An observation of *Aciphylla aurea* recovery following the exclusion of lagomorphs in the Canterbury High Country

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Introduction

Hares (*Lepus europaeus occidentalis*) and rabbits (*Oryctolagus cuniculus cuniculus*) (collectively referred to as lagomorphs) were introduced to New Zealand in 1851 and 1777, respectively (Flux 1990, Gibb and Williams 1990). Since their introduction lagomorphs have become widespread throughout the South Island high country (Flux 1990, Gibb and Williams 1990). Rabbits prefer open habitat with pasture species and some intact vegetation to use as refugia (Norbury 2017), whereas hares are generally more common at higher elevations (Norbury 2001). The introduction of lagomorph species to some ecosystems can be catastrophic. For example, rabbits on Macquarie Island denuded the coastal slopes of their vegetation leading to landslides (Costin and Moore 1960, Saunders et al. 2013).

Lagomorphs have been recorded eating a wide range of New Zealand native plants as well as introduced species (Norbury 1996). Many studies on lagomorph browse have focused on pasture species (Norbury 2001, Latham et al. 2020) or have measured vegetation biomass as part of a study looking at wider ecosystem species interactions (Ramsey and Norbury 2009, Norbury et al. 2013). However, few studies examine the impacts of lagomorphs at an individual species level (Norbury 2001, Grüner and Norton 2006), despite lagomorphs being suspected as the cause of decline in numerous species of New Zealand plants (Norbury 1996).

A common problem with understanding browse pressure on New Zealand vegetation is separating out the effects of multiple herbivores, as ecosystems often contain numerous introduced mammals that overlap in diet (Forsyth et al. 2000, Norbury 2001, Latham et al. 2020). Exclosure plot experiments are one approach to teasing out who is eating what. However, in high country locations exclosures often fail following snowfall (Mark et al. 2011, Norton and Young 2016).

Aciphylla

A genus often recorded as browsed by lagomorphs is *Aciphylla* (Campbell 1981, Norbury 1996, Wilson et al. 2006), and it has been suggested that *Aciphylla* may be useful indicator species for understanding the impacts of rabbit and hare browse (Wong and Hickling 1999) on native plants. Taramea (*Aciphylla*) Family Apiaceae species are a taonga to Ngāi Tahu and are particularly important as a source of perfume (Dobson-Waitere et al. 2022). New Zealand has ~40 species of *Aciphylla* (Allan 1961). *Aciphylla* are renowned for their sharp-tipped leaves – it is in the name *Aci* - needle, and *phylla* - leaf (Mark 2012). Atkinson and Greenwood (1989) suggest that *Aciphylla* plants were eaten by moa, and long spines (>10 cm) are known to deter ratite browsing in other plants (Lee et al. 2010). *Aciphylla* seedlings are much more supple and grass-like than their adult forms, so perhaps moa targeted these (Atkinson and Greenwood 1989). As early as 1883 Petrie noted the decline of *A. colensoi* and attributed it to browsing by rabbits (Norbury 1996). The carrot like taproot is eaten by pigs (Atkinson and Greenwood 1989, O'Donnell et al. 2017).

While undertaking *Veronica armstrongii* sampling with the Department of Conservation (DOC) in April 2021, I observed a stark contrast in the number of *A. aurea* plants in the rabbit fenced plot compared to either the stock fenced and unfenced plots. The aim of this paper is to record that observation with a discussion of lagomorph browse in New Zealand.

Methods

Study Site

The DOC exclosure plots are found on the Flora Terraces of Mt White Station, near Arthurs Pass National Park in Canterbury. The plots sit on moraine and outwash surfaces above Flora Stream at approximately 775 m elevation. Johnson and Molloy (1988) describe the vegetation of Pūkio Stream, and the DOC exclosure plots are located near site O in their paper. The plots are at the drier end of a rainfall gradient from the Mounds of Misery (2000 mm per year) to the Esk River (1000 mm per year) (Johnson and Molloy 1988). Vegetation surrounding the plots is mixed short-tussock grasslands (e.g. *Festuca novae-zelandiae*, *Trisetum tenellum*, and *Agrostis capillaris*), *Racomitrium* mossfields, and shrubs (e.g. *Halocarpus bidwillii, Veronica armstrongii, Ozothamnus leptophyllus,* and *Discaria toumatou*). The site is grazed by cattle and sheep. Feral pigs, deer, and chamois are known from the area. Both hares and rabbits are present.

Study species

Aciphylla aurea / taramea (golden Spaniard) is found mostly east of the main divide in the South Island of New Zealand from Mount Stokes in the north to near Te Anau in the south (Allan 1961). *Aciphylla aurea* is a plant of montane to subalpine areas (Allan 1961). Plants are dioecious and exhibit mast flowering (Mark 1970). Adult plants have formidable, rigid, sharply tipped leaves, but seedlings are softer and flexible.

Plot set-up

The Department of Conservation established three exclosure plots (Table 1) on the little Flora Terraces sometime between 1990 and 1994 (Norbury 1996, Hustedt 2002). Unlike two previous exclosure studies (Mark et al. 2011, Norton and Young 2016) the Flora Terrace plots appear to have remained uncompromised by snowfall. The initial intent of the exclosures was to understand the potential damage of livestock (cattle and sheep) and lagomorphs on the Nationally Endangered shrub *Veronica armstrongii* (Hustedt 2002, de Lange et al. 2018). All plots are set up in a continuous block across the same contour and so are part of a contiguous vegetation type.

Table 1. Plot treatment, size, and animal exclusion of the DOC Flora Terrace *Veronica armstrongii* monitoring plots.

Plot Treatment (replicates)	Size (m)	Notes on animal exclusion
Unfenced (1)	20 x 30	Open to all animals.
Stock fencing (1)	40 x 30	Excludes cattle and sheep, but open to all other animals.
Lagomorph fencing (1)	25 x 30	Excludes lagomorphs but open to deer, chamois, and possums.

Aciphylla aurea *counts and photographs*

Aciphylla plants were counted in two size categories (≤ 15 cm and >15 cm in height). These size categories were chosen as they are consistent with measurements used in other plant surveys like the seedling counts used by the Tier 1 monitoring programme (DOC 2017).

Photographs were taken from each corner of the three plot types looking into the centre of the plot. A second set of photographs was also taken down the uphill slope of the plot looking down the fenceline between the lagomorph fenced and stock fenced plots.

Results

The lagomorph fenced plot on the Flora Terraces had 15 times more small (≤ 15 cm) *A. aurea* plants than the stock fenced plot (Table 2), despite being smaller than the stock fenced plot (equivalent to 0.60 and 0.02 small plants per square metre in lagomorph and stock fenced plots, respectively). This pattern continued with the larger plants (>15 cm), which were seven times more abundant in the lagomorph fenced plot than in the stock fenced plot (equivalent to 0.18 and 0.02 larger plants per square metre, respectively) (Table 2). Numbers of small (≤ 15 cm) *A. aurea* were comparable between the unfenced and stock fenced plots, but larger plants were over twice as common in the stock fenced plot than the unfenced plot (but note that the stock fenced plot is twice the size of the unfenced plot).

Table 2. Counts and equivalent densities of *Aciphylla aurea* plants in two size categories from three different plot types.

Plot Treatment	***A. aurea* ≤ 15 cm**		***A. aurea* > 15 cm**		**Total**	
	Count	Plants / m^2	Count	Plants / m^2	Count	Plants / m^2
Unfenced	24	0.04	6	0.01	30	0.05
Stock fencing	29	0.02	20	0.02	49	0.04
Lagomorph fencing	450	0.60	138	0.18	588	0.78

The greater density of larger *A. aurea* plants in the lagomorph fenced plot (Fig. 1, p.40) is clear when compared with the unfenced plot (Fig. 2, p. 40); and at the fenceline between lagomorph and stock fenced plots (Fig. 3, p. 41), which is what drove the idea to count *Aciphylla* plants across the three plots.

Figure 1. Looking into the centre of the lagomorph fenced plot of the Flora Terrace *Veronica armstrongii* plots. More than 20 adult *Aciphylla aurea* can be seen.

Figure 2. Looking into the centre of the unfenced plot of the Flora Terrace *Veronica armstrongii* plots.

Figure 3. Looking down the fenceline between **Left,** the lagomorph fenced plot, and **Right,** the stock fenced plot of the Flora Terrace *Veronica armstrongii* plots.

Discussion

Hustedt (2002) notes that DOC was limited in its ability to set up a replicated fencing experiment on the Flora Terraces. Therefore, any extrapolation beyond the three plots should be done with caution. However, the length of time (>30 years) since the exclosures were established does provide some value to observations on vegetation differences between fencing type. The dominance of *Aciphylla* in the lagomorph fenced plot when compared to the stock fenced and unfenced plots is a strong indicator that lagomorphs are influencing the recruitment and survival of *A. aurea* plants on the Flora Terraces. The striking difference in the number of small *A. aurea* plants between the lagomorph fenced plot and the other two suggest that rabbits and hares are targeting the small plants. As Atkinson and Greenwood (1989) suggested for moa, perhaps hares and rabbits prefer the softer leaves of younger plants.

During the 2021 visit to measure the *V. armstrongii* there was extensive pig damage to the bog pine (*Halocarpus bidwillii*) vegetation around the exclosure plots. Wong and Hickling (1999) mention the Flora Terrace plots and include pigs as one of the animals excluded by the stock fencing. However, observations of faeces and rooting from the April 2021 visit showed that pigs have accessed the stock fenced plot and removed *Aciphylla* plants. In combination, pigs and lagomorphs are probably causing the absence of *Aciphylla* as a common component in the Esk Valley flora. Johnson and Molloy (1988) also noted the absence of *Aciphylla* during their vegetation surveys, except on an island in one of the Mounds of Misery tarns. While Johnson and Molloy (1988) also noted the presence of pigs, they attributed the lack of *Aciphylla* to the hares. In January 2022 I visited the Flora Terraces and the Mounds of Misery again, this time covering a lot of terrain on foot.

Aciphylla were noticeably absent or in very small numbers everywhere except the DOC exclosure plots and the island noted by Johnson and Molloy (1988).

Recovery of *A. aurea* has also been observed elsewhere following the removal of grazing. A 30-year post-grazing monitoring study in Central Otago saw an increase in *A. aurea* after the removal of livestock grazing in a system where lagomorph numbers were low (Mark and Dickinson 2003). However, *A. aurea* was even more abundant in areas that had been burnt previously (Mark and Dickinson 2003).

The lack of replication in the fencing experiment on the Flora Terraces limits the ability to say that lagomorph exclusion is the sole driver of *A. aurea* increase. Other factors could also be contributing. For example, a study of the dryland Holocene vegetation history in the Mackenzie Basin and Central Otago found an increase in *A. aurea* abundance and distribution following droughts and localised burning (McGlone and Moar 1998). Without also having long-term measurements for other variables at the Flora Terrace plots, it is hard to be sure that another variable like climate has not contributed to the recovery of *A. aurea*. However, the lack of *A. aurea* across the wider Flora Terrace area and the sheer numbers of plants in the lagomorph exclosure plots does suggest that browse is the key driver.

The only other study in New Zealand that looked at lagomorph browse impacts at an individual species level used two species of *Carmichaelia* (Grüner and Norton 2006). These authors found that one species (*C. juncea*) was detrimentally browsed by lagomorphs leading to a decrease in reproductive output and subsequent recruitment. Contrastingly, the other species (*C. vexillata*) appeared more resistant to browse, a factor Grüner and Norton (2006) attributed to the compact growth habit of *C. vexillata* with the flowers and fruits protected by growing within the mat of the plant rather than out on easily browsed branchlets. A study on broader vegetation changes following the removal of grazing (rabbits and sheep) also reported recovery of *Carmichaelia* species (Meurk et al. 2002). Therefore, lagomorphs can impact the population of palatable species through browsing pressure.

Predator Free 2050 aims to remove five invasive predatory mammals from New Zealand. But removal of a single species to benefit another is rarely straightforward (e.g. Bergstrom et al. 2009, Dowding et al. 2009). Predators are not the only driver of biodiversity decline in New Zealand; other drivers like herbivory could be having a greater impact in some places (Linklater and Steer 2018). One Central Otago study reported reductions in mustelids and cats that then drove an increase in lagomorphs with subsequent reductions in palatable shrubs and grasses (Peltzer et al. 2019). However, rabbits are more limited by non-predation factors like disease and burrow flooding (Norbury and Jones 2015). Therefore, in most cases, it is high rabbit numbers supporting populations of feral cats and ferrets rather than the predators suppressing the rabbits (Norbury 2017). But if lagomorphs are released from predation by the success of Predator Free 2050, even in localised spots, vulnerable plant species like *A. aurea* could disappear from an ecosystem.

A further factor influencing the abundance of lagomorphs is the availability of suitable habitat. Intensification of dryland ecosystems towards pasture grasses creates better habitat for rabbits (Norbury 2017). Intensifying in the presence of less developed short tussock grasslands and shrublands, is likely to cause a spill over into adjacent undeveloped areas (Norbury 2017). Understanding the effects of lagomorph browse on palatable species and then monitoring these species could provide a useful tool for monitoring ecosystems in the face of intensification. Including palatable species with known responses to lagomorph browse in outcome monitoring would greatly improve understanding of whether lagomorph control is working to restore dryland ecosystems.

Conclusions and suggestions for further research

This observation indicates that lagomorph (and pig) browse could have a role in suppressing *A. aurea* at the Flora Terraces. The Flora Terrace DOC exclosure plots are limited by the lack of replication in fencing treatment and the extreme variation in size between treatments. Therefore, it would be useful to standardise the plot size and expand the fencing experiment to include more replication. Having observed the increase in *A. aurea* on the Flora Terraces, it would also be useful to set-up monitoring now in other high-country locations where rabbit-proof fencing has recently been established, such as in the Lance McCaskill Scientific Reserve, particularly if the less common and Declining *A. subflabellata* is also present (de Lange et al. 2018). Future studies on animal browsing should consider what impacts lagomorphs (and pigs) may be having at an individual species level. And this could mean including species like *A. aurea* in lagomorph control outcome monitoring even when browse is not obviously evident, or the species is not currently present or abundant at a site. Despite the lack of replication in the Flora Terrace plots, the dramatic difference in *Aciphylla* numbers between plots does provide an interesting insight into what plant species might be missing from our intermontane tussock grasslands in the presence of lagomorph herbivores.

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