

# *Hieracium lepidulum* invasion of indigenous ecosystems

Susan Wiser, Rob Allen  
Landcare Research  
Private Bag 1930  
Dunedin

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# 1. Background

It is increasingly apparent that *Hieracium lepidulum* is aggressively invading indigenous ecosystems in addition to induced tussock grasslands - and that this is a consequence of a wider set of factors than land degradation. As a consequence the Otago Conservancy (Department of Conservation) requested a review of *H. lepidulum* invasion of beech forest and subalpine shrublands/herbfields.

Questions for which advice/service is required:

1. What are the implications for conservation of the research results to date on invasions by beech forest ecosystems by *Hieracium lepidulum*?
2. What is known about ecosystem components that make *H. lepidulum* invisable, and processes which enable invasion of indigenous ecosystems such as beech forest and subalpine shrublands/herbfields?
3. Recommendations (if any) for future research on this topic that will assist management of the conservation estate.

To answer these questions requires a review of the biology *Hieracium lepidulum*, what is known about the invisibility of ecosystems, what is known about the impacts of that invasion, and what possibilities there are for management to minimise these impacts. Although our review considers to some degree the wider literature, the focus of the review and research recommendations is whether that information is relevant to beech forests and subalpine shrublands/herbfields.

## 2. Biology of *Hieracium lepidulum*

*Hieracium lepidulum* (Asteraceae, subgenus *Hieracium* in the *H. vulgatum* group, Tutin et al. 1993) is a plant that is native to Europe. It belongs to a taxonomically complex group. As is typical for this group, it is a broad-leaved, tufted perennial herb with leaves in a basal rosette and along the stem. It has no stolons and reproduces by plumed, wind-dispersed seeds (Webb et al. 1988). Species in this subgenus produce large quantities of seed and are apomictic (Grime et al. 1988). Apomictic plants produce seed with no sexual reproduction; in effect the seeds produce plants that are clones of the parent. If the species is one that mutates rapidly, these mutations can be rapidly fixed in new populations and may allow colonisation of previously unsuitable habitats. Distribution in Britian and Europe suggests that species in the group can be dispersed over long distances, perhaps with the aid of humans (Grime et al. 1988). Their roots have vesicular-arbuscular mycorrhiza which play a

role in P uptake and N nutrition. Species in this subgenus are naturally distributed throughout Europe and the British Isles and north into Sub-arctic and Arctic regions. They occur in a range of shaded and unshaded habitats, but are absent from wetlands and the most acidic soils. In middle Europe, they are widespread in woods and ascend to subalpine areas (G. Gottschlich, pers. comm.). Because of taxonomic difficulties, however, it is difficult to apply information about the home range of *H. lepidulum* to its potential range in New Zealand.

*H. lepidulum* was first recorded in New Zealand in 1941 from Tim's Creek, in the Broken River catchment, Craigieburn Range, Canterbury. The first published record is based on a specimen collected from the nearby Avoca Valley in 1945 (Healy 1946), which probably came in as seed contamination. Presumably, it spread from pastoral situations and short tussock grasslands to stream beds, landslide scars, beech forests, subalpine and alpine areas. It is more shade-tolerant than the other common *Hieracium* species, and this allows it to persist and reproduce under forest and scrub. Rose & Frampton (1999) compared microsite characteristics in *Chionochloa* grasslands where *Hieracium* seedlings had successfully established with those where they had not. While high amounts of overhanging cover and proximity of the canopy plant tends to discourage seedlings of *H. pilosella*, these are the conditions where *H. lepidulum* seedlings are more likely to occur. Hunter (1991) described *H. lepidulum* as occurring relatively far west in high rainfall areas, in comparison to other hawkweeds. This is supported by its less conservative water-use than some other invasive *Hieracium* species (Ian Payton unpubl. data).

In New Zealand, the only other species in this subgenus are the apparently relatively uncommon *H. murorum* and *H. pollichae*. They share many of the described biological features with *H. lepidulum*. *H. murorum* has been present in New Zealand since at least 1940 and still has a relatively restricted distribution (Webb et al. 1988). *H. pollichae* was first collected in New Zealand in 1975. While its distribution is also relatively limited, it can be abundant where it does occur at Hanmer Springs under black beech canopies (P. Bellingham, S. Wisser, and R. Allen, pens. comm). Because these two species are superficially similar to *N. lepidulum*, it is possible that they have been recorded as such if they occurred on study plots.

## 3. Invasibility of ecosystems

### 3.1 DISTRIBUTION

Herbarium records show *H. lepidulum* was widely distributed (but probably localised and with low frequency) in central Canterbury by 1970 - notably several specimens are from beech forest (CHR specimens: Staveley (1962 - beech forest edge), Craigieburn Range (1967 - beech forest), Rockwood Bush (1968 - beech forest), Kowai Bush (1970 - beech forest). That *H. lepidulum* first established in central Canterbury is supported by Connor's (1992) ob-

servations (1960-1965) of this species being present, but rare, at sites around the Craigieburn Range, but absent to the north and south in Canterbury.

From 1970 on, we can also consider observations from widespread plot data. Because of the standard electronic formats used, we were able to rapidly search a large amount of data stored in the National Vegetation Survey (NVS) database that includes Protected Natural Area (PNA) and Reconnaissance (Recce) plot data. Other data sets that may usefully supplement those reviewed here are those held by Knight Frank Ltd. and by individuals in universities (e.g. Alan Mark and Kath Dickinson at Otago University). PNA and Recce surveys collect total plant composition data from point locations. The strength of these data are in the wide range of habitats and geographic regions that have been surveyed. Their coverage, however, is uneven across the country; for example, there are few in National Parks. Data from 4943 plots across 19 PNA surveys (1985-1997) known to contain *H. lepidulum* and 2431 plots from 14 Recce surveys (1982-1998) known to contain *H. lepidulum* were examined.

In his review of the distribution of hawkweed species in the South Island, Hunter (1991) described the geographic distribution of *H. lepidulum* in New Zealand as "Taranaki (Mt Egmont), Nelson, Marlborough, Canterbury and Otago." The vegetation survey data gave *H. lepidulum* as being widely distributed in four DOC conservancies - Nelson-Marlborough, Canterbury, Otago, and Southland. It was recorded on about 1 100 plots; of which about half are in beech forest or in treeless ecosystems above 1000 m. In some plots *H. lepidulum* provided a dominant ground cover - the progression to this stage is described in permanent plot subsections below. CHR herbarium specimens reflect the increased extent of *H. lepidulum* with many Canterbury specimens between 1980 and the present. Notably, there were also collections from the Matukituki River (beech forest and matagouri scrub (1980, 1987)) and Lake Hawea (manuka (1994)) in Otago, and the Otira Valley (scree (1994)) and Kokatahi Catchment (shrubland 1996) in Westland. Johnstone et al. (1999) describe *H. lepidulum* as a species of wetter mountain climates in Otago. From rapid assessments made in 1999 by Geoff Rogers it appears that *H. lepidulum* is now established in headwaters west of the main divide in southern Westland and northern Fiordland. Our observations in subalpine shrubland and beech forests of Otago (e.g. Rob Roy Valley) suggest that it is at this location where it reaches maximum cover and extent. We hypothesise that this may be a consequence of higher soil fertility in west Otago beech forests than those soils derived from greywacke in Canterbury.

To determine what types of communities are being invaded, a plant community classification was made on the combined PNA and Recce plots containing *H. lepidulum* that either occur in beech forest or are from sites over 1000 m - a total of 618 plots. To strengthen the interpretation relative to forest, sub-alpine and alpine zones, this classification was constrained by altitude (using the software COINSPAN, Carleton 1996). This enabled a very broad classification of community types where *H. lepidulum* occurs in these zones to be described:

- Mountain beech forest (mean elevation 950 m). This included the drier mountain beech forests of inland Canterbury (Craigieburn Range) and areas to the west with higher rainfall;

- montane grasslands (mean elevation 1 194 m). This included those dominated by herbaceous species (e.g. *Festuca* and *Anthoxanthum*) and at marginally higher altitude those including *Podocarpus nivalis* as a dominant;
- alpine grasslands (mean elevation 1372 m). This included grasslands with *Chionochloa rigida* and *Gaultheria depressa* as a dominants as well as those at higher elevations which include *Anisotome aromatica* and *Celmisia lyallii*.

These analyses are constrained by where plot data have been collected and also may not distinguish communities making up a small part of the landscape. *H. lepidulum* is common on rock outcrops in beech forests. Herbarium specimens in forest have often been collected on moist sites near streams and it appears that the diverse riparian communities of alpine and subalpine zones are also invaded. *H. lepidulum* has been recorded on plots reaching as high as 1768 m; this is in Dunstan Range, Otago. A herbarium specimen at CHR collected in 1987 records it even higher - at 1890 m in the Ryton Valley, Canterbury. The habitat is described as 'a north-facing sward of *Rytidosperma setifolium* on sloping ledges of rock bluffs'.

### 3.2 DETAILED CHANGES OVER TIME

Possibly because central Canterbury was the initial area invaded by *H. lepidulum* this area provides two long-term data sets, described below, that document the invasion. The permanent plots have further advantages, as they provide quantitative measures of species abundance via seedling subplots in forest and 6 inch ring transects in grasslands. These may miss a species that is very sparse, but provide a useful way to examine change as a species becomes more abundant.

#### Permanent plots in alpine and subalpine grasslands

Because many grassland permanent plots have not been remeasured in recent years, we have few long-term data to allow us to assess which subalpine and alpine ecosystems have been invaded by *H. lepidulum*, how rapid this invasion has been, and when the most rapid increases were. One of the better data sets available to make such an assessment is the long-term subalpine grassland plots in the Harper and Avoca catchments in the headwaters of the Rakaia River (see Rose et al. 1995). These plots were established in 1960 and 1965 and different subsets of them were remeasured in 1975, 1980, 1985 and 1990. Changes in frequency and abundance of *H. lepidulum* on plots higher than 1200 m (treeline elevation in the area) are shown in Table 1. The invaded plots are dominated by snow tussocks, with species such as *Rytidosperma setifolia*, *Anisotome aromatica*, *Wahlenbergia albomarginata*, *Poa colensoi*, and *Gaultheria depressa* common.

Table 1. Changes in occurrence of *Hieracium lepidulum* on subalpine grassland plots

Year	No. of plots (> 1200 m) surveyed	No. of plots (> 1200 m) with <i>H.lepidulum</i>	Mean frequency on plots where it is present
1960	27	0	0
1965	41	1	2
1970	33	2	1
1980	30	8	9
1985	4	4	23
1990	5	5	33

Although there are at least 30 other surveys that included plots in subalpine or alpine zones, most of these have not been remeasured since 1980, when the increase in *H. lepidulum* first became apparent in the Harper-Avoca area. The only surveys with plots that have been remeasured are in the Kaweka Range (1982), the Caples Valley (1984), the Kaimanawa Mountains (1981), and the Waitaki Catchment (1984). Electronic searches of the first three of these data sets showed that no *H. lepidulum* was recorded. *H. lepidulum* was recorded from the Waitaki in 1974. NVS does not have electronic data from the 1984 survey.

### Permanent plots in forest and shrubland

The most detailed study to date of *H. lepidulum* in forests is that of Wisser et al. (1998). The study examines changes in *H. lepidulum* on 250 permanent plots in beech forest in the Harper and Avoca catchments and in the Craigieburn Range, Canterbury, over the period 1970 to 1993. Frequency of *H. lepidulum* increased from 11 % to 43% to 57% from 1970 to 1985 to 1993. The plots invaded in 1970 were more likely to be close to the forest margin; at this stage it appeared that dispersal limitation was controlling the forest sites that were invaded. By 1993 the forest area was sufficiently invaded that dispersal limitation was no longer influencing large-scale patterns. At this time, sites that were invaded tended to have more fertile soils (higher levels of cations, phosphorus and nitrogen), to be in protected topographic positions (e.g. moist gullies), and to have higher numbers of native species in the understorey. There were only very weak relationships between invasion and past disturbance to the forest canopy.

That species-rich sites were more likely to be invaded has subsequently been supported by ecological work in forests, and some other ecosystems, elsewhere in the world (Stohlgren et al. 1999, Lonsdale 1999). This is of particular concern, as sites rich in native species are often of high conservation value.

### 3.3 CONTROLS ON THE PROGRESS OF INVASION

Although the mountain beech study (Wisser et al. 1998) has shown that the factors, and the predictability, of *H. lepidulum* invasion vary over time, it is worth considering in a little more detail what controls the progress of its invasion. In a broad sense the increase in *H. lepidulum* coincides with a

period of marked reduction in introduced ungulate numbers - possibly the invasion has been promoted by rather open browsed communities, e.g. beech forests, subalpine herbfields, where the browse pressure has been reduced. Natural disturbance regimes will also have a role in controlling invasion, particularly at a local scale. *H. lepidulum* can be common on recently disturbed mineral surfaces in riparian areas in both subalpine shrublands and beech forest. Wisser et al. (1998) considered canopy disturbance was unimportant in mountain beech forests. Subsequently, observations in the same beech forest following the 1994 Arthur's Pass earthquake show a marked further invasion into the beech forests where the mineral soil has been exposed by landslides caused by the earthquake. We may expect that changes in vegetation structure and composition following disturbance will also affect invasibility. For example, in the mountain beech forests it has been shown that, as stands develop following disturbance, the increasing amounts of nutrients stored in the increasing biomass result in a decrease in soil nutrient availability (Allen et al. 1997). As *H. lepidulum* prefers fertile beech forest soils, it may have difficulty invading high-biomass stands. A more comprehensive overview of what explains temporal and spatial variability in *H. lepidulum* distribution will no doubt add further factors because of the incidental nature of most observations to date.

## 4. Impacts of *Hieracium lepidulum* invasion

The justification for any form of control will largely be based on the importance and extent of impacts. As for the invasibility of ecosystems, impacts will depend upon many factors, yet the basis for any comment is rather thin and largely anecdotal. Given *H. lepidulum* is commonly a component of diverse herbaceous communities in the subalpine zone and in beech forests, the most obvious impact may be the competitive displacement of indigenous species. Potentially *H. lepidulum* may outcompete other species for light, moisture or nutrients. There are field observations supporting a displacement of indigenous species. On alluvial terraces in subalpine streams forming the headwaters of the Rakaia River our observations suggest the death and break-up of otherwise robust *Raoulia* mats occurs following the establishment into them of *H. lepidulum* seedlings. Similarly, Geoff Rogers has noted the apparent decline of certain shrub species (*Hebe subalpinca*) in the subalpine following the establishment of *H. lepidulum*. Wisser et al. (1998) showed that this species invades the relatively diverse mountain beech forest understories but did not analyse their data as to which species have been displaced. Certainly an early part of further work should be a careful analyses of what species appear displaced by the invasion, including subsequent testing by experimental manipulations.

We know that leaf turnover is rapid in *H. lepidulum* and that its foliage has high nutrient concentrations (Ian Payton unpubl. data). *H. lepidulum* can have very high foliar K (4.8%) and P (0.41%) concentrations, so that litter



inputs may have consequences for litter decomposition and below-ground processes. Duanne Pelzer is hoping to work with David Wardle and Susan Wiser on the importance of *H. lepidulum* litter in below-ground processes in Canterbury mountain beech forest. This adds to fertiliser experiments being undertaken in mountain beech forest at Craigieburn to test the influence of nutrient supply on invasiveness. Potentially there are other plant interaction mechanisms, for example, *Hieracium* species (from other groups) have been shown to produce phytotoxic compounds (Makepeace 1985) and modify soils (McIntosh et al. 1995).

Impacts on diverse herbaceous communities may not be the only foci of impacts. *H. lepidulum* invasion of habitats containing rare plant species also appears important. Geoff Rogers has noted the invasion of rock outcrops containing rare herbaceous plants (e.g. *Ischnocarpus novae-zelandiae*) in western Otago beech forests.

## 5. *Hieracium lepidulum* management

Research is currently under way to investigate the biology and host specificity of four insects that feed on *Hieracium* species in Europe (Syrett et al. 1997). These species have been selected for study because indications are that they have a very narrow host range, and cause substantial damage to their host plants. Preliminary results from laboratory tests show two of these species (*Cheilisia praecox* and *C. psilophthalma*) can attack *H. lepidulum*. These species are syrphid flies whose larvae feed on young leaves and in the root crown. The rust fungus, *Puccinia pilosellioidarum* var. *hieracii*, is highly host-specific and does not attack *H. lepidulum*. The selection of biological control agents has focused on those appropriate for *Hieracium* species that propagate vegetatively. As *H. lepidulum* reproduces by wind-dispersed seeds, and is without stolons, Pauline Syrett has suggested a shift in biological control agents to seed-feeding insects.

A second group of control strategies could be developed and applied on specific sites. Herbicides (e.g. "Versatile") are effective on *Hieracium* species and have been applied in a selective way by painting individual leaves. Care must be taken to avoid rain washing off, and redistributing, the herbicide. Manual weeding is also possible and also a reduction in fitness could be brought about by removing seedheads. It may be possible to find naturally occurring pathogens that could be used to develop a selective mycoherbicide. All these methods are extremely tedious or speculative - and their desirability will depend upon conservation gains that can be made.

Finally, if there are any relationships between human-related disturbances and *H. lepidulum* performance there is the potential to modify these impacts. Clearly the most obvious one is disturbance by introduced ungulates - and their control. Locally, tramping tracks, and their use, may be important.

# Research recommendations

We believe there is enough evidence that *H. lepidulum* poses a threat to indigenous biodiversity in subalpine shrubland, rock outcrop, and beech forest communities to warrant further work. The logical sequence for this work should be:

- Firstly, a more complete reconstruction of the temporal distribution of *H. lepidulum*, and of the factors controlling its local and regional abundance throughout its range. Areas for more intensive local-scale assessment will become apparent after the wider-scale survey is completed, but may be expected to include western Otago and central Canterbury. In part this will involve a characterisation of the types of habitats in which it occurs (using past and new observations), and a careful partitioning of patterns related to stage of invasion from those related to competitive interactions, disturbance (human and natural), and environment. This will allow a determination of where the problem is most serious, including a focus on those situations with a high conservation value.
- Secondly, based on analyses of the distribution, and related observations, there should be more explicit tests of *H. lepidulum* impacts. Clearly some of the work on ecosystem processes and *H. lepidulum* biology should be supplemented by analyses of time-series data from widespread permanent plots, in at least Canterbury and Otago, to determine the biodiversity impacts of the invasion. Experimental manipulations of *H. lepidulum* populations would also be useful in some habitats, for example, rock outcrops, diverse subalpine riparian communities and Raoulia mats.
- Finally, and based on the outcome of the first two research areas, we may need to look at control options. One can imagine a need for intensive techniques appropriate for high-priority sites and more extensive approaches to manage more pervasive impacts.

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