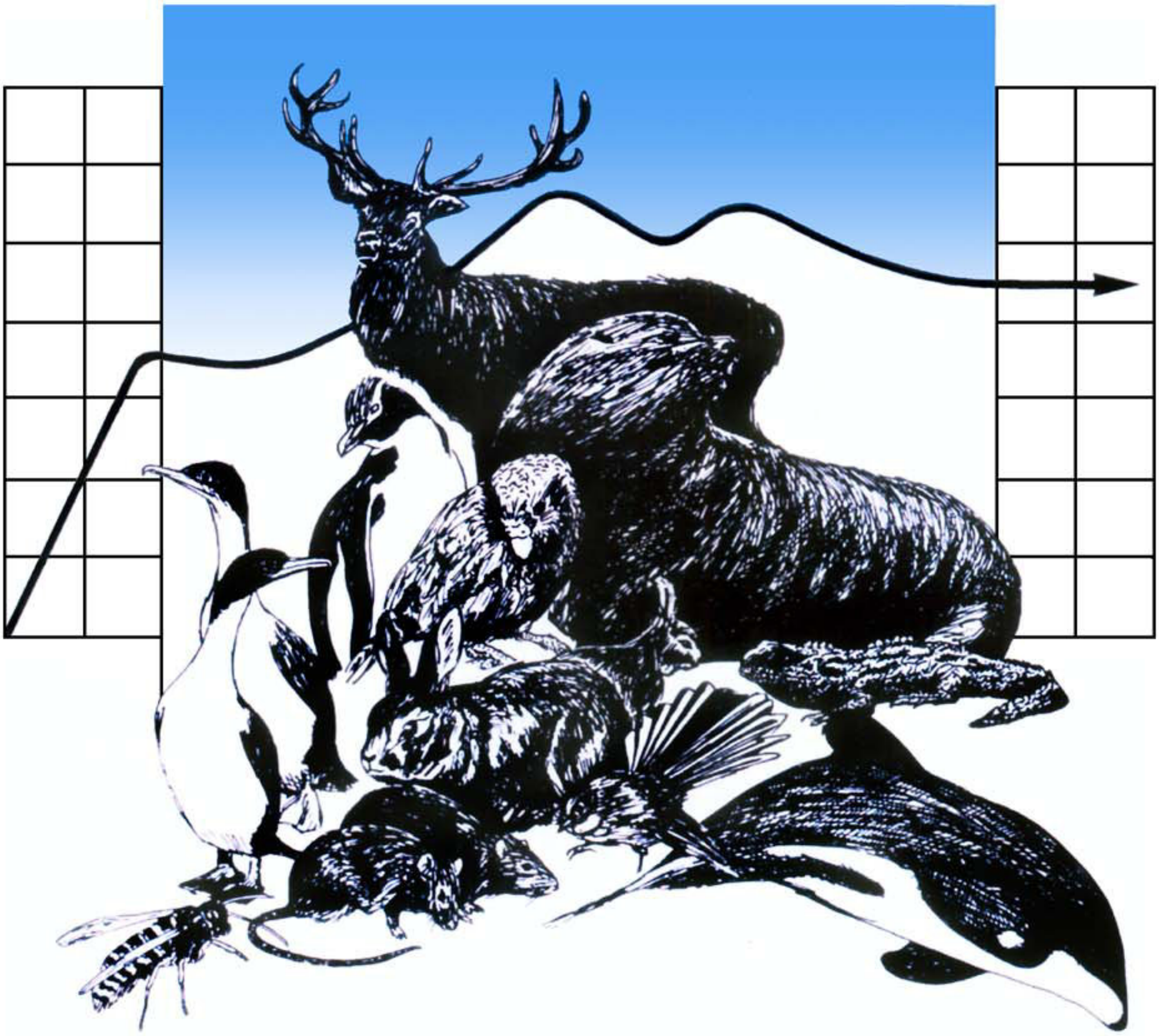
UNIVERSITY of OTAGO

Te Whare Wānanga o Otāgo

NEW ZEALAND

DEPARTMENT OF ZOOLOGY



WILDLIFE MANAGEMENT

An assessment of cleared-plot faecal pellet counts as an abundance estimation method for European hares (Lepus europaeus) in the alpine zone of Nelson Lakes National Park.

Jenny Long

A report submitted in partial fulfilment of the
Post-graduate Diploma in Wildlife Management

University of Otago

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Summary

The European hare (Lepus europaeus) is a pest herbivore that is widespread throughout most of New Zealand, including the alpine zone. Historically hares' impact on alpine vegetation was considered to be relatively minor compared to that of larger mammalian herbivores, however anecdotal evidence from recent decades has challenged this assumption. To enable accurate assessment of hare impact, and thus informed management decisions, a reliable and practical means of estimating hare abundance is necessary. This study aimed to evaluate the cleared-plot faecal pellet count method of abundance estimation for its use in long-term monitoring of alpine hare populations in Nelson Lakes National Park, and to provide recommendations for future studies employing a similar methodology.

The results indicated a dramatic increase in hare numbers from those found by a study done in the 1960s in the same area, although the validity of the comparison is questionable due to wide confidence intervals for the current pellet recruitment rate estimates and the many potential sources of error in the calculation of absolute hare numbers. However, the cleared-plot pellet count method could still prove useful as an index of relative hare abundance for future long-term monitoring, particularly if recommendations for improvement of the technique are put into practice.

Contents

1. Introduction

1.1 The impact of hares in New Zealand's alpine zone

The European hare (Lepus europaeus; also known as the brown hare) was intentionally introduced to New Zealand during the mid to late 1800s as a game animal, has since spread throughout the majority of the country and is now a recognised pest species (Wong & Hickling, 1999). Hares are most frequently seen in low-altitude grasslands, but can also be present in the sub-alpine and alpine zones up to 2,000m above sea level (asl) in areas with appropriate habitat (Wong & Hickling, 1999).

The alpine flora of New Zealand is unique, with a high level (around 93%) of endemism (Mark & Adams, 1995), hence negative impacts of introduced herbivores are of concern to conservation managers. Hares have long been considered to have a relatively minor impact on alpine vegetation compared to larger herbivorous mammals (Wong & Hickling, 1999), such as deer (Cervus sp.) and chamois (Rupicapra rupicapra). This perception was based on several factors: the relative stability and low densities of hare populations (the average density in New Zealand is 0.1 hares per hectare, reaching a maximum of 2-3 ha^{-1} in the eastern southern alps (Wong & Hickling, 1999)), the manner of feeding whereby browsed plants are not killed and feeding is spread thinly over a large area, and finally, the fact that hares do not generally burrow into the ground (Flux, 1990)

However, the validity of the assumption that hares and other small mammalian herbivores such as possums (Trichosurus vulpecula) had little impact on alpine vegetation has been reconsidered over recent decades, due to observations during the 1980s-90s of continued deterioration of vegetation in some areas despite control operations having substantially decreased numbers of large herbivores at those locations (Wong & Hickling, 1999).

Wong and Hickling (1999) carried out a thorough review of hare impact on high-altitude vegetation in New Zealand. They reported that two studies in alpine grasslands (Flux, 1967 and Horne, 1979) found Chionochloa sp., Celmisia sp. and Poa colensoi to form the bulk of the diet, with a wide range of herbs and other plant matter making up the balance. Solly (1998) found evidence of significant diet selectivity, however was trialling a new method and acknowledged that the results needed to be validated by further research. Flux (1967), Horne (1979) and Blay (1989, cited in Wong & Hickling, 1999) also observed some degree of preference for certain species, but these preferences differed with season, location and population density, so it is difficult to form general conclusions.

Results of studies into the effect of hare browsing on vegetation communities are mixed. Rose and Platt (1992) found that hare herbivory alone was sufficient to prevent the recovery of snow tussocks that had been released from sheep grazing pressure for 34 years. Norbury (2001) concludes that hares can negatively impact some habitats but not others, citing a study by Allen et al (1995) which had similar results to Rose and Platt (1992), but another by Rogers (1994) that found no significant effect of hares on tussock regeneration.

The only published research into the impacts of alpine hares since Wong and Hickling (1999)'s review that could be found is that of Wilson et al (2006), which included hares in a study of small mammals in high-altitude vegetation. They found that hare densities in their Fiordland study site were similar to those elsewhere in New Zealand, but nothing more conclusive, and consider that further research is necessary. It therefore appears that Wong and Hickling (1999)'s statement that hare impact on alpine grasslands relative to that of other herbivores is poorly understood still holds true, and the concerns of conservation managers remain based primarily on anecdotal evidence.

The overall impact of hare browsing may not actually yet be manifest due to the longevity of snow tussocks (Wong & Hickling, 1999). Furthermore, increased hare reproduction has been observed in

Europe alongside increases in winter temperatures (Smith et al, 2005), so climate change may cause the effects of hares to be greater in the future than they have been in the past.

Hares were not being targeted in 2000 by any conservation-oriented control operation in New Zealand (Forsyth et al, 2000), and this appears to still be the case nationwide, definitely so in Nelson Lakes National Park (G. Harper, DOC, pers. comm.). Long-term monitoring of temporal and spatial patterns in hare abundance would inform management decisions concerning the need for such control.

1.2 Hare abundance estimation

Successful long-term monitoring requires a reasonably accurate means of estimating hare abundance at a given place and time. A wide range of methods has been used to make such estimates in the past, which is thoroughly reviewed by Langbein et al (1999) and Wong and Hickling (1999). However, most reviewed techniques would be impractical in New Zealand's alpine zone. For instance, spotlighting is not feasible because the terrain is generally too difficult to manoeuvre in, and the snow tussocks and shrubs are too tall (Wong & Hickling, 1999). Furthermore, spotlighting can only discern large changes when populations are at low densities (Parkes, 2001). Mark-recapture surveys would be overly labour- and time-intensive because the low densities in alpine areas cause runs to be indistinct (Wong & Hickling, 1999). Standing crop pellet counts rely on accurate knowledge of pellet decay rates, which is often unavailable (Langbein et al, 1999), or on having fieldworkers age pellets which can introduce observer bias (Prugh & Krebs, 2004). This method was also found by Murray et al (2005) to correlate poorly with hare densities. As a final example infra-red surveys, although potentially effective if done aerially (Wong & Hickling, 1999), are not otherwise practical in this situation due to poor vegetation penetration, poor performance over distances greater than 40m, the highly insulative coats of alpine mammals, and the relatively high expense of equipment (Boonstra et al, 1994).

One potentially practical method for long-term monitoring is the cleared-plot faecal pellet count technique, which has been used and reviewed extensively in monitoring of snowshoe hares (Lepus americanus) in Canada (Krebs et al, 1987 & 2001; Murray et al, 2002 & 2005; Prugh & Krebs, 2004) and has been trialled in a few short-term studies on European hares in New Zealand (Parkes, 1981 & 1984, cited by Wong & Hickling, 1999; Wilson et al, 2006). Because plots are cleared of old pellets an unknown/variable decay rate does not influence the density calculation (Wong & Hickling, 1999). Krebs et al (1987) also found strong correlations between density estimates from this method and from mark-recapture surveys. Plot clearing and counting is not unduly labour- or time-intensive, equipment is relatively inexpensive and if plots are marked discreetly then hare behaviour is unlikely to be affected (Parkes, 2001). Finally, the resulting pellet recruitment rate data can either provide an index of relative hare abundance over time/between habitats, or can be converted into an estimate of absolute numbers in the sampled area (Murray et al, 2005).

This study aimed to assess the practicality and limitations of a cleared-plot faecal pellet count methodology (based on that outlined by Parkes (2001), with some modifications), for estimating hare abundance in the alpine zone of Nelson Lakes National Park, and to provide recommendations should the technique be adopted for long-term monitoring.

Department of Conservation (DOC) staff had noticed an apparent increase in hare numbers over recent years in the national park, and there had been similar anecdotes from recreational users about the nearby Kahurangi National Park. This study was therefore carried out at the same site as that of Flux's (1967) 3-year study of hare impact, so that the results of the two studies could also be compared in an attempt to verify the extent to which these observations reflected reality.

2. Methods

2.1 Study site

The study site was Cupola basin (E1577883, N5351970; NZTM projection), an alpine basin in the Travers range, Nelson Lakes National Park. The study area was approximately 78.1ha, spanning an altitudinal range of 1,300-1,700m asl and ranging in aspect from northwest through north to east. The vegetation is alpine grassland, with a clear treeline at around 1,350m asl below which lies Nothofagus beech forest. There are some small areas of boggy ground and tarns, and multiple greywacke scree slopes/boulderfields intersect the basin, as do several minor tributaries to Cupola creek.

The grassland is dominated by snowgrass (Chionochloa flavescens and C. pallens), short tussock (Poa colensoi and Festuca mathewsii) and carpet grass (C. australis), with some smaller patches of Schoenus pauciflorus and C. rubra (Flux, 1967). Patches of shrubs are present in the lower-altitude half of the basin, common species including Podocarpus nivalis, Phyllocladus alpinus, Dracophyllum uniflorum and Hebe pauciramosa. Interspersed throughout these grasses and shrubs is a range of herbs, which includes Aciphylla colensoi, Astelia nervosa, Wahlenbergia albomarginata and Celmisia sp. (see Flux (1967) for a more comprehensive list of vegetation).

Snow covers the basin during the June-September period (Flux, 1967), with intermittent snowfalls possible over the remainder of the year. During the course of this study there were two snowfalls down to 1,300m asl, the snowcover melting away within 2-3 days.

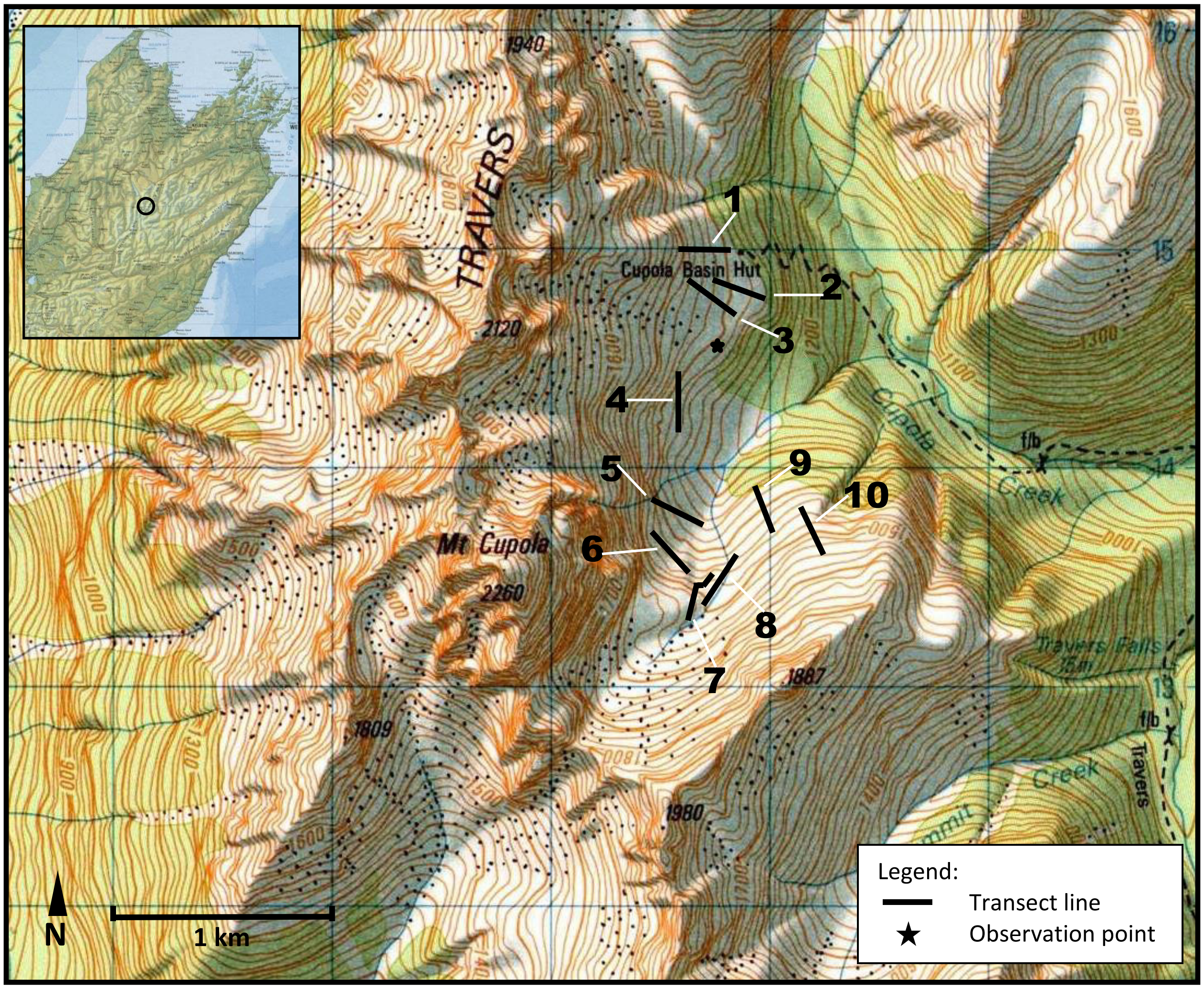

Figure 1. The distribution of 10 transects and an observation point within Cupola basin in the Travers mountain range, Nelson Lakes National Park.

2.2 Data collection

2.2.1 Cleared-plot faecal pellet counts

Ten transects were spread throughout the study area (see figure 1 for the layout and appendix 8.1 for details of individual transects) using a topographical map and randomly-generated starting points and bearings, that were then adjusted where necessary in the field to avoid unsafe areas such as steep scree and bluffs. Each transect was 250m long with 50 plots at 5m intervals. Plots were marked at the centrepoint with a bicycle spoke pushed into the ground (see figure 2), as these were suggested to not affect hare behaviour by Parkes (2001). The spokes were tagged at ground-level with a $1cm^2$ piece of blue cardboard (preliminary research indicating that lagomorphs cannot discern the colour blue (G. Harper, DOC, pers. comm.)), and had an averaged GPS location taken of their position (GPS model 60CSx from Garmin, Olathe, Kansas), to assist relocation in long tussock. The plot perimeter was determined using a rigid radius measurer made from a spoke with one end bent into a loop that was placed over the plot-marker spoke (see figure 2). The measurer was marked so as to delineate a circular plot of $0.1m^2$ when spun around the plot-marker spoke.

Figure 2. Plot set-up for measuring faecal pellet density of European hares (Lepus europaeus) in Cupola basin, Nelson Lakes National Park. A: plot radius measurer. B: Faecal pellet. C: Bicycle spoke pushed into the ground at plot centrepoint.

Three 11-day sampling periods took place during January-March, 2012. On days 1-2 plots were cleared of faecal pellets, and on days 10-11 any hare pellets present in the plots were counted, with a 10-day interval maintained between inspections for any given plot. Any pellet partly within the plot perimeter was counted as being within the plot.

When plots were cleared, pellets close to but not within the perimeter of the plot were also removed and discarded far away, in order to minimise the chance of pellets being blown or otherwise moved back into the plot.

Any plots where spokes were found to be missing or knocked out during the pellet-counting inspection were recorded as such in lieu of a pellet-count value, and were then replaced before the pellet-clearing inspection of the next sampling period in order to maintain sub-sample sizes.

2.2.2. Direct observation

During days 3-9 of each sampling period when weather permitted (mist at dawn and/or dusk frequently obscured visibility), observation of the basin was made. This was done for 2 hours at dawn, beginning just prior to sunrise (05:45-07:45) and for 4 hours during late afternoon-dusk (ranging between 15:00-21:30), as these were the time periods when Flux (1967) noted it was possible to see the generally nocturnally-active hares feeding during summer.

Extra observations were also intermittently made between 09:00-16:00, as diurnally-active hares had been witnessed by the author in Canterbury. 10x50 magnification field binoculars were used from the location of the now-removed hide that had been used by Flux (1967) (see figure 1), which provides a clear view of the majority of the basin area while offering some cover for the observer.

Any dead hares found were recorded, photographed and a GPS location taken of their position.

2.3 Data analysis

Pellet recruitment rate calculations were performed using Microsoft Excel version 14.0.6112.5000, following the spreadsheet format of NPCA (2006). Each transect was treated as one sample and each plot as a subsample as per Murray et a1 (2002), because plots within a transect were too close to be considered independent. Statistical analyses were performed using R version 2.12.2 (The R Foundation for Statistical Computing).

3. Results

3.1 Cleared-plot faecal pellet counts

3.1.1 Statistical analysis

The data followed a Poisson distribution instead of being normally distributed, and displayed overdispersion with the variance being greater than the mean for all three sampling periods. A generalised linear model (glm) with a dispersed poisson distribution was therefore fitted. As seen in figure 3, there was no significant difference in mean recruitment rate between sampling periods (between 19-31 January and 7-18 February: $t = 1.434$, $df = 27$, $p = 0.163$, between 7-18 February and 27 February-9 March: $t = 0.465$, $df = 27$, $p = 0.645$, between 19-31 January and 27 February-9 March: $t = 1.018$, $df = 27$, $p = 0.318$).

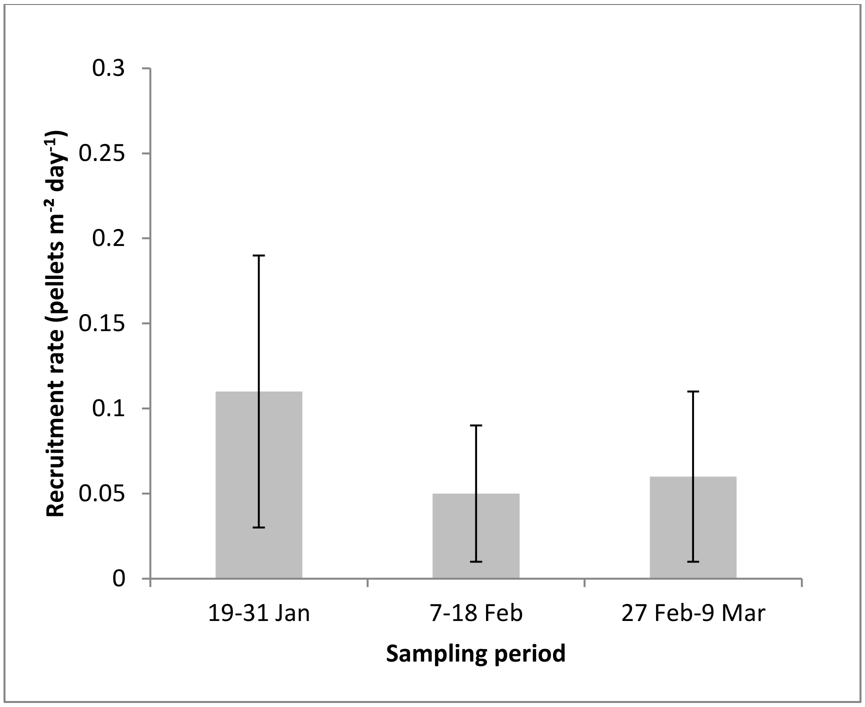

Figure 3. The recruitment rate of European hare (Lepus europaeus) faecal pellets (pellets m^{-2} day^{-1} ± 2SE) in Cupola basin, Nelson Lakes National Park, over 3 sampling periods during January-March, 2012.

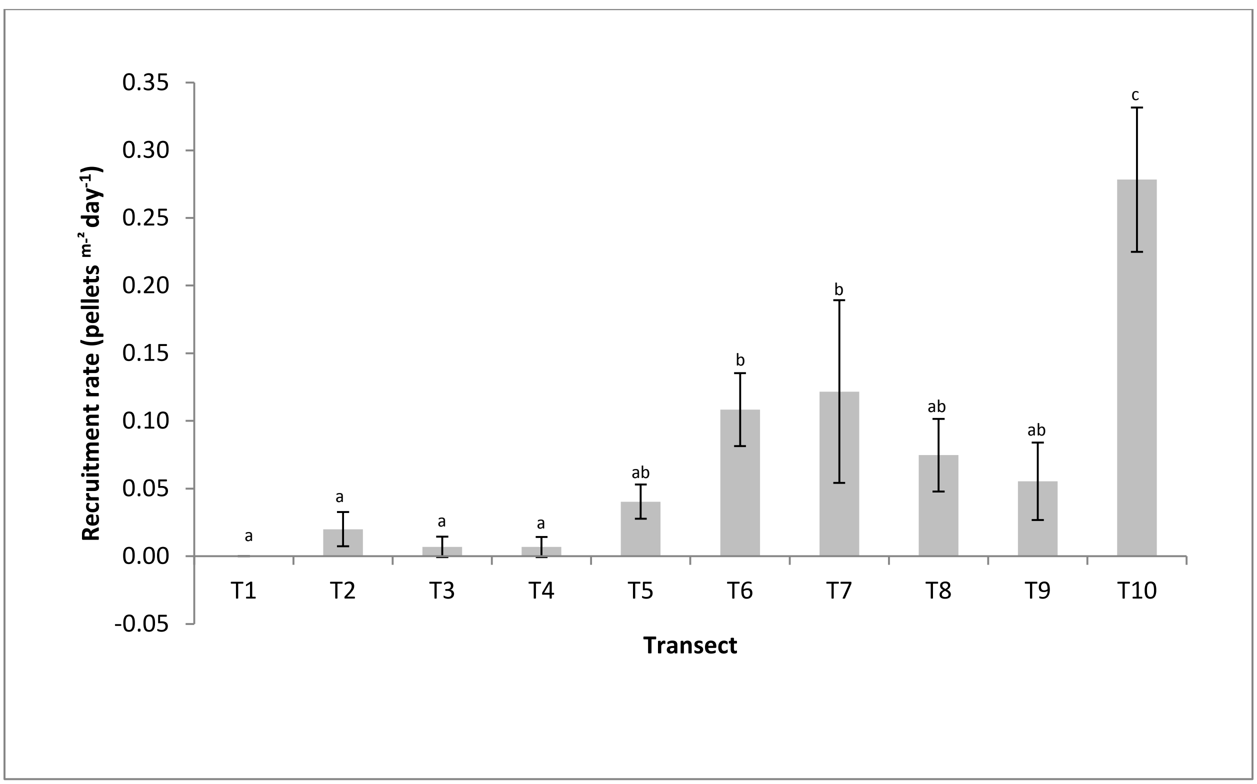

Figure 4. The mean recruitment rate of European hare (Lepus europaeus) faecal pellets (pellets m^{-2} day^{-1} ± 2SE) in 10 transects within Cupola basin, Nelson Lakes National Park, over the course of 3 sampling periods during January-March, 2012. Transects that have no significant difference in pellet density at α = 0.05 are indicated by sharing the same 'a' 'b' or 'c' label.

A second glm was applied to compare pellet recruitment rates between transects. Since there were only three sampling periods sample sizes were very low, so the results from statistical tests are unlikely to be robust. However, as seen in figure 4, transect 10 had a significantly higher recruitment rate than all other transects (t always >3.9, df = 9, p always <0.001) and transects 1-4 had a significantly lower rate than transects 6 and 7 (t always >2.4, df = 9, p always <0.03).

Figure 5 provides a spatial display of the data, demonstrating that transects over approximately 1,400m in altitude on north-northeast facing slopes consistently had higher recruitment rates than the others.

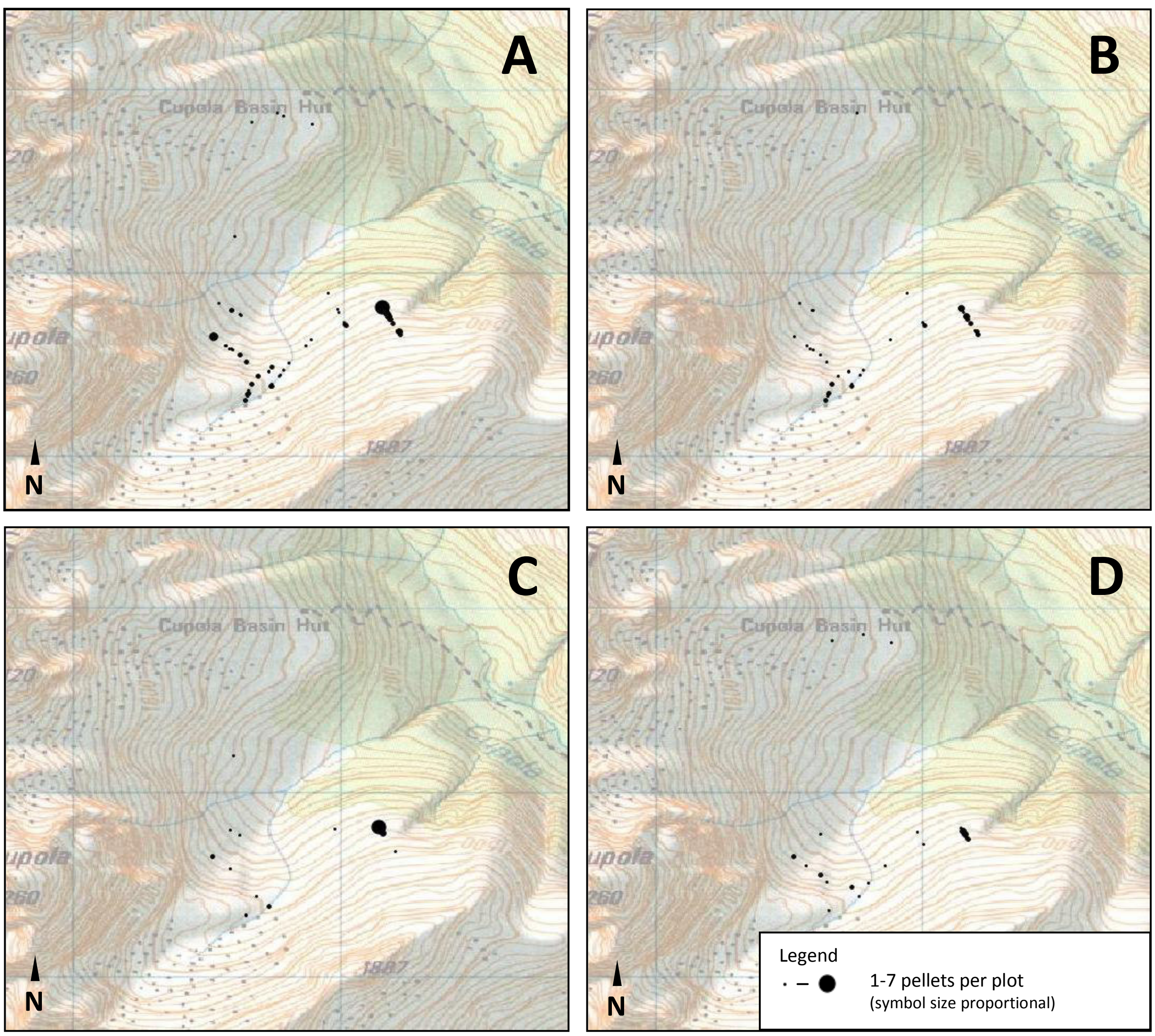

Figure 5. Distribution of European hare (Lepus europaeus) faecal pellets that accumulated within transect plots in Cupola basin, Nelson Lakes National Park. A: Pellets from all 3 sampling periods. B: Pellets from the 19-31 January sampling period. C: Pellets from the 7-18 February sampling period. D: Pellets from the 27 February-9 March sampling period.

3.1.2 Absolute hare abundance

Applying the mean recruitment rates from the sampling periods with the lowest (7-18 February) and the highest (19-31 January) values (see table 1) to the sampled area of 78.1 ha gives a result of 39,050-85,910 pellets being produced daily by hares in Cupola basin. Using Flux (1967)'s best estimate of 410 as the daily pellet production of wild hares in the basin, this produces an absolute estimate of 95-210 hares being present, or 1.2-2.7 hares ha^{-1}.

The overall minimum recruitment rate with 95% confidence is 0.01 pellets $m^{-2}day^{-1}$, and the maximum is 0.19 pellets $m^{-2}day^{-1}$ (see table 1). Applying the same calculation as before reveals that the true absolute number of hares could be anywhere between 19 and 362, or 0.2-4.6 hares ha^{-1}.

Table 1. Pellet recruitment rates (pellets $m^{-2}day^{-1}$) and estimates of absolute European hare (Lepus europaeus) numbers within Cupola basin, Nelson Lakes National Park, over three sampling periods during January-March, 2012.

Sampling period	Mean recruitment rate	Minimum rec. rate (95%CI)	Maximum rec. rate (95% CI)	Mean number of hares	Minimum number of hares	Maximum number of hares
19-31 Jan	0.11	0.03	0.19	210	57	362
7-18 Feb	0.05	0.01	0.09	95	19	171
27-9 Mar	0.06	0.01	0.11	114	19	210

3.2 Direct observation

Over the course of 15 mornings and 14 afternoons/evenings of observation, no live hares were observed. Chamois were observed on open slopes frequently and at all times of day, with a maximum of 9 animals being seen at one time. Red deer (Cervus elaphus) were also observed, but less frequently, only at dusk or dawn, and in lower numbers. Red deer favoured the bush edges and the basin floor.

A tramper reported flushing a hare on 11 February in the area higher up towards the pass above the start point of transect 7, and two DOC workers flushed a second hare on 28 February by the bushline below the start point of transect 9.

In the course of travelling through the basin to access transects, three hare carcasses were found. One had died relatively recently as soft tissues were still present, whereas the remaining two were skeletons for which the time of death could not be established. Two were curled under rock outcrops, while the other skeleton was scattered on a slope so it was impossible to tell what position the hare had died in.

4. Discussion

4.1 Hare abundance estimate and potential sources of error

The lack of statistically significant difference in mean faecal pellet recruitment rate between the three sampling periods could be interpreted as supporting the claim that the cleared-plot pellet count technique produces consistent estimates for a given place and season. The mean recruitment rate ranged between 0.05-0.11 pellets $m^{-2}day^{-1}$, lying between the rate ranges observed by Wilson et al (2006; 0.01-0.03 pellets $m^{-2}day^{-1}$) and Parkes (1981; 0.12-0.2 pellets $m^{-2}day^{-1}$). However, the wide confidence intervals due to high sample variance in this study demonstrate that the mean values may not be particularly accurate.

If converted into estimates of absolute numbers, the results suggest that 95-210 hares occupy Cupola basin (1.2-2.7 hares ha^{-1}). Yet it can only be said with confidence that there are between 19 and 362 hares present, which does not allow for a meaningful comparison with Flux's estimate from 1967.

Nevertheless, if such a comparison is made, then the current mean estimate is far higher than the 8 hares thought to be present by Flux (1967). These results also put Cupola basin's hare density much higher than the supposed New Zealand average of 0.1 hares ha^{-1}, which is contrary to the general pattern of densities being lower within the alpine zone than in sub-alpine and lowland areas (Wong & Hickling, 1999).

It is possible that there has indeed been an increase in hare numbers within the basin since Flux's 1967 study. The aforementioned anecdotal evidence from DOC staff, hunters, helicopter operators and trampers supports this, and trends of increasing hare abundance were found by Norbury et a1 (2002) in central Otago. Norbury's suggested explanation that a reduction in the use of 1080 (sodium monofluoroacetate) to control rabbits (Oryctolagus cuniculus) led to fewer hares being killed through incidental poisoning is not applicable to Nelson Lakes National Park, as 1080 has not been applied to this area (N. Joice, DOC, pers. comm.).

The discrepancy between the abundance estimates of this study and of Flux (1967) is likely to be due to a combination of several factors, one of which may be a real increase in hare abundance over time. Other possible contributing factors are the following:

Inadequate sampling: lack of within-basin habitat stratification

Although the two live hares flushed during the course of the study demonstrate that hares exist throughout the altitudinal range of the basin, significant differences in pellet recruitment rates between several transects imply that habitat use is heterogeneous. This is not unexpected, both Flux (1967) and Hayward (1977, cited by Wong & Hickling, 1999) observed hares more frequently in shorter grasslands and on dry slopes with a north or northwest aspect, and Solly (1998) found they exhibited a significant preference for vegetation less than or equal to 20cm tall.

In this study transects were distributed as randomly as possible in an attempt to capture this variation. As a consequence, most transects spanned multiple vegetation communities (see appendix 8.1), so it was not possible to retrospectively stratify the sampling. If this technique is used to estimate absolute hare numbers in future monitoring, then ideally the basin should be stratified into more specific habitat types in order to obtain more representative sampling and a correspondingly more accurate final estimate.

Inadequate sampling: insufficient transects/plots

This study had 10 transects of 250m, each with 50 plots. This enabled transects to be easily distributed within the basin's dimensions, but low sample sizes may have contributed to the high sample variance in the results. Parkes (2001) recommends using a large number of transects, and cites Parkes (1981) who used 20 transects with a minimum of 50 plots in each. However, at 78.1ha Cupola basin is less than half as large as the 350ha site of that study.

Krebs et al (2001) found that increasing the number of plots within a transect led to significant improvements in precision, and suggest that there should be no fewer than 80 plots per transect. A minimum of 10 transects with 100 plots per transect is recommended by NPCA (2006), although they acknowledge that the optimal number of transects and plots is unknown as yet due to limited research.

If it proves difficult to fit more and/or longer transects within the confines of Cupola basin, then it may be worth locating an alternative site of larger area for long-term monitoring.

Parkes (1981, cited by Parkes, 2001) found that using $0.09m^2$ plots allowed up to 1000 plots to be inspected per fieldworker per day in short-tussock grassland. This figure does not apply to Cupola basin, where there was a dramatic difference in the time taken to inspect a transect between vegetation types. Transects in long, dense tussock took around twice as long to complete as those in shorter grasslands, primarily due to difficulties in relocating plots, but also because it took longer to move between plots. The terrain was also frequently slow to negotiate when navigating between transects. Therefore if the number of plots was increased significantly beyond the number used in this study, a minimum of two fieldworkers would be necessary in order to collect data over the same time interval for all transects.

Variability in pellet production

The daily pellet production per hare must be known if pellet recruitment rate is to be converted into an estimate of absolute numbers. This study made use of Flux's (1967) best estimate of 410 pellets day^{-1} $hare^{-1}$, however this was based on a small sample of only 7 hares, and Flux (1967) states that the real production rate could be anywhere between 300-600. Murray et al (2005) also found that pellet production changed with diet and was slightly higher for adults than juveniles. Further research into in situ pellet production would be required for this source of variability to be removed.

Variability in pellet decay rate

One reason for using cleared-plot counts over short time intervals, as opposed to standing crop counts, is to avoid the problem of unknown rates of pellet decay (Prugh & Krebs, 2004). Decay rate is influenced by long-term climatic conditions and the timing of rainfall relative to the time of deposition (Langbein et al, 1999), as well as diet, for example the consumption of particular plants such as "hairy-leaved" Celmisia may make pellets more likely to disintegrate in rain (Flux, 1967). The best estimate of decay rate for Cupola basin is 3 years (Flux, 1967), hence the number of pellets lost to decay over the 10-day intervals of this study is considered insignificant. However, unaccounted-for decay may have caused previous estimates of pellet recruitment that were measured over much longer periods to be biased towards lower numbers, causing this study's results to appear high by comparison.

Pellet misidentification

It is also possible that faecal pellets from other sympatric herbivores were sometimes mistakenly identified as hare pellets, incorrectly inflating pellet recruitment rate.

Rabbit pellets are the most likely to be confused with hare pellets, being very similar in appearance (see figure 6), although hare pellets are larger and more fibrous (Flux, 1990) and hares deposit pellets individually, not in heaps as do rabbits (Flux, 1967). This is unlikely to be a problem in Cupola basin as rabbits' altitudinal limit in New Zealand is generally 1000m asl (Gibb & Williams, 1990, cited by Flux, 2001). However, Flux (2001) observed a rabbit colony living at 1700-1800m asl in Tongariro National Park, so it may not be an impossibility in all alpine areas.

Chamois and deer are definitely present in Cupola basin, but their pellets are generally identifiable by being deposited in heaps, and those of deer being somewhat elongated in shape (see figure 6). However, if heaped pellets are scattered by grazers or rockfall they may prove less distinctive.

Little information on the appearance of different species' faecal pellets could be found prior to the commencement of fieldwork. Therefore, to minimise the chances of misidentification, if any pellets were found within a plot the surrounding area was also searched in order to rule out the possibility that they had been scattered from a nearby heap. In future studies fieldworkers should be made aware of all sympatric herbivores likely to be present within the study area, and if possible be shown the difference between faecal pellets in the field by someone with experience in this area.

Figure 6. Faecal pellets of four mammalian herbivores. A: European hare (Lepus europaeus). B: chamois (Rupicapra rupicapra). C: rabbit (Oryctolagus cuniculus). D: deer of unknown species (Cervus sp.). (photo D sourced from yay royalty-free images, www.yaymicro.com/stock-image/deer-droppings/991812.)

Attraction of hares to plots

A balance must be struck between having markers be conspicuous enough to be able to be relocated, but not so conspicuous that hares are attracted to them and use them as latrine sites, as has been observed to happen with protruding pegs (Parkes, 2001). Bicycle spokes pushed into the ground were found to not influence hare behaviour by Parkes (2001), so these were used as markers in this study.

However, in the long-leaved Chionochloa tussocks of Cupola basin it proved extremely difficult to relocate bare plot-marker spokes. For this reason, it was decided to push each spoke through a $1cm^2$ piece of blue cardboard at ground-level. This improved ease of relocation dramatically, the bright blue contrasting well with the brown-green of the tussocks. The colour blue was chosen because preliminary research indicated that lagomorphs are unable to distinguish blue from green (G. Harper, DOC, pers. comm.). However, further post-fieldwork research found literature suggesting the opposite: that lagomorphs can distinguish between blue and green, but not green and red (Krempels, 1996; Lumpkin & Seidensticker, 2011). Clarification of this point is necessary, and if it proves that red would be less conspicuous to hares then spokes should be marked with red or fluorescent pink in the future.

In addition to the presence of the spokes themselves, the act of repeatedly locating and inspecting plots inevitably flattened the long tussocks around the plots to a certain degree, which could have increased the visibility of the spokes to hares.

However, as Lazo et al (1992) point out, if the data obtained from future pellet counts were to be used solely as an index, then it does not matter if hares are somewhat attracted to the plots, provided that the same plot-marking method is used in successive measurements so that any effect remains constant.

Incorrect assumption of area occupied by hares

Based on geographical features such as the bushline, upper altitudinal limit of vegetation, steep bluffs and large boulderfields, a 78.1ha area was delineated for sampling in this study. However, it is not known whether this space accurately represents the area currently occupied by hares in Cupola basin. Since calculating absolute numbers from recruitment rates relies directly on knowing the area of occupation, this may contribute to inaccurate estimates.

Determining the true boundaries of hare habitat could prove difficult. A broader-scale presence/absence survey of faecal pellets is one possibility, but would be time- and labour-intensive and the results may not be conclusive. Once again, this problem would be avoided if the results were simply to be used as an index, provided the area sampled in successive measurements remained the same.

Duplicate plots created through the re-establishment of 'lost' plots

Over the course of all 3 sampling periods, 11 plots could not be relocated at all at the end of a 10-day interval, and 5 plots had had their marker spokes knocked out but they were found loose nearby. Spokes could have been knocked out by grazing animals, by trampers (an official tramping route to Mt Travers crosses the basin), or by the fieldworker either while trying to relocate plots or when moving between transects. One spoke was found loose 12 metres upslope from its plot, indicating that it may have caught on the coat of a grazing herbivore and been dragged. To reduce the chance of this occurring, the bent head of spokes should be cut off in future studies.

Aside from littering the basin with lost spokes, there is a small chance that these events could have affected the results of this study. If a plot was deemed lost then it was re-established before the next sampling period in order to maintain sample sizes, with a new spoke inserted to mark the new plot. However, it was difficult in long, dense tussock to be 100% certain that a spoke had actually been removed from the plot, rather than it simply not being able to be found despite being present. Therefore theoretically, if a spoke was simply missed but not gone, a new plot could be cleared of pellets on day 1 but the old plot be relocated on day 10. Consequently pellet recruitment over a period longer than 10 days would be recorded, creating a bias towards a higher rate. As less than 0.01% of plots were lost and re-established, and never more than 2 plots in a single transect, it is unlikely to have made a significant difference. However, to avoid the problem entirely lost plots should not be replaced in the future, instead there should be enough plots per transect that some attrition does not affect sample sizes too severely.

Inoptimal size/shape of plots

This study used small (0.1m²) circular plots, as suggested by Parkes (2001) to maximise the number of plots able to be inspected in a given amount of time, thereby maximising sample size. Murray et al (2002) evaluated three different plot sizes and shapes for use in snowshoe hare monitoring, and found large circular plots of 1m² to be the best, having lower sample variance and reducing the likelihood of finding no pellets within plots purely by chance in areas where hares were actually present. They rejected completely the use of small (referring to plots of 0.16m²) circular plots, due to wide confidence intervals and poor correlation with hare abundance estimates obtained by other methods. Murray et al (2002) claim that the higher perimeter:area ratio of smaller plots often leads to a bias towards higher recruitment rate estimates, as fieldworkers are more likely to include than exclude pellets near the perimeter.

The larger plots recommended by Murray et al (2002) may be practical in short grassland, but in the dense long-leaved tussocks that cover much of Cupola basin pellets could easily be overlooked within a large plot. A more feasible approach is for fieldworkers to simply take care when using the plot radius measurer to determine whether a pellet is within a plot or not.

4.2 Results from direct observations

Flux (1967) asserted that direct counts of live/dead hares in an area “multiplied by an appropriate factor gained from experience” would provide more accurate estimates of hare numbers than would faecal pellet counts, due to the many sources of error in the latter. However, such approaches could be problematic for long-term monitoring, as different people are likely to be involved in data collection over time, with different levels of observational skill and experience.

To illustrate this, no live hares were observed during 29 observation attempts in this study, whereas 4 adult hares were observed by Flux (1967). Although there are obvious difficulties in observing generallynocturnal species, it is uncertain why no hares at all were observed this summer when Flux (1967), from the same vantage point, saw at least one hare on 33 out of 43 observation attempts. One possibility is that the 10x50 field binoculars used in this study did not provide enough magnification to enable the observer to identify hares at low light levels. It is unknown what equipment was used by Flux (1967), but future attempts could benefit from the use of a spotting scope with higher magnification.

Another possibility is that the basin's tussocks are currently more profuse if deer and/or chamois numbers have decreased significantly since Flux's (1967) study, deeper foliage thus providing hares with more cover. However, this is purely speculation and no information could be found concerning changes in ungulate numbers in the area.

Flux (1967) also made an estimate of hare abundance based on annual mortality data, calculating that an average of 3.8 dead hares being found per year represented approximately eight live hares being present. No abundance estimate can be extrapolated from the hare carcasses found during this study as the year of death was unknown for two out of the three carcasses, and the entire study lasted much less than a year. Mortality data is unlikely to be useful for long-term monitoring as it relies on an observer being present in the basin for a significant proportion of each year.

4.3 Practical recommendations for future studies

In addition to the recommendations already made to address identified problems, the following points provide practical advice for facilitating data collection in future studies following a similar method:

- The coloured cardboard spoke tags faded in sunlight, were chewed by insects and disintegrated if wetted repeatedly. Coloured plastic would be more durable, or alternatively the spokes themselves could be painted the appropriate colour.

- The use of a headtorch, even during daylight hours, facilitates the detection of faecal pellets amongst litter and fine scree at the base of dense tussock and shrubs.
- Marking each individual plot on a GPS, rather than solely the starting point of each transect, is recommended. The main benefit is that it enables transects to be inspected in the opposite direction from that which they were initially set up in, improving the time-efficiency of data collection. It also allows plots to be identified without the need for an identification tag on the plot marker itself, and assists fieldworkers to avoid disturbing plots unintentionally while travelling through the study area. Finally, to a certain extent it aids plot relocation despite only being accurate to within 3m.
- Having two fieldworkers perform transect set-up could improve the accuracy of transect bearings, facilitating plot relocation. However, during the data collection phase having only a single fieldworker inspect transects minimises the trampling of tussock around plots.
- The relocation of plots on transects running perpendicular to the contours in dense tussock on steep slopes is much easier when moving in the uphill direction.
- The use of a rigid plot-radius measurer (see figure 2) is more practical in dense tussock than using a piece of string as suggested by Parkes (2001), as it proved difficult to pull the string taut to get an accurate measurement.

4.4 Future research directions

Although the results of this study are inconclusive, if hare numbers in Cupola basin have genuinely increased significantly then hares may currently be having a greater impact on the alpine vegetation throughout Nelson Lakes National Park than has been believed to be the case in the past. However, more research would be required to determine how that impact is manifested, and how it compares and interacts with that of other sympatric herbivores.

In his 1967 study, Flux formed the opinion that the hares in the basin were having little impact relative to the abundant red deer and chamois present. It is unknown whether these species have increased or decreased in abundance since that time, but currently the only control of these pest species in the area is recreational hunting (G. Harper, DOC, pers. comm.). To aid management decisions about whether additional pest control is necessary, research using exclusion plots and some measure of vegetation biomass and/or diversity would help to differentiate the effects of hares from that of other herbivores. Studies on hare diet and diet selectivity would also be valuable. This could be done either by relating the relative abundance of different plant species to results of stomach contents or faecal pellet composition analyses (Wong & Hickling, 1999), or via more indirect methods such as that of Solly (1998), who made inferences regarding feeding preferences through point sampling of both pellet density and vegetation.

Regarding interactive effects, hare densities were found to decline after control operations targeting red deer and chamois in the Harper-Avoca catchments, due to increases in alpine grassland density following its release from ungulate grazing (Batcheler & Logan, 1963, cited in Forsyth et al, 2000). The multi-species pest management approach advocated by Forsyth et al (2000) may therefore be applicable to Nelson Lakes National Park if active control of red deer and chamois could also indirectly control hare numbers.

Snow-tracking was suggested by Flux (1967) to be a more effective technique for abundance estimation than pellet counts. An equivalent assessment to this study could be carried out to investigate the practicality of snow-tracking for long-term monitoring in Cupola basin. This method has been applied successfully overseas to other species (e.g. O'Donoghue et al, 1997 and Sulkava & Liukko, 2007), and Litvaitis et al (1985) review its application in the analysis of habitat use by snowshoe hares, but little mention of its use in estimating hare abundance could be found. Some potential problems include that at high densities it may prove difficult to differentiate between tracks of individual animals (O'Donoghue et al, 1997) with observer skill-level therefore greatly influencing results (Sulkava & Liukko, 2007), and that individuals may move around more when in low density populations (Stephenson & Karczmarczyk, 1989, cited by O'Donoghue et al, 1997). Whether these concerns apply to hares or not is unknown.

If it is decided to engage in long-term monitoring of hare abundance, then investigation into the relationship between hare numbers and environmental factors such as temperature and mast flowering/seeding events of beech and tussock could also prove valuable. Hares were one of the alpine mammals considered likely to fluctuate in abundance with such events by Wilson et al (2006), and improved understanding of any patterns would assist predictions of future changes in hare numbers.

5. Conclusion

It is impossible to know whether the dramatically higher hare abundance estimate in this study compared to that of Flux (1967) is due to a genuine increase in hare numbers, due to artefacts of the cleared-plot pellet count method, or some combination of the two. For this reason, no meaningful comparison can be made between the results of the two studies. There are several reasons to doubt the accuracy of this study's estimate of absolute hare numbers, however, the method employed could provide a practical index of relative hare abundance for long-term monitoring of temporal changes in abundance from now on. The method's utility for spatial comparisons, on the other hand, is likely to be limited given that changes in hare diet and weather conditions between areas may influence faecal pellet recruitment rates.

The methodology as used in this study requires little expensive equipment and is practical to be carried out by a single fieldworker over a reasonably short timeframe. Data collection is more challenging in dense long-leaved tussock than in short grasslands, but if the recommendations made are followed it should facilitate fieldwork in future attempts.

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8. Appendices

8.1 Transect details

Transect 1: start point E1577811, N5353318 (NZTM projection), bearing 250°, altitude range 1398-1513m. Vegetation mainly short wiry grass and scattered long tussock. Herbs and rushes also present, some shrubs and a patch of boulders (no plots established in this stretch). The slope is gentle at first then steep towards the end, the transect running perpendicular to the contours. Thin snow covered the higher-altitude end during the two snowfalls.

Transect 2: start point E1577749, N5353181, bearing 90°, altitude range 1376-1431m. Vegetation mainly short wiry grass and rushes, with scattered red tussock, herbs and shrubs. A few tarns present in the central stretch. The slope is very gentle, with the transect running perpendicular to the contours.

Transect 3: start point E1577845, N5353019, bearing 290°, altitude range 1396-1454m. Vegetation mainly short wiry grass, scattered long tussock and herbs. The slope is mainly gentle, turning steep at the end, with the transect running perpendicular to the contours.

Transect 4: start point E1577618, N 5352757, bearing 190°, altitude range 1360-1399m. Vegetation mainly short wiry grass and scattered long tussock, with patches of shrubs and assorted herbs spread throughout. There are small patches of rushes and the odd flax near some tiny creeks and minor scree areas that intersect the transect. The slope is gentle, with the transect running parallel to the contours.

Transect 5: start point E1577490, N5352189, bearing 100°, altitude range 1363-1402m. Vegetation mainly short wiry grass with scattered long tussock and herbs on a base of loose scree at the beginning, descending into dense long tussock, herbs and shrubs. The slope begins moderate then flattens out, with the transect running at an angle to the contours.

Transect 6: start point E1577638, N5351847, bearing 290°, altitude range 1438-1461m. Vegetation mainly long tussock and herbs with areas of loose scree. The slope is moderate, with the transect running parallel to the contours. Thin snow covered the entire transect during the two snowfalls.

Transect 7: start point E1577630, N5351642, bearing 355°, altitude range 1479-1525m. Vegetation mainly short wiry grass at the beginning, descending into an area with tarns surrounded by rushes, short grass, herbs and scattered long tussocks before crossing a very steep old landslide scar with fine shattered greywacke (hence the kink in the transect). The slope is gentle apart from the stretch spanning the landslide, with the transect running perpendicular to the contours. Snow covered the entire transect during the two snowfalls.

Transect 8: start point E1577883, N5351970, bearing 180°, altitude range 1456-1507m. Vegetation a mix of long and short tussocks with herbs and boulders throughout. The transect crosses a minor tributary to Cupola creek, with scattered shrubs around this area. The slope is gentle, with the transect running at an angle to the contours. Snow covered the entire transect during the two snowfalls.

Transect 9: start point E1577941, N5352227, bearing 135°, altitude range 1371-1471m. Vegetation mainly long tussocks at the beginning, changing to short grasses at the very end, with scattered shrubs throughout. The slope is steep, with the transect running perpendicular to the contours. Snow covered the upper third of the transect during the two snowfalls.

Transect 10: start point E1578245, N5351947, bearing 315°, altitude range 1466-1573m. Vegetation is mainly short grasses with scattered long tussock at the beginning, descending into an area dominated by Chionochloa rubra. The slope is steep at first then becomes gentle towards the end, with the transect running perpendicular to the contours. Snow covered the entire transect during the two snowfalls.

8.2 Wide-scale photos of the terrain

Plate 1. The area within Cupola basin, Nelson Lakes National Park, that contained transects 1-3 (camera pointing northwest).

Plate 2. The area within Cupola basin, Nelson Lakes National Park, that contained transects 4-10 (camera pointing south).

8.3 Faecal pellet count data

L = plot lost
K = plot marker spoke knocked out but found, plot re-established.

19-31 January sampling period.

Plot	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
1	0	1	0	0	0	0	2	0	L	L
2	0	0	0	0	0	1	0	1	0	L
3	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	1	0
5	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	1	0	0	0
7	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	1	0	0	0
9	0	0	0	0	0	0	2	0	0	0
10	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	1	0	0	0	0
12	0	0	0	0	1	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	2
14	0	0	0	0	0	0	0	L	0	0
15	0	0	0	0	0	0	0	0	0	1
16	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	2
18	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	1	2	0	0	1
20	0	0	0	0	0	0	1	0	0	0
21	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	1	0	0	0	0
23	0	0	0	0	0	0	0	0	L	0
24	0	0	0	0	1	0	0	0	K	0
25	0	0	0	0	1	0	0	0	0	0
26	0	0	0	0	0	1	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	2
29	0	0	0	0	0	K	0	0	0	0
30	0	0	0	0	0	0	0	1	0	0
31	0	0	0	0	0	0	1	0	0	0
32	0	0	0	0	0	0	L	0	0	0
33	0	0	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0	0	2
35	0	0	K	0	0	0	0	1	0	0

36	0	0	0	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0	0	0
38	0	0	0	0	0	1	0	0	0	3
39	0	0	0	0	0	0	0	0	0	0
40	0	0	0	0	0	0	0	0	0	0
41	0	0	0	0	0	0	0	0	0	0
42	0	0	0	0	0	0	0	0	0	0
43	0	0	0	0	0	0	1	0	1	0
44	0	0	0	0	0	0	1	0	0	1
45	0	0	0	0	0	0	0	0	0	0
46	0	0	0	0	0	L	0	0	1	0
47	0	0	0	0	0	0	0	1	2	1
48	0	0	0	0	0	0	0	0	0	3
49	0	0	0	0	0	0	0	2	0	0
50	0	0	0	0	0	0	0	0	0	0
total pellets	0	1	0	0	3	6	12	6	5	18
total L	0	0	0	0	0	1	1	1	2	2
total K	0	0	1	0	0	1	0	0	1	0

7-18 February sampling period.

Plot	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
1	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	1	0	0	0
8	0	0	0	0	0	0	1	0	0	0
9	0	0	0	0	K	0	0	0	0	0
10	0	0	0	0	0	0	0	L	0	0
11	0	0	0	0	0	0	0	L	0	0
12	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	1
18	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	1	0	0	0	0

21	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	1	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	1	0
28	0	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	1	0	0	0
32	0	0	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0	0	0
34	0	0	0	0	1	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0	0	0
38	0	0	0	0	0	2	0	0	0	0
39	0	0	0	0	0	0	0	0	0	0
40	0	0	0	0	0	0	0	0	0	0
41	0	0	0	0	0	0	0	0	0	0
42	0	0	0	0	0	0	0	0	0	3
43	0	0	0	0	0	0	0	0	0	0
44	0	0	0	0	0	0	0	0	0	0
45	0	0	0	0	0	0	0	0	0	0
46	0	0	0	0	0	0	0	0	0	0
47	0	0	0	1	0	0	0	0	0	0
48	0	0	0	0	0	0	0	0	0	0
49	0	0	0	0	0	0	0	0	0	7
50	0	0	0	L	0	0	0	2	0	0
total pellets	0	0	0	1	2	3	3	2	1	11
total L	0	0	0	1	0	0	0	2	0	0
total K	0	0	0	0	1	0	0	0	0	0

27 February-9 March sampling period

Plot	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
1	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	1	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0

7	0	0	0	0	0	0	0	0	0	0
8	0	1	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	2	0	1	0	0
11	0	0	0	0	0	0	0	0	0	0
12	0	0	L	0	0	0	1	0	0	0
13	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	1	0	0
22	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	1	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	1	0
30	0	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	0
32	0	0	0	0	1	0	0	0	0	0
33	0	1	0	0	0	0	0	0	0	2
34	0	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0	2
36	0	0	0	0	0	0	0	1	0	0
37	0	0	0	0	0	0	0	0	0	0
38	0	0	0	0	0	1	0	0	0	0
39	0	0	0	0	0	2	0	0	0	0
40	0	0	0	0	0	0	0	0	0	3
41	0	0	0	0	0	0	0	0	0	0
42	0	0	0	0	0	0	0	0	0	0
43	0	0	0	0	0	0	0	0	0	0
44	0	0	0	0	0	0	0	0	0	0
45	0	0	0	0	0	0	0	0	0	3
46	0	0	0	0	0	0	0	0	1	1
47	0	0	1	0	0	0	0	0	0	0
48	0	0	0	0	0	0	0	0	0	1
49	0	0	0	0	0	0	2	0	0	0

50	0	0	K	0	0	0	0	0	0	0
total pellets	0	2	1	0	1	7	3	3	2	12
total L	0	0	1	0	0	0	0	0	0	0
total K	0	0	1	0	0	0	0	0	0	0