum* were both observed in the vicinity of the hut, but were insufficiently frequent to be recorded in quadrats. Elsewhere in Takahe Valley, three exotic species not present at the hut site were observed. *Hieracium pilosella* and *Cirsium arvense* form locally dense patches in red tussock grassland along the shore of Lake Orbell, with the former species occasionally seen in alpine tussock grassland in the head basin of the valley. *Cirsium vulgare* plants were observed growing in shallow soil on open limestone ledges on bluffs below treeline.

The majority of the exotic species recorded in quadrats were found in close proximity to the hut (Fig. 3), where a sward of exotic grasses was present. Three quadrats in this area did not contain any indigenous species. Four exotic species (*Festuca rubra*, *Poa annua*, *Phleum pratense* and *Trifolium repens*) were restricted to the immediate vicinity of the hut, two (*Anthoxanthum odoratum* and *Hypochaeris radicata*) ranged to a distance of 25 m and two (*Agrostis capillaris* and *Dactylis glomerata*) were found 100 m from the hut at the ends of two of the longest transects. The third 100m transect passed into a wet, infertile area where species at the extreme right of the species ordination diagram were common. No exotic species were recorded in this area, although they were present along the track leading to it in an area of well-drained shrubland. Exotic species did not penetrate far into the forest (Fig. 3).

Relative irradiance and distance from the hut were both positively correlated with the primary axis of the quadrat ordination ($r = 0.58$, $P < 0.001$; $r = 0.72$, $P < 0.001$ respectively). Relative irradiance was also positively correlated with ordination axis 2 ($r = 0.22$, $P < 0.05$) but distance from the hut was not ($r = 0.07$,

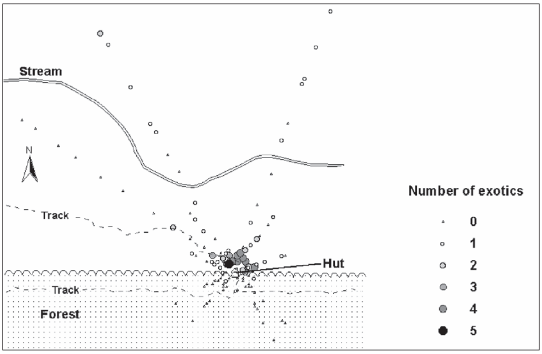

Figure 3. Map of site showing distribution of weed species. Quadrats are denoted by circles, with circle size and degree of shading increasing as the number of weed species in the quadrat increases.

$P = 0.5$). The percentage of exotic species in quadrats was negatively correlated with distance from the hut ($r = -0.23$, $P < 0.05$), but was not related to relative irradiance ($r = 0.14$, $P = 0.15$). When quadrats containing *Nothofagus* (the canopy tree species) were excluded from analysis, the negative correlation between percentage of exotics and distance from the hut was stronger ($r = -0.37$, $P < 0.01$), but again there was no relation with relative irradiance ($r = -0.03$, $P = 0.8$). Excluding forest quadrats, the number of exotic species in a quadrat was negatively correlated with the number of indigenous species ($r = -0.39$, $P < 0.01$).

Discussion

At Takahe Valley, the hut is a focus for both the naturalisation and the dispersal of exotic plant species in the eastern Murchison Mountains. Similar suites of exotic species have been observed around facilities elsewhere in Fiordland (Poole, 1951; Given, 1973, Johnson, 1982). The majority of the 14 exotic species recorded in Takahe Valley have established within a few metres of the hut, along and adjoining the track where a combination of high irradiance, disturbance, and probable nutrient enrichment maintain the competitive advantage of predominantly pasture grasses over the local native plant species. A subset of these exotic plant species have spread into the surrounding shrubland and grassland vegetation, mostly in open-canopied sites, a process which has been documented elsewhere in the New Zealand back country (Jesson *et al*., 2000). While source-sink relations remain uncertain because of the possibility of grass species establishing from other sources, the disturbed area around the hut is the most likely source of invading grasses at Takahe Valley.

In addition to these two sets of species, a third group are distributed elsewhere in the valley and not found at the hut at all. These are all members of the Asteraceae and their seeds may have dispersed from farmland on the eastern side of Lake Te Anau (a distance of around 10 km), since the intervening land cover is either lake or forest. However these species may also have invaded with human assistance. Given (1973) recorded *Cirsium arvense* at three sites remote from tracks and huts in Wet Jacket Arm and Dusky Sound, and cited dumping of rubbish, packing used in airdrops, and the use of remote campsites as alternative sources of weed invasion. Poole (1951) reported two other species of Asteraceae, *Hypochaeris radicata* and *Senecio jacobaea*, from disturbed beach heads in George and Caswell Sounds. Five of the ten exotic plant species observed at these sites and at Hankinson Hut in 1949 (Poole, 1951) were also present in Takahe Valley in 2002.

Vegetation type has a strong effect on the establishment and persistence of weeds in Takahe Valley, with no exotic plant species having been able to penetrate continuous *Nothofagus* forest, even in areas where human activities have disturbed the understorey and ground cover, presumably because of low irradiance levels. This contrasts with the study of Wiser *et al.* (1998), who showed sustained increases over 23 years in the distribution and frequency of *Hieracium lepidulum* in *Nothofagus* forest in Canterbury. *Hieracium lepidulum* occurred more frequently in species-rich tall herb communities within the Canterbury forest system, possibly because they were located in relatively well-lit microhabitats such as flushes and streamsides. Wiser *et al.* (1998) did not measure local site irradiance directly, but used slope and aspect measurements to derive potential solar radiation estimates.

Light levels appear to be less important for controlling the distribution of exotic plant species in the grassland and shrubland where exotics are more constrained by proximity to hut seed sources and local edaphic factors. The exotic plant species present in the valley have failed to colonise the sparse vegetation growing on poorly drained peat. Thus low vegetation stature may not automatically lead to invasion of exotics (cf. Timmins & Williams, 1987) if environmental conditions are sufficiently harsh. However none of the exotic species present at Takahe Valley are wetland plants, although these are known from other huts in Fiordland (Poole, 1951). In general, exotic species at Takahe Valley were restricted to well drained shrubland and valley floor tussock grassland below tree line. Only *Hieracium pilosella* has been able to colonise alpine tussock grassland, where it is much less abundant than in valley floor grassland.

Our results for Takahe Valley are broadly similar to a study by Godfree *et al.* (2004) of an Australian sub-alpine system, where the exotic species were mostly grasses and Asteraceous herbs, comparatively few (12%) species actually invaded communities beyond the immediate vicinity of the roadside, and forests and bogs were relatively resistant to invasion. There were also clear differences in the types of exotic species found along disturbed roadsides (herbs and grasses) compared to those invading more intact vegetation (broadleaved herbs), which is similar to the pattern evident in our local study.

The suite of exotic plants present in Takahe Valley in 2002 differs in both number and composition from that observed by Johnson (1982). Turnover of species is apparent, with *Capsella bursa-pastoris* and *Juncus bulbosus* recorded in the 1970s but not seen there three decades later. However the most significant change between the two sampling periods is the apparent invasion of Takahe Valley by six new species, two grasses (*Festuca rubra* and *Phleum pratense*) and four herbs (*Cirsium arvense*, *Cirsium vulgare*, *Hypochaeris radicata*, *Hieracium pilosella*), the latter all members of the Asteraceae. The source of the new grass species was probably contamination associated with boots or gear of visitors. This appears to be a common pathway for dispersal of weeds into the back country (Given 1973; Poole 1951). The Asteraceae herbs present in the valley probably arrived as seed in hay used for packaging air-dropped supplies, a practice which stopped in the late 1960's, although they may have arrived independently through long distance dispersal.

The pattern of establishment of exotic plant species around the Takahe valley hut suggests clear differences in the vulnerability of different indigenous vegetation types, and the importance of disturbance immediately around the hut for maintaining a suite of exotic plant species. These results indicate that most weeds can be effectively controlled by focussing management near the hut, with occasional eradication of outliers. In addition, locating amenity facilities in sites that are within or buffered by resistant vegetation types, such as forest, wetland or other low fertility habitats, could be an important strategy for minimising weed invasion.

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