Potential of Tier 1 and alternative monitoring networks to assess the ecological integrity of alpine vegetation exposed to tahr grazing

Condensation of a report on the best way to monitor the condition of alpine vegetation in relation to tahr grazing prepared for DOC by Manaaki Whenua Landcare Research, October 2018

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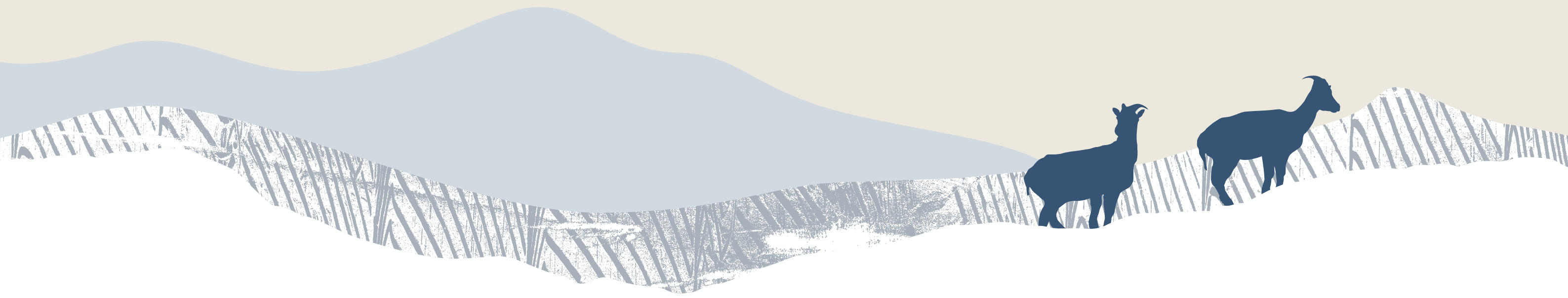
Summary

The report evaluated the suitability of existing plot networks to report effects of tahr in alpine and subalpine ecosystems. There is a solid basis upon which to build a robust and comprehensive, fit-for-purpose monitoring programme. Some improvements to current methods should be made, but most importantly, the current monitoring plot network needs to be complemented with finer scale monitoring (Tier 2) and research (Tier 3). This will enable the Department to assess the ecological integrity of alpine and subalpine ecosystems, evaluate the impact of tahr and other herbivores, and meet its obligations under the tahr control plan.

Cover image: Juvenile males.
Photo: Dylan Higgison



Background

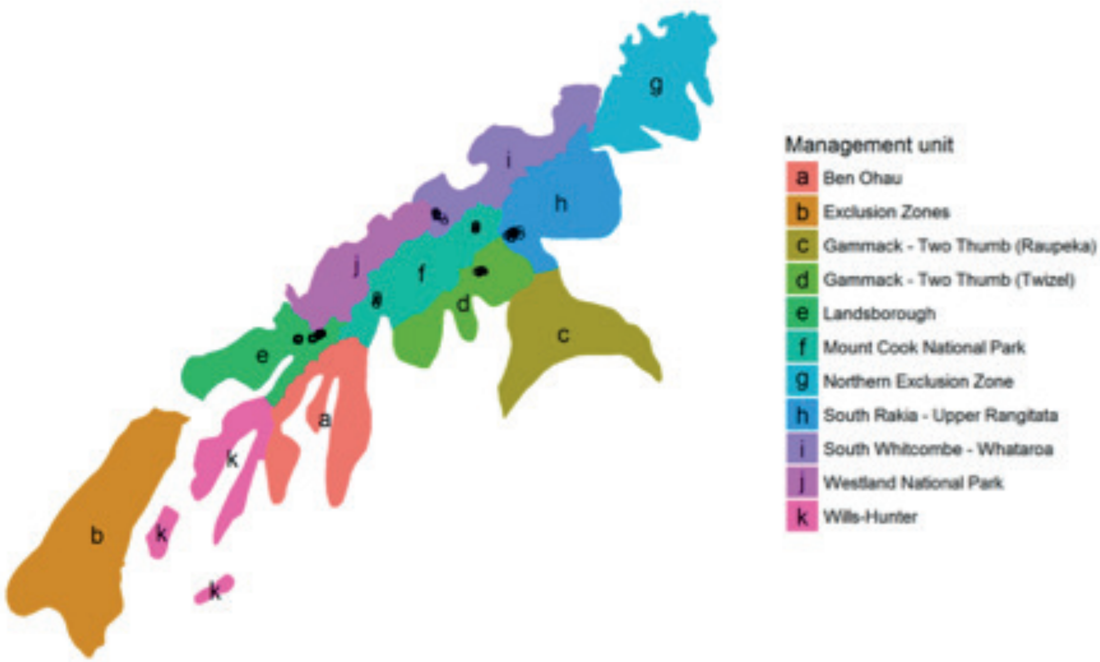
Himalayan tahr (*Hemitragus jemlahicus*) were introduced to New Zealand in the early 1900s with only a few animals near Mt Cook. They multiplied and spread, and today occupy a range of about 6,000km² (Forsyth & Tustin 2005), numbering at least 24,777 and possibly as many as 47,461 animals (Ramsey & Forsyth 2018).

New Zealand plants are thought to be vulnerable to grazing and trampling by tahr (and other introduced mammal species), because they evolved in the absence of mammalian herbivores. In severely impacted areas, tall snow tussocks disappeared and were replaced by shorter grasses and herbs (Burrows 1974; Wilson 1976; Wardle 1977, 1979); subalpine shrublands died and were replaced by ferns (Wilson 1976; Wardle 1979). Importantly, tahr impacts are also highly variable in space and time. Patches of severely affected vegetation are often immediately adjacent to seemingly unaffected vegetation (Wilson 1976), and impacts vary over time as animals move seasonally about their feeding range or snow-covered areas are temporarily unavailable. Tahr may also affect soils properties and biota, as demonstrated for other ungulates in other ecosystems, e.g., by compacting the soil or fertilising areas with their urine and faeces (Bardgett 2005; Harrison & Bardgett 2008). This could drive feedbacks and potentially alter species composition.

Tahr management is currently guided by the Himalayan Tahr Control Plan and the Tahr Management Policy (Department of Conservation 1993). These documents specify that the total tahr population should be no more than 10,000 animals within a tahr management zone in the central Southern Alps. To the north and south of this management zone are exclusion zones, which are supposed to be kept free of tahr to stop the spread of the species.

The potential effects of tahr on alpine and subalpine ecosystems are of concern for the Department, because it may fail to deliver on its goal of maintaining or restoring the ecological integrity of these ecosystems. To assess and report on this, the Department needs robust information on

- what healthy alpine and subalpine ecosystems look like,
- what factors drive their natural diversity in the absence of introduced herbivores,
- what the effects of tahr and other co-occurring herbivores are,
- whether and how severely affected communities can be restored, and
- what ecologically acceptable tahr numbers are.



▲ Layout of the subjectively-located plots with regard to the management units. In this figure, each separate management unit as defined in the Himalayan Tahr Control Plan is shown. The exclusion zones are named “Northern Exclusion Zone” and “Exclusion Zones”. These names are as provided by the Department of Conservation. The black dots represent the subjectively-located plots.

Monitoring of alpine and subalpine vegetation

Scientifically-based monitoring of tahr impacts on alpine vegetation began in the 1990s, when 117 permanent vegetation plots were established in eight small catchments within the tahr management zone. The sites were selected subjectively and plots placed into snow tussock grasslands to measure the impacts of tahr on these communities. Several snow tussock, shrub and herb species that were known to be important in the diet of tahr were selected as indicators and their presence and size in the plots recorded. The frequency of faecal pellets of ungulates, hares and possums around the plots was also assessed to gauge the level of recent activity of introduced herbivores at each plot. Since their establishment, the 117 plots have been repeatedly measured. An analysis of the data up to 2013 showed that tahr reduce the height of snow tussocks. A decline in tussock height over time suggested tahr numbers in the study catchments had not been maintained at ecologically acceptable levels (Cruz et al. 2014, 2017). Because of the subjective design of this study, the results cannot be generalized to other areas of the tahr management zone. This is a serious limitation. The Department needs to be able to assess and report on the condition of alpine and subalpine vegetation across all public conservation land including the entire tahr management zone.

DOC conducts national-scale monitoring of biodiversity and ecosystems using a regular sample of sites located at the intersections of an 8 km × 8 km grid (Tier 1 Monitoring programme). In 2016, the Department added extra measurements of plants that tahr eat (indicator species) to Tier 1 plots in the tahr management and exclusion zones.

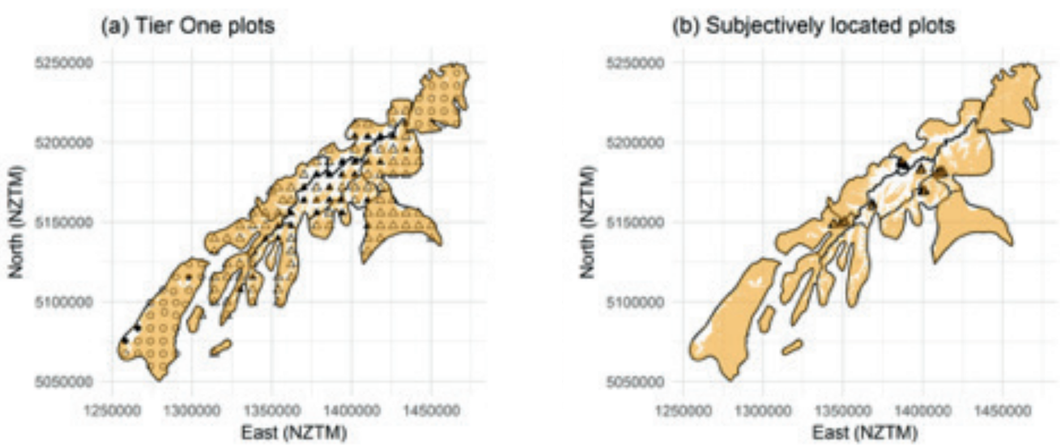
In this report we look at whether Tier 1 monitoring plots, with additional measures of plants that tahr eat, and subjectively-located plots will provide the Department with the information it requires to assess the ecological integrity of alpine and subalpine ecosystems, and to understand the effects of tahr and other introduced herbivores.

Our key questions were:

- What are the environmental and biological differences between the tahr management and exclusion zones, and can these be addressed in comparisons of indicators between the zones?
- How useful are the selected indicator species for detecting tahr impacts?
- How useful are the current methods to detect changes in the size or the abundance of indicator species?
- What do the subjectively located plots contribute to our understanding of tahr impacts?

We also conducted a preliminary analysis comparing the tahr management zone with the exclusion zones.

In undertaking this analysis, the Department's goal is to develop an efficient and comprehensive monitoring programme that provides robust data to underpin decisions on the management of alpine and subalpine ecosystems and the management of the tahr herd.



◂ Mapped distribution of red deer within the tahr range (orange polygons) and the distribution of (a) Tier One plots and (b) subjectively-located plots.

Key analyses and findings

We had data for three groups of plots: the Tier 1 plots in the tahr management zone, the Tier 1 plots in the exclusion zones, and the subjectively located plots from the earlier study (also located within the tahr management zone but restricted to eight small catchments). For each plot we had vegetation relevé data, i.e. data on all plant species present at a plot, data on the indicator species and data on the frequency of faecal pellets around the plots.

(1) Differences between plot groups

We compared the abiotic environment, their vegetation and the presence of introduced mammals across the three groups of plots.

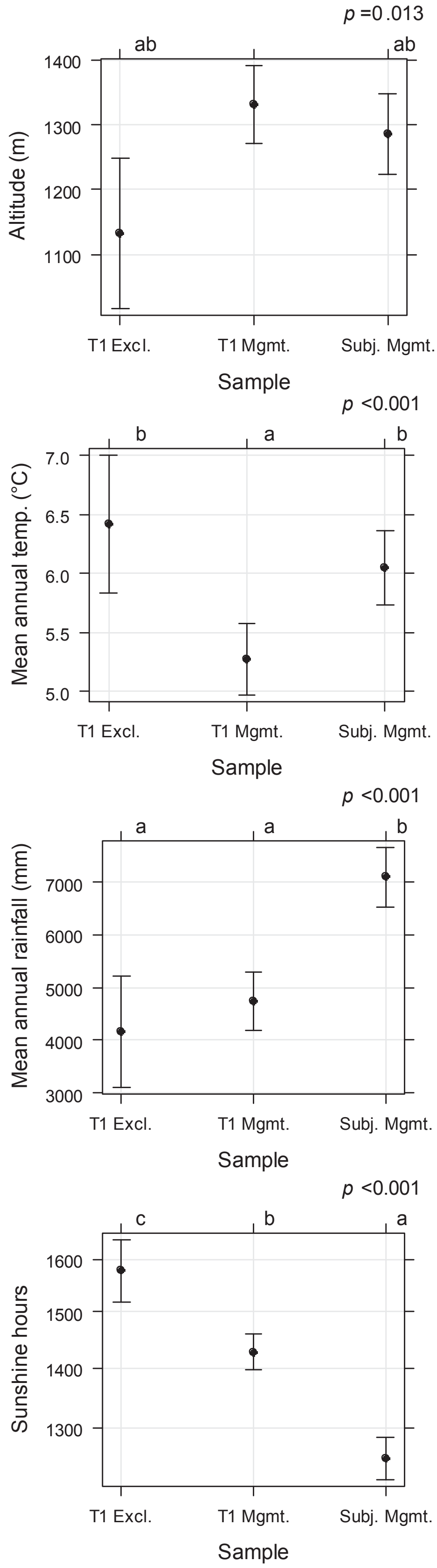
Abiotic environment

For this analysis, we obtained environmental and climate data for each plot. The environmental variables we looked at were altitude, aspect, latitude, slope, soil chemistry, potential solar radiation and various climate variables relating to temperature, rainfall and sunshine. The results showed that the average environmental conditions differ between the three plot groups. For example, the Tier 1 plots in the tahr management zone are on average at higher altitude and tend to be colder than those in the tahr exclusion zones, which in turn tend to receive more sunshine and have more days conducive to plant growth. The subjectively located plots are, on average, also warmer with more growing days than the Tier 1 plots in the tahr management zone, but their altitude is not significantly lower. The subjectively located plots are wetter and receive less sunshine than both the Tier 1 tahr management and exclusion zone plots.

Vegetation

We undertook three separate analyses based on the vegetation relevé data from the plots:

- We assigned the plots to vegetation communities pre-defined by Wiser et al. (2011, 2016) and Wiser & De Cáceres (2013). This gave us a picture of the range of vegetation communities present in each plot group.
- We classified the plots into 'woody' or 'non-woody' based on whether half or more of their vegetation cover was made up by woody species or not.
- We put the data through an ordination which groups plots based on the similarity of their species composition. The resulting clustering of plots was then related back to environmental variables to gain an ecological understanding of apparent vegetation gradients.



▲ Environmental contrast between tahr exclusion and management areas corresponding to Tier 1 or subjectively located plots. The statistical significance of the linear model as P values and error bars illustrate confidence intervals. Different letters on top of boxes indicate that treatment levels were significantly different from each other (Tukey test, $P > 0.05$).

The results confirmed that the subjectively located plots were primarily located in snow tussock grasslands, generally dominated by the tussocks *Chionochloa pallens* or *C. crassiuscula*. Accordingly, the subjectively located plots showed least diversity in vegetation communities and species. They were also less woody than the Tier 1 plots. The Tier 1 plots in the exclusion zones were the most woody. The dominant environmental drivers behind vegetation gradients were altitude, mean annual temperature, percent rock and ground cover, and mean annual rainfall.

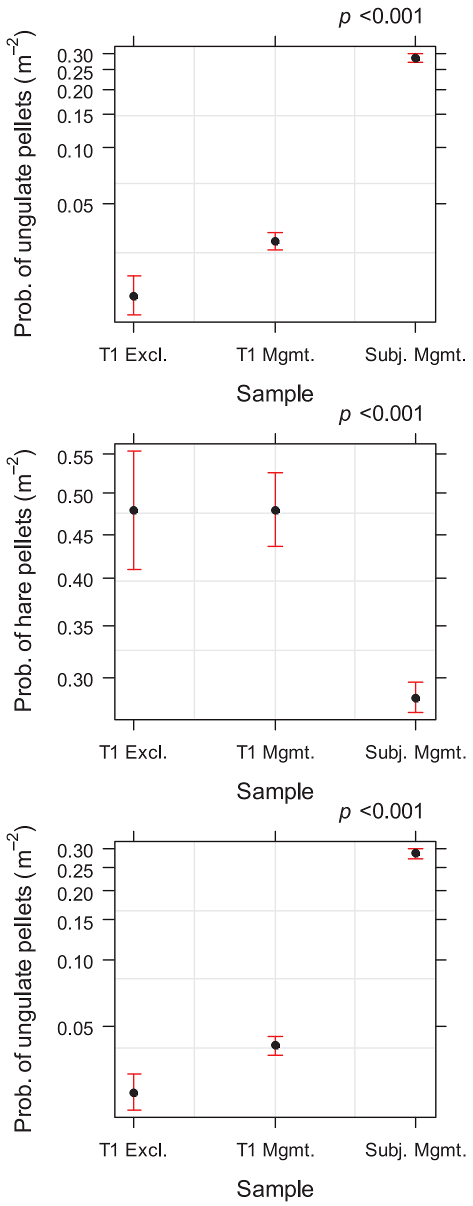
Introduced mammals

We used national-level distribution maps for 19 introduced mammals to calculate the proportion of plots that are likely to have these species present. This analysis suggested that a higher proportion of subjectively located plots and Tier 1 plots in the exclusion zone are likely to have hare, possum and red deer compared to Tier 1 plots in the tahr management zone. In contrast, the faecal pellet data from the plots showed that ungulate pellets were more common inside the tahr management zone than in the exclusion zones. They were most common around the subjectively located plots – nearly eight times as common as around the average Tier 1 management zone plot. Hare pellets were encountered with similar frequency at Tier 1 management and exclusion zone plots, and much more common than ungulate pellets in both zones. However, at the subjectively located plots, hare pellets occurred less frequently and with about the same frequency as ungulate pellets.

Findings

The observed differences between the three plots groups suggest that differences in the condition of vegetation or indicator species need to be interpreted with caution. When comparing vegetation indicators between the tahr management and exclusion zones, analyses will need to account for differences in their abiotic environments and co-occurring mammalian herbivores (e.g., propensity-scoring methods).

The differences between the subjectively located plots and the Tier 1 tahr management zone plots confirmed that the subjectively located plots are not representative of the overall tahr management zone. Because of their subjective placement, these plots are not representative of all vegetation in the catchments that they sample, e.g. shrublands are not sampled.



▲ Probabilities of observing ungulate or hare pellets within 1m2 tahr management and exclusion areas with objectively (Tier1) or subjectively (Subj.) located sampling networks. Estimates for ungulate pellets are presented for (a) intact and (c) for combined intact and non-intact pellets.

(2) Indicator species

In this analysis, we focused on the snow tussocks and herbs selected as tahr-sensitive indicator species. We analysed how often each indicator species was found in each of the three plot groups to see whether they are widespread enough to provide useful data. We also looked at the climate space occupied by each species in relation to the climate space present in each plot group. The climate space for a species was calculated as the range of mean annual rainfall and temperature found at all locations where a species has been recorded based on national distribution data. The climate space for a plot group was the range of mean annual rainfall and temperature found at the plots.

Frequency in plot groups

The indicator species occurred with similar frequencies in the Tier 1 management and exclusion zone plots, while frequencies in the subjectively located plots differed. Some indicator species occurred in less than 10% of plots.

Climate space analysis

The indicator species differed in their climate spaces suggesting three groups – low, medium and high rainfall species. The climate spaces of the species did not always match the climate spaces provided by the plot groups.

Findings

The analysis showed that snow tussocks and some of the herbs selected as indicator species are widespread enough to provide enough data for analysis. However, species that occurred in less than 10% of plots are too rare to give useful data. A way around this would be to group species for analysis, e.g. to analyse all spaniard (*Aciphylla*) species together to have more data. However, this is only valid if all species in the group have a similar response to grazing and are ecologically similar so that the group response can be confidently attributed to grazing rather than other factors. The ecological differences between the species in the analysis of climate space suggest that grouping needs to be done with caution. Grouping by genus, e.g. analysing all *Aciphylla* or all snow tussock species together, would lump species that may have very different ecology and make interpretation difficult.

In forest ecosystems, we have a much better understanding of the ecology of species and the drivers behind diversity and vegetation change. We also have detailed knowledge about ungulate food preferences (Forsyth et al. 2002). This provides a robust basis for the grouping of species for analysis. Research is required to gain the same understanding for alpine and subalpine ecosystems.

(3) Tussock measurements

Currently abundance of snow tussocks is measured in two different ways: (i) the diameter of all tussock plants is measured at their base to allow calculation of a basal area estimate, and (ii) crown cover and height are estimated in each subplot and over the whole plot. We analysed the data collected to date to evaluate and compare the two methods.

Findings

Cover estimated directly and cover estimated from basal diameters yielded very similar results. This means that individual measurements of basal diameter are superfluous and discontinuing their measurements would mean a significant increase in monitoring efficiency. Height was used as the main indicator variable by Cruz et al (2017), who showed a small but significant decline in tussock height over c. 20 years. We recommend continuing measurement of tussock cover and height at subplot scales.

(4) Detecting change

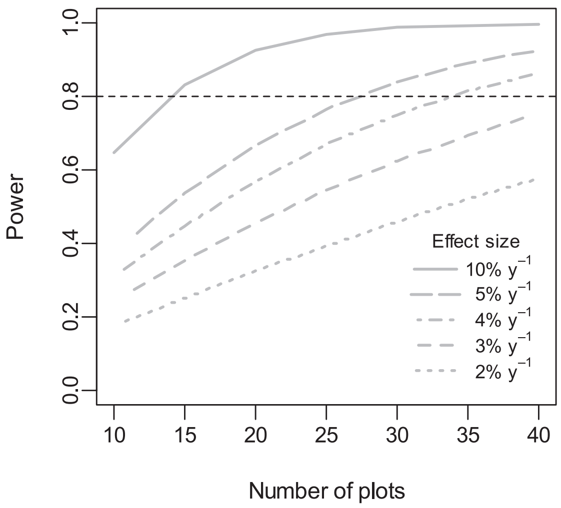
We analysed the data on the indicator species to determine how sensitive the monitoring will be to detect (i) a difference in indicators between the Tier 1 tahr management zone and exclusion zone plots at a given point in time and (ii) a difference in the rate of change of indicators between the plot groups over time. This was based on a sample size of 30 plots in each zone.

Findings

When comparing the thar management and exclusion zones at a point in time, 30 plots are enough in each zone to detect differences in tussock cover ≥20%, corresponding to a ≥6% difference in basal area. The current plot network could only detect very large differences in counts or cover of indicator herbs. Many more plots would be needed to detect smaller changes. For example, when analysing all spaniard species together (which is contentious, see above), only an 8-fold difference in counts and a 4-fold difference in cover can be detected. For another herb, *Celmisia semicordata*, 30 plots in each zone only allow detection of a 40-fold difference in counts.

For changes over time, 30 plots provide enough data to detect a change in tussock cover of about 22.5% over a 5-year measurement cycle, equivalent to a 4.5% change per year.

The estimates of what can be detected with the monitoring are conservative and we recommend continuing with the current measurements.



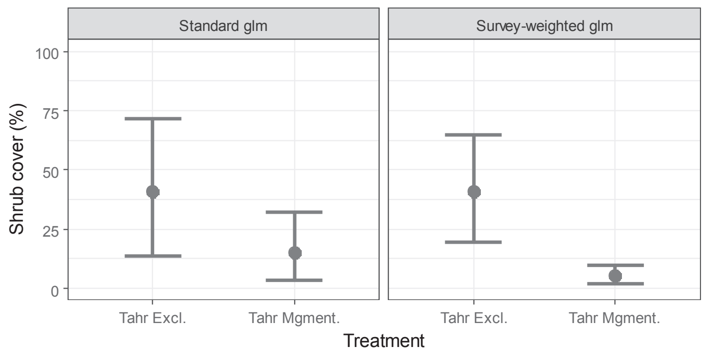
▲ Power to detect differences in rate of change in total tussock cover between tahr management and exclusion areas. Power estimates are based on 2-sided power t-tests. Variance was estimated from observed rates of change in tussock cover (based on visual estimates of plot-level cover, taking the largest cross-species sum cover value recorded in any tier). Cover estimates were arcsine transformed to conform with t-test assumptions of a normal error distribution (Crawley 2007). Effect sizes would be the equivalent of 10-, 20-, 25-, 33- and 50-year periods to attain 100% cover from no initial cover in one treatment and no temporal change in the other treatment.

(5) Comparing tahr management and exclusion zones

This analysis used a statistical method called propensity scoring to determine whether there were differences in indicators and vegetation metrics between the tahr management and exclusion zones, accounting for differences in their environments.

Findings

We found no differences in total vegetation cover, the presence and abundance of indicator species, and tussock height between the two zones. However there was lower shrub cover in the management zone than the exclusion zone. This could be an effect of tahr browse, but sample sizes in the analysis were small (only 6 plots in the exclusion zone were included). The analysis should be seen as a 'proof of concept', with more reliable results becoming available as more plots are established and as change with time is measured.



▲ Fitted means and standard errors for indicators from standard GLMs and survey-weighted GLMs using propensity scores. Refer to Table 6.

Discussion

The monitoring currently done as part of the Department's Tier 1 programme and on the subjectively located plots presents a solid basis for building a robust and comprehensive monitoring programme that will provide the Department with the information needed for the effective management of subalpine and alpine ecosystems. Some efficiencies could be gained by simplifying measurements.

By design, the Tier 1 plots provide an objective sample of the ecological integrity of alpine and subalpine ecosystems and provide critical interpretive power to determining effects of tahr. For example, vegetation change within the range of tahr can be interpreted against a background of change across all alpine and subalpine ecosystems (e.g., in response to climate change).

Determining effects of tahr at fine scales (e.g., catchment, National Park) requires new intervention-level monitoring and research. This fits well with the framework of the Department's National Biodiversity Monitoring and Reporting System (NBMRS) consisting of Tier 1 – National level biodiversity monitoring, Tier 2 – Intervention level monitoring and Tier 3 – Research. The subjectively located plots are a valuable component of Tier 2 monitoring. Their main strength is that they provide data on changes in snow tussock grasslands going back to the 1990s, but the limitations we demonstrated in this report mean that they are not sufficient to understand tahr impacts across the entire tahr management zone or across vegetation types.

New Tier 2 (Intervention level) monitoring needs to include multiple catchments across environmental gradients (i.e., west and east of Ka Tiritiri o te Moana), the full range of vegetation types and indicators, and it requires coupled measurements of all mammalian herbivores and vegetation and a commitment to long-term periodic measurement. Observed changes can then be assessed against the background of the Tier 1 data to disentangle widespread, pervasive causes of change from those attributable to the effects of tahr.

Tier 3 research will provide much needed knowledge on alpine and subalpine vegetation and species and their dynamics. In particular, we do not understand the resilience and recovery rates of alpine and subalpine ecosystems. Seasonal dietary preferences of tahr and other herbivores in alpine ecosystems and subalpine shrublands are another gap in our knowledge that limits our ability to interpret observed change.

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