Assessment and management of hare impact on high altitude vegetation

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Prepared for: Science and Research Division, Department of Conservation

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1. ABSTRACT

The introduced hare *Lepus europaeus* has generally been perceived to have a minimal impact on high altitude vegetation in New Zealand. In 1995, however, five Department of Conservation Conservancies documented their concerns that hares may be causing unacceptable damage to these habitats, particularly in alpine grasslands. However, the conservancies noted that this impact is difficult to separate from that of rabbits *Oryctolagus cuniculus*, possums *Trichosurus vulpecula* and larger grazing mammals. In response to these concerns the Department of Conservation requested this review of the literature assessment and management of hare impacts on high altitude vegetation.

Hares are found in most pastoral and grassland areas of New Zealand. The average density of the national population is estimated to be 0.1 hares.ha\(^{-1}\). They typically occur at high densities in subalpine areas and at much lower densities in alpine areas. Hares are most abundant along the dry, eastern side of the Southern Alps, where densities of 2-3 hares ha\(^{-1}\) are common.

Hare diet composition generally reflects the composition of the vegetation community, although some preference for particular species is evident.

Only three studies have quantified the impact of hares on high altitude vegetation. These suggest that hares reduce the growth and inhibit regeneration of vegetation in some high altitude habitats but in other habitats have little impact. In some parts of their range, hares are the main herbivore and are likely to be consuming more forage per hectare than possums, chamois, thar or deer. Elsewhere, however, the impact of these other grazers is probably far more significant than that of hares.

The following methods are recommended for research into hare impact in areas of high conservation value:

- diet and diet selection studies, using stomach or dropping analysis, that can be related to vegetation availability data obtained by field survey;
- development and validation of a suitable cleared plot technique for assessing hare population density and determining habitat use;
- investigation of long-term hare impact using both exclusion-plot and population reduction techniques.

A critical issue for managers is how much control is needed to achieve conservation goals in an area, which in turn determines the methods and costs that will be involved.

Hare management is only one particular component of managing high altitude vegetation, and needs to be integrated into a more general conservation framework for these areas. A case study of the 'priority place - critical pest' approach is recommended. Any expenditure on hare control should be supported by long term vegetation monitoring to assess the benefits of the control.
2. INTRODUCTION

The impact of hares on New Zealand's high altitude vegetation has been identified by the Department of Conservation as a probable area of concern. Hares have been identified as a 'critical pest' in only a few areas of New Zealand; Mt. Egmont and two small nature reserves in inland Canterbury. Elsewhere, traditionally, they are not thought to have a significant impact on high altitude vegetation due to their low, stable densities in these habitats. In recent decades, however, the abundance of larger grazing mammals has decreased significantly in all alpine and subalpine grasslands (J. Parkes pers. comm.), yet some of these grasslands continue to degrade. Methods are therefore needed for assessing, and in priority conservation areas managing, the impact of hares.

The objectives of this report are:

- review the literature on hare impacts on high altitude vegetation;
- recommend methods for assessing hare abundance, and for identifying and scoring hare browse.

Methods of hare control are also briefly discussed. This report has been prepared for and funded by, the Science and Research Division of the Department of Conservation.

2.1 The history of hares in New Zealand

Hares, *Lepus europaeus occidentalis*, also called brown hare, common hare, European hare and field hare, were first liberated in New Zealand in 1851 (Wodzicki 1950). The majority of introductions occurred in the 1860s and 1870s at major ports around the country. Sport and harvesting for food supplies were the primary motivations behind these introductions. During the late 1800s hares spread rapidly throughout most of the North and South Islands. They were protected from unrestricted hunting from 1861 until 1866, when landholders were given permission to control them as pests (Flux 1990).

Hare distribution has remained largely unchanged since this initial rapid increase in numbers and distribution. They are now present throughout both the North and South Islands in suitable habitat (see section 3.2) from sea level to 2000m, except for parts of South Westland, most of Fiordland (Parkes, Tustin & Stanley 1978) and an area from Auckland city to about 80 km north. They are absent from all other New Zealand islands. The highest densities of hares occur in subalpine grasslands along the eastern side of the Southern Alps (Wodzicki 1950, Parkes 1981).

2.2 High altitude vegetation

This report defines high altitude vegetation as alpine and subalpine vegetation types, which encompass tussock lands, forests, shrub lands and herb fields. Indigenous communities still dominate these landscapes, but are heavily modified in many places (Newsome 1987). The tussock grasslands and associated communities are the main habitat of hares in New Zealand at high altitude, and so are the main foci of this report.

Native grasslands at high altitudes are dominated by various species of *Chionochloa* tussock, which are similar in appearance but have distinct ecological preferences. These
Hare impact on high altitude vegetation

Grasslands are widespread in the mountain ranges of both main islands, descending to sea level in southern regions. Where undisturbed, *Chionochloa* tussocks can form dense stands with thick litter beneath, but usually other grasses and herbs form the lower tiers. According to drainage and fertility, these vegetation communities range from typical grassland assemblages to those associated with wet-heath and bog. The proportion of forbs and small herbs increases on rocky ground, on steep topography and along watercourses. *Chionochloa* grasslands below the treeline occur on a few special habitats, such as frosty or poorly drained soils, or are a result of deforestation over the last thousand years (Wardle 1991).

Other important genera of New Zealand's alpine and subalpine tussock grasslands include: the mountain daisies *Celmisia*, the speargrass *Aciphylla*, *Anisotome*, buttercups *Ranunculus*, various herbs of the genera *Ourisia*, *Forstera*, *Lobelia*, *Hebe* and *Geum*, tussocks of *Astelia*, the summer-green bulbous geophyte *Bulbinella*, and various mosses, liverworts and liverworts (Wardle 1991).

### 2.3 Hares and land managers

Hare impact on high altitude vegetation in New Zealand has generally been considered an issue of low priority. However, in 1995 five Department of Conservation Conservancies (Nelson/Marlborough, Canterbury, Southland, Hawkes Bay and Wanganui) documented their concerns that hares may be causing unacceptable damage to high altitude vegetation in their regions, particularly in alpine grasslands. As it is difficult to separate hare impact from that of rabbits, possums and larger grazing mammals, these conservancies suggested that the precise nature of the impact that hares are having was unclear and there was a need for research on this issue.

There are problems particular to each conservancy. For example, in the Nelson/Marlborough Conservancy, an expansion of hare range was noted by the Forest Research Institute in mid-eighties (Hawes et al. 1986). Hares have spread into some alpine tussock grasslands in this area in only the last five years and some ranges may still be free from hares (K. Walker pers. comm.).

Field staff at Mt. Cook in the Canterbury Conservancy have in recent years observed the progressive destruction of herbs throughout the alpine grasslands and the decrease in the prominence of *Celmisia*. These grasslands are continuing to change and this appears to be associated with an apparent increase in hare numbers (R. Bellringer pers. comm.).

Southland Conservancy staff are concerned about hare impact in sub-alpine mixed shrubland, grassland and herbfield. Areas of particular concern include the Blue Mountains, Mt. Bee, Takitimu and the Mavora Lakes (C. West pers. comm.).

The three central North Island conservancies (Hawkes Bay, Wanganui and Tongariro/Taupo) are concerned about the continuing degradation of red tussock grasslands and associated herbfields as a result of hare browsing (G. Walls, C. Speedy and B. Fleury pers. comm.). In many parts of the montane grasslands east of the volcanoes hares appear to have become the main grazers (B. Fleury pers. comm.), including the alpine area of Mt. Egmont.
This review has been requested by the Department of Conservation in response to these Conservancies' concerns. It aims to review the known effects of hares on high altitude vegetation and identify shortfalls in this knowledge. Methods of hare impact research are then reviewed and recommended. At present, the relative importance of hare impact and thus the priority for hare control is largely unknown. However, if control of hares were deemed necessary, then improved control methods would need to be developed. Therefore, this review also considers future management options.

3. HARE BIOLOGY AND HABITAT USE

3.1 Biology
Hares are similar in appearance to rabbits but can be distinguished by their larger size, proportionally larger hind legs, more rakish build, richer tawny colour, black-tipped ears and their characteristic loping, tail-down run in the open when disturbed (Wodzicki 1950, King 1990). Weight and body measurements of adult hares are shown in Table 1.

<table>
<thead>
<tr>
<th></th>
<th>Female</th>
<th>Male</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight (kg) (range)</td>
<td>3.8 (2.4-4.8)</td>
<td>3.3 (2.4-4.4)</td>
</tr>
<tr>
<td>Hind foot length (mm)</td>
<td>143.8</td>
<td>144.1</td>
</tr>
<tr>
<td>Skull length (mm)</td>
<td>96.6</td>
<td>97.3</td>
</tr>
<tr>
<td>Skull width (mm)</td>
<td>46.1</td>
<td>46.1</td>
</tr>
</tbody>
</table>

3.1.1 Field sign
Hares can be identified by their distinctive footprints where the large hind feet overreach the forepaws. Tracks made at slow speed show asymmetrically placed hind foot prints, unlike rabbits which have the hind footprints side by side. Tracks made by hares travelling at high speed show a completely symmetrical gait. On soft surfaces such as snow the five hind toes are spread, leaving prints like a dog's, and the four toes on the small forepaws are kept close together to give a pearshaped print; forefoot prints follow each other in line, about 10-20 cm apart (Flux 1990).

Hares are primarily nocturnal (Flux 1990). By day they crouch in a “form”, an oval shaped depression in vegetation or soft ground approximately 200 x 400 mm in size (Flux 1990). Hares typically begin feeding at dusk (earlier in spring), and may move some distance to find grazing. They habitually use the same paths or “runs”. In deep grass these may become conspicuous depressions 100-200 mm wide, running along ridges and up and down slopes.

Hares may travel 15 km while feeding in one night in snow above the timberline (Flux 1967a). In a subalpine valley (the Avoca River, west of the Craigieburn Range, Canterbury), five adult home ranges varied from 30 ha (for one adult female) to 70 ha (for one adult male) with an average of 53 ha (Parkes 1984). Most of the hares' time was spent in small centres of activity; half their time was spent within 10% or less of their home range. During March to May, the non-breeding season, hares extended their ranges from lower mountain slopes down onto river terraces (Parkes 1984). Hares showed little
emigration from an area, moving on average 280-640 m from their initial capture site during and between two breeding seasons (Douglas 1970).

Hare droppings (also referred to as faecal pellets, pellets, faeces and scats) are typically flattened spheres, 15 mm x 10 mm, with a slight tail on one side. They are similar to rabbit droppings, but larger, paler and more fibrous in appearance (Flux 1990), and less rounded in shape (Horne 1979). Rabbits droppings tend to be found in small piles whereas hare droppings tend to be scattered widely, although they do accumulate at favoured stopping places.

Hares clip vegetation with a characteristic 45° cut. The tips of plants are often left on the ground with a few droppings nearby (Flux 1990). *Chionochloa* tussocks are grazed one tiller at a time in a semi-circle that is distinctive from all other introduced herbivores except possums. Hares often eat only the more nutritious bottoms of tussocks and leave the tops intact and lying on the ground, unlike deer which tend to graze tussocks more evenly (J. Parkes pers. comm.).

3.1.2 Reproduction and population regulation
Hares start breeding soon after the shortest day of the year. The breeding season extends from early July until mid-March (Parkes 1989), with over 90% of females pregnant from August to February (Flux 1990). The average litter size in one New Zealand study (Flux 1967b) was 2.14, allowing for pre- and post-implantation loss, and the average number of successful litters per year was 4.59. This gave an annual production of 9.8 young per female.

Hare population densities are self-limiting by some behavioural mechanism, and do not undergo the kinds of population irruptions seen in rabbits (Flux 1990). Their densities do not exceed 3. ha⁻¹, but it is uncertain why this is so as there is no evidence that they are limited by food, they are not territorial, and direct aggressive interactions are rare (Flux 1981a).

3.1.3 Predators and parasites
Adult hares are remarkably free from predation in New Zealand (Flux 1990). They are, however, preyed upon on occasion by harriers, stoats, ferrets, weasels and cats. As with most mammals, it is the young that are most susceptible to predation (Douglas 1970).

Hares are also relatively free of parasites, as are many other mammal species in New Zealand. Many of the diseases which affect or can be transmitted by hares in Europe; such as European brown hare syndrome, plague, rabies, tularaemia, brucellosis and myxomatosis; are not present in New Zealand (Flux 1990).

3.2 Hare habitat
Hares are found in most pastoral and grassland areas of New Zealand. The average density of the national population is estimated to be 0.1 ha⁻¹ (Flux 1981b). They typically occur at high densities in subalpine areas and at much lower densities in alpine areas. At their highest numbers along the dry, eastern side of the Southern Alps, densities of 2-3 hares ha⁻¹ are common (Parkes 1984). A study in inland Canterbury (Douglas 1970) estimated their population density at 1 ha⁻¹. In areas where hares are at high densities they are often the most important mammalian herbivore present, particularly in the many
areas where commercial hunting has reduced the number of wild ungulates (Parkes 1981). There are relatively few hares at high altitudes, but they can survive and maintain their numbers in this habitat as there is an absence of competition (Flux 1990).

In Nelson Lakes National Park hares are more common on short carpet grass swards than on dense tall tussock areas, and preferred the dry north- and northwest-facing slopes (Hayward 1977). In grasslands above the timberline in west Nelson, hares used the red tussock Chionochloa rubra association significantly less than the C. flavescens and C. pallens tall tussock association. Dropping survey detected little use of forest, and no hare droppings were found on fell-field plots (Hickling 1985). In winter hares shelter by day in forest 100 - 1000 m from grassland (they do not produce pellets during the day). In Wairau catchment, Nelson, hare density was correlated with the proportion of grassland in an area. Alpine carpet grasslands, particularly those depleted by animals and erosion, were particularly favoured (Bathgate 1974).

As previously mentioned, northwest Nelson is one area in New Zealand into which hares may still be spreading. In the mid 1980s hares were found to be slowly spreading along the alpine tops of the Domett Range and extending their distribution around and south along the Marshall and Morgan Ranges (Hawes et al. 1986). They were expected to spread further; by establishing on suitable open valley floor sites, and to increase in density in those areas where they were uncommon or occasional. There may still be some catchments in this area that are still free of hares (K. Walker pers. comm.). An alternative explanation to the observed range expansion is re-invasion after local extermination by snow freeze. Populations on mountain tops are low so gaps are common. Some peaks in the Taranua mountains, North Island, are clear of hares for periods of 1-5 years and then are recolonised by 1-2 hares (J. Flux pers. comm.)

3.2.1 Hare diet

Like other introduced herbivores in New Zealand, hares eat a wide variety of plant species. The only information on hare diet in New Zealand high altitude vegetation comes from three studies, one in alpine tussock on Mt Ruapehu (1100-1600m elevation) (Horne 1979), one in the alpine tussock grassland of Cupola Basin in Nelson Lakes National Park (1200-1700m) (Flux 1967a), and one on a modified fescue tussock (Festuca novae-zealandiae) grassland on the Avoca River flats in central Canterbury (600-700m) (Blay 1989).

In the two alpine grasslands studies, the main species eaten by hares was Chionochloa tussocks, followed by Celmisia spp. and Poa colensoi. Many herbs, other grasses, shrubs, mosses and seeds comprised the remainder of the diet. The diet composition of hares at these sites is contrasted in Table 2 (species with an asterisk have been introduced to New Zealand).

In the subalpine grassland study, Hieracium pilosella* was the most common item in the hares diet (32.3%), followed by grasses (Anthoxanthum odoratum*, Agrostis tenuis*, Holcus lanatus*) (22.2%), and tussocks (Festuca novae-zealandiae and Poa colensoi) (16.2%). Other species consumed were Racomitrium lanuginosum, Carex coriacea, moss, Trifolium* spp., Carmichaelia spp., Corokia cotoneaster, Rumex acetosella*, Hypocheris radicata, Digitalis purpurea*, Luzula crinita, Schoenus pauciflorus, Taraxacum officinale, Juncus effusus, Epilobium melanocaulon and Rosa rubiginosa*.
that hares increased their consumption of *Festuca* at the start of summer, the time of new shoot growth.

### 4. GRAZING IMPACTS ON HIGH ALTITUDE VEGETATION

Until European settlement, New Zealand's alpine grasslands were browsed only by flightless indigenous birds and invertebrates (Rose and Platt 1987). Now, almost no New Zealand grassland has escaped the effects of human settlement, in particular grazing by feral animals (e.g., Wardle 1991). Most are subject to grazing by various combinations of domestic and feral sheep, cattle, horses and goats and wild hares, rabbits, deer, chamois, thar, wallabies, pigs and possums.

Such grazing affects the survival, growth and reproduction of plant communities. Grazing can influence species richness, the relative abundance of species, and the physical structure of the community (Crawley 1983, Rose and Platt 1987), but its effects in high altitude vegetation communities are complex. For example, species richness and vigour can either increase or decrease in response to grazing (Rose and Platt 1987, Huntly 1991, Wilson 1994).

Evidence that grazing can depress plant diversity is widespread (Wilson 1994). Selective feeding can modify competitive relationships between plant species by allowing a normally uncompetitive plant to replace its more palatable competitors. Non-selective feeding can, for example, allow tall plants to suffer disproportionately low rates of feeding while small herbs are completely defoliated (Crawley 1983). In the most extreme cases heavy grazing can lead to extinction of preferred species (Wilson 1994), but as yet, there are no known examples of grazing-induced plant extinction in the New Zealand high altitude grasslands.

Where grazing is less extreme preferred species may persist, but at a greatly reduced abundance. Examples of grazing decreasing plant diversity include: alpine grasslands in northern Fiordland, where there was a significant recovery in the diversity and growth of plants preferred by deer when deer numbers were reduced (Rose & Platt 1987); subalpine herbaceous vegetation in the Australian Snowy Mountains, where nine species of herbs were found to be present only in plots that excluded rabbits (Leigh et al. 1987); and the subalpine meadows in Colorado, where plant species richness increased following exclusion of the lagomorphs pikas *Ochotona princeps* (Huntly 1987).

In contrast, when grazing is gap-forming an increase in plant diversity can occur. Selective feeding on a previously dominant species can reduce its vigour and open spaces that otherwise could not have been colonised by less competitive species (Carr & Turner 1959, Crawley 1983, Gibson & Kirkpatrick 1989, Wilson 1994). A New Zealand example is the sub-alpine, highly modified short tussock *Poa cita* grassland of the Port Hills, Canterbury; sheep grazing has maintained indigenous plant species by suppressing the growth of introduced grasses between tussocks (Lord 1990).

Heavy grazing can reduce plant vigour. For example, mountain hares *Lepus timidus* caused heather plants to remain in or revert to a juvenile, non-flowering physiological state (Moss & Hewson 1985). Grazing by hares, as well as rabbits, in inland Canterbury...
Hare impact on high altitude vegetation

is thought to prevent *Hebe armstrongii* from flowering (R. Smith *pers. comm.*). Artificial defoliation of mid-ribbed snow tussock *Chionochloa pallens* (to simulate deer grazing) in the Murchison Mountains, Fiordland caused an increase in tiller density, but depressed tiller size and total tussock biomass (Lee *et al.* 1988). Lee *et al.* concluded that the severe effects of defoliation on *C. pallens* tussocks, and their slow rate of recovery, meant that two decades would be required for the tussocks to recover from a single defoliation event.

Sometimes, where grazing is less severe an increase in vigour can sometimes occur. For example, bushes that had been heavily browsed by snowshoe hares *Lepus americanus* in Kluane, Yukon recovered rapidly after hare numbers declined (Smith *et al.* 1988). In this ecosystem (where the plants were adapted to the native herbivores), hare browsing had a stimulatory effect on the growth of the woody plants.

### 4.1 Hare grazing impact

Despite the ubiquity of hares in New Zealand their impact on the native grasslands has received little attention. They are generally perceived to have a minimal impact on the environment because they live at relatively low densities, hedge palatable plants without killing them, graze only a few leaves from many plants over a wide area, and do not dig burrows (Flux 1990). The only published work quantifying hare impact on high altitude vegetation details their effect on snow tussock regeneration (Rose & Platt 1992), while an unpublished report describes hare impact in three central North Island habitats (Rogers 1994) and an unpublished thesis (Blay 1989) describes hare impact in a subalpine, fescue tussock grassland.

Rose & Platt (1992) found browsing by hares alone sufficient to inhibit snow tussock *Chionochloa macra* recovery in montane-subalpine, formerly forested sites in the Avoca and Harper River valleys, central Canterbury. Hare browsing pressure was reported to have been “heavy” in the study site, where sheep had long been excluded. Parkes (1984) reported that hare density in this area was at the highest level recorded in New Zealand. Almost all (97%) snow tussocks showed browsing damage. Snow tussocks lengths in this hare browsed stand were comparable to a similar stand grazed only by sheep, with 17% of tussocks senescent. At the study site, snow tussocks inside a hare-exclusion enclosure showed pronounced recovery after 10 years; tussocks >5 cm in diameter were about twice as tall as those on the stand grazed only by sheep and only 2% of tussocks were senescent. No seedlings were found in either hare affected area and in both of these areas juvenile tussocks made up <10% of each population, compared with 12% and 67% in similar areas which had been retired from sheep grazing for 20 and 33 years, respectively. Lack of seedling regeneration was reflected in the low basal area of tussocks remaining as seed sources, high seedling mortality rates and low seed production as a result of poor tussock vigour (Rose and Platt 1992).

Rogers (1994) investigated impacts of hares in different habitat types in the Moawhango Ecological District, central North Island, by measuring the vegetation in and out of plots subdivided to exclude hares on one side and large ungulates and hares on the other. In a *Schoenus pauciflora* wetland plot established in 1989 hares appeared to have a small dampening affect on the recovery of native sedges, exotic grasses and native herbs compared to the area excluding all introduced grazers. In two, plateau, red tussock-hard tussock grassland plots established in 1989 and 1979/80 the exclusion of hares did not
affect the biomass, stature or recruitment of either hard or red tussock; in this area hares appeared to feed on exotic grasses. However, on a hillslope red tussock-hard tussock grassland plot established in 1989 hares and rabbits had a substantial dampening effect on the rates of recovery of red tussock, hard tussock and exotic grasses. Three other similar exclosure plots subdivided for hares have been constructed in the central North Island, two in mountain beech forest and one in manuka-inaka scrub, but as yet no data are available from these plots (G. Rogers pers. comm.).

Blay (1989) excluded hares from a fescue tussock, subalpine grassland in central Canterbury and during two successive, six month periods found 18.5% and 19.9% more plant material inside the exclosures compared with equivalent hare affected plots.

These three studies, which are relatively short term and poorly or not replicated, suggest that hares reduce the growth and inhibit regeneration of vegetation in some high altitude habitats but in other habitats have little effect. There are anecdotal reports of both regeneration (Hooker Valley of Mt Cook National Park, Wilson 1986; Mt Egmont alpine herbfieids after poison baiting for possums, B. Fleury pers. comm) or progressive degradation (Mt Cook area, R. Bellringer pers. comm.; Nelson ranges, K. Walker pers. comm.; Castle Hill buttercup in the Lance McCaskill Nature Reserve, McCaskill 1980) of New Zealand high altitude vegetation communities after the exclusion of grazing mammals other than hares.

In some situations hares may be beneficial to New Zealand grasslands. These situations are when grazing suppresses exotic grasses, as described above, or an introduced weed. For example, Blay (1989) suggests that hare grazing in the Avoca Valley, Canterbury, of Hieracium pilosella is beneficial to the native flora. A study of moth faunas in montane, tussock grasslands of the Waimakariri River Valley in Canterbury (White 1991) observed that areas with conspicuous hare pellets had a greater frequency of low herbs and low shrubs, and a more diverse moth fauna, than did surrounding areas of rank Agrostis. Indigenous moth diversity decreases when invasive sward species displace endemic species, so the increasing scarcity of some endemic food-plants (especially herbs), could ultimately lead to loss of local fauna dependent on them. It may be that an optimised level of hare grazing of Agrostis could help conserve indigenous insect fauna in these modified grasslands, without overgrazing the endemic plant species (White 1991). Another area where hares may be beneficial to New Zealand grasslands is in the transfer of nutrients from their feeding grounds on the valley floor to higher slopes where they spend the day on mountain lands (Flux 1990). However, there has been no quantitative investigation of this claim.

4.2 Relative impacts of grazing by hares and other introduced herbivores
It is very difficult to differentiate the impact of hares on the grassland from the impacts of other mammalian grazers, such as deer, chamois, thar and possums. The distribution of hares overlaps with rabbits at lower altitudes, with chamois, thar and deer at high altitudes, and also with wild horses and possums (Blay 1989, Hawes et al. 1986, Horne 1979). Hares also share their habitat with many insect species. Compared to the grazing ungulates, which tend to pull tussocks out by the roots, cut the soil with their hooves, and have high per capita forage requirements, hares seem to do less damage (Flux 1967a). Compared to rabbits, hares seldom graze as closely and occur at much lower densities (Flux 1967a).
In several areas of New Zealand hares are reported to be the main grazer, greatly outnumbering the larger ungulates. These areas include the high country of the West Coast of the South Island (T. Farrell pers. comm.) and some of the montane grasslands of the central North Island (B. Fleury pers. comm.). A comparison of relative metabolic requirements and forage intake of various introduced herbivores is given in Table 3. This suggests that hares could be responsible for a fairly high proportion of grazing damage to vegetation in some areas, depending on the abundance of other species present. Before initial control of one or more herbivore species in a high altitude area, managers should consider these types of calculations, which may aid in identifying the species that should be prioritised for control in that particular area. Diet selectivity of the various species is a further consideration that requires better quantification; this is discussed further in section 6.

Rabbits have been observed to dominate hares in 45 of 55 encounters on a communal feeding area (Flux 1981a). If rabbits numbers were substantially reduced by a biocontrol agent such as Rabbit Caliciviruses Disease, then it is possible that hare numbers and impacts would increase in such areas. For example, hare numbers in the UK increased in the late 1950s and early 1960s following the spread of myxomatosis in the rabbit population (Tapper 1992).

The main insect herbivores that hares share their habitat with are grasshoppers. Grasshoppers are low volume grazers, but they are selective on important ground cover species with low biomass, which thus may be under high grazing pressure (White 1974). In low-productivity tussock grasslands, the frequent paucity of inter-tussock vegetation may reflect persistent grazing pressure on preferred plant species by grasshoppers (White 1974).

### Table 3 Relative metabolic rates and vegetation consumption of introduced herbivores in high altitude areas

<table>
<thead>
<tr>
<th>Species</th>
<th>Weight (kg)</th>
<th>Basal metabolic rate (kcal day^-1)</th>
<th>BMR relative to hares</th>
<th>Density where present (ha^-1)</th>
<th>Forage intake relative to hares</th>
</tr>
</thead>
<tbody>
<tr>
<td>rabbit</td>
<td>1.7</td>
<td>104</td>
<td>0.6</td>
<td>1-10</td>
<td>3.5</td>
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<tr>
<td>possum</td>
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<td>105</td>
<td>0.6</td>
<td>0.1-1</td>
<td>0.3</td>
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<tr>
<td>hare</td>
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<td>179</td>
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<td>1.0</td>
</tr>
<tr>
<td>chamois</td>
<td>31</td>
<td>920</td>
<td>5.1</td>
<td>0.01-1</td>
<td>0.3</td>
</tr>
<tr>
<td>goat</td>
<td>33</td>
<td>972</td>
<td>5.4</td>
<td>0.1-0.5</td>
<td>3.1</td>
</tr>
<tr>
<td>thar</td>
<td>45</td>
<td>1216</td>
<td>6.8</td>
<td>0.02-1</td>
<td>0.8</td>
</tr>
<tr>
<td>red deer</td>
<td>58</td>
<td>1478</td>
<td>8.3</td>
<td>0.01-0.1</td>
<td>0.5</td>
</tr>
</tbody>
</table>

1. Average of female and male (adapted from King 1990)
2. Basal metabolic rate assumed equal to 70W0.75 for eutherians and 48.6W0.75 for marsupials (Robbins 1983).
3. Figures based on King (1990), J. Parkes pers. comm. and personal observations. Different estimates will apply in each management area.
4. Calculated from BMR x minimum density where present, assuming an average hare abundance of 0.176 ha^-1. These values will vary depending on the relative abundance of each species in each management area and will typically be an order of magnitude higher when such species are near the high end of their density range.
In low-productivity tussock grasslands, the frequent paucity of inter-tussock vegetation may reflect persistent grazing pressure on preferred plant species by grasshoppers (White 1974). Batcheler (1967) estimated grasshopper biomass on alpine grassland bordering screes at 20-30 kg ha\(^{-1}\), a greater biomass than all the introduced mammals together (Gibb & Flux 1973). The grasslands are presumably adapted to grazing by indigenous invertebrate fauna, as hares may be having their greatest impact in these intertussock areas (G. Rogers pers. comm.), it is likely that the present-day impacts of these grazers is confounded.

### 4.4 Key findings of hare impact studies in New Zealand

- Hares can inhibit the recovery, regeneration and recruitment of snow tussocks (p 11).
- Hares can affect the recovery of native sedges, exotic grasses and native herbs in wetland (p 12).
- In some red tussock-hard tussock grasslands hares can affect the rates of recovery of red tussock, hard tussock and exotic grasses (p 12).
- Hares can reduce the available plant material in fescue tussock, subalpine grassland (p 12).
- In some parts of their range, hare populations are likely to be consuming more forage per hectare than possums, chamois, thar or deer (p 13). However, elsewhere, the impact of these grazers is probably far more significant than that of hares.

### 5. RESEARCH NEEDS

Research on hare impact in high altitude vegetation in New Zealand is very limited, but it is likely that hares are causing grassland degradation in at least some areas (see Section 4). There are many gaps in our knowledge of hare impact around New Zealand, including population estimation, diet composition and selection, habitat use, and the long term impact on our indigenous vegetation communities. Research that could help fill these knowledge gaps is discussed in this section. Methods of hare control are also reviewed but are given less emphasis, as their use depends on the results of appropriate impact studies.

#### 5.1 Counting hares

The goal of hare management is to limit their impact on plant communities. Nevertheless, the evaluation of specific management actions such as hare control is likely to require monitoring of hare abundance. It is important that any hare survey should be accompanied by an evaluation of its accuracy and by a statement of the constraints and definitions under which the hares were counted (Lancia et al. 1994). The numerous methods used to estimate abundance are reviewed below.

**5.1.1 Direct counts**

Seldom, if ever, is it possible to obtain a total count of hares by direct observation over an entire survey area. Direct counts of hares in small areas have been made in New Zealand by hide observations and dead hare counts (Flux 1967a), and overseas by flushing (e.g., Lechleitner 1958, Flux 1970, Hewson 1976), spotlighting (Lord 1961, Anderson & Shumar 1986), from an aircraft (Windberge & Keith 1977) and by line transect sampling (Webb 1942).
Flux (1967a) observed hares from a hide overlooking Cupola Basin, Nelson for 19 evenings and 24 mornings during summer; a maximum of four adult hares was seen in a 300 acre area. The evening counts, averaged 1.9 hares, with the maximum number of hares seen on 6 occasions. These were more reliable than the morning counts, which averaged 1.5 hares, with the maximum number of hares seen on only one occasion. Juvenile hares were secretive and were not seen from the hide. In autumn, about 50% of the population is the young of the year, so Flux estimated the autumn population of his study site to be about 8.

Dead hare numbers in an area can provide an indication to the numbers of live animals present (Flux 1967a). In Cupola Basin, an average of 3.8 dead hares were found during each year of the study, with most dying in winter. Based on mortality data from a population of mountain hare *Lepus timidus* in Scotland (Flux 1970), this indicated that roughly 8 hares were present.

Spotlighting was used to obtain estimates of relative hare numbers by Anderson & Shumar (1986) and Lord (1961). This method requires the area of investigation to be flat, free from high vegetation and easily accessible, which is rarely the case in New Zealand alpine and subalpine areas (e.g., Horne 1979). It has, however, been used to obtain satisfactory results to monitor rabbit populations over time for a reasonable amount of effort (Frampton & Warburton 1994).

Aerial counts can be accurate in low vegetation or snow, but would often be unsuitable for the vegetation of many New Zealand areas. Aerial counts using a forward looking Infrared (FLIR) camera has recently been trialed on New Zealand possums with some success (Livingstone 1995), and could be an effective method for hare survey if the expense could be justified.

Flushing hares is labour intensive and produces poor estimates as there is extreme variation in flushing distances and hares do not always flush (John Parkes *pers. comm.*).

Line transect sampling (Webb 1942, Lancia *et al.* 1994) involves transects of a designated length set out randomly within the area to be sampled. Counts of all animals seen are made as the observer travels along these transects (although maximum observation distance beyond which animals are not counted is sometimes established). The proportion of animals present that are actually seen is then estimated and the actual counts adjusted. Either perpendicular distance data, or both sighting distance and sighting angle data, are required to estimate sighting probabilities. The effort required to apply this technique to hares in New Zealand is unknown, but is likely to be considerable. There is also the problem of hares not always flushing.

5.1.2 Trapping and shooting

Standard ‘mark and recapture’ methods (reviewed in Seber 1982) involve tagging livetrapped hares, releasing them, and then estimating the proportion of tagged hares that are either retrapped, or at least reobserved, on a subsequent occasion. This method can produce reliable estimates of hare numbers and densities (e.g., Krebs *et al.* 1986a), but is very labour intensive. Hares are likely to be difficult to trap in alpine grasslands, where their densities are low and runs indistinct (J. Parkes *pers. comm.*).
Trapping and hunting methods that involve capture without release can also be used to estimate hare abundance. Removal methods can provide an absolute estimate of abundance and density, whereas catch-rate data (e.g., hares caught per 100 trap nights) can provide indices of relative abundance. Flux (1969) used “minutes to shoot one hare” as an index of hare population density in three study areas in East Africa. This index correlated well with estimates based on spotlight counts from a four-wheel drive vehicle. Difficulties associated with these methods include, the huge effort required to catch an adequate sample of hares and bias by weather, season, visibility and the observer. Biases must be carefully controlled for comparisons of indices generated from different surveys to be valid.

5.1.3 Sign counts: tracks and droppings

It is often easier to work with animal sign than to attempt to catch fast-moving individuals.

Counts of hare tracks on snow (e.g., Flux 1967a, Shibata 1985, Thompson et al. 1989) can provide a measure of hare abundance, but the necessity for winter surveys has obvious disadvantages. Flux (1967a) found that tracking hares in snow was most successful after a fresh snowfall during the night, as it was then possible to count only the tracks of the hares returning to their forms after a night’s feeding. Track counts from consecutive years in Cupola Basin, Nelson were found to consistently indicate seven and six hares, respectively.

Counting droppings has been used with mixed success to estimate hare numbers in New Zealand (e.g., Flux 1967a, Horne 1979, Parkes 1984) and overseas (e.g., Johnson & Anderson 1984, Krebs et al. 1986a). In general, this is not a labour intensive method and can be performed by one person. Droppings can be counted using either “standing crop” or “cleared plots”.

In New Zealand, estimates of hare densities from the standing crop of droppings have proven too variable to be useful. Absolute densities have been derived, but these require a number of measurements, each of which has a large scope for variability (Flux 1967a). In Cupola Basin, Flux (1967a) estimated hare numbers from droppings using the calculation:

\[
N = \frac{\text{total number of droppings}}{\text{defecation rate} \times \text{dropping decay rate}}
\]

The defecation rate equalled the average production rate of droppings of captive hares and of hares tracked in the snow over a whole night’s travel (hares do not produce droppings during the day in their forms)(average = 410 droppings). The dropping decay rate was measured from different sets of fresh pellets at different altitudes (average = 3 years). The number of droppings in the basin was calculated by counting the number of droppings in quadrats along line transects situated through representative vegetation types and extrapolating densities in favourable and unfavourable habitats over the whole area occupied by hares (total = 4.29 million droppings). Thus:
Hare impact on high altitude vegetation

\[ N = \frac{4290000}{410 \times (3 \times 365)} = 9.5 \text{ hares.} \]

This estimate was close to Flux's other measurements of population size. Unfortunately, however, given the scope for variability in each estimate, the number of hares could have been anything between 2 and 109. In Tongariro National Park, Horne (1979) used similar methods to Flux (1967a) and also had problems with the accuracy of estimation of dropping decay rates and defecation rates. Neither Flux nor Horne considered their methods of density estimation to be sufficiently accurate to be useful.

Cleared plot methods avoid some of the problems inherent to counting standing crops of droppings, such as variable decay rates. “Turd transects” have been successfully used to estimate the population density of snowshoe hares *Lepus americanus* near Kluane Lake, Yukon Territory Canada (Krebs et al. 1986a). Droppings were cleared from each of fifty optimally sized quadrats (5.08 x 305 cm = 0.155m²) in six areas of variable habitat. The quadrats were counted annually for seven years, clearing each quadrat as it was counted. Optimal quadrat size was determined by measuring fifty quadrats of five different shapes (square, rectangular) and sizes (0.25 - 0.8m²) and selecting the size that produced dropping estimates with the lowest variances that could be effectively sampled by one or two persons. Because plots were cleared each year, and the pellets all lasted at least that long, there was no need to estimate dropping decay rates. A similar cleared-plot method was used to estimate the densities of mountain hares *Lepus timidus* in Sweden (Angerbjorn 1983), also with successful results. Parkes (1981, 1984) used cleared plots in New Zealand to estimate a change in hare density after poisoning and to determine hare habitat use (see section 5.3).

The Yukon turd counts were highly correlated (\( r = 0.94 \)) with estimates generated by Jolly-Seber mark-recapture techniques (Seber 1982, Krebs et al. 1986a). Since the two techniques provided similar data, the much less laborious pellet count method was favoured thereafter by the researchers.

Cleared plot methods can be biased by hares being attracted to and defecating around plot pegs (J. Flux *pers. comm.*). Clearing a plot may also attract hares. Other problems that need to be considered are diets that produce pellets that disintegrate in the first shower of rain (e.g., *Celmisia*) and pellets blowing onto cleared plots (fewer can blow off if they get removed; in standing crop counts this balances out).

The advantages and disadvantages of the abundance survey methods described above are summarised in Table 4.

5.2 Hare diet

The plant species that hares impact on can be investigated by assessing the composition of their diet, although such studies obviously cannot provide information on species that have already disappeared from an area (Flux 1967a). Research to date (Flux 1967a,
## Table 4 Advantages and disadvantages of hare population estimation methods.

<table>
<thead>
<tr>
<th>Method</th>
<th>Advantages</th>
<th>Concerns</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Direct Counts</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observations from hide</td>
<td>more reliable in the evening; inexpensive</td>
<td>unsuitable for large areas; requires many days</td>
<td>Flux 1967a</td>
</tr>
<tr>
<td>Dead hares counts</td>
<td>dead animals don’t move; inexpensive</td>
<td>need to know how dead hare numbers relate to live population numbers; this may vary from year to year</td>
<td>Flux 1967a, Flux 1970</td>
</tr>
<tr>
<td>Spotlight counts</td>
<td>suit large areas, can provide precise indices of abundance with acceptable sampling effort</td>
<td>biased by weather, season and observer; free from vegetation with easy access; heavy equipment</td>
<td>Lord 1961, Horne 1979, Anderson &amp; Shumar 1986, Frampton &amp; Warburton 1994</td>
</tr>
<tr>
<td>Aerial counts</td>
<td>suit very large areas; reliable in low vegetation single event</td>
<td>vegetation will often obstruct; expensive</td>
<td>Windberg &amp; Keith 1978</td>
</tr>
<tr>
<td>Flushing counts</td>
<td></td>
<td>labour intensive; results often inaccurate; animals relocate or hide</td>
<td>Lechleitner 1958, Flux 1970, Hewson 1976</td>
</tr>
<tr>
<td>Line transect counts</td>
<td>one observer can cover large areas</td>
<td>animals relocate or hide; assumes all animals on line are detected; distance and angles must be measured accurately</td>
<td>Webb 1942, Lancia et al. 1994</td>
</tr>
<tr>
<td><strong>Trapping and shooting</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mark-recapture</td>
<td>can provide an estimate of absolute density</td>
<td>labour intensive; low trap success; unsuitable for large areas</td>
<td>Flux 1969, 1970, Krebs et al. 1986a</td>
</tr>
<tr>
<td>Shooting</td>
<td>contributes to hare control; provides material for diet analysis</td>
<td>huge effort required to catch adequate sample size; biased by weather, season and observer</td>
<td></td>
</tr>
<tr>
<td><strong>Sign Counts</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Counting tracks</td>
<td>successful after fresh snow falls</td>
<td>requires extended periods of winter fieldwork</td>
<td>Flux 1967a</td>
</tr>
<tr>
<td>Dropping counts (i) standing crop</td>
<td></td>
<td>highly variable results</td>
<td>Flux 1967a, Horne 1979</td>
</tr>
<tr>
<td>Dropping counts (ii) cleared plots</td>
<td></td>
<td>need at least two sampling occasions; plots must be relocatable</td>
<td>Angerbjorn 1983, Parker 1984, Krebs et al. 1986a</td>
</tr>
</tbody>
</table>

^1 New Zealand examples are in italics
Hare impact on high altitude vegetation

Horne 1979, Blay 1989) suggests that hare diet primarily reflects plant availability, but with some plant selectivity (see Section 3.2.1).

Casual observations of plants eaten by hares may give a misleading impression of their importance in the diet; some plants show bite marks readily or recover slowly from hare damage. *Hymenanthera alpina* bushes are very palatable to hares and show severe hedging in Cupola Basin, Nelson, yet are not a major food item (Flux 1967a). Hares rarely killed such hedged plants, although they did take most of the current growth year after year.

Quantitative data on diet in a particular area can tell a different story about hare impact than casual observations of hare browsed plants. Hare diet can be quantified before, during or after digestion (Table 5).

| Table 5. Advantages and disadvantages of hare diet analysis methods |
|------------------------|----------------|---------------------------------|------------------|
| Method | Advantages | Concerns | Examples |
| **Before digestion** | | | |
| Observations from a hide, following tracks in snow, radiotracking | plants are easily identified; little lab work required | may be difficult to differentiate between hare browse and other animal browse marks; long hours in the field | Flux 1967a, Pulliainen & Tunkkari 1987, Johannessen & Samset 1994 |
| **During digestion** | | | |
| Stomach content analysis | Provides detailed qualitative and quantitative information; reduced time in field | require adequate samples of shot hares; staff experienced in cuticle identification; long hours in the laboratory | Sparks 1968, Homolka 1986, Blay 1989 |
| **After digestion** | | | |
| Dropping analysis | easily collected throughout the year | requires at least two visits; experienced staff; long hours in the laboratory | Horne 1979, Johnson & Anderson 1986, Daniel et al. 1993 |

1 New Zealand examples are in italics

Direct observation of feeding hares is one method to determine diet. A hide was used at Cupola Basin, Nelson, to record hare feeding localities. Each locality was then further examined for the number of bites taken from each plant species (Flux 1967a). To locate where hares had fed during winter, Flux (1967a) followed tracks made by hares after fresh snow falls. A similar technique was used to determine the winter diet of mountain hares *Lepus timidus* in Finnish Forest Lapland (Pulliainen & Tunkkari 1987). Mountain hares were followed by radiotelemetry to determine their diet in Norway (Johannessen & Samset 1994). Horne (1979) attempted to use an infra-red night viewer to locate and observe feeding hares, but was unsuccessful. A major problem with direct observations of hare is differentiating between their browse marks and those of other animals (particularly possums) on soft vegetation.

Diet determination during digestion involves detailed examination of dead animals' stomach contents, which can provide both qualitative and quantitative information about
Hare impact on high altitude vegetation

Hare diet (e.g., Sparks 1968, Homolka 1986, Blay 1989). Plant material from the stomach is identified with a microscope by cuticle analysis; a time consuming process that requires training in cuticle identification. There is considerable variation in the stomach contents of individual hares and an adequate number of hares must be killed to obtain reliable data (Horne 1979). Stomach samples will give a biased indication of hare diet if some species are rapidly digested or are difficult to identify.

Dropping analysis, or after digestion dietary analysis, is the simplest and most frequently used method of analysing hare diet (e.g., Horne 1979, Johnson & Anderson 1986, Daniel et al. 1993). Droppings can be readily obtained from most habitats in practically unlimited quantities throughout the year. Plant remains in each dropping are identified by microscope (Sparks & Malecher 1968, Horne 1979); as with stomach content analysis this is time consuming and requires training. Data obtained by dropping analysis are similar (both quantitatively and qualitatively) to that obtained by stomach content analysis (Homolka 1986). It is also fairly similar to pre-digestion analysis data, although Flux (1967a) found that the winter proportion of Chionochloa to Celmisia was higher by field observation than by dropping analysis (the two methods gave similar results in summer).

The most common method of dropping analysis involves the establishment of plots that are cleared at regular intervals. Depending on how frequently droppings can be collected, they can be used to assess monthly or seasonal variation in diet.

Of the dietary analysis methods reviewed above, dietary analysis from droppings collected from plots located randomly within stratified habitats is probably the most practical technique for use in New Zealand. Droppings can be collected and carried by a single person so that time in the field is minimised using this technique.

5.3 Habitat use and diet selection

Habitat use and diet selection studies often use similar techniques and so are combined in this section. Direct methods include observation and radiotracking. Indirect methods are dependant on evidence of hare activity within an area, for example browsed vegetation, droppings or tracks (Litvaitis et al. 1994).

Hare presence or absence can be most readily determined by the presence or absence of their droppings (Flux 1967a, Bathgate 1974, Hayward 1977, Hawes et al. 1986). Dropping abundance can also provide some information on broad habitat preferences of hares, e.g., between forest and grassland in west Nelson (Hickling 1985). However, since droppings may persist for months or years, "standing crop" counts are not suitable to assess short term or seasonal shifts in habitat use.

The cleared plot technique (as per section 5.3) provides better habitat preference information than do standing crop counts. For example, Parkes (1981) used cleared, relocatable, 0.09m² circular plots counted at 60-day intervals to determine seasonal changes in habitat use in the Avoca River catchment, Canterbury. Dropping counts were also used to provide a measure of the effect of a poisoning program in the catchment. A similar technique was used by Hewson (1989) to determine grazing preferences of mountain hares Lepus timidus on heather moorland and hill pastures in Scotland. In Nevada, USA, monthly counts of blacktailed jackrabbits Lepus californicus droppings
were used as an index of jackrabbit use of new rangeland seeding (McAdoo et al. 1987); the number of jackrabbit droppings was assumed proportional to jackrabbit grazing intensity.

The optimum plot size and counting interval for any given habitat will give dropping counts with homogeneous variances and should be able to be easily sampled by one person. These need to be determined by a pilot study. The counting interval needs to take into account hare diet; as previously mentioned some diets produce pellets that disintegrate in the first shower of rain. A suitable size is likely to be 0.1 m² (J. Parkes pers. comm.).

Selection for particular plants by hares can simply be determined by comparing dietary composition to vegetation surveys of a particular area (e.g., Horne 1979, Blay 1989). A wide range of food preference indices are available and are reviewed by Norbury & Sanson (1992).

Plant selection can also be determined by estimating the amount of foliage consumed from the amount of droppings produced. For example, in a northeastern Colorado rangeland, USA, the amount of herbage that blacktailed jackrabbits were consuming was determined by sampling at 3-month intervals 20 permanent plots (30 x 50 cm). These were distributed in a regular-random pattern to serve as sub-sample units for assessment of total dropping production (Hansen 1972). The plots were initially cleared and newly deposited droppings collected, dried and weighed to give a measure of herbage intake. The relative abundance of plants in the diet was calculated by examination of pellets contents under a microscope (Sparks & Malecher 1968). A digestion index (Arnold & Reynolds 1943) was used to calculate the total amount of foliage removed. Similar methods were used in a study of brown and mountain hares Lepus timidus grazing in heather moorlands in northeast Scotland (Welch 1984), but hare damage was estimated by assessing the percentage of shoots and leaves grazed in plots and relating this to dropping density. Diet selection of the mountain hare in Finnish Forest Lapland was determined by measuring the size of “cut” twigs and comparing the amount of twigs consumed (measured by weight) with the amount of material available (Pullianinen & Tunkkari 1987).

In New Zealand, a method for estimating the proportion of foliage eaten by introduced herbivores was developed by Nordmeyer and Evans (1985) in west Nelson. This involved stripping the leaves of plant species, drying and weighing them. Plant height - leaf biomass relationships were then determined by linear regression and used to generate forage biomass estimates from plant height data obtained from field surveys. The available biomass estimate were then compared with herbivore dry matter intake rates obtained from the literature.

Plant selection can also be assessed from browsing sign, provided that the marks left can be separated from the browse marks of other animals. This is difficult in New Zealand but has been done successfully overseas. For example, a study of snowshoe hares Lepus americanus in two Canadian forests measured their browse selection by randomly selecting plots in different forest types (Telfer 1972). Within each plot hare browsing was distinguished from deer browsing by the way twigs were clipped. The number of browsed twigs was estimated for each plant species and related to estimates of the
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amount of browsable plant material that remained to obtain a measure of food plant preference. Such data can also be used to determine habitat use. The extent of blacktailed jackrabbit *Lepus californicus* browsing of desert shrubs in New Mexico, USA was measured by classifying the number of branches browsed on shrubs as none, low (1-5 branches browsed) or high (>5 branches browsed) (Ernest 1994). Krebs *et al.* (1986b) used a photographic technique to assess the amount of woody twigs browsed by snowshoe hares *Lepus americanus* in southwestern Yukon.

Measurements of foliage consumption could also record the part or age class of a particular plant that has been grazed. This aspect of diet selectivity has not been investigated in New Zealand, but is likely to be important in impact studies.

Hares can be followed by radiotracking and spotting scopes to determine diet selection. Spotting scopes give better detail than radiotracking (J. Flux *pers. comm.*). The amount of each species grazed is estimated and then compared to the availability of each plant species in the area. The proportions of different food plants grazed are assumed to represent the hares’ diet. Diet selection of mountain hares *Lepus timidus* in a low-alpine area in southern Norway was assessed in this way; radiocollared hares were tracked at dawn and dusk (Johannessen & Samset 1994). Studies of hares at only dawn and dusk are likely to be misleading; J. Flux (*pers. comm.*) found the diet of Scottish hares on the way to the feeding grounds, and on the way back (dawn and dusk) was 80% heather, but all night they searched for white clover or grass seed-heads (as did the hares in Cupola Basin, Nelson).

Radiotracking has been used by Parkes (1981) to assess hares’ seasonal use of different parts of his study area in the Avoca river catchment. Twenty five hares were fitted with radio transmitters and their movement was monitored using two fixed double-yagi aerials set about 800m apart along the river edge of the valley flats. The hares were tracked for four 24 hr periods each month for a year. The results from the radiotelemetry were similar to those obtained by cleared plot dropping counts.

A summary of the methods used to determine habitat use and diet selection of hares is given Table 6.

5.4 Long term vegetation impacts

5.4.1 Study design

Hares have been present throughout much of their New Zealand range for many decades. Their past impacts may have been significant in some areas, but in many cases will have been masked and confused by the presence of other introduced grazers. Their present impact may not seem great, but the full effects of hare browsing now or in the past may not yet be evident. For example, hares inhibit the regeneration of snow tussock (Rose & Platt 1992). These long lived plants may only show the consequences of this after many years, e.g., lack of regeneration may mean that affected snow tussock stands eventually die out. Hares may prevent regeneration of the threatened *Hebe armstrongii*; the only known individual to flower in the wild was surrounded by wire mesh (R. Smith *pers. comm.*). Other plants, such as *Hymenanthera* bushes, may show marked damage from hare grazing, despite being a minor component of their diet (Flux 1967a). Thus, it is
A different approach to exclusion plots was used by Rose and Platt (1992) in their study of snow tussock in montane-subalpine, formerly forested sites in the Avoca and Harper river valleys. Their plots ranged in size from 24-900 m², so as to include a pre-determined number of tussocks (in this case 30) in each plot.

Three exclusion plots have been set up in a stand of the threatened Hebe armstrongii to investigate the effect of different herbivores. One plot excludes all herbivores, another excludes pigs, cattle and sheep but allows hares and rabbits to graze, and the other is a control plot. No results are yet available from this work (R. Smith pers. comm.)

Three potential problems with exclusion plots that have not been dealt with in the literature are their initial placement, subsequent maintenance, and potential effects on grazing. Firstly, plots need to be located in areas where hares are having an impact; this can be determined from studies of diet, habitat use and diet selection. Plot placement is of particular importance in the alpine zone where hare habitat is often patchy. This problem is evident in recent hare impact studies, where photopoint monitoring is being used to supplement exclosure plot data (Miller 1995). The second problem is maintaining exclosures in true alpine areas where they are subject to avalanches and rockfall and seldom last for more than a year (J. Parkes pers. comm). The third potential problem is that hares are attracted to plot pegs and markers (see Section 5.1).

An alternative approach to measuring long term hare impact, which has not been used in New Zealand, is to reduce hare numbers in large treatment areas and compare subsequent changes in the vegetation with non-treatment areas where hare numbers remain high. Reduction in pest numbers, rather than complete elimination, is the most likely scenario for hare control programs so that the latter type of study is likely to be the most relevant for managers. A reduction in hare numbers may significantly change the impact they are having on the environment, e.g., a study of snowshoe hares Lepus americans in Kluane, Yukon (Smith et al. 1988), found heavily browsed bushes rapidly recovered after a natural decline in hare numbers.

A critical issue for managers is how much control is needed to achieve conservation goals in an area, which in turn determines the methods and costs that will be involved. Only one study (Parkes 1981) has investigated hare population recovery after control. In the Avoca River valley, inland Canterbury, it took only one breeding season for the hare population to recover from this control to about half its pre-poisoned level (Figure 5.1). However, the population has never subsequently recovered to its original size, possibly due to a change in the vegetation community. It is not known whether the population recovered by breeding or immigration or a combination of both. Rapid recovery means that any control programs will require an ongoing investment in regular poisoning operations if conservation benefits are to be achieved. Planning of ongoing control requires research into the likely rates of hare immigration into control areas from surrounding habitats, which has implications for the optimal size of control areas.

5.4.2 Plot sampling
Interpretation of the impact of introduced browsing animals requires that changes in the population structure and seedling regeneration of browsed grassland communities be measured over time (Rose & Platt 1990). Successful vegetation monitoring requires methods that are able to accommodate the problems associated with sampling New
Zealand native tussock grassland and shrubland. Firstly, large and small plants occur together and an adequate sampling of both is required; in the tussock grassland most forage is supplied by small plants, whereas the tussocks are the physiognomically important plant determining the microclimate within the vegetation community. Secondly, the canopy spread of the larger plants varies at different levels within the vegetation, and hence needs to be measured at a range of different heights. This is particularly important in areas that receive deep winter snow cover that allows hares to browse much higher in the vegetation than would otherwise be possible in summer. Thirdly, most study areas will include a range of vegetation types on steep slopes (Scott 1965).

Figure 5.1 Changes in hare abundance (indexed as the number of pellets recruited every 60 days) on short-tussock river flats of the Avoca River, inland Canterbury before and after hare control in mid-1980. Pellet density was measured annually between March and May, each year when hare density is at a maximum (J. Parkes unpub. data).

Frequency sampling is often used in vegetation reconnaissance survey because it is a simple field technique that integrates several aspects of a plant's abundance. However, frequency is a complex characteristic determined by plant density, cover, pattern and by quadrat size, so frequency sampling is seldom suitable for intensive work (Scott 1965).
When intensive sampling is required, the point analysis method is often used. This method can be extended to measure plant height. However, the point analysis method is time consuming and requires that the plants remain stationary and hence is often unsuitable for work in windy New Zealand (Scott 1965).

The Scott height-frequency sampling method is a variation of point analysis which considers the plants as entities and measures their vertical distribution by recording species frequency in successive layers within a vegetation community (Scott 1965). Rogers (1991, 1994) successfully used this technique for hare damage monitoring and recommended it for future studies (see also Dickinson et al. 1992).

Rose and Platt (1992) and Rose et al. (1990) used a sampling approach that involved mapping each tussock. For each, the basal diameter, height, number of flowering culms and the presence/absence of recent browsing damage were recorded. Crown death was estimated for tussocks >5 cm in diameter and tiller counts were made for a sample of individuals <15 cm in diameter. Population structures were then analysed by determining diameter class and age-state distributions. Rose et al. (1990) recognised four putative age states - seedling, juvenile, mature and senescent - that differed in basal diameter, number of tillers, leaf length and crown depth. Other species were not accounted for, although the approach could possibly be adapted to do so.

A simpler and less time-consuming method of monitoring vegetation uses indicator species, which has been suggested for monitoring thar impact in New Zealand (Miller 1995). An indicator species must be carefully chosen; common species such as tussocks can provide a good, general indication of community condition but do not necessarily reflect impacts on less common plants. However, rare plants do not usually make good indicators (D. Given pers. comm.). Possible indicator species are the Aciphyllas which only seem to be grazed by hares (J. Parkes pers. comm.).

A further important consideration of hare impact studies is the slow growth of many indigenous plants in alpine and subalpine environments; monitoring will need to be over a very long period of time. Adequate baseline data should be collected in both treatment and non-treatment areas before hares are excluded or controlled; replication of treatment areas is obviously important, although costly to achieve.

To summarise (see Table 5), determining the long term impact of hares on high altitude vegetation could be assessed by reducing the number of hares either through population control or permanent exclusion plots and measuring the vegetation response. Plots can be designed to measure hare impact or the impact of other grazers as well. Vegetation response can be measured using the Scott height frequency method, by mapping tussocks or with indicator species. To date, the Scott height frequency method has provided the best information on vegetation community response to hare browse.

5.5 Hare control
Hares have been controlled in agricultural land since soon after their introduction to New Zealand because of their impact on a wide variety of shrubs, herbaceous plants, crops and young plantation trees. In contrast, there have been a few attempts to control hares in subalpine environments and no attempts in alpine environments. This section briefly reviews methods of hare control and previous control attempts. It does not attempt to
Table 5 Advantages and disadvantages of methods for measuring the long term impacts of hares on the environment.

<table>
<thead>
<tr>
<th>Method</th>
<th>Advantages</th>
<th>Concerns</th>
<th>New Zealand examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>(i) by reduction of numbers in control areas</td>
<td>information directly relevant to managers</td>
<td>difficult to maintain the population at a low level</td>
<td>none</td>
</tr>
<tr>
<td>(ii) by exclusion from semi-permanent plots</td>
<td>easily monitored over a long period of time</td>
<td>provides little or no information on the benefits of sustained hare control</td>
<td>Rogers 1991, 1994; Rose and Platt 1992</td>
</tr>
</tbody>
</table>

**Exclosure plot type**

| (i) Excludes all mammals (including hares) | maximises the potential vegetation response | does not differentiate between hare and other animal damage | Blay 1989; Rose & Platt 1992 |
| (ii) Bisected - excluded all mammals on one side, and all mammals except hares on the other. | Provides information of damage done by both hares and other mammals | extra cost and effort; possums and rabbits may still have access | Rogers 1991, 1994 |

**Vegetation sampling method**

| (i) Scott height-frequency | provides comprehensive details on plant composition, and structure | does not specifically measure tussock condition | Scott 1965; Rogers 1991, 1994 |
| (ii) Tussock mapping | provides detail on tussock condition | need to combine with another method to measure intertussock flora | Rose & Platt 1990; Rose & Platt 1992 |
| (iii) Indicator species | quick to monitor | does not necessarily reflect impacts on all species; determining an appropriate species | Miller 1995 |
| (iv) Photo-point analysis | quick to monitor | does not provide detail on individual species | Miller 1995 |
Hare impact on high altitude vegetation

deal comprehensively with the many problems associated with the control and eradication of pest species in New Zealand (King 1993; Parkes 1993).

Methods which have been used for hare control include shooting, snaring, hare-proof fencing, poisoning, and biological control with predators.

Shooting has been considered by some to be the most cost effective method of controlling hares on agricultural land (e.g., Wellington Regional Council) because these habitats provide good access and visibility for shooters. In alpine basins, however, the rugged nature of the terrain poses both access and visibility problems for shooters. Although it could be possible to control hares by shooting (J. Parkes pers. comm.), the cost would be very high and the level of population reduction achieved might not be sufficient to provide any significant conservation benefits.

Snares placed in hares' runs and checked on a daily basis have been used where hares occur in high densities. In the alpine areas, however, hare populations are low and their runs indistinct, so snaring is unlikely to be efficient (J. Parkes pers. comm.).

Hare proof fencing (e.g., a netting fence at least one metre high with mesh no larger than 8-10 cm or electric fencing with the lower four wires about 10 cm apart), has been found to be ideal for small horticultural blocks or nurseries but is obviously of limited use in the alpine environment. It been used since 1948 to attempt to exclude hares, rabbits and other grazing mammals from rare plant communities in The Lance McCaskill Nature Reserve (approximately 6 ha) in inland Canterbury near Castle Hill (McCaskill 1980, 1982). The current fencing is 17 gauge, 1066 mm wide, 41 mm mesh netting which stands 900 mm above the ground with the remaining netting bent out along the ground. A further 450 mm wide netting is laid along the ground attached to it. However, these have not been sufficient to keep rabbits and hares out as they either dig under the fence or climb over it when there is a deep cover of snow on the ground. Periodic shooting is therefore required to keep the reserve free of these animals (R. Smith pers. comm.). The nearby Enys Scientific Reserve (also approximately 6 ha) which is also fenced to protect a rare species, Hebe armstrongii, has similar problems and additional fencing is used inside the reserve to protect transplanted seedlings (R. Smith pers. comm.).

Poison baiting of hares has been trialed with varied success. Previous attempts (Logan 1956, Parkes 1981) have been on river terraces in subalpine basins using boiled oats as bait; these were dyed green and impregnated with sodium monofluoroacetate (1080). These trials were in winter when the food was assumed to be in shortest supply so that hares might be more likely to accept the bait. Radiotracking studies, however, suggested that autumn would be the season when hares were most likely to encounter poison baits laid on river terraces. Only two of five hares monitored over a year in the Avoca River basin, Canterbury used the river terraces (Parkes 1981, 1984). Thus, in order to place the whole population at risk, baits would need to be either long-lasting or else spread over the hill slopes as well as the terraces.

One attempt at controlling hares on the Avoca Valley river flats (Parkes 1981) found that hare use declined by 40% after poisoning. Subsequent control by shooting reduced the population by a further 60%. However, the hare population subsequently recovered, rapidly, although not to its original size (see Section 5.4 and Figure 5.1). As previously
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mentioned, rapid recovery means that hare control programs will require an ongoing investment in regular poisoning operations if conservation benefits are to be achieved.

No studies have been done on the impact of poisoned oats on non-target species, such as birds or insects. There was no evidence of birds taking the bait in the Avoca Basin study of Parkes (1981, 1984, pers. comm.), however, kea are absent from this area. In lowland areas, birds are known to feed on and die from the chaff from cereal and carrot 1080 baits (e.g., Harrison in Spurr 1994), much of which is similar size to oats.

Other toxins used for rabbit and possum control in New Zealand (e.g., pindone) are more costly than 1080 and have not been trialed on hares.

Predators such as feral cats and ferrets, originally introduced into high country areas in an attempt to control rabbits, probably kill some hares, but it is uncertain whether they have any regulatory effect on hare populations. It is difficult to see how predator numbers could be enhanced to reduce hare numbers without having an unacceptable impact on non-target species.

Biological control using pathogens is arguably the only long term solution to hare problems in New Zealand. In Europe, widespread death of hares has been attributed to European brown hare syndrome (EBHS) (e.g., Gavier & Morner 1989, Sostaric et al. 1991, Duff et al. 1994, Scicluna et al. 1994). This host-specific disease was first isolated from hares in 1982 and has symptoms similar to Rabbit Calicivirus Disease (RCD) which has recently been introduced into southern Australia and is causing currently widespread death of rabbits. However, it is questionable whether EBHS or other pathogens would spread effectively among the sparse hare populations found in high altitude habitats, and resistance to the disease might eventually develop.

6. HARE MANAGEMENT IN HIGH ALTITUDE VEGETATION

Hare management is only one component of high altitude vegetation management (Figure 6.1), and so needs to be integrated into a more general conservation framework for these areas.

6.1 Identification of conservation values
The first question that land managers need to ask is what areas of high conservation value, such as localities containing rare plant species or communities, are possibly under threat from browsing mammals?

As there is no national list of such areas, each Department of Conservation Conservancy needs to identify rare plants and habitats that are potentially at risk from hares, using tools such as lists of threatened plants (e.g., Cameron et al. 1995) combined with geographic information systems (when these become available). Possums and goats are currently considered the greatest threats to New Zealand's vegetation communities and
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Figure 6.1 Flowchart of decisions involved in the management of hare impact on high altitude vegetation.
consequently the habitats which are considered most at risk are predominantly forests (J. Parkes pers. comm.) If hares do pose a threat to the indigenous flora, and there now exist many high altitude areas where hares outnumber the larger ungulates, then these areas may deserve more attention.

6.2 Vegetation trend assessment
The Department of Conservation, Landcare Research and some other groups monitor a range of vegetation in selected high altitude grasslands, primarily in areas where past or present grazing by domestic stock is an issue. However, vegetation trends in most areas are not currently formally assessed and concern about hare impact is consequently based largely on anecdotal evidence (see Section 4.1).

Any expenditure on hare control should be supported by long term vegetation monitoring to assess the effect of control (see Section 5.4).

6.3 Identification of critical pests.
A regime of “priority place - critical pest” has been suggested by Parkes and Nugent (1995) for an integrated national pest control strategy. They stipulate that the following crucial factors must be considered: the need to maintain conservation gains achieved under the present “worst pest - priority place” model (e.g., funding for hare control should not undermine any existing goat or possum control programme); the need for any system to provide sustained action; and the need for research to identify critical pests.

Potential critical pests can be identified at the most basic level from distribution maps of introduced herbivores. These are being compiled by Landcare Research, but are currently incomplete. If abundance data are available, Section 4.2 describes a method for assessing pest species status by estimating foliage consumption using relative abundance and metabolic rate data. Dietary studies can provide further information on critical pests: by contrasting the diet of sympatric herbivores in a particular area the animal which is responsible for the impact on particular species can be assessed. This approach has been used to identify the damage that different pests, (thar, deer and possum) are responsible for in the Rangitata/Rakaia area of the Southern Alps for thar management (Parkes & Thomson 1995). Each pest species was found to partition their food resources with thar eating mainly grass, chamois eating mainly shrubs and herbs and possums eating different species of shrubs, herbs and fruit when available. An earlier study in Cupola basin, Nelson Lakes National Park, compared the habitat, biomass and diet of deer, chamois, hares and grasshoppers and suggested that grasshoppers might have been the critical “pest” (Gibb & Flux 1973).

At present, there are few places where hares are obviously the main cause of grazing damage. One such place is the alpine area of Mt. Egmont, where hares are the only introduced grazing pest (J. Parkes pers. comm.).

6.4 Hare management
Parkes (1993) has highlighted the need for managers to clearly separate question of control strategy (e.g., should the objective of management be eradication or sustained control?); control tactics (e.g., should shooting or 1080 oats be used?); and control
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logistics (e.g., how much will it cost and how long will it take?). The main strategies available for hare control, ordered by decreasing benefit for conservation values are:

1. Local eradication
   If there are any isolated areas where hares could be eradicated (i.e., the entire population could be targetted and the prospects of recolonisation are negligible) then a one-off eradication programme might be worthwhile.

2. Prevention of range expansion
   It may be easier to prevent colonisation of areas that hares have not yet invaded or have undergone local extinction (e.g., parts of Nelson and Fiordland) than to control hares in areas where they are established.

3. Sustained control.
   In priority areas for hare control, the level of control necessary must be determined. Exclosures will be of limited use in addressing this question, because complete eradication of hares is unlikely to be a feasible management option. The benefits (or otherwise) of sustained control need to be assessed by controlling hare numbers in treatment areas and comparing vegetation responses with untreated areas. The self-regulatory nature of hare population density poses further problems for any control program, because they do not appear to be food limited and are likely to recover quickly. Adequate baseline data, and long term monitoring, will be essential for these studies.

4. Do nothing
   New Zealand has a high degree of endemism in its indigenous vascular flora and between 10 - 15% of these are considered to be at risk of extinction (Norton 1991). Until the impact of hares on these species is clarified it is unwise to assume that we can afford to do nothing about hares.

7. RECOMMENDATIONS

The following methods are recommended for hare research in areas of high conservation value:

- diet and diet selection studies, using stomach or dropping analysis, that can be related to vegetation availability data obtained by field survey (Sections 5.1, 5.3).

- development and validation of a suitable cleared plot technique for assessing hare population density and determining habitat use (Sections 5.2, 5.3)

- investigation of long term hare impact using both exclusion-plot and population reduction techniques (Section 5.4).

- Integration of data about hares and other introduced herbivores into an integrated pest management framework for one selected catchment, as a case study of the “priority place - critical pest” approach (Section 6.1).
These management recommendations should be initiated as soon as possible, not only for the sake of New Zealand's indigenous resources, but also to take advantage of the enthusiasm of the concerned Department of Conservation Conservancies that initiated this review. Three conservancies have already offered to support field studies on hares: Hawke's Bay Conservancy is prepared to provide sites and logistic support for field research; Southland Conservancy will contribute materials for construction of exclosures within the conservancy, study site access and expertise for monitoring; and Nelson/Marlborough Conservancy is willing to help establish and maintain hare exclosures.

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8. REFERENCES


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