Seasonal and Altitudinal Variations in Diet and Abundance of the European Hare (*Lepus europaeus* Pallas) in Tongariro National Park, New Zealand.

A thesis presented in partial fulfilment of the requirements for the degree of Master of Science in Zoology at Massey University.

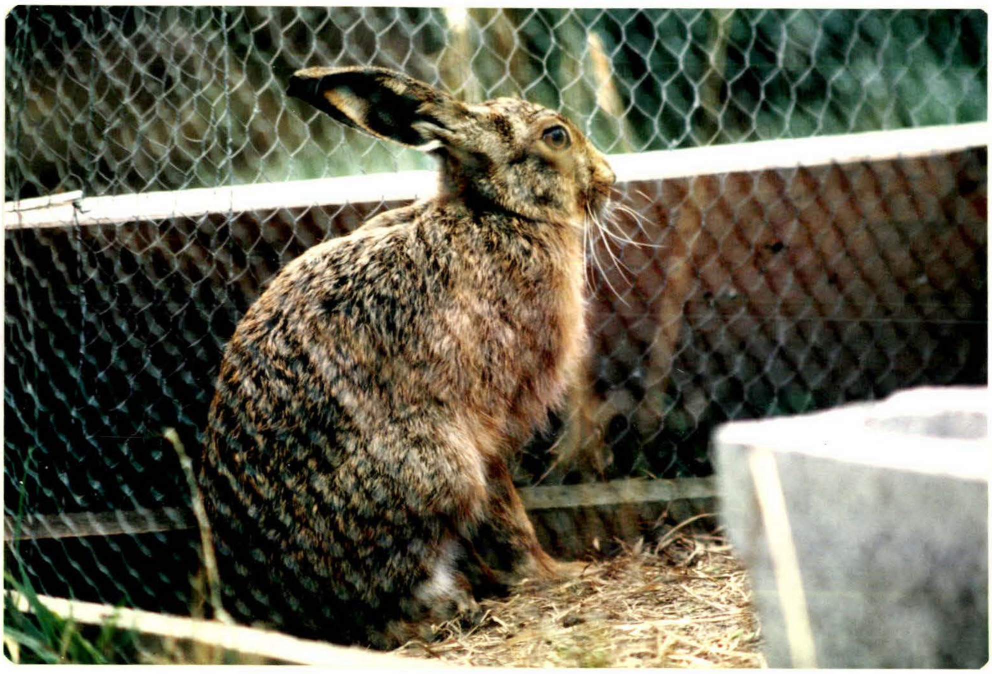
Rosemary Sylvia Claire Horne

February 1979.

To Tony,

with gratitude and love.

Frontispiece: Captive hare (*Lepus europaeus*).



ABSTRACT

The seasonal and altitudinal variations in diet and abundance of European hares (Lepus europaeus) in Tongariro National Park was studied from May 1977 to May 1978.

The main study area situated on the northern slopes of Mt. Ruapehu, adjacent to the Bruce Road, extended from 900 m to 1600 m a.s.l. A secondary study area established on the south-western slopes, adjacent to the Ohakune Mountain Road, extended from 700 m to 1500 m a.s.l. Transects were established altitudinally at 100 m intervals.

Dietary analysis was undertaken by identification of plant cuticles found within fresh faeces, collected monthly from the area surround each transect. Cuticle analysis results were supplemented by feeding using captive hares, direct field observations of browsed plant species and pellet samples from other areas within the Park.

Relationships between seasonal and altitudinal variations in chemical composition and availability of plant species are discussed with reference to dietary changes.

Faecal pellet density estimates were made along each transect, defecation rates of captives were determined and the affects of various factors on decomposition rate of pellets is discussed. Results of these three sections are combined to give an estimate of hare abundance.

Conclusions are drawn as to the importance of various factors in determining the diet of hares within the Park.

ACKNOWLEDGEMENTS

I wish to thank the many people who helped me in the preparation of this thesis. In particular, I gratefully acknowledge the help from my supervisor Dr. R.A. Fordham, whose constructive criticism and assistance was invaluable.

My thanks too, to the National Parks Board for its financial assistance for this study and to Mr. K. Mawhinney and Mr. W. Cooper, of the Tongariro National Park Staff for their assistance, especially with transport.

I am also particularly grateful to Dr. J.E.C. Flux for his helpful discussions and loan of reference material. Mr. J.G. Ryan gave invaluable help with the computer analyses and Mr. R. Wilman of the North Wairarapa Pest Destruction Board aided in the capture of hares. My fellow student, Mr. J. Wright also gave helpful discussions and suggestions.

My mother patiently corrected and typed the initial draft and Mrs. B. Billington typed the final manuscript. Finally, a special thanks to Tony for his patience and assistance throughout this study, which carried it through to completion.

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CHAPTER 1: INTRODUCTION

1.1. GENERAL.

The Order Lagomorpha contains over 60 species of rabbits, hares and pikas, inhabiting most parts of the world except Antarctica and Madagascar. Rabbits and hares were introduced to Australasia and Chile by settlers. (Harlow and Parsons 1974).

Although Lagomorphs were once included in the suborder Duplicidentata, as they superficially resembled rodents, fossil evidence has shown that the two orders were distinct by the Eocene (c. 60 million years b.p.). (Matthews 1952).

The lagomorphs are small to medium-sized animals, clothed in soft fur and with a short tail, or tail-less. They are digitigrade, or digitigrade on the fore-feet and plantigrade on the hind-feet; the toes - five on the fore and four or five on the hind-feet - are provided with claws, and the soles of all feet are hairy. Absence of canine teeth creates a wide gap between cheek teeth and the incisors, which are chisel-edged, have open pulp cavities, and grow continuously. Although the teeth have essentially the same general arrangement in lagomorphs and rodents, they are dissimilar in one main respect: rodents have one pair of incisors in each jaw, but lagomorphs have an extra pair, set behind the upper incisors.

In lagomorphs most food passes through the digestive tract twice. In the hare those pellets produced during the day are re-ingested directly from the anus. It is believed that refection provides the animal with vitamin B produced by bacterial action in the caecum but not absorbed there. (Matthews 1971).

The lagomorphs are divided into two families, the Ochotonidae containing a single genus and 14 species generally known as pikas, and the Leporidae containing nine genera and 52 species of rabbits and hares. (Harlow and Parsons 1974).

The hares belong to the largest genus <u>Lepus</u> with over 24 species, including the American Jackrabbits and Varying Hare, often called the Snowshoe Rabbit.

Hares are solitary animals and none of the species digs burrows either for shelter or to hold nests for their young. They rest up during the day among vegetation in slight depressions known as 'forms'. When born, the leverets are fully furred and have their eyes open. They soon leave their mother, each finding its own 'form' and being visited by the doe only to be fed. (Matthews 1952). According to Barrett-Hamilton (1912), 'A hare is as exclusively a vegetable feeder as any known animal. Its food consists of various kinds of herbage particularly of the mixture known as 'grass'; but its choice is much more restricted than that of the rabbit and it is said to select comparatively few plants.'

The brown hare <u>Lepus europaeus</u> Pallas ranges throughout Europe down to the Mediterranean, eastwards into Western Asia and south-eastwards to Asia Minor and Iran. It has been introduced into Scandinavia, Finland, Australia, New Zealand, Chile and the Great Lakes region of North America. (Southern 1964).

Southern (1964) describes the pelage as a typical 'agouti' colour; the underside is while and the cheeks, insides of limbs and feet are yellowish or ruddy. The species can be distinguished by long black-tipped ears, the tail, which is black on top, and the straw-coloured iris of the eye.

1.2 INTRODUCTION AND DISTRIBUTION OF HARES IN NEW ZEALAND

The English form of the common or brown hare described as Lepus europaeus occidentalis de Winton was liberated to provide sport and also perhaps to improve the food supply of the early settlers. (Wodzicki 1950). Donne (1924) states that the first hares to reach New Zealand arrived at Lyttleton in 1851, and that some months later they were reported on Banks Peninsula. In 1868 or 1869 more were imported from Australia and these arrived at Auckland. (Donne 1924).

Hares increased rapidly in numbers and soon spread in the years following their liberation. Donne believes that 'wherever introduced they have acclimatized' and Thomson (1922) gives several examples of this. By the early 1920's hares were recorded as being 'common from Cook Strait to Foveaux Strait' and well distributed in the North Island. (Thomson 1922). Wodzicki (1950) states that 'such a successful initial increase and spread was mainly possible because of the suitable climate, abundant food supply and a virtual lack of natural enemies'. From the report of Wodzicki (1948) and Gibb and Flux (1973) it appears that hares are today widespread, except for parts of Northland and Fiordland, and they are absent from Steward Island, the off-shore and sub-antarctic islands.

Habitats preferred by hares are scrub and native grasslands both below and above the timber line. Although hares are seen on agricultural land, this is considered by Gibb and Flux (1973) to be a secondary habitat, although there is some evidence that numbers are increasing due primarily to Rabbit Control Programmes of Pest Destruction Boards.

In tussock grassland, hares reach a higher altitude than rabbits. In the Kurow district (North Otago) they are reported 'everywhere up to 7,000 feet' (2130 m) and 'there are quite a number above the snowline. They will live in snowgrass under snow'. (Murdoch 1948). L.europaeus is common in alpine regions, whereas in Europe it would be replaced by the mountain hare *L. timidus* above 600 m. (Southern 1964).

Climate seems to be an important factor regulating the distribution of hares, with the drier eastern areas (Hawke's Bay, Marlborough, Canterbury and North Otago) carrying a greater density than western areas.

Summing up, Wodzicki (1950) suggests that after their initial abundance, hares, like other introduced mammals, have now reached a more or less stable position. The population has filled all suitable habitats and is now subject only to inherent fluctuations and to changes induced by control measures and other limiting factors.

1.3 PREVIOUS RESEARCH

In North America more has been written on the food habits of various Jackrabbits than any other aspect of their ecology. Studies include those of Vorhies and Taylor (1933), Aldous (1936, 1937), Arnold and Reynolds (1943), Haskell and Reynolds (1947), Bider (1961), Currie and Goodwin (1966), Hayden (1966), James (1967), Sparks (1968), Hansen and Flinders (1969), Flinders and Hansen (1972, 1973, 1975), Hansen (1972), Telfer (1972), Holter et al (1974) and Wolff (1978).

Across the Atlantic, in Europe and Great Britian hares are of great value as game animals and consequently extensive studies have been undertaken to improve their management. Dietary studies include those of Lund (1959), Flux (1962), Hewson (1962, 1974, 1976, 1977), Novikov and Timofeeva (1964), Fadeev (1966), Matuszewski (1966), Miller (1968), Myrcha (1968), Walker and Fairley (1968), and Lindlof et al (1974 (a) and (b)).

While a significant amount of literature has been written overseas, in New Zealand studies of L europaeus have been restricted to papers by Flux (1965 (a)) concerning the timing of the breeding season, the incidence of ovarian tumors (1965 (b)), the occurrence of a white wrist band (1966), reproduction and body weights (1967 (a)) and numbers and diet in an alpine basin (1967 (b)); and Douglas (1970) discusses movement of hares in the high country.

As little was known of the diet and abundance of hares in New Zealand, it was felt that a follow-up study to that of Flux (1967 (b)), in a different region, would be of significant value to the study of the ecology of the hare.

CHAPTER 2: STUDY AREAS

2.1 CHOICE OF SITES.

Recent geological evidence shows that New Zealand has been isolated from the rest of the world since the Cretaceous (c.70 million years b.p.). As a result of this isolation the forests and grasslands evolved in the absence of grazing and browsing mammals. The main aim of this study was to examine the diet of hares, being introduced mammals, living in an indigenous alpine environment. As adjuncts the effects of altitude and season on the diet and abundance of hares were also studied.

Modification of the indigenous vegetation within the Tongariro National Park by man and grazing and browsing mammals is relatively slight when compared with other mountain areas within New Zealand. The hare is probably the major browsing mammal above the timber-line, as deer are uncommon and opossums, though abundant, are generally confined to the forest. As it was known that hares were readily to be found in the area, and that the effects of other browsing mammals were minimal, the Park was chosen as the ideal site for this study.

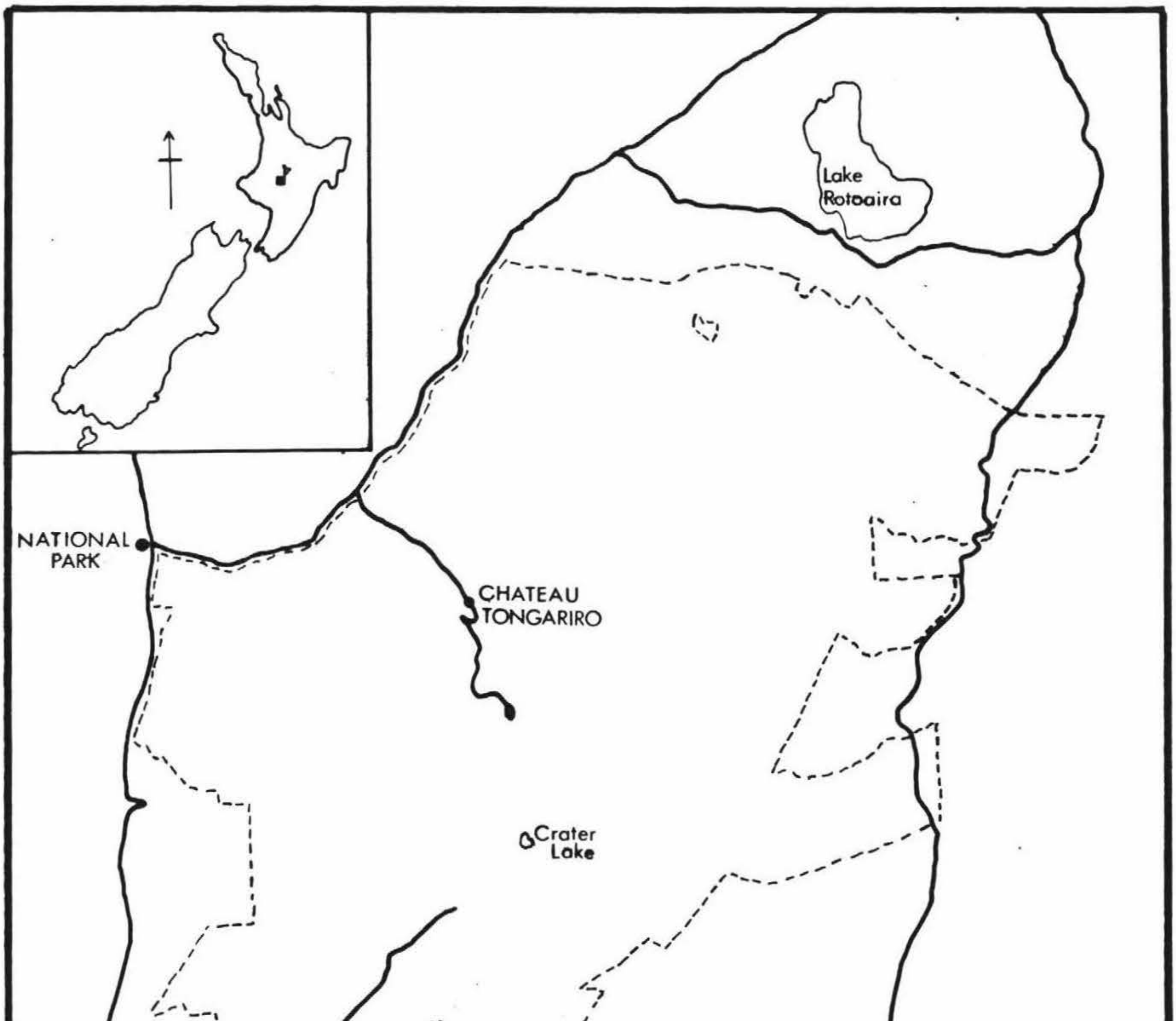
Tongariro National Park, situated on the central volcanic plateau of the North Island, was New Zealand's first National Park, being established in 1887 by a gift of 2,600 ha from Te Heuheu Tukino, paramount chief of the Ngati-Tuwharetoa tribe. By periodic additions of land the Park has increased in size to 70,100 ha and further extensions are planned.

The vegetation of the Park has been described both qualitatively and quantitatively in considerable detail: Cockayne (1908, 1928); Girdlestone (1909); Turner (1909); Aston (1927); Smith (1935); Chambers (1958-59); Atkinson (1961, 1971); Esler (1965); Rennison et al (1965) and Scott (1977 (a), (b), (c)).

The main study area, situated on the northern slopes of Mt. Ruapehu, adjacent to the Bruce Road, extended from 900 m to 1600 m a.s.l. A secondary study area, established on the south-western slopes adjacent to the Ohakune Mountain Road, extended from 700 m to 1500 m a.s.l.

Other areas of the Park were used for collection of pellets for dietary analysis and for additional vegetation observations.

Studies continued from May, 1977 to June, 1978.



Lake
Rotoaira
NATIONAL
PARK
CHATEAU
TONGARIRO
Crater
Lake
OHAKUNE
WAIOURU
kilometers
0 1 2 3 4 5 6 7 8
0 1 2 3 4 5
miles

2.2 SOILS AND CLIMATE.

The three major volcanic peaks included within the Park boundaries; Tongariro (1968 m), Ngauruhoe (2291 m), and Ruapehu (2797 m), lie at the southern end of the volcanic zone extending north-east through the centre of the North Island, and continuing for 1600 km across the South East Pacific. The volcanoes are of Quaternary (two million b.p.) to recent origin, and the rocks within the study area are principally andesites* typically containing phenocrysts of calcic plagioclase (aluminium silicates of Ca), hypersthene (Fe and Mg silicates), augite (Ca/Fe and Mg/Al silicates), and to a lesser extent basalts (Gregg 1960 (a) and (b)).

The comparatively young andesitic ash soils of Mt. Ruapehu make it an atypical alpine area. Most New Zealand alpine areas are derived from greywacke and schist with associated soils. The upper surface of the Ruapehu area has been covered with successive layers of andesitic ash following eruptions from Mt. Ruapehu and the neighbouring volcanoes. There is little development of soil profiles, particularly in soils beneath dense vegetation on steep well-drained slopes. Outwash areas with rapid accumulation of material also show little profile differentiation apart from the alternating layers of different texture. Scott (1977 (a)). A description of the soils is given by New Zealand Soil Bureau (1968), Read (1974), with a more detailed account by Cole (1978).

The climate of the study area is montane and has been reviewed by Coulter (1967). Table 1 summarises climate measurements taken at the Chateau Tongariro near the middle of the altitudinal range studied. Salient features are: high annual precipitation with rain days spread throughout the year, though somewhat lower during

* Dark grey to black rocks commonly speckled with white crystals of feldspar.

the three summer months; generally cool temperatures with ground frosts throughout the year; cool spring and early summer (October to December), with January to March being the warmest months; and winter snow which on higher elevations persists well into October and November. The mountains are exposed to all winds, however, the prevailing wind is westerly. Winds from the west to north-east bring most of the rain, and southerly winds are frequently strong and snow-bearing in winter. Rainfall figures for the south-western slopes of Ruapehu are about half that recorded for the northern slopes.

Table 1: Summary of temperature, humidity and precipitation for Chateau Tongariro 1930 - 70 (N.Z. Meteorological Service 1973).

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Mean Daily Maximum (°C)	16.7	16.8	15.2	12.1	9.0	6.5	5.8	6.7	8.6	10.7	12.7	15.1	11.3
Mean Daily Minimum (°C)	6.6	7.4	6.1	3.9	1.6	-0.3	-1.3	-0.5	0.5	1.9	3.5	5.3	2.9
Relative Humidity (%)	76	78	79	80	83	86	87	83	79	78	76	76	80
Normal Rainfall (mm)	188	206	178	224	257	292	269	251	244	279	262	264	2914

2.3 VEGETATION AND ANIMALS.

The first botanical survey of the Tongariro National Park was undertaken in 1908 by Dr. Leonard Cockayne who listed 259 plant species within the Park boundaries. A further 56 species were listed by C.M. Smith after a later survey in 1935. Today, there are estimated to be at least 530 different species within the Park, excluding mosses, liverworts, lichens and fungi. (Esler 1965).

Cockayne (1908) classified some 42 plants as being "truly alpine or sub-alpine", but as he remarked, "it is hard to draw the line as to what plants should be included". The present study was carried out in sub-alpine and alpine tussock grassland described by Cockayne as 'shrub-steppe'. This grassland occupies by far the largest part of the Park, forested areas being much smaller in extent.

Below 1000 m on the north-western slopes of Ruapehu, heather (*Calluna vulgaris*) is the dominant vegetation. It was introduced into the Park from 1910 to 1924, and was intended as cover and food source for the grouse which were later introduced as game. (Mazey 1974). Between 1000m and 1200m there is a patchwork of vegetation dominated by inaka (*Dracophyllum filifolium*) and red tussock (*Chionochloa rubra*) as well as the associated fernlands and rushlands. Extending beyond this to 1500 m the inaka is replaced by mountain inaka (*Dracophyllum recurvum*) and other alpine shrubs such as snow totara (*Podocarpus nivallis*), pigmy pine (*Dacrydium laxifolium*), mountain snowberry (*Gaultheria depressa*), mountain toatoa (*Phyllocladus alpinus*), whipcord hebe (*Hebe tetragona*), *Senecio bidwillii* and *Celmesia incana*. Rock screes occupy most of the upper slopes of all three main mountains above 1400 m, and vegetation is sparse.

On the south-western slopes of Ruapehu, mountain beech forest extends from the Park boundary at 700 m to 1520 m. Above and interspersed the vegetation is similar to that found on the northern slopes at equivalent altitudes.

The report of a survey by Dr. L. Cockayne in 1908 states: 'The introduced animals are chiefly important on account of the damage they may do to the vegetation. The grasslands in the vicinity of the Park, excepting to the south-east have never been let for grazing purposes. At the same time, the Natives own land is in proximity, and their cattle or the wild progeny of these have roamed at large over the Crown Lands. Especially is this the case at the north end of Tongariro, where the pasture is much richer than elsewhere. Also for a long time there have been herds of wild horses pasturing on the grass-steppe. Quite recently too, a few sambar deer have been liberated. Hares also are very abundant. But, so far as I was able to observe, all the above have not been sufficient as yet to work much, if any, change in the vegetation, though this fact is no excuse for their presence in what is virtually a sanctuary for indigenous plants and animals'.

Little recent information is available concerning introduced animals within the Park. 37 species of bird and one species of New Zealand bat have been recorded within the Park. (Esler 1965).

Esler (1965) states that 'There is no stand of forest in the Park without deer tracks. Nevertheless these animals seem to be fewer than in many other mountain districts'.

Red deer (Cervus elaphus) from the Kaimanawa Ranges first strayed into the Park in the mid 1920's, and Sika deer (Cervus nippon) also appear to have migrated from this area.

Feral pigs (Sus scrofa) have been recorded, generally below 900 m, and on the northern slopes of Tongariro the shrubby understory of the Hall's totara forest has been seriously damaged by them. On the north-eastern slopes the combined action of pigs and deer has completely removed the understory of the Red Beech - Silver Beech Forest.

Opossums (Trichosurus vulpecula) are present in large numbers in the rimu forest on the western and south-western slopes of Ruapehu, and reach even greater numbers where secondary forest has regenerated following milling of the original rimu.

Hares browse on the areas of red tussock and locally wild horses (Equus caballus) have caused some damage. Rabbits (Oryctolagus cuniculus) are reported to be numerous on the Onetapu Desert (eastern slopes of Ruapehu).

The overall effect of the browsing of all these animals has been comparatively light within the Park itself, but they have caused some changes in the vegetation. (Pascoe 1974).

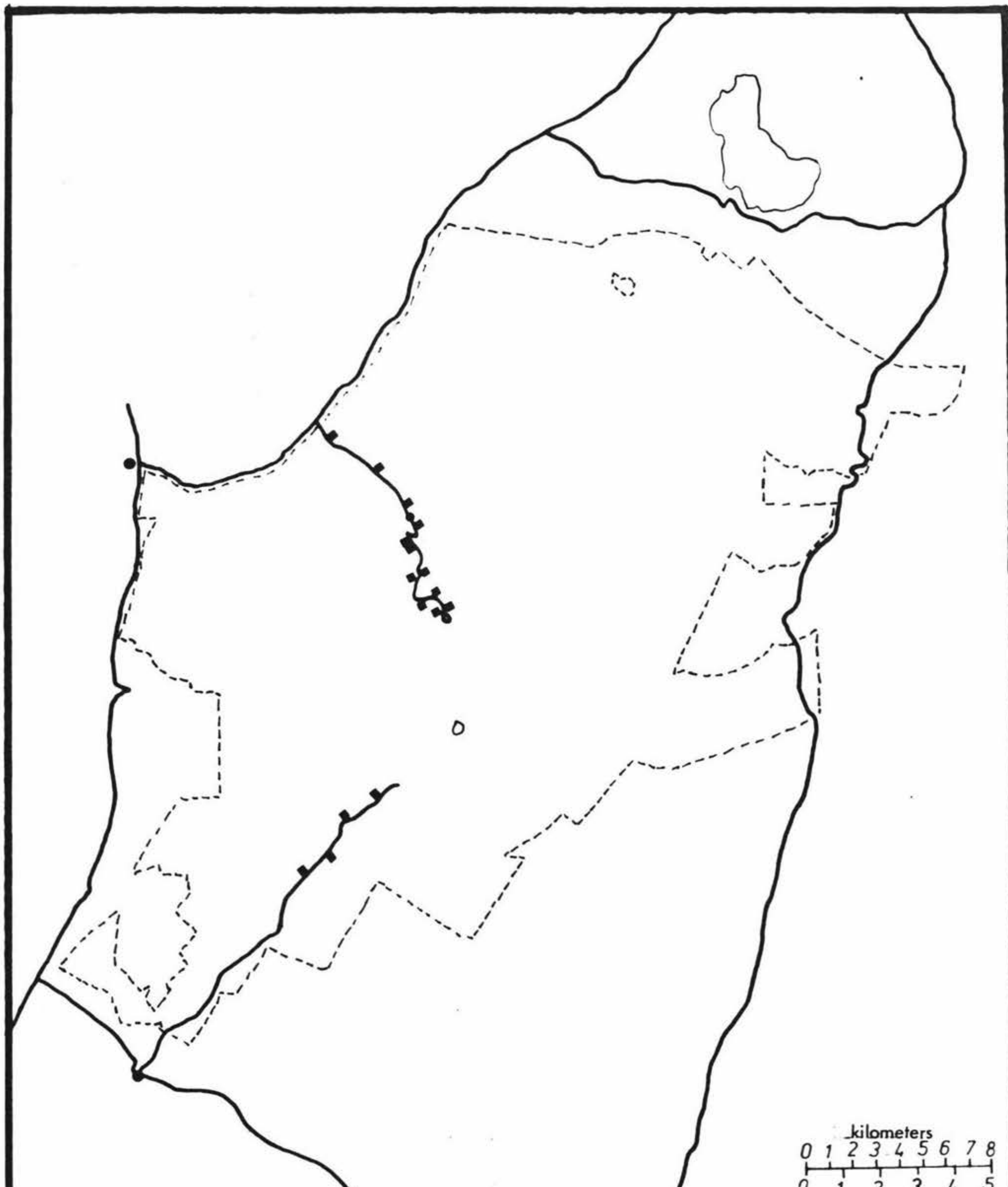
Mustelids, feral cats (Felis catus) and rodents are all present, and probably have an appreciable effect on bird life.

2.4 TRANSECTS.

These were established at intervals of 100 m from 900 m to 1600 m at the Chateau site and from 1200 m to 1500 m at the Ohakune site. Where possible two transects each 100 m in length were established at each altitude. Consequently at the Chateau site there were two 100 m transects at 1600 m, 1500 m, 1400 m, 1300 m, and 1200 m; one 150 m transect at 1100 m and a further 100 m transect at 1000 and 900 m.

The Ohakune site included numerous cliffs, so that the terrain was difficult to work and transects were limited to one 100 m transect at 1500 m, 1400 m, 1300 m, and a 150 m transect at 1200 m. Pellet collections were made at 900 m and 700 m because at these altitudes there was relatively easy access into the bush.

The 1200 m transect at the Chateau and 1200 and 1400 m transects at the Ohakune site ran partly through mountain beech forest.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miles

CHAPTER 3: METHODS

3.1. DIETARY HABITS

The plant composition of an animals's diet can be analysed by a variety of methods. Generally, forage may be evaluated before, during, or after digestion.

Direct assessment can be made by close observation of feeding animals. This approach is made difficult, if not impossible, by nocturnal habits, and by animals being shy and elusive. This method was abandoned after repeated attempts, using an infra-red night viewer to observe hares feeding, proved unsatisfactory.

The use of exclosures or enclosures was not tried, as it was felt that the changes in plant composition and growth would not be significant in the time available for the study.

Examination of forage consumption during digestion involves oesophageal and rumen fistulation or gut analysis from dead specimens. The bulk of the work on fistulation has been done on closely confined domestic animals, and the use of this technique on situations in the wild would involve many problems. The examination of gut contents of dead animals can provide detailed qualitative and quantitative information about diet, this method being probably the most accurate, provided the sample size is large enough. Initially it was intended that shot samples would be obtained monthly, but it was found that insufficient numbers could be obtained regularly by this method.

For this study, it was decided that faecal analysis would be used as the basic method for dietary analysis, with direct observation of food consumed by captives and of vegetation in the field being undertaken as comparative methods.

Faecal analysis overcomes many of the objections to alternative methods previously mentioned as samples can be collected even while studying a shy and elusive animal such as the hare. The data obtained is both qualitative and quantitative, and the faecal material can easily be stored until required for analysis.

The identification of plant remains by cuticle analysis is based on the assumption that there is little or no digestion of the epidermis encased in cutin. Consequently, fragments of leaf cuticle which are specifically recognisable in the faeces are identifiable. The areas of leaf cuticle of each plant species can be determined by microscopic analysis. It is also assumed that the areas of each plant species in the faeces are proportional to those ingested. This latter assumption is valid only if leaf cuticle is unaffected, or if all species are equally affected, by digestion.

In this study, it is assumed that there is no differential digestion of cutin, though the limitations of this assumption are recognised. However, many of the plants living in the alpine environment have a relatively tough and fibrous leaf form as an adaptation to the harshness of the habitat, and it is suggested that the assumption that there is no differential digestion is, in this situation, more justifiable than it might be in areas which are in a less extreme physical environment. In any case, should subsequent studies reveal differential cuticle survival, it would not be difficult to apply appropriate correction factors to the present results.

A second possible difficulty with the technique is that material with no cuticle, or a very thin one, may not be retained. This difficulty did not appear to arise during this study as seeds, pollen grains, roots, flowers and bark were readily identifiable in the preparations made.

3.1.1. Pellet Collection.

From the area surrounding each transect 'fresh' pellets were collected for analysis of the constituents. Fresh pellets were identified by their moist shiny mucous

Plate 1: Fresh Hare Faeces.

coating. In general all pellets found within the time available were collected from as many different sites as possible, to try to avoid obtaining a sample voided by a single hare. Usually between 10 and 50 pellets were collected, but on one occasion 200 were found.

Care was taken to avoid collecting rabbit faeces which are similar in appearance to hare faeces to the unskilled eye. In comparison, rabbit faeces are smaller, darker and generally not as rounded as hare faeces.

Pellets collected were placed in air tight, labelled jars, and covered with ten per cent formalin until analysed.

3.1.2. Cuticle Analysis.

Several papers have been published on the potential for using various techniques for estimating the botanical composition of hebrivore diets from the microscopic examination of faeces: (Dusi 1949; Crocker 1959; Hercus 1960; Storr 1961; Stewart 1967; Williams 1969; Dunnet *et al* 1973).

For the purposes of this study analysis of cuticles within faeces was undertaken following the basic method described in Dunnet *et al* (1973).

After mixing the pellets from the monthly collection made at each altitude, a sub-sample of five pellets was disintegrated by hand; a mortar and pestle were not used in case this harsher method of grinding destroyed any delicate plant fragments.

Macerating fluid, made up as follows, was added: 250 g chromium trioxide in 250 ml water (= 50% chromic acid) and 50% concentrated industrial nitric acid, mixed in the proportions 60 ml chromic acid: 40 ml nitric acid. The faecal material was allowed to stand at room temperature in this solution for 60 - 90 minutes. Then the material was washed through coarse grade filter paper, transferred to a labelled bottle and covered with formalin acetic alcohol (FAA) (consisting of ten parts 40% formaldehyde, five parts glacial acetic acid and 85 parts 70% alcohol), until required for analysis.

For analysis, samples were re-filtered and five slides made up from the residue mounted in glycerine. Each sample was mixed thoroughly on the slide to produce an even, and so far as possible, single-layered distribution of fragments, and covered with a 22 x 40 mm coverslip.

The slides were examined under a compound microscope at a magnification of x 40, although with some fragments identification required a magnification of x 100.

In order to obtain an index of the area of fragments present a 1 mm^2 graticule in the eyepiece was used to measure the area of cuticle fragments in arbitrary units on a scale of one to five. (1 = 0.41mm^2 2 = 0.82mm^2 3 = 1.22mm^2 4 = 1.63mm^2 5 = 2.04mm^2).

Twenty systematically located fields were examined on each slide (Sparks and Malechek 1968), and the species present at the centre of a micrometer eyepiece was recorded together with its approximate area. Thus a percent frequency was computed for each species present.

Cuticle fragments were identified from photomicrographs of a reference collection of species from the study area. The reference collection was prepared by cutting plant material into small pieces, approximately 3mm x 2mm and placinq them in the macerating solution until the cuticles floated to the surface, approximately 90 minutes later. The cuticles were mounted in glycerine on slides and photographed using a Carl Zeiss Ergaval microscope and camera, x 125 and x 320. Introduced grasses, mosses, seeds or bark were not identified to species level.

Monthly percent frequencies of occurrence of each species were then combined seasonally. A 'composite average area' (A) was determined, following the method described in Siegfried (1972): the number of items in each size class multiplied by the mean area of that size class, the values summed and the total divided by the total number of food items.

3.1.3. Feeding Trials.

To lend support to results from faecal analysis, feeding trials using captive hares were carried out.

Initially three partly-grown hares were captured with the aid of the North Wairarapa Pest Destruction Board, using motor-bikes and spot-lights. The procedure involved dazzling the hare at night with two spot-lights from different directions, then slowly closing in and finishing with a 'rugby tackle'. The hares froze for a short period when dazzled, and capture was relatively easy provided the 'tackler' was quick and accurate. In this manner the hares were obtained on 8th., 9th., and 15th. February 1978.

The hares were housed in a 1.8 x 3.7 x 1.8 m grassed wire run with an attached concrete floored sleeping compartment of 2.4 x 0.9 x 1.8 m. Boxes containing hay provided cover and sleeping accommodation.

Prior to and between feeding trails the hares were fed cabbage, lettuce and Massey University rabbit pellets (EHR/77) manufactured by Farm Products (Manawatu) Ltd., together with water ad lib.

During feeding trials the hares were confined to the concrete-floored sleeping compartment to prevent them eating grass in the run, and to enable recovery of alpine plant species remaining after the trial.

Samples of plants known to be eaten by hares were collected from areas adjacent to the study area; but outside the Park boundaries; whole plants were collected and their roots kept in water until required. The species collected were: Chionochloa rubra, Celmisia spectabilis, Notodanthania setifolia, Calluna vulgaris, Aciphylla squarrosa, Poa colensoi and Schoenus pauciflorus.

Each plant sample was weighed ± 0.5 g placed on a large metal tray, and set in the cage along with a known weight of rabbit pellets and water ad lib. After 24 hours the tray and any remaining plant fragments were removed. The amount of each species remaining was weighed. and the next feeding trial begun.

Two feeding trials were carried out. The first covered three days, the second six days.

The three half-grown captives were sexed, weighed, measured and marked with collars and ear tags, and released on 9th. April 1978.

In addition to the three half-grown captives, three leverets (approximately one to two weeks old) were obtained in reply to advertisements placed in local shop windows. Horie was obtained on 22nd February 1978, and Sam and Charlie on 6th March 1978. Initially all three were housed indoors in experimental opossum cages. Their diet consisted of cow's milk diluted by one third with glucose added, fed from an eye-dropper, and supplemented by lettuce, biscuits (Webb 1955), and rabbit pellets.

The leverets were later placed outside in a rabbit hutch, and moved to fresh grass daily while continuing the above diet. Body weights were recorded regularly on kitchen scales ± 0.5 g. They were kept in this manner until the death of Sam and Charlie on 28th. March 1978.

A third feeding trial begun with Horie was not completed because he died of unknown causes on 25th. April 1978.

3.1.4. Field Observations.

No feeding was observed directly in the field; however. signs of feeding deduced to have been by hares were recognised on plants: the bite marks were at an angle of 45 degrees, and there was generally a group of pellets of similar age to be found at the base of the plant (Bang and Dahlstrom 1974). Some observations concerning plants that would seem to be preferred by hares were made.

3.1.5 Samples From Other Areas.

During the study various sites within the Park, in addition to those on the transects (see Section 2.4), were visited, and pellet samples collected from a range of vegetation types and altitudes. These pellets were analysed by the same method as previously mentioned (see Section 3.1.2.), in the anticipation that an overall picture of the diet of hares within the Park would be obtained.

3.2. VEGETATION ANALYSIS.

Studies by Dodds (1960), Sparks (1968), Telfer (1972) and Wolff (1978) suggest an important factor which determines the composition of the hares diet is the density and frequency of occurrence of a particular species in a given habitat.

Another factor in determining food preference is the nutritive value of each plant species. Differences in the nutritional status of browse are found between species, between plants of the same species and even within plants (Bailey 1967, Williams et al 1977, 1978 (a), (b), (c)). Site exposure to sunlight may cause different food values within an apparently homogeneous habitat; there are likewise seasonal variations in nutritional content of many species. (Tew 1970, Williams et al 1978 (b)).

Several plant species may be required in the daily diet of a hare to provide the minimum requirements of energy, protein and other nutrients (Holter et al 1974, Linloff et al 1974 (a) and (b)). It has also been suggested that hares may change their food preferences with a season to make up for nutrient and energy deficiences. (Sparks 1968, Wolff 1978).

3.2.1. Point Analysis of Vegetation.

To determine species composition and frequency of plants available to hares, and to look for evidence of selectivity by hares, measurements of vegetation were carried out at quarterly intervals (July, October, January and April).

It was hoped that in so doing any seasonal changes in the availability of plants would be detected. Also any selectivity by hares of minor species in the vegetation would be noted.

Measurements were made by point analysis with a pointer dropped vertically at one metre intervals along each altitudinal transect. Per cent frequency composition was subsequently calculated. Only the plant which the pointer actually touched was recorded; per cent cover was not determined, (Chamrad and Box 1968).

All plant names follow Allan (1961), Moore and Edgar (1970) and Mark and Adams (1973).

3.2.2. Chemical Composition Of Important Dietary Plants.

Chemical analysis of the major plants in the hares diet was undertaken to ascertain whether seasonal changes in diet were related to seasonal changes in plant chemistry.

Samples of plant material were collected seasonally (August, November, February and April). Three samples of each species were obtained from each transect under study. One sample was taken from each end of the transect, and another from the middle, to ensure that sampling was uniform and not biased by soil composition at one particular point.

The species collected were: Chionochloa rubra, Notodanthania setifolia, Poa colensoi, Celmisia spectabilis, Aciphylla squarrosa, Calluna vulgaris, Sencio bidwillii, and Schoenus pauciflorus.

Samples were kept in plastic bags and frozen as soon as possible, within 36 hours after collection. (Williams et al 1976). Samples were then cut into lengths of between 3-5 cm; roots and dead leaves being discarded. Wet weights were taken before samples were dried to constant weight at 100°C for approximately 48 hours. After drying. samples were placed in sterile, screw-top containers until ashed. Dry weights were measured before ashing at 600°C for 24 hours. Ashed samples were again placed in screw-top containers until required for chemical analysis.

Chemical analysis for sodium and potassium was carried out by standard methods using the emission from a Corning-Eel Flame Photometer. Atomic absorption analysis for Magnesium (2025 Å), Calcium (4226.7 Å), Iron (2483.3 Å) and Zinc (2138.6 Å) was carried out using percentage transmission from a Varian Techtron AA-5 Atomic Absorption Spectrophotometer, (Williams and Twine 1967).

For analysis 40 ± 3 mg of ashed sample was weighed out and dissolved in 20 ml of 2 M redistilled hydrochloric acid containing 2.415 g/l anhydrous Sr $(NO_3)_2$. The samples were then made up to 25 ml in volumetric flasks. A further dilution of 1:25 was also made. Both solutions were stored in stoppered polyethylene tubes until reading.

Standard curves were plotted using previously prepared standard solutions and readings converted to mg/ml. After further calculations, results were as recorded mg/g dry weight. An analysis of varience was undertaken on the data using the SPSS computer package.

3.3. HARE ABUNDANCE.

Although a wide variety of techniques has been devised for assessing the numbers of individuals in free-ranging mammalian populations, most demand a great deal of time and effort.

Flushing methods have been used extensively in Europe, Flux (1962 and 1970), Hewson (1965, 1976), Rajska (1968), Pielowski (1969), and in North America, Webb (1942), Lechleitner (1958). This technique, however, is labour intensive and results are not always accurate as there is extreme variation in flushing distances.

A spotlight census is useful when relative population estimates only are required for comparison of different areas in the same season or the same area in different years. (Lord 1961, Salzmann-Wandeler and Salzmann 1973). For accurate results the area investigated should be flat, free from high vegetation and easily accessible. The topography of Tongariro National Park precluded the use of this method.

Mark and recapture methods probably give the most reliable population estimates. Animals, however, may become trap shy or be lost through capture procedures (Douglas 1970), consequently the results of preceding counts are affected.

Recent studies have used aerial counts of populations (Windberge and Keith 1977) to obtain accurate hare population densites. For obvious reasons this method was not adopted.

For the purposes of this study it was decided to use a pellet census technique first described by Taylor and Williams (1956) and modified by Batcheler (1975 (a), 1975 (b)). This method is labour unintensive and able to be undertaken by the author, alone. The pellet census requires a precise knowledge of pellet decomposition rate and pellet production rate. It is also necessary to know the effects climatic factors in force during the period under study.

In addition, recordings of visual sightings of hares, faeces and footprints were made to support findings of the pellet census.

3.3.1. Pellet Density.

In order to determine numbers of hares living in the two study areas, pellet densities were estimated following Batcheler (1973, 1975 (a), 1975 (b)). In this method densities of pellets are calculated from distances measured up to a chosen maximum distance R (60 cm) for each of N sample points. Defining the nearest member to the point as rp, its nearest neighbour as rn and rn's nearest neighbour (exclusive of rp) as rm.

These data were used to calculate several statistics defined in Batcheler (1975 (a)) equations 6 to 9.

By modifying Taylor and Williams' (1956) model for estimating rabbit population density, Batcheler (1975 (a), equation 5) derived a formula for estimating the number of animals present in a given area by the pellet density, and taking into consideration the variables of decay rate of pellets and rate of defecation.

Pellet density and the probable limit of error (PLE) were calculated by means of a computer program supplied by Mr. C.L. Batcheler and adapted by Mr. J.G. Ryan of the Massey University Computer Unit.

The final calculation to estimate numbers of hares present within the study area was made by substitution of estimates of rate of decay of pellets and rate of defecation as described in preceding sections (3.3.2 and 3.3.3.).

3.3.2. Pellet Decomposition Rates.

At each altitude a sample of 50 fresh pellets was placed to determine their rate of decay. These pellets were placed on the ground and enclosed by an identifiable perimeter of painted stones or sticks. Other pellets were cleared away from the immediate vicinity to avoid confusion. The pellets were not protected by frames (Cochran and Stains 1966) as this would alter the micro-climate inside the frame, and the area would cease to be typical. Also the exclusion of grazing animals would allow a greater rate of vegetation growth. As far as possible pellets from the different altitudes were placed at sites to experience similar exposures, vegetation heights, etc. The groups of pellets were checked monthly - when not covered by snow - and the number estimated to be less than half decayed noted. Pellets more than half decayed were ignored.

A second experiment to determine rate of decay of pellets was begun in October 1977, following the same method as described above.

In June 1977 fresh pellets were placed at 1100 m and each month subsequently a random sample of five pellets was taken. These were weighed, and their length and breadth measured.

3.3.3. Defecation Rates of Captives.

During the previously mentioned feeding trials when the three captive hares were fed alpine plants, the average number of pellets produced by each animal was determined. The hares were confined to the concrete-floored sleeping compartment and all pellets produced during each 24 hour period of the trial were carefully removed, counted, and the dry weight noted.

3.3.4. Weather Data.

Various factors including humidity, rainfall, temperature, altitude, exposure and pellet composition are known to affect the rate at which faeces decay. (Flux 1967 (b)).

Monthly records from the meteorological stations at the Chateau Tongariro (1120 m) and Ohakune Ranger

Station (629 m) were transcribed. In addition maximum/ minimum thermometers were placed at 1600 m and 900 m on the Chateau site, and 1500 m and 1200 m on the Ohakune site.

Thermo-hygrographs were placed with the maximum/ minimum thermometers, but froze during the winter months, and consequently were of no use.

3.3.5. Questionnaires.

In addition to the estimates of hare abundance derived from pellet densities, questionnaires concerning numbers of fresh faeces, footprints, or hares seen, were placed in Park Headquarters at the Chateau Tongariro and at Ohakune in July 1977, and collected at the end of the study.

CHAPTER 4: RESULTS

4.1. DIETARY HABITS.

4.1.1. Cuticle Analysis.

Table 2 (a - j) shows seasonal and altitudinal frequency of occurrence of plant species found in hare faeces. Data from transects at 1600 m lt and 1500 m rt have been excluded as no 'fresh' faeces were collected from these altitudes during the study. Results from the two transects at altitudes of 1400 m, 1300 m and 1200 m respectively have been combined.

Five species appear as the major dietary components: Chionochloa rubra, Celmisia spectabilis, Senecio bidwillii, Poa colensoi, and moss. The percent frequencies of occurrence of these five species have been graphed to show seasonal variation, Fig. 3 (a - j) and altitudinal variation in diet composition, Fig. 4 (a - h).

C.rubra was the principal species consumed during winter, intake declined in spring, and peaked again in summer, with amounts consumed generally declining again in autumn. Ingestion of C.spectabilis complemented fluctuations of C.rubra with peaks in spring and autumn. Intake of S.bidwillii showed peaks in either spring or summer, while consumption of moss peaked in winter or spring, but with low percentage frequencies, ($>$ 15%). P.colensoi intake increased dramatically in autumn, as did intake of seeds.

Consumption of C.rubra declined gradually with increasing altitude, Fig. 4 (a - h), (C.rubra comprised 60% of the diet at 1100 m but only 20% at 1600 m), while intake of C.spectabilis, S.bidwillii, and moss increased with increasing altitude. Consumption of P.colensoi also increased with rising altitude to 1400 m. Table 2 (a - j) indicates that seeds and introduced grasses were increasingly consumed with falling altitude.

Composite average area (A) results indicate that in general, cuticle fragments of *C.spectabilis* and *P.colensoi* fell into size class three (0.82 - 1.22mm^2), while *S.bidwillii* and *C.rubra* fragments fell into size class two (0.41 - 0.82 mm^2) and moss into size class one (0.41 mm^2).

Table 2 (a): Seasonal Percent Frequency Composition of Diet at 1600 m Chateau.

	Winter			Spring			Summer			Autumn		
Species	$\bar{x}$	S.D.	A	$\bar{x}$	S.D.	A	$\bar{x}$	S.D.	A	$\bar{x}$	S.D.	A
Moss	5.5	4.9	0.44	21.0	21.7	0.83	8.3	10.2	0.74	14.0	16.4	0.62
N.solandri												
A.squarrosa												
C.spectabilis	26.5	2.1	0.83	36.3	8.7	1.11	32.7	5.0	0.89	38.0	7.2	0.86
S.bidwillii	19.0	1.4	0.54	25.0	16.8	0.77	31.7	6.7	0.77	28.0	5.3	0.67
H.odora	0.7	1.2	0.42	0.3	0.7	0.21						
S.pauciflorus												
C.rubra	47.0	4.2	0.44	14.3	16.4	0.91	27.0	14.7	0.64	18.0	5.3	0.68
N.setifolia				0.3	0.6	0.21				0.7	1.2	0.62
P.colensoi				1.0	1.0	0.83	0.3	0.6	0.62			
C.vulgaris												
Grass												
Seeds										1.3	1.2	0.62
Bark												
Unknown	1.0	1.0	0.21									

Table 2 (b): Seasonal Percent Frequency Composition of Diet at 1500 m Chateau.

	Winter			Spring			Summer			Autumn		
Species	$\bar{x}$	S.D.	A	$\bar{x}$	S.D.	A	$\bar{x}$	S.D.	A	$\bar{x}$	S.D.	A
Moss	8.7	4.2	0.45	12.7	5.7	0.69	5.7	4.5	0.80	2.0	2.0	0.62
N.solandri												
A.squarrosa												
C.spectabilis	35.0	4.4	1.04	24.6	1.2	0.75	30.0	7.0	0.84	32.7	9.9	0.67
S.bidwillii	21.7	7.4	0.63	25.0	5.0	0.62	26.3	13.8	0.76	19.3	1.2	0.65
H.odora	0.3	0.6	1.03	0.3	0.6	0.21						
S.pauciflorus				0.7	1.2	0.21				1.3	2.3	0.62
C.rubra	34.3	11.0	0.75	33.3	12.4	0.76	37.7	19.9	0.76	42.7	9.0	0.78
N.setifolia				0.7	1.2	0.62				1.3	2.3	0.62
P.colensoi				3.3	3.1	0.70	0.3	0.6	0.62			
C.vulgaris												
Grass												
Seeds										1.3	2.3	0.21
Bark												
Unknown										0.7	1.2	0.62

Table 2 (c): Seasonal Percent Frequency Composition of Diet at 1400 m Chateau.

	Winter			Spring			Summer			Autumn		
Species	$\bar{x}$	S.D.	A	$\bar{x}$	S.D.	A	$\bar{x}$	S.D.	A	$\bar{x}$	S.D.	A
Moss	13.8	5.6	0.43	6.3	3.01	0.69	2.5	1.2	0.55	5.7	6.3	0.63
N.solandri												
A.squarrosa												
C.spectabilis	29.3	13.6	1.00	34.2	10.4	0.96	26.8	16.9	0.97	22.7	10.2	0.69
S.bidwillii	13.2	6.5	0.66	29.7	10.4	0.62	30.2	2.9	0.78	22.0	7.8	0.75
H.odora	2.5	4.2	0.78									
S.pauciflorus												
C.rubra	32.3	19.6	0.57	17.3	17.6	0.83	35.8	20.5	0.76	21.7	7.5	0.63
N.setifolia	0.7	1.2	0.62				0.7	1.2	0.62			
P.colensoi	7.0	4.1	0.37	6.0	4.8	0.70	3.8	2.4	0.71	26.0	13.7	0.67
C.vulgaris	1.3	1.5	0.76									
Grass												
Seeds										2.0	3.5	0.62
Bark												
Unknown	0.8	0.8	0.93							0.7	1.2	0.21

Table 2 (d): Seasonal Percent Frequency Composition of Diet at 1300 m Chateau.

	Winter			Spring			Summer			Autumn		
Species	$\bar{x}$	S.D.	A	$\bar{x}$	S.D.	A	$\bar{x}$	S.D.	A	$\bar{x}$	S.D.	A
Moss	11.3	2.5	0.45	8.0	5.3	0.61	1.3	2.3	0.83	0.7	1.2	0.62
N.solandri												
A.squarrosa												
C.spectabilis	21.7	13.6	0.89	13.0	14.2	0.93	9.3	7.6	0.99	18.7	5.0	0.72
S.bidwillii	10.0	6.1	0.50	8.7	3.1	0.55	18.0	7.2	0.63	9.3	10.1	0.48
H.odora	1.0	1.7	0.48									
S.pauciflorus				1.0	1.7	1.03				1.3	2.3	0.21
C.rubra	51.0	18.7	0.64	53.7	9.3	0.88	58.7	3.1	0.64	45.3	23.7	0.66
N.setifolia												
P.colensoi	3.3	2.1	0.36	10.3	8.7	0.70	9.3	3.1	0.53	21.3	12.7	0.74
C.vulgaris												
Grass							4.0	6.9	0.62			
Seeds										3.3	5.8	0.21
Bark												
Unknown	1.3	2.3	0.94	5.7	8.9	0.62						

Table 2 (e): Seasonal Percent Frequency Composition of Diet at 1200 m Chateau.

	Winter			Spring			Summer			Autumn		
Species	$\bar{x}$	S.D.	A	$\bar{x}$	S.D.	A	$\bar{x}$	S.D.	A	$\bar{x}$	S.D.	A
Moss	9.2	6.7	0.37	5.5	2.9	0.76	2.5	1.8	0.62	0.7	1.0	0.62
N.solandri												
A.squarrosa				0.3	0.8	0.62						
C.spectabilis	21.0	12.6	0.53	13.8	7.0	0.78	8.7	6.9	0.65	11.7	11.1	0.73
S.bidwillii				3.2	2.9	0.69	5.0	7.1	0.57	0.7	1.0	1.03
H.odora												
S.pauciflorus	0.7	0.3	1.03	0.7	0.3	1.84	3.0	7.3	1.84			
C.rubra	50.8	16.1	0.54	49.7	24.6	0.74	56.7	15.3	0.66	44.0	19.1	0.67
N.setifolia	0.3	0.8	0.62									
P.colensoi	2.3	5.2	0.50	8.2	7.4	0.80	8.0	11.7	0.69	13.3	13.9	0.76
C.vulgaris												
Grass							7.0	12.9	0.42	23.3	17.5	0.89
Seeds	4.3	10.6	0.42							4.7	8.2	0.62
Bark							0.3	0.8	0.21	0.7	1.6	1.03
Unknown												

Table 2 (f): Seasonal Percent Frequency Composition of Diet at 1100 m Chateau.

	Winter			Spring			Summer			Autumn		
Species	$\bar{x}$	S.D.	A	$\bar{x}$	S.D.	A	$\bar{x}$	S.D.	A	$\bar{x}$	S.D.	A
Moss	2.3	2.5	0.38	5.0	5.8	0.54						
N.solandri												
A.squarrosa	6.3	11.0	0.21	0.7	1.2	0.21	1.0	0.6	0.62	2.0	3.5	0.21
C.spectabilis	17.6	9.6	0.56	28.0	14.1	0.49	12.0	9.2	0.75	22.7	16.29	0.64
S.bidwillii	0.7	1.2	0.21				1.0	1.0	0.62			
H.odora	1.3	2.3	0.62									
S.pauciflorus	1.3	2.3	0.52	0.7	1.2	0.62	3.7	6.4	0.80			
C.rubra	59.3	20.7	0.49	57.0	35.4	0.39	80.3	4.9	0.55	47.3	30.55	0.65
N.setifolia	0.3	0.6	0.21				0.3	0.6	0.62			
P.colensoi	2.0	1.7	0.42	5.0	5.8	0.21	0.7	1.2	0.62	9.3	16.17	0.53
C.vulgaris	1.3	2.3	0.21									
Grass										6.7	3.1	0.54
Seeds										4.0	5.3	0.21
Bark										8.0	6.0	0.21
Unknown	7.7	6.7	0.55	2.0	3.5	1.03	1.0	0.6	0.82			

Table 2 (g): Seasonal Percent Frequency Composition of Diet at 1500 m Ohakune.

	Winter			Spring			Summer			Autumn		
Species	$\bar{x}$	S.D.	A	$\bar{x}$	S.D.	A	$\bar{x}$	S.D.	A	$\bar{x}$	S.D.	A
Moss	14.5	16.3	0.55	16.5	10.6	0.68	20.7	3.1	0.63	12.7	12.1	0.48
N.solandri												
A.squarrosa												
C.spectabilis	36.5	9.2	0.98	13.0	4.2	0.73	19.0	10.5	0.68	26.7	5.0	0.63
S.bidwillii	23.0	7.1	0.60	19.5	14.9	0.88	28.0	11.1	0.63	17.3	12.2	0.71
H.odora	0.5	0.5	1.03									
S.pauciflorus												
C.rubra	20.0	19.8	0.63	64.5	27.6	0.70	38.0	8.7	0.66	26.0	10.6	0.25
N.setifolia	1.0	1.4	0.62	0.5	0.5	0.62	0.7	1.2	0.62			
P.colensoi	4.0	5.7	0.72	0.5	0.7	0.62				12.7	17.0	0.61
C.vulgaris												
Grass												
Seeds										4.0	5.3	0.62
Bark												
Unknown	0.5	0.5	1.84	0.5	0.5	1.43	0.3	0.6	0.62	0.7	1.2	0.21

Table 2 (h): Seasonal Percent Frequency Composition of Diet at 1400 m Ohakune.

Species	Winter			Spring			Summer			Autumn		
	$\bar{x}$	S.D.	A	$\bar{x}$	S.D.	A	$\bar{x}$	S.D.	A	$\bar{x}$	S.D.	A
Moss	10.5	7.8	0.44	9.0	4.0	0.64	6.7	2.0	0.64	4.0	4.0	0.62
N.solandri												
A.squarrosa												
C.spectabilis	33.5	4.9	0.78	22.7	4.5	1.03	22.3	11.7	0.84	18.0	15.1	0.77
S.bidwillii	23.0	4.2	0.53	21.3	8.5	0.65	16.3	9.1	0.78	0.7	1.2	0.21
H.odora												
S.pauciflorus	0.3	0.6	1.03				0.7	1.2	0.62			
C.rubra	31.5	3.5	0.49	45.0	9.9	0.82	47.7	16.8	0.64	47.3	22.3	0.64
N.setifolia	0.5	0.5	0.21				1.0	1.0	0.62			
P.colensoi	1.0	1.4	0.83	1.3	2.3	1.30	0.7	1.2	0.62			
C.vulgaris												
Grass										3.3	5.8	0.21
Seeds										25.3	11.0	0.70
Bark												
Unknown							1.3	1.2	0.62			

Table 2 (i): Seasonal Percent Frequency Composition of Diet at 1300 m Ohakune.

	Winter			Spring			Summer			Autumn		
Species	$\bar{x}$	S.D.	A	$\bar{x}$	S.D.	A	$\bar{x}$	S.D.	A	$\bar{x}$	S.D.	A
Moss	7.0	4.6	0.32	9.6	9.3	0.55	1.7	2.1	0.62	1.3	2.3	0.62
N.solandri	0.3	0.6	0.62									
A.squarrosa												
C.spectabilis	32.0	10.5	0.84	18.0	14.0	0.82	24.7	11.4	0.67	22.7	8.3	0.91
S.bidwillii	16.3	9.7	0.53	10.0	8.0	0.53	11.3	5.0	0.82	14.7	9.9	0.74
H.odora	1.0	1.7	0.35	0.3	0.6	0.62						
S.pauciflorus	1.7	2.9	0.70									
C.rubra	3.9	14.0	0.56	59.7	23.8	0.69	57.7	10.7	0.55	51.3	22.0	0.68
N.setifolia	6.7	1.2	0.21									
P.colensoi	4.3	5.9	0.34	2.3	4.0	0.44	2.0	3.5	0.76	6.0	8.7	0.52
C.vulgaris												
Grass				2.7	4.6	0.52						
Seeds										4.0	5.3	0.62
Bark												
Unknown												

Table 2 (j): Seasonal Percent Frequency Composition of Diet at 1200 m Ohakune.

	Winter			Spring			Summer			Autumn		
Species	$\bar{x}$	S.D.	A	$\bar{x}$	S.D.	A	$\bar{x}$	S.D.	A	$\bar{x}$	S.D.	A
Moss	10.0	0.0	0.37	18.3	15.3	0.54	1.3	2.3	0.62			
N.solandri												
A.squarrosa												
C.spectabilis	23.0	0.0	0.62	24.0	8.7	0.67	5.7	6.0	0.70	19.3	8.3	0.43
S.bidwillii				11.3	14.5	0.72	0.3	0.6	0.83	4.7	4.2	0.45
H.odora												
S.pauciflorus												
C.rubra	67.0	0.0	0.39	40.0	26.2	0.71	76.0	14.1	0.58	30.0	8.7	0.63
N.setifolia				0.3	0.6	0.62						
P.colensoi				0.7	1.2	0.44	0.7	1.2	1.03	4.0	6.9	0.21
C.vulgaris												
Grass				5.3	9.2	0.67	2.7	4.6	0.62	21.3	6.4	0.62
Seeds							5.3	9.2	0.62	20.0	3.5	1.03
Bark										0.7	1.2	1.03
Unknown												

<u>Figure 3</u>: Seasonal Variation in Percent Frequency Occurrence of the Five Major Dietary Species.

a: 1600 m (Chateau).

b: 1500 m (Chateau).

c: 1400 m (Chateau).

Key:

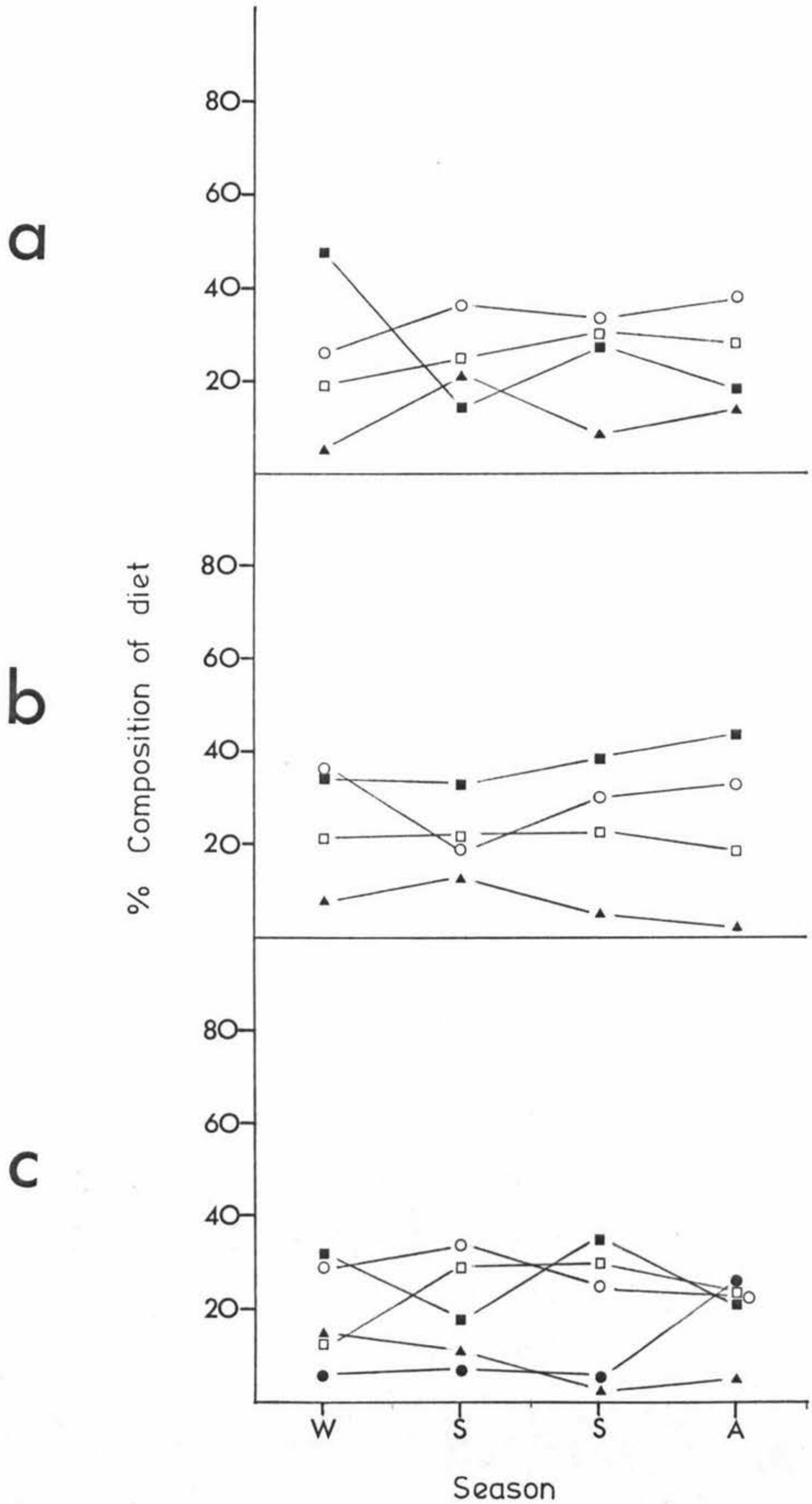
■ *Chionochloa rubra*

○ *Celmisia spectabilis*

□ *Senecio bidwillii*

● *Poa colensoi*

▲ Moss


a
b
c
80
60
40
20
% Composition of diet
W
S
S
A
Season

d: 1300 m (Chateau).

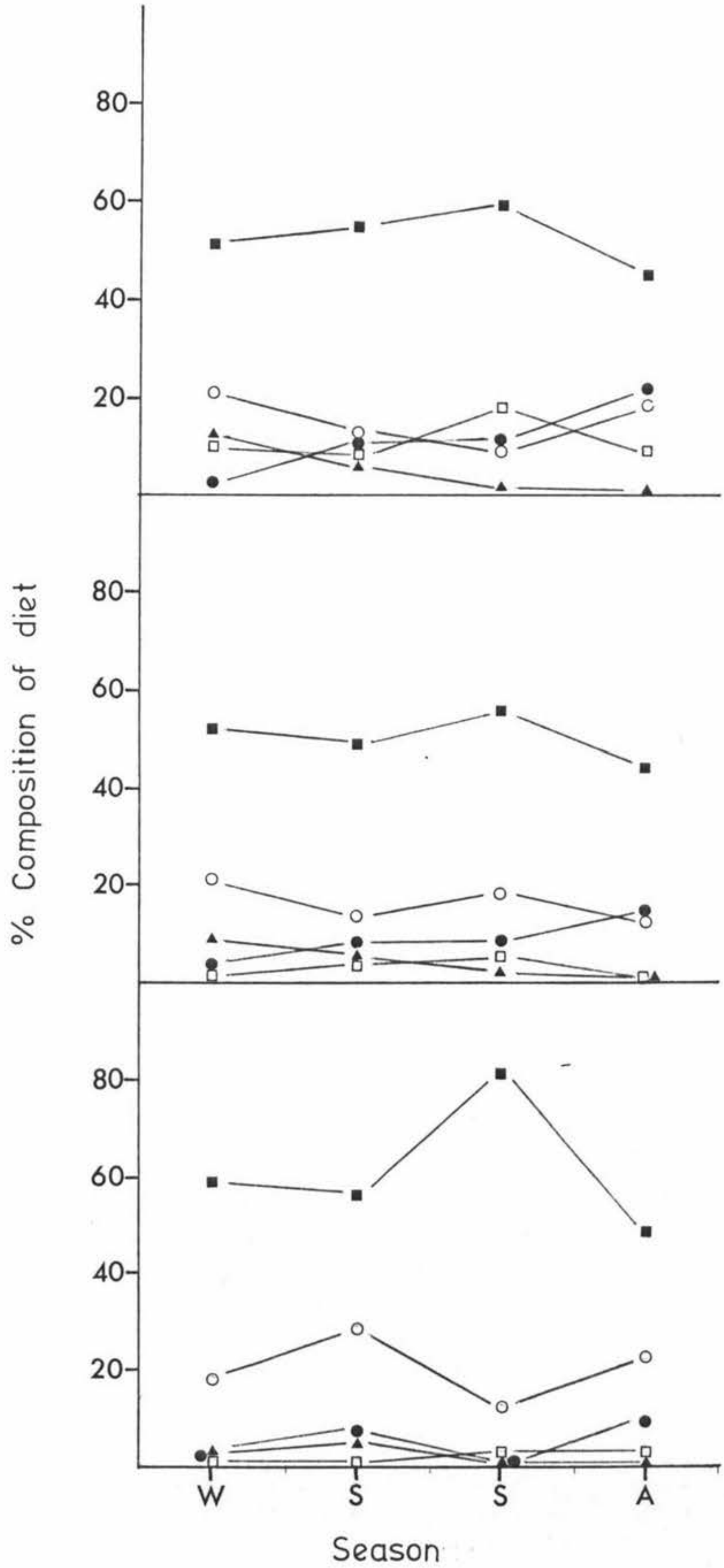
e: 1200 m (Chateau).

f: 1100 m (Chateau).

d

e

f

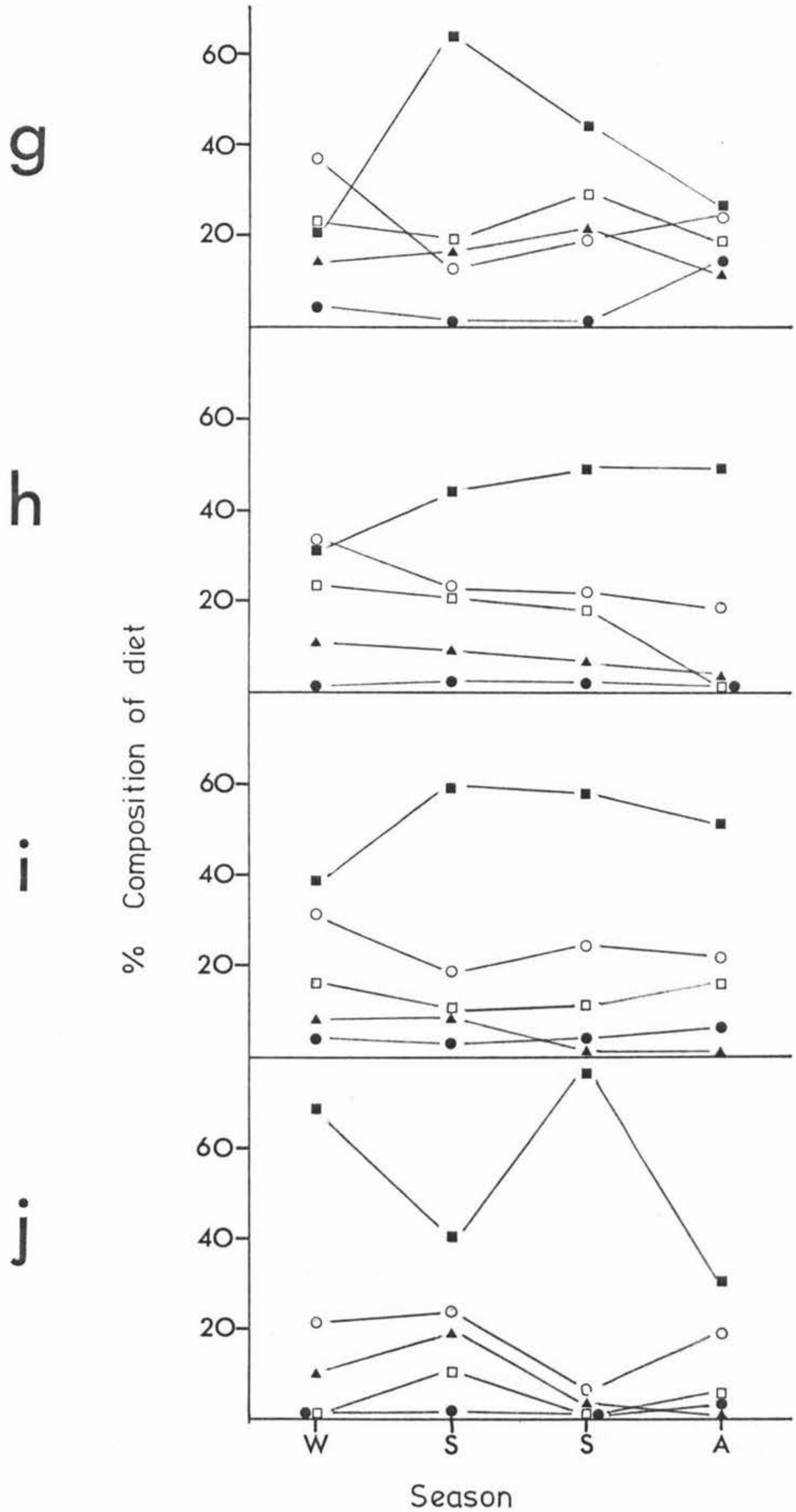

80
60
40
20
80
60
40
20
80
60
40
20
% Composition of diet
W
S
S
A
Season

g: 1500 m (Ohakune).

h: 1400 m (Ohakune).

i: 1300 m (Ohakune).

j: 1200 m (Ohakune).



g
h
i
j
60
40
20
% Composition of diet
W
S
S
A
Season

Figure 4: Altitudinal Variation in Percent Frequency Occurrence of the Five Major Dietary Species.

a: Winter (Chateau).

b: Spring (Chateau).

c: Summer (Chateau).

d: Autumn (Chateau).

Key:

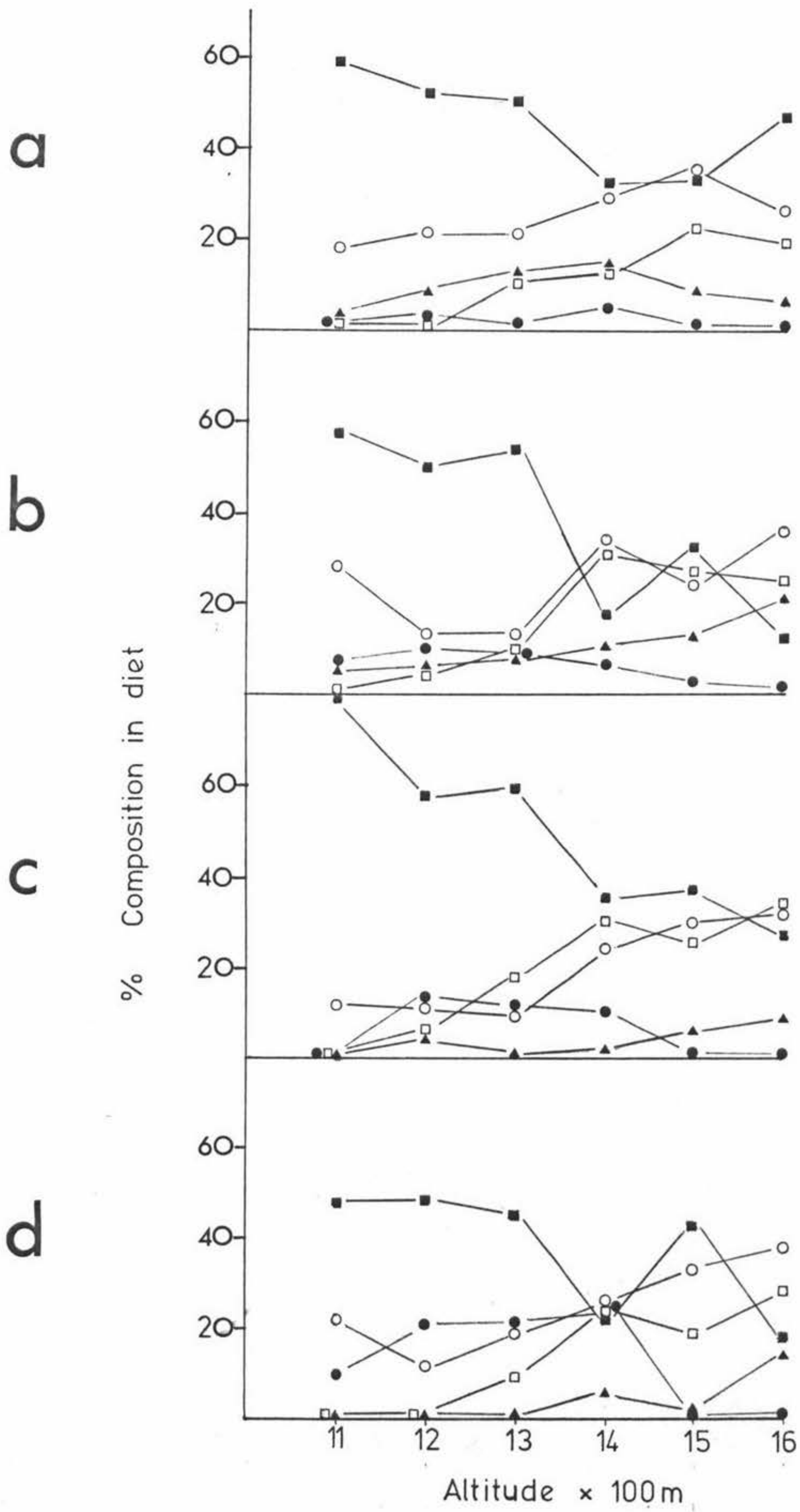
■ Chionochloa rubra

○ Celmisia spectabilis

□ Senecio bidwillii

● Poa colensoi

▲ Moss

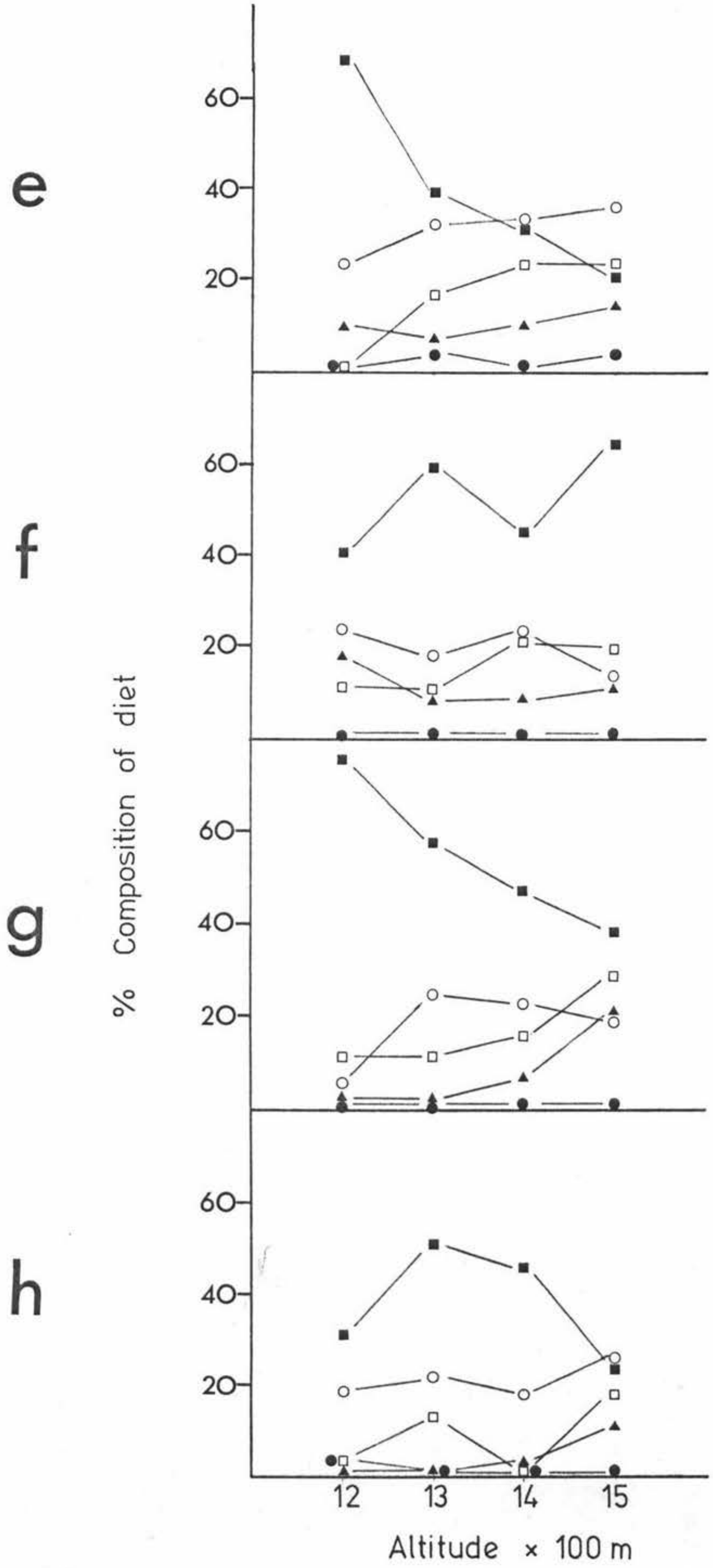

a
b
c
d
60
40
20
% Composition in diet
11
12
13
14
15
16
Altitude × 100m

e: Winter (Ohakune).

f: Spring (Ohakune).

g: Summer (Ohakune).

h: Autumn (Ohakune).


e
f
g
h
60
40
20
% Composition of diet
12
13
14
15
Altitude × 100 m

4.1.2. Feeding Trials.

Results from feeding trials carried out using the captive hares are given in Tables 3, 4 and 5.

Feeding Trial 1 (Table 3) lasted two days, during which four alpine species were offered as follows: 250 g each of Chionochloa rubra, Notodanthania setifolia, and Calluna vulgaris, and 50 g of Aciphylla squarrosa. In addition 350 g of rabbit pellets were provided, and water ad lib.

Table 3: Food consumed, in grams wet weight and as a percentage of the total daily consumption, during Feeding Trial 1. (3 hares).

	Day 1		Day 2		Mean
Species	grams	%	grams	%	grams
A.squarrosa	50.0	12.4	-	-	50.0
C.rubra	67.0	16.6	51.0	18.0	59.0
N.setifolia	12.0	3.0	10.0	3.5	11.0
C.vulgaris	20.0	5.0	42.0	14.8	31.0
Rabbit Pellets	255.0	63.1	180.0	63.6	217.5
Total	404.0	100.0	283.0	100.0	368.5

Totals of 404 g/day or 234.1 g/day/hare, and 283 g/day or 94.3 g/day/hare were consumed. Over both days C.rubra constituted the major portion of alpine species consumed: 16.6% and 18.0% respectively. Consumption of all the A.squarrosa provided suggests that this is also a preferred species.

In the second feeding trial lasting six days, (Table 4), 150 g of each of five alpine species were offered daily, together with 300 g of rabbit pellets and water ad lib.

In both trials more food was consumed on the first day than on any subsequent day, perhaps as the hares adjusted to the new diet. Accordingly mean calculations from Trial 2 were made omitting results from Day 1, but no adjustment was made to the results of Trial 1, which

Table 4: Food consumed, in grams wet weight and as a percentage of the total daily consumption, during Feeding Trial 2. (3 hares).

	Day 1		Day 2		Day 3		Day 4		Day 5		Day 6		Mean
Species	g	%	g	%	g	%	g	%	g	%	g	%	g
C.spectabilis	69.0	9.7	36.0	6.9	45.0	7.6	55.0	10.9	50.5	8.8	39.0	7.3	45.0
S.pauciflorus	74.0	10.4	35.0	6.8	49.1	8.3	39.5	7.8	57.0	9.9	47.0	8.8	45.5
C.rubra	82.0	11.6	30.0	5.8	90.5	15.3	75.0	14.9	107.0	18.7	102.0	19.2	80.9
P.colensoi	67.0	9.4	30.0	5.8	34.0	5.7	35.0	6.9	57.0	9.9	47.0	8.8	45.5
C.vulgaris	118.0	16.6	85.5	16.6	74.5	12.6	-	-	-	-	-	-	80.0
Rabbit Pellets	300.0	42.3	300.0	58.1	300.0	50.6	300.0	59.5	300.0	52.5	300.0	55.9	300.0
Total	710.0	100.0	516.5	100.0	593.1	100.1	504.5	100.0	671.5	100.0	532.0	100.0	334.9

lasted only two days.

From Table 4, it can be seen that in Trial 2 daily food consumption averaged 591.5 g/day, or 197.2 g/day/hare. C.rubra and C.vulgaris were preferred species with mean daily consumptions of 80.9 and 80.0 g/day respectively. Approximately half, 45.1, 45.5 and 40.0 g/day respectively of the other species C.spectabilis, S.pauciflorus and Poa colensoi were injested.

In Trial 3 (Table 5) 100 g of A.squarrosa and S.pauciflorus, 95 g of C.vulgaris, 50 g of C.spectabilis and P.colensoi, and 26 g of C.rubra plus water ad lib were offered daily to one hare, Horie.

Table 5: Food consumed, in grams wet weight and as a percentage of the total daily consumption, during Feeding Trial 3. (1 hare).

	Day 1	
Species	grams	%
A.squarrosa	88.0	40.2
C.spectabilis	12.0	5.5
S.pauciflorus	27.5	12.6
C.rubra	14.0	6.4
P.colensoi	22.0	10.1
C.vulgaris	55.5	25.3
Total	219.0	100.0

Daily food consumption totalled 219 g/day. Results were comparable to those of previous trials. A.squarrosa was clearly a preferred species comprising 40.2% of the diet, while C.vulgaris made up 25.1% of the food eaten.

The three hares used in Feeding Trials 1 and 2 weighed individually 2.6, 2.5, and 2.8 kg at the end of Trial 2. At the finish of Trial 3 Horie weighed 1.4 kg.

Dry weights of pellets produced fell slightly during the first two feeding trials. (Tables 6 and 7).

Table 6: Dry weights (g) of pellets produced during each day of Feeding Trial 1.

Day	1	2	$\bar{x}$	SD
g	76.3	72.9	74.6	2.4

Table 7: Dry weights (g) of pellets produced during each day of Feeding Trial 2.

Day	1	2	3	4	5	6	$\bar{x}$	SD
g	82.0	82.2	98.9	71.1	79.0	71.2	80.7	10.2

Mean dry weights were respectively for Trial 1, 74.6 g/day or 24.9 g/day/hare, and for Trial 2, 80.7 g/day or 26.9 g/day/hare.

4.1.3. Field Observations.

The species showing obvious signs of browsing by hares were:-

Aciphylla squarrosa
Chionochloa rubra
Schoenus pauciflorus
Celmisia spectabilis
Poa colensoi

Signs of hare browsing have also been recognised on the leaves of *Senecio bidwillii*. (D. Clifton pers.comm.)

Plate 2: Browsing Signs on *Chionochloa rubra*.

Plate 3: Browsing Signs on *Celmisia spectabilis*.

Plate 4: Browsing Signs on *Aciphylla squarrosa*.

Plate 5: Browsing Signs on *Schoenus pauciflorus*.

4.1.4. Samples From Other Areas.

Thirty-five samples of faecal pellets were collected during the research period from other areas within Tongariro National Park. (See Location Map Fig. 5). Results are presented in Table 8 (a - i).

Table 8 (a): Percent Frequency Composition of Samples collected on the Silica Springs Track, May 1977.

Species	Altitude and Vegetation Type.				
	Bush 1130m	Clearing 1160m	Bush 1190m	Bush 1310m	Tussock 1310m
Moss	-	-	-	4	-
C.spectabilis	14	8	20	36	22
S.bidwillii	-	-	-	2	-
S.pauciflorus	-	-	4	-	-
C.rubra	48	40	52	44	32
P.colensoi	4	-	-	14	12
Grass	6	52	22	-	32
Unknown	18	-	-	-	1

Table 8 (b): Percent Frequency Composition of Samples collected under a Canopy of Mountain Beech.

Species	Month and Altitude.						
	May 1200m	June 1200m*	June 1220m	**Sept. 1100m	Sept. 1100m	Sept. 1200m	May 1200m
C.spectabilis	-	26	2	-	2	-	32
S.bidwillii	4	-	-	-	-	2	-
S.pauciflorus	-		-	-	-	-	-
C.rubra	34	20	34	6	22	32	14
N.setifolia	4	-	-	-	-	-	-
P.colensoi	34	8	-	-	-	16	14
Grass	24	34	-	36	28	50	40
Roots	-	-	-	32	-	-	-
Unknown	-	12	64	24	48	-	-

* indicates sample was collected on the Ohakune site.

** indicates pellets were those of a Leveret.

Table 8 (c): Percent Frequency Composition of Samples collected in September 1977 from Waihohonu Track (E) and Frost Flat (N.E.)

Species	Area and Altitude.		
	Waihohonu 1000m	Waihohonu 1050m	Frost Flat 750m
C. spectabilis	34	26	-
C.rubra	56	38	38
Grass	10	36	62

Table 8 (d): Percent Frequency Composition of Samples collected in October 1977 from above the Karioi Pine Forest (S.W.)

Species	Area and Altitude.	
	Bush 1200m	Tussock 1200m
Moss	8	-
C. rubra	44	46
N. setifolia	34	48
Grass	12	6
Unknown	2	-

Table 8 (e): Percent Frequency Composition of Samples collected during October 1977 along the Waihohonu - Ketetahi Track.

Species	Area and Altitude.				
	Waihohonu 1000m	Waihohonu 1100m	Oturere 1250m	Ketetahi 1500m	Ketetahi 1100m
Moss	-	-	-	30	-
C. spectabilis	12	38	8	36	24
S. bidwillii	14	-	-	14	-
C. rubra	44	54	70	16	58
N. setifolia	-	8	-	-	-
P. colensoi	-	-	-	8	-
Grass	18	-	22	-	18
Unknown	12	-	-	-	-

Table 8 (f): Percent Frequency Composition of Samples collected during November 1977 above Lake Rotoaira (N.E.).

Species	Altitude
	800m
C.spectabilis	12
C.rubra	28
Grass	50

Table 8 (g): Percent Frequency Composition of Samples collected during December 1977 along the Mangatapopo Track (N).

Species	Altitude			
	1000m	1100m	1200m	1300m
Moss	-	-	4	-
A.squarrosa	-	-	2	-
C.spectabilis	30	12	20	26
S.bidwillii	-	-	24	4
C.rubra	68	76	42	30
N.setifolia	-	2	2	6
P.colensoi	-	-	6	-
Grass	-	-	-	34
Unknown	2	10	2	-

Table 8 (h): Percent Frequency Composition of Samples collected during December 1977 along the Tukino Road (E.).

Species	Altitude			
	1100m	1200m	1300m	1400m
Moss	-	12	6	10
S.spectabilis	24	-	16	28
S.bidwillii	-	-	-	6
C.rubra	18	14	40	44
N.Setifolia	-	-	6	-
P.colensoi	18	-	8	-
Grass	14	24	18	12
Seeds	6	-	-	-
Unknown	20	50	6	-

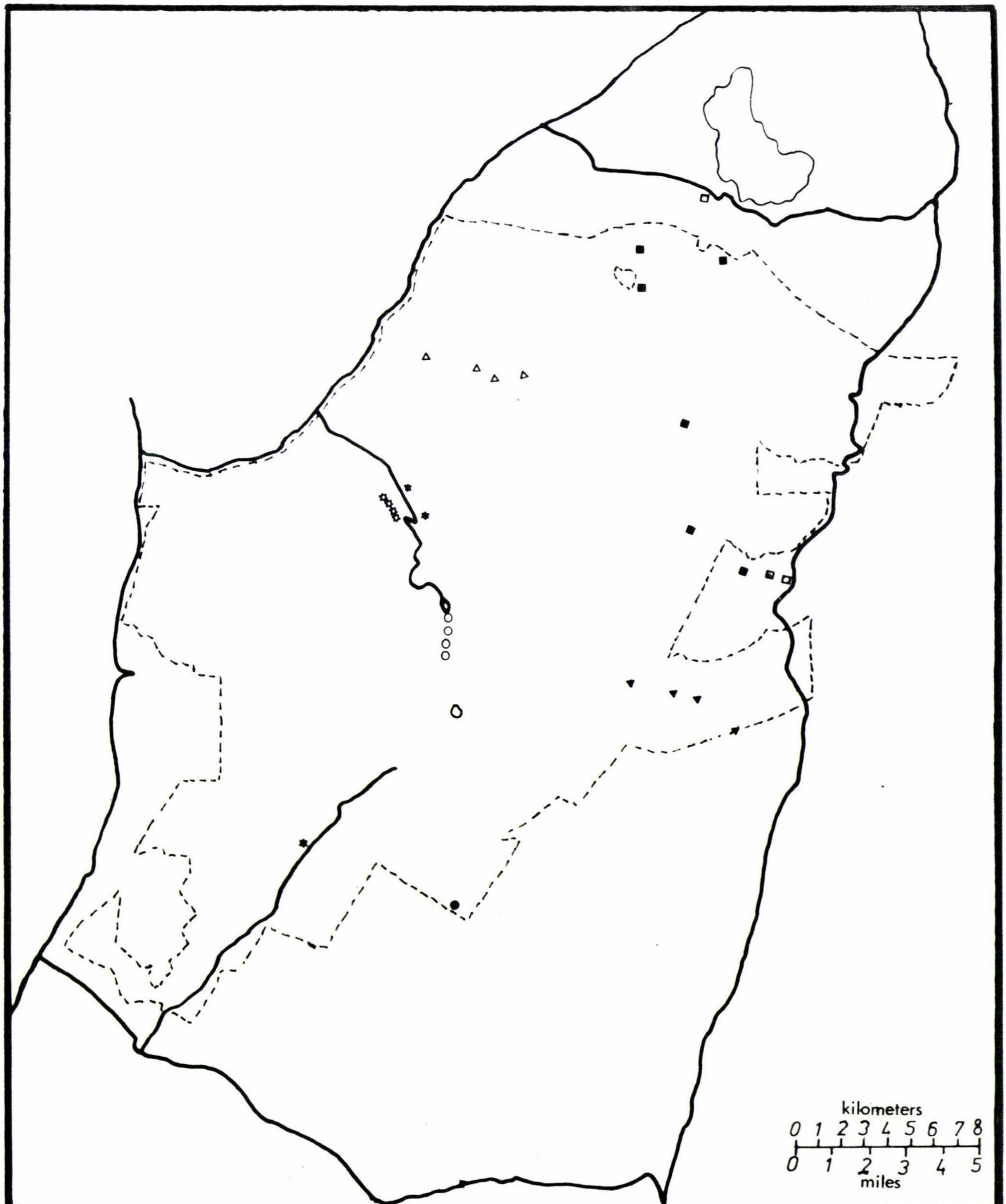
Table 8 (i): Percent Frequency Composition of Samples collected during February 1978 on the Whakapapaiti Skifield (N).

Species	Altitude			
	1800m	1900m	2000m	2100m
Moss	38	44	64	48
C.spectabilis	26	26	18	24
S.bidwillii	24	-	-	14
C.rubra	12	16	8	12
Seeds	-	-	-	2
Unknown	-	14	10	-

Figure 5: Map Showing Location of Collections of Additional Samples.

Key:

- ☆ Table 8 (a)
- ✱ Table 8 (b)
- ◻ Table 8 (c)
- ● Table 8 (d)
- ▣ Table 8 (e)
- ▦ Table 8 (f)
- △ Table 8 (g)
- ▲ Table 8 (h)
- ○ Table 8 (i)


kilometers
0 1 2 3 4 5 6 7 8
0 1 2 3 4 5
miles

4.2. VEGETATION ANALYSIS.

4.2.1. Seasonal and Altitudinal Availability of Vegetation.

From Table 9 (a - i) the major seasonal variation in availability of vegetation results from snow cover in winter (June) and spring (September), especially at the higher altitudes. Snow covered approximately 80% of the transects at 1600 m Chateau and 1500 m Ohakune during these two seasons.

The dominant species at 1600 m, 1500 m Chateau and 1500 m Ohakune were D.recurvum, G.colensoi, S.bidwillii and moss. Striking differences in vegetation composition on the two transects at 1600 m and 1500 m Chateau were also observed. Bare ground occupied about 70% of the transect at 1600 m lt, compared with less than 12% at 1600 m rt. The 1500 m rt transect was about 80% bare ground, but the transect at 1500 m lt had only 18% bare ground.

Dominant plant species at 1400 m Chateau and Ohakune were D.recurvum, moss, C.rubra, and P.colensoi. The transects at 1300 m and 1200 m Chateau and 1300 m Ohakune had vegetation described as Empodisma/Gleichenia swamp (Scott 1977(a)), with E.minus, G.circinata, moss and D.recurvum being the dominant species.

Introduced grasses and C.vulgaris comprised approximately 60% of the 1100 m transect, and C.vulgaris alone dominated at 1000 m Chateau.

The transect at 900 m was again covered by Empodisima/Gleichenia swamp.

Point analysis of transect vegetation indicates that availability of the five major dietary species, C.spectabilis, moss, P.colensoi and S.bidwillii increases with increasing altitude, while availability of C.rubra decreases.

(For complete generic names see Appendix 1).

Table 9 (a): Seasonal Changes in Percent Frequency Composition of Vegetation.

ALTITUDE.	1600 m lt				1600 m rt			
SPECIES.	Wi.	Sp.	Su.	Au.	Wi.	Sp.	Su.	Au.
Lichen								
R.lanuginosum						2	11	10
L.australianum		5	3	5				
G.circinata								
P.vestitum								
P.nivalis								1
D.bidwillii								
D.laxifolium								
P.alpinus								
P.buxifolia								
L.scoparium								
N.solandri								
A.squarrosa								
A.aromatica							1	1
G.colensoi	4	4	8	12	4	1	11	15
P.pumila				4	1		1	
C.juniperina								
C.fraseri	1			2				
E.alpina								
D.filifolium								
D.recurvum	4	2	5	5	4		27	23
C.cheesemanii	1				1			
C.incana							1	1
C.spectabilis						1	5	9
R.australis								
C.vauvilliersii			2					
S.bidwillii							5	6
O.vulcanica								
H.odora								
H.tetragona							9	
P.tenax								
J.gregiflorus								
E.minus								
S.pauciflorus								
C.rubra							2	6
N.setifolia								
P.colensoi	7	4	9	5	7	11	11	8
C.fylvida								
C.vulgaris								
Grass							12	6
Snow	83	50			83	80		
Bare Ground		35	73	67		5		12
Unknown								

Table 9 (b): Seasonal Changes in Percent Frequency Composition of Vegetation.

ALTITUDE.	1500 m lt				1500 m rt			
SPECIES.	Wi.	Sp.	Su.	Au.	Wi.	Sp.	Su.	Au.
Lichen								
R.lanuginosum		11	7	13	6	10	32	25
L.australianum								
G.circinata	3							
P.vestitum								
P.nivalis		5						
D.bidwillii								
D.laxifolium								
P.alpinus			7	4				
P.buxifolia		1						
L.scoparium								
N.solandri								
A.squarrosa								
A.aromatica								
G.colensoi	5	3	9	6	4	4	5	5
P.pumila								
C.juniperina								
C.fraseri								
E.alpina	1							
D.filifolium								
D.recurvum	21	23	35	23	5	3	8	7
C.cheesemanii		3	3	3				
C.incana								
C.spectabilis	1	3	2	6		1	1	1
R.australis						1	1	1
C.vauvilliersii			1					
S.bidwillii	4	5	8	7				
O.vulcanica								
H.odora								
H.tetragona	2	1	6	4				
P.tenax								
J.gregiflorus								
E.minus								
S.pauciflorus		1		1				
C.rubra	6	3	3	11	2			
N.setifolia								
P.colensoi	1		1	4	2	3	1	3
C.fylvida								
C.vulgaris								
Grass								
Snow	44	38			43	39		
Bare Ground	10	1	18	18	35	39	51	58
Unknown	1				3			

Table 9 (c): Seasonal Changes in Percent Frequency Composition of Vegetation.

ALTITUDE.	1400 m lt				1400 m rt			
SPECIES.	Wi.	Sp.	Su.	Au.	Wi.	Sp.	Su.	Au.
Lichen	1				4			
R.lanuginosum	22	5	15	9	16	8	5	10
L.australianum								
G.circinata	1	2	1	5	5			
P.vestitum			1					
P.nivalis		7				1	4	2
D.bidwillii			5		1		5	
D.laxifolium				1				
P.alpinus			13		3		3	
P.buxifolia		5	8	8	1	5	9	4
L.scoparium			1	2				
N.solandri								
A.squarrosa								
A.aromatica			1				1	
G.colensoi	1				4			
P.pumila					1			
C.juniperina								
C.fraseri								
E.alpina								
D.filifolium								
D.recurvum	24	16	33	45	34	31	31	34
C.cheesemanii	1		1		4	1	6	2
C.incana								
C.spectabilis	4	2	5	7	4	5	1	7
R.australis								
C.vauvilliersii		1	4					
S.bidwillii	2			1	3		3	1
O.vulcanica					1			
H.odora	7				4			
H.tetragona		2		1		2	2	2
P.tenax								
J.gregiflorus								
E.minus				4				
S.pauciflorus			4	2				
C.rubra	5	7	8	7	5	12	11	15
N.setifolia								
P.colensoi	2	1		2	5	3	15	17
C.fylvida								
C.vulgaris								1
Grass								
Snow	12	50			1	24		
Bare Ground	7	1		3	1		4	3
Unknown	10				4			

Table 9 (d): Seasonal Changes in Percent Frequency Composition of Vegetation.

ALTITUDE.	1300 m - 1				1300 m - 2			
SPECIES.	Wi.	Sp.	Su.	Au.	Wi.	Sp.	Su.	Au.
Lichen								
R.lanuginosum	22	19	10	3	14	19	2	7
L.australianum								
G.circinata	34	23	26	23	36	20	30	34
P.vestitum			1					
P.nivalis		2	1			1		1
D.bidwillii								
D.laxifolium								
P.alpinus							1	
P.buxifolia		1	2				4	1
L.scoparium				1				
N.solandri								
A.squarrosa								
A.aromatica								
G.colensoi								
P.pumila								
C.juniperina								
C.fraseri								
E.alpina								
D.filifolium	1				1			
D.recurvum	8	7	13	8	11	16	40	22
C.cheesemanii			1	1	3	4	7	3
C.incana								
C.spectabilis	3	7	5	4	7	7	6	6
R.australis								
C.vauvilliersii			2					
S.bidwillii								
O.vulcanica								
H.odora								
H.tetragona		2	1			1	1	3
P.tenax								
J.gregiflorus								
E.minus	22	18	32	52	15	7	2	14
S.pauciflorus		1	2	3		1		1
C.rubra	5	5	3	2	8	10	5	7
N.setifolia					1			
P.colensoi				1				1
C.fylvida								
C.vulgaris								
Grass	1		1	2				
Snow		14				14		
Bare Ground	1				2			
Unknown	3				2			

Table 9 (e): Seasonal Changes in Percent Frequency Composition of Vegetation.

ALTITUDE.	1265 m				1200 m			
SPECIES.	Wi.	Sp.	Su.	Au.	Wi.	Sp.	Su.	Au.
Lichen	1							
R.lanuginosum	25	20	12	23		8	1	3
L.australianum								
G.circinata	28	24	35	25		12	15	15
P.vestitum								
P.nivalis		2	2	5			1	
D.bidwillii			16	1				
D.laxifolium								
P.alpinus								
P.buxifolia	2	2		1				
L.scoparium							1	
N.solandri								
A.squarrosa								
A.aromatica			1					
G.colensoi	1	2	1	1				
P.pumila								
C.juniperina								
C.fraseri								
E.alpina								
D.filifolium	2	2		3		1	3	1
D.recurvum	15	9	18	10				
C.cheesemanii	5	1	3	3				
C.incana				1				
C.spectabilis	1	1	1	3		3	1	2
R.australis								
C.vauvilliersii							2	
S.bidwillii								
O.vulcanica	1							
H.odora								
H.tetragona								
P.tenax								
J.gregiflorus								
E.minus	3	1		1		24	23	26
S.pauciflorus								3
C.rubra	6	4	7	10		2	3	1
N.setifolia								
P.colensoi			2	4				
C.fylvida								
C.vulgaris			2	1				
Grass								
Snow		18						
Bare Ground	7	4		8				
Unknown	5							

Table 9 (f): Seasonal Changes in Percent Frequency Composition of Vegetation.

ALTITUDE.	1100 m				1000 m			
SPECIES.	Wi.	Sp.	Su.	Au.	Wi.	Sp.	Su.	Au.
Lichen								
R.lanuginosum		2			3	3		
L.australianum								
G.circinata	1				8	10	9	8
P.vestitum								
P.nivalis								
D.bidwillii								
D.laxifolium								
P.alpinus								
P.buxifolia							1	
L.scoparium						1	1	3
N.solandri								
A.squarrosa		1	1	1				
A.aromatica								
G.colensoi					1			
P.pumila								
C.juniperina								
C.fraseri								
E.alpina								
D.filifolium	2							1
D.recurvum								
C.cheesemanii	2				6	8	4	3
C.incana								
C.spectabilis								
R.australis								
C.vauvilliersii						1		
S.bidwillii								
O.vulcanica		1						
H.odora								
H.tetragona								
P.tenax								
J.gregiflorus	5			3	1	9		6
E.minus	2						1	2
S.pauciflorus								
C.rubra	1		2	1	4	3	3	4
N.setifolia		12			1	2		
P.colensoi	11	15	1		1	1		1
C.fylvida								
C.vulgaris	36	22	31	19	62	52	66	63
Grass	26	25	41	47	3	5	4	6
Snow								
Bare Ground	25	22	25	29	6	4	9	3
Unknown					4	1		

Table 9 (g): Seasonal Changes in Percent Frequency Composition of Vegetation.

ALTITUDE.	900 m							
SPECIES.	Wi.	Sp.	Su.	Au.	Wi.	Sp.	Su.	Au.
Lichen	6	2						
R.lanuginosum								
L.australianum								
G.circinata	38	42	37	45				
P.vestitum								
P.nivalis								
D.bidwillii								
D.laxifolium								
P.alpinus								
P.buxifolia								
L.scoparium	3	1	2	1				
N.solandri								
A.squarrosa								
A.aromatica								
G.colensoi								
P.pumila								
C.juniperina								
C.fraseri								
E.alpina								
D.filifolium	1	1	1	4				
D.recurvum								
C.cheesemanii								
C.incana								
C.spectabilis								
R.australis								
C.vauvilliersii								
S.bidwillii								
O.vulcanica								
H.odora								
H.tetragona								
P.tenax	3	5	4	4				
J.gregiflorus	6	5	2	2				
E.minus	34	38	43	39				
S.pauciflorus								
C.rubra	4	1	1					
N.setifolia								
P.colensoi								
C.fylvida								
C.vulgaris	3	5	10	3				
Grass				1				
Snow								
Bare Ground								
Unknown	2							

Table 9 (h): Seasonal Changes in Percent Frequency Composition of Vegetation.

ALTITUDE.	1500 m 0				1400 m 0			
SPECIES.	Wi.	Sp.	Su.	Au.	Wi.	Sp.	Su.	Au.
Lichen	1							
R.lanuginosum			5	1		8	4	3
L.australianum			6			1	1	
G.circinata						8	8	10
P.vestitum								
P.nivalis		3	12	17		11		12
D.bidwillii				3				
D.laxifolium								
P.alpinus				1	1	1	1	1
P.buxifolia								
L.scoparium								
N.solandri								
A.squarrosa								
A.aromatica								
G.colensoi				1				1
P.pumila								
C.juniperina								
C.fraseri								
E.alpina								
D.filifolium			2		1		6	
D.recurvum	6	10	37	23	10	24	13	18
C.cheesemanii	1		1	2	2			
C.incana			12	16	1	2		1
C.spectabilis			9	10		8	9	7
R.australis								
C.vauvilliersii								
S.bidwillii	2	3	10	5				
O.vulcanica			1					
H.odora								
H.tetragona	2	2	1	3				
P.tenax								
J.gregiflorus								
E.minus	1			2	1	3	6	6
S.pauciflorus		2	2	10			3	11
C.rubra	1	2	1	2	7	14	10	7
N.setifolia	1							
P.colensoi				2				2
C.fylvida								
C.vulgaris								
Grass								
Snow	81	78			66			
Bare Ground	1		1	2	2	18	29	19
Unknown	3				9			

Table 9 (i): Seasonal Changes in Percent Frequency Composition of Vegetation.

ALTITUDE.	1300 m 0							
SPECIES.	Wi.	Sp.	Su.	Au.	Wi.	Sp.	Su.	Au.
Lichen								
R.lanuginosum	12	17	8	11				
L.australianum			1					
G.circinata	30	28	29	38				
P.vestitum								
P.nivalis		13	15	9				
D.bidwillii				1				
D.laxifolium								
P.alpinus	2							
P.buxifolia				1				
L.scoparium								
N.solandri								
A.squarrosa								
A.aromatica								
G.colensoi								
P.pumila								
C.juniperina								
C.fraseri								
E.alpina								
D.filifolium	6		1					
D.recurvum	9	11	16	12				
C.cheesemanii								
C.incana	4	8	8	6				
C.spectabilis	2	3	3					
R.australis								
C.vauvilliersii								
S.bidwillii	1							
O.vulcanica								
H.odora								
H.tetragona								
P.tenax								
J.gregiflorus								
E.minus		2		3				
S.pauciflorus		3	12	16				
C.rubra	6	11	7	3				
N.setifolia	1							
P.colensoi								
C.fylvida		2						
C.vulgaris								
Grass	3							
Snow	19							
Bare Ground		2						
Unknown	5							

Plate 6 (a): Transect at 1600 m lt during winter.

Plate 6 (b): Transect at 1600 m lt during summer.

Plate 7 (a): Transect at 1400 m rt
during winter.

Plate 7 (b): Transect at 1400 m rt
during summer.

Plate 8 (a): Transect at 1100 m during winter.

Plate 8 (b): Transect at 1100 m during summer.

4.2.2. Chemical Composition of Important Dietary Plants.

Analysis of varience (ANOVA) expresses a measure of the total variability of a set of data as a sum of terms, each of which can be attributed to a specific source, or cause, of variation. Complete ANOVA tables appear in Appendix II. The second column lists the sum of squares (SS) or the measure of the total variation of the set of data, the third column lists the degrees of freedom (DF) or the number of independent deviations from the mean on which the respective sums of squares are based. The fourth column details the mean squares (MS) which are obtained by dividing the sums of squares by their respective degrees of freedom; the fifth column gives the F statistic and the final column gives the significance of F (P).

Summaries of ANOVA results appear in Tables 10 and 11 where only significance of F values (P) are listed. P values are considered not significant (ns) if $p > 0.05$.

Table 10: P Values from ANOVA Test (Chateau Site).

Source of varience.	Na	K	Ca	Mg	Fe	Zn
Season	.001	.001	.003	.001	.006	ns
Plant	.001	.001	.001	.001	.001	.002
Altitude	.001	ns	ns	.001	.001	ns
S x P	ns	.001	ns	.001	ns	ns
S x A	.017	.037	.010	.001	.001	ns
P x A	ns	.001	.001	.001	ns	ns
S x P x A	.045	.005	ns	.001	.001	ns

Table 11: P Values from ANOVA Test (Ohakune Site).

Source of varience.	Na	K	Ca	Mg	Fe	Zn
Season	ns	.001	.005	.050	.001	.001
Plant	.001	.001	.001	.001	.001	.001
Altitude	.003	.002	ns	ns	.011	.037
S x P	ns	.002	.001	ns	ns	.001
S x A	.015	.018	ns	ns	ns	ns
P x A	ns	.046	ns	.029	ns	ns
S x P x A	ns	.001	.001	ns	ns	ns

The effects of season are significant for all elements except Zn on the Chateau site and Na on the Ohakune site. The effects of plant are significant for all elements; altitude however has varying significance on different elements. When the effects of season and plant, season and altitude and plant and latitude were combined varying effects on element concentration observed, similarly when all three variables are combined.

The multiple classification analysis table (MCA) is a method of displaying the results of ANOVA especially when there are no significant interaction effects. It is particularly useful when the factors examined are 'attribute' variables that are not 'experimentallv manipulated' and therefore are correlated. Given two or more inter-related factors, it is valuable to know the net effect of each variable when the differences in the other factors are controlled for (Nie et al 1975). Complete MCA tables are presented in Appendix 111. The numbers in the second column are the means of each category, expressed as a deviation from the grand mean, these values are not adjusted for other factors or for covariates. The third column indicates the adjusted mean values for each category (again expressed as deviations from the grand mean) when the other factors are adjusted for. Actual adjusted mean values (ie. the deviation from the grand mean has been added or subtracted) are presented in Tables 12 to 17.

Table 12: Adjusted Mean Values (mg/g/ dry wt.) for the Effects of Season (Chateau Site).

Season	Na	K	Ca	Mg	Fe	Zn
Winter	0.34	3.90	3.64	0.56	0.15	0.02
Spring	0.43	5.47	3.56	0.81	0.12	0.02
Summer	0.27	5.27	3.09	0.83	0.07	0.02
Autumn	0.41	4.81	2.68	0.57	0.12	0.02

Table 13: Adjusted Mean Values (mg/g dry wt.) for the Effects of Season (Ohakune Site).

Season	Na	K	Ca	Mg	Fe	Zn
Winter	0.23	3.50	2.51	0.49	0.13	0.01
Spring	0.28	4.50	2.29	0.83	0.02	0.00
Summer	0.23	5.94	2.66	0.51	0.07	0.01
Autumn	0.25	3.97	1.63	0.51	0.11	0.02

It is apparent (Tables 12 and 13) that plants generally contained higher amounts of K and Mg during spring and summer. Highest amounts of Fe were recorded in winter and autumn; levels of Na and Zn remained relatively static throughout while lowest levels of Ca occurred in autumn.

Table 14: Adjusted Mean Values (mg/g dry wt.) for the Effects of Plant. (Chateau Site).

Plant	Na	K	Ca	Mg	Fe	Zn
C.spectabilis	0.38	7.16	4.91	0.86	0.10	0.02
C.rubra	0.23	4.06	2.94	0.24	0.03	0.01
S.bidwillii	0.64	10.16	11.98	2.20	0.12	0.05
S.pauciflorus	0.36	3.01	0.87	0.41	0.08	0.02
P.colensoi	0.33	1.95	0.73	0.30	0.28	0.03
C.vulgaris	0.26	1.65	3.40	1.35	0.09	0.02
A.squarrosa	0.38	16.57	11.97	2.30	0.09	0.02

Table 15: Adjusted Mean Values (mg/g/ dry wt.) for the Effects of Plant. (Ohakune Site).

Plant	Na	K	Ca	Mg	Fe	Zn
C.spectabilis	0.27	6.11	3.49	0.95	0.11	0.01
C.rubra	0.19	3.57	0.48	0.26	0.03	0.01
S.bidwillii	0.46	11.39	9.63	1.39	0.06	0.03
S.pauciflorus	0.19	2.41	1.54	0.53	0.06	0.01
P.colensoi	0.35	2.60	0.68	0.29	0.22	0.00

Greatest variability in element composition between plants occurred in levels of K and Ca. Aciphylla squarrosa, Celmisia spectabilis and Senecio bidwillii clearly contained the highest amounts of these elements. (Tables 14 and 15).

Table 16: Adjusted Mean Values (mg/g/dry wt.) for the Effects of Altitude. (Chateau Site).

Altitude	Na	K	Ca	Mg	Fe	Zn
900	0.27	4.60	3.68	0.72	0.10	0.02
1000	0.29	5.05	2.85	0.50	0.06	0.02
1100	0.35	5.08	2.75	1.06	0.05	0.02
1200	0.32	5.50	3.70	0.79	0.05	0.03
1265	0.29	5.52	2.95	0.84	0.15	0.02
1300-1	0.23	4.91	2.90	0.74	0.09	0.02
1300-2	0.28	4.24	2.71	0.64	0.05	0.02
1400 lt	0.34	4.76	3.44	0.78	0.12	0.03
1400 rt	0.32	4.71	3.40	0.69	0.21	0.02
1500 lt	0.41	5.34	3.58	0.68	0.17	0.02
1500 rt	0.71	4.15	4.13	0.64	0.12	0.04
1600 lt	0.58	5.30	3.07	0.52	0.16	0.02
1600 rt	0.29	5.00	3.01	0.52	0.09	0.01

Table 17: Adjusted Mean Values (mg/g/ dry wt.) for the Effects of Altitude. (Ohakune Site).

Altitude	Na	K	Ca	Mg	Fe	Zn
Ohakune						
1200	0.30	5.29	1.94	0.62	0.07	0.01
1300	0.20	3.77	2.31	0.51	0.03	0.01
1400	0.21	4.59	2.12	0.48	0.09	0.01
1500	0.30	4.77	2.37	0.72	0.11	0.01

No trends were observed regarding the effects of altitude (Tables 16 and 17) on element content.

4.3 HARE ABUNDANCE.

4.3.1. Pellet Density.

The best estimate of pellet density is where the N/P (ie. the number of neighbours/number of point numbers found) is consistently over one-half and when the per cent error of the estimate is smallest (C.L. Batcheler pers. comm.). Taking this into consideration, the pellet densities which occurred as close as possible to a common point frequency (estimated to be 0.193) were taken as being the best density estimate for that sample.

As a large number of samples is always required to achieve a density estimate with a reasonable limit of error (C.L. Batcheler pers. comm.) samples from two altitudes (ie. four transects) were combined. (Table 18).

These data were incorporated in the formula:

$$P = \frac{(M_2 - M_1\ K_2/K_1)\ \log_e\ (K_1/K_2)}{(1-K_2/K_1)\ d\ T}$$

from Batcheler (1975(a))

(see Section 3.3.1.) K values (Table 19) used were calculated from mean decay rates (see Section 4.3.2.) for the combined altitudes, d was calculated to be 409 pellets per day (see Section 4.3.3.) and T 92, 91, 90 and 92 days respectively.

Final results of hare density are shown in Table 20.

Table 18: Pellet Density Estimates.

	Winter		Spring		Summer		Autumn	
Altitude	Density (m^2)	PLE	Density (m^2)	PLE	Density (m^2)	PLE	Density (m^2)	PLE
1600m + 1500m	0.278	0.351	4.850	3.564	2.473	1.993	2.837	2.160
1400m + 1300m	10.285	4.954	18.195	11.386	10.846	6.350	16.518	8.405
1200m + 1100m	9.525	6.915	1.133	0.758	3.999	1.923	3.290	2.037
Ohakune	6.224	2.401	6.091	3.104	14.927	8.411	22.333	11.475

Table 19: Mean values for K, decay rates.

	Winter		Spring		Summer		Autumn	
Altitude	K_1	K_2	K_1	K_2	K_1	K_2	K_1	K_2
1600m + 1500m	50	37.5	39	27	24	4.5	24	45
1400m + 1300m	46	27.5	22.5	20	27	24.5	20	11
1200m + 1100m	34	8	7	2	40	33	40	33
Ohakune	50	38.5	50	38.5	50	38.5	50	38.5

Table 20: Population Density Estimates (hares/hectare).

Altitude	Wi	Sp	Su	Au
1600m + 1500m	10.41	5.24	0.15	2.63
1400m + 1300m	16.06	17.94	12.76	12.15
1200m + 1100m	3.07	3.86	1.73	14.92
Ohakune	3.02	20.28	17.19	36.57

4.3.2. Faecal Decay Rates.

Results from the first experiment begun in late autumn (Fig. 6 (a)) indicate that in general pellets at higher altitudes took longest to decay. The time taken for 50% of the pellets to decay was 7 months at 1600 m, 4.5 months at 1500 m, 9 months at 1400 m, 1.5 months at 1300 m and 1200 m, and 4 months at 1100 m. Some pellets, however, still remained intact after 12 months at all altitudes except at 1200 m and 1300 m.

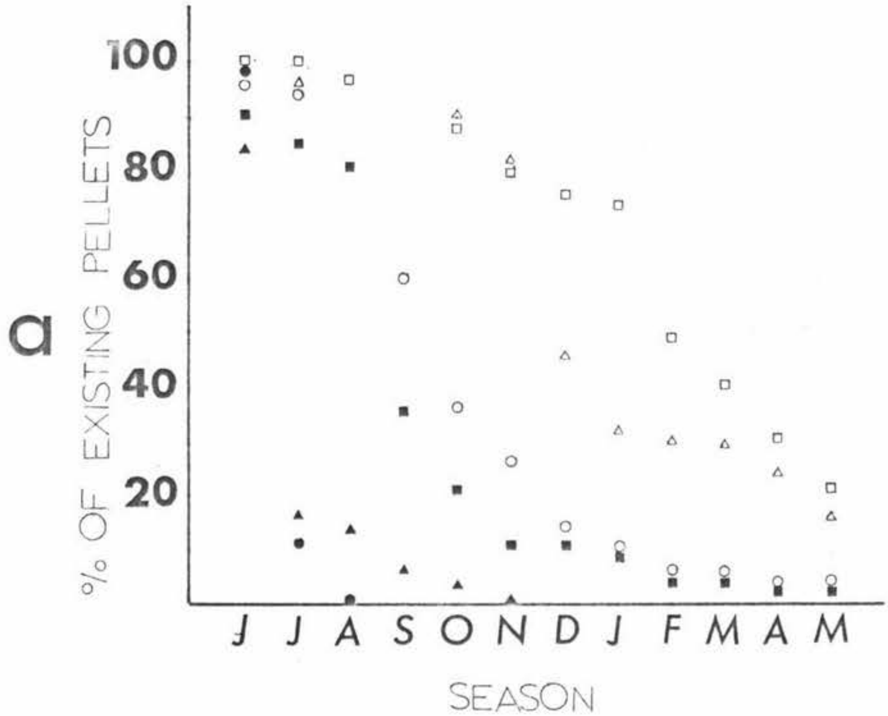
Pellets in the second experiment, begun in mid-spring (Fig. 6 (b)) decayed faster than those just described. Half the pellets had decayed in 2 months at 1600 m, 3.5 months at 1500 m. 4.5 months at 1400 m, and in less than 1 month at 1300 m and 1200 m. After 7 months, at the close of the study. 66 of the original 100 pellets still remained at 1100 m. As in the first experiment, some pellets, with the exception of those at 1200 m, remained after the 7 months. The rate of decay of pellets at 1500 m on the Ohakune site was much slower than that of pellets at the same altitude on the

Figure 6 (a): Decay rate of pellets at various altitudes. Experiment one begun in May.

Figure 6 (b): Decay rate of pellets at various altitudes. Experiment two begun in October.

Key:

△ 1600 m
○ 1500 m
□ 1400 m
▲ 1300 m
● 1200 m
■ 1100 m
▽ 1500 m (Ohakune)


a
% OF EXISTING PELLETS
100
80
60
40
20
J J A S O N D J F M A M
SEASON

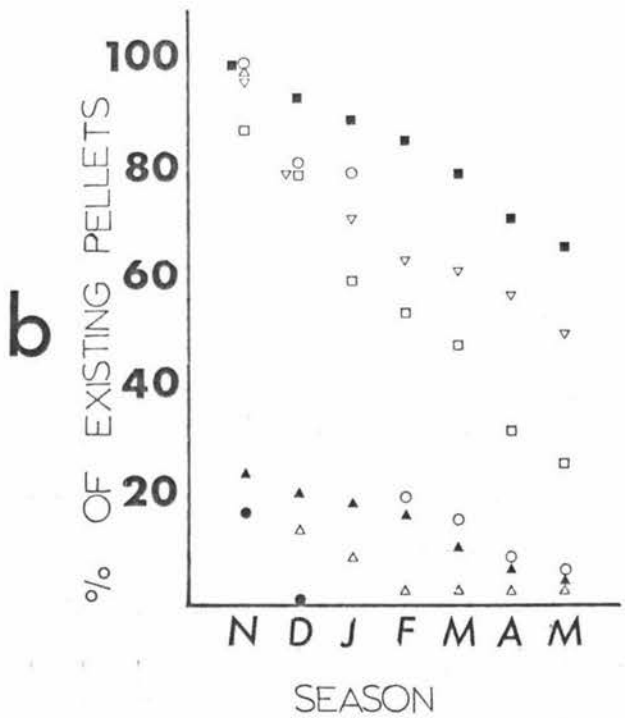
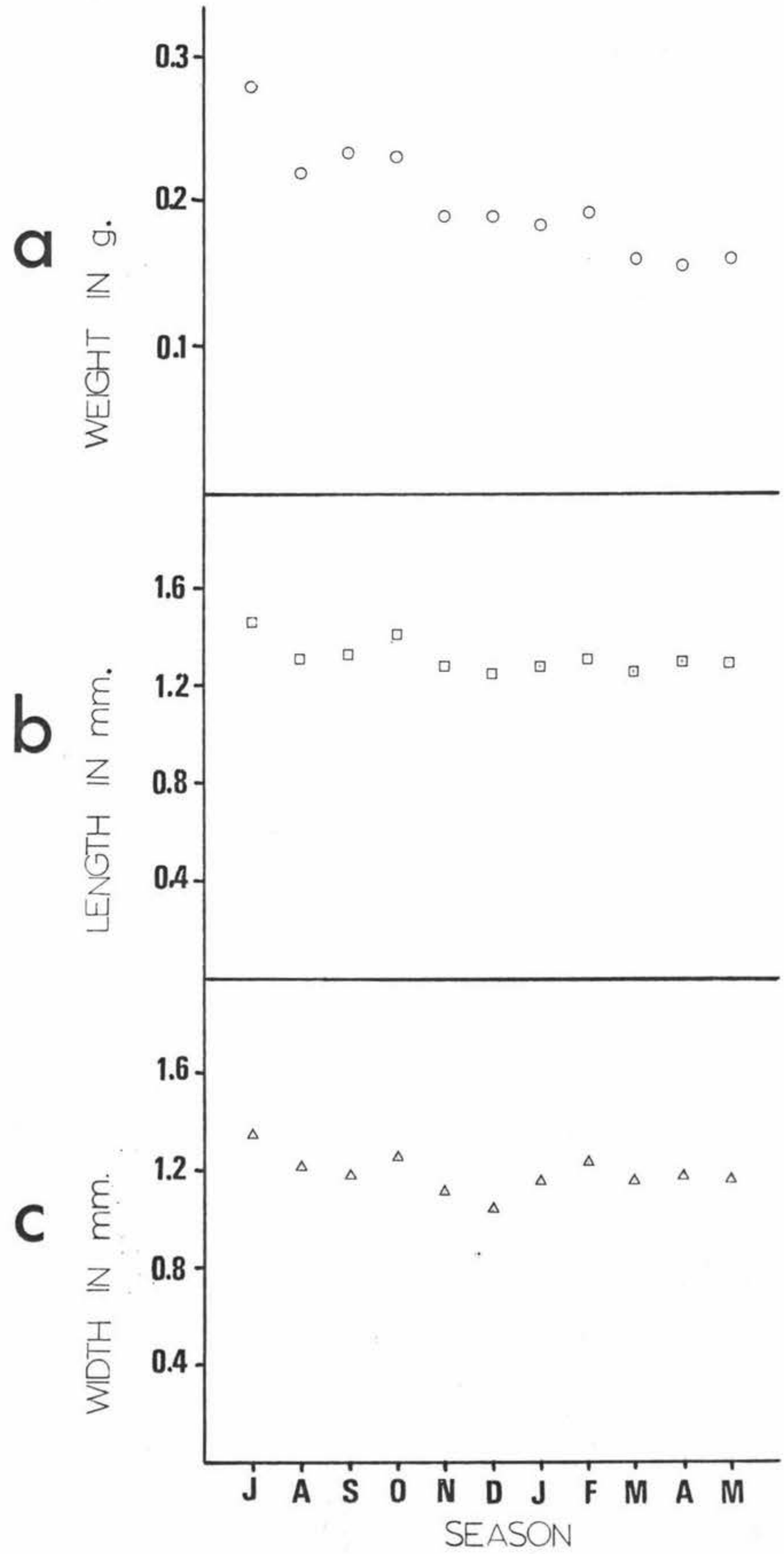

b
% OF EXISTING PELLETS
100
80
60
40
20
N D J F M A M
SEASON

Figure 7: Mean measurements of pellets in decay rate experiment (July 1977 - May 1978) at 1100 m (N = 5).

a: Mean loss in weight (g).

b: Mean loss in length (mm).

c. Mean loss in width (mm).



a
WEIGHT IN g.
0.3
0.2
0.1
b
LENGTH IN mm.
1.6
1.2
0.8
0.4
c
WIDTH IN mm.
1.6
1.2
0.8
0.4
J A S O N D J F M A M
SEASON

Chateau site; half of the original pellets still remained at the close of the study after 7 months.

Mean measurements of 100 fresh pellets were: mean weight 0.27$\pm$ 0.03 g, mean length 1.49$\pm$ 0.09 mm and mean width 1.29$\pm$ 0.07 mm. Fig. 7 (a), (b) and (c) records mean losses in weight, length and width of pellets placed at 1100 m.

4.3.3. Defecation Rates of Captives.

Counts of pellets produced during Feeding Trials 1 and 2 (Tables 21 and 22) show the mean numbers of pellets produced per hare per day were 376 and 425 respectively. When all data are combined the mean number is 409 pellets/hare/day.

Table 21: Numbers of Pellets Produced During Feeding Trial 1. (3 Hares).

	Total	No./Hare
Day 1	1199	399.7
Day 2	1131	377.0
Day 3	1057	352.0
Mean	1129	376.2

Table 22: Numbers of Pellets Produced During Feeding Trial 2. (3 Hares).

	Total	No./Hare
Day 1	1298	432.7
Day 2	1234	411.3
Day 3	1373	457.7
Day 4	1224	408.0
Day 5	1381	460.3
Day 6	1139	379.7
Mean	1274.8	424.9

4.3.4. Weather Data.

Weather data collected from the meteorological station at Chateau Tongariro (1120 m a.s.l.) are shown in Table 23.

Table 23: Monthly Weather Data (May 1977 - May 1978) for the Chateau Tongariro. (1120 m).

Month	Rainfall (mm)	Humidity (%)	Max. (°C)	Min. (°C)
May	348.7	88.0	8.4	-1.1*
June	437.4	94.1	6.6	-0.9
July	229.5	91.2	7.1	-0.3
Aug.	251.0*	85.6	7.6	1.0
Sept.	327.7	89.7	6.1	-1.4
Oct.	135.6	81.8	11.1	1.7
Nov.	260.4	80.9	12.5	2.2
Dec.	239.0	82.1	13.9	3.9
Jan.	29.2	82.3	19.7	7.5
Feb.	30.7	72.4	17.6	7.5
Mar.	304.4	81.3	16.9	6.1
April	205.3	90.0	16.9	6.3
May	104.0	83.0*	9.0*	1.3
Total / Mean	2450.2	84.9	12.0	3.1

Total rainfall from May 1977 to May 1978 was 2450.2 mm (no record for August)*; average humidity for the same period was 84.9% with a mean maximum temperature of 12.0°C and a mean minimum temperature of 3.1°C (no record for May)*. Rainfall was high; over 200 mm during all months except October (135.6 mm), January (29.2 mm) and February (30.7 mm). Highest maximum temperatures were recorded during summer and early autumn (January - April) and lowest minimum temperatures were during winter and spring (June - November).

Table 24: Monthly Weather Data (May 1977 - May 1978) for Ohakune. (629m).

Month	Rainfall (mm)	Humidity (%)	Max. (°C)	Min. (°C)
May	219.9	90.8	9.6	1.6
June	244.4	93.8	8.6	2.5
July	113.2	99.0	7.5	1.2
Aug.	91.5	91.9	10.2	1.8
Sept.	220.2	89.4	12.1*	1.9
Oct.	68.0	77.9	14.5*	4.3
Nov.	89.4	85.7	16.2	5.1
Dec.	111.8	88.3	17.5	7.2
Jan.	15.0	90.0	22.6	9.8
Feb.	7.3	90.3	23.2	10.7
Mar.	64.5	96.5	20.4	8.4
April	77.0	95.6	18.7	8.2
May	60.0	87.8*	11.8	3.5
Total Mean	1322.2	90.8	15.4	5.2

Weather data collected from Ohakune Junction meteorological station (629 m a.s.l.) (Table 24) show, compared to the Chateau, a lower yearly rainfall (1322.2 mm) and higher average humidity (90.8%); mean maximum temperature (15.4°C), (no records for September or October)* and mean minimum temperature (5.2°C). The driest months were again January (15.0 mm) and February (7.3 mm). Highest maximum temperatures were recorded from November to April, while lowest minimum temperatures were from May to September.

* Where no records were available, substitutions from summaries of climatological observations (N.Z. Metero-logical Service) have been made.

Temperature records (October 1977 to May 1978) from maximum/minimum thermometers placed at 1600 m and 900 m on the Chateau site, and at 1500 m and 1200 m on the Ohakune site appear in Tables 25 and 26.

Table 25: Temperature Records (October 1977 - May 1978) from Maximum/Minimum Thermometers for Chateau Site.

Month	1600m Max (°C)	1600m Min (°C)	900m Max (°C)	900m Min (°C)
Oct.	45.0	-5	38.0	-6
Nov.	40.0	-2	39.0	-8
Dec.	16.0	0	44.0	-6
Jan.	32.0	-1	50.0	-4
Feb.	32.0	-2	51.0	-4
Mar.	35.0	-1	42.0	-6
April	26.5	-2	42.0	-6
May	17.0	-4	32.0	-9

Table 26: Temperature Records (October 1977 - May 1978) from Maximum/Minimum Thermometers for Ohakune Site.

Month	1500m Max (°C)	1500m Min (°C)	1200m Max (°C)	1200m Min (°C)
Oct.	32	-5	31	-6
Nov.	32	-5	33	-7
Dec.	33	-5	42	-6
Jan.	37	+1	41	-4
Feb.	43	+4	42	+5
Mar.	40	-1	31	-6
April	51	-1	25	-5
May	48	-3	18	-8

These thermometers were not protected from direct sunshine, consequently monthly temperatures were much higher than those recorded at meteorological stations. The exposed readings however, were probably more representative of temperatures experienced by pellets used in the decay rate experiments. Generally highest maximum and minimum temperatures were recorded over the summer months (December - February), and lowest maximum and minimum temperatures during April and May.

4.3.5. Questionnaires.

Replies to questionnaires placed in Tongariro Park Headquarters indicate that during the period July 1977 to May 1978, 21 hares were observed around Park Headquarters (1100 - 1200 m a.s.l.). Fresh pellets were observed in the Whakapapaiti valley (north slopes of Mt. Ruapehu) at 1650 m in July and 1600 m in December. On the north-eastern slopes of Mt. Tongariro two hares were observed above the Ketetahi hut at 1400 m in October and November. The highest observation of a hare was at 1800 m on the Tukino skifield, eastern Mt. Ruapehu.

Questionnaires from the Ohakune Ranger station, south-western Mt. Ruapehu, cited six hares observed adjacent to Park Ranger accommodation between 600 and 700 m a.s.l. Fresh pellets were observed at the summit of the Ohakune Mountain Road (1600 m), and a hare near the Wanganui High School Hut (1340 m) in January.

Four hares were observed during research trips to the study area. The only hare seen on a transect was observed at 1100 m in February at 1500 hrs. Elsewhere, in October a hare was seen hopping slowly under the Whakapapaiti Bridge (1150 m) at 1300 hrs., and another was seen above the Karioi Forest (1200 m) at 1400 hrs. Also one was observed above Lake Roroaira (800 m) at 0900 hrs. in November.

Reports of skeletons and footprints of hares, rabbits and opossums being found at the summit of Mt.

Ruapehu (2797 m) were received during this study, but they remain unconfirmed.

CHAPTER 5: DISCUSSION

5.1. Dietary Habits.

5.1.1. Cuticle Analysis.

Several authors have noted seasonal changes in the diet of hares: Vorhies and Taylor (1933), Severald (1941), Flux (1962, 1967 (b)), Hewson (1962), Novikov and Timofeeva (1964), Currie and Goodwin (1966), Fadeev (1966), Hayden (1966), Sparks (1968), Flinders and Hansen (1972) and Wolff (1978).

In Europe and North America hares usually forage on the bark and twigs of coniferous and deciduous trees and shrubs during winter and on grasses and shrubs during summer.

In New Zealand, results of dietary analysis by Flux (1967 (b)) indicate a dramatic seasonal change from Chionochloa and Celmisia spp during winter to Poa colensoi during the summer months. No such dramatic fluctuations occurred, however, during my study. Greater amounts of C.rubra were consumed at the higher altitudes (1600, 1500 and 1400 m) on the Chateau site during winter and during spring on the Ohakune site (1500 and 1400 m). Intake of C.spectabilis and S.bidwillii remained relatively constant throughout the year, while greater amounts of moss were consumed during winter and spring.

The effects of altitude also influence the diet of hares. Generally, consumption of C.rubra decreases with increasing altitude, while consumption of C.spectabilis, S.bidwillii, P.colensoi and moss increase with increasing altitude. These trends reflect the availability of the plant species (see Section 4.2.1.).

Except for certain species such as Podocarpus nivalis and Phyllocladus alpinus, which are strongly aromatic and were not eaten although abundant, the plants eaten reflected their general availability. Snow covered the higher altitudes during the three winter months, with the heaviest fall occurring in September.

During this period much of the vegetation normally available to the hares was buried by snow. Only those species which grew on exposed ridges or were tall enough to penetrate the snow covering, were available. C.rubra was the only major dietary species which was readily available.

Below 1400 m C.rubra comprises at least 50% of the diet in all seasons. These altitudes were not covered by snow for long periods and no sharp rise in consumption of C.rubra occurred during winter.

Other findings which confirm the suggestion that plant availability is an important factor in determining the hares diet was that A.squarrosa, a preferred species during feeding trials, (see Section 4.1.2.) was only found in samples of pellets collected from 1200 and 1100 m. This species was not abundant and was found only during vegetation analysis at these altitudes. The moss cuticles identified in the diet consisted of capsules, probably those of Rhacomitrium languginosum. Consumption of moss peaked in winter and spring and this was possibly correlated with the time at which capsules were being produced. Intake of seeds increased during autumn; a fact also noted by Sparks (1968). The seeds recorded were probably those of P.colensoi and consumption of leaves of this species also increased significantly in autumn. Introduced grasses were mainly consumed at the lower altitudes where they were more abundant. Only one occurrence of ingested mountain beech (Nothofagus solandri var cliffortioides) was recorded. This was at 1300 m on the Ohakune site during winter where the transect was surrounded by beech forest. No other evidence for hares browsing beech on the transects which passed through forest was found. Flux (1967 (b)) records that captive hares ate mountain beech avidly, but it was almost completely ignored by wild hares in the Cupola Basin. Consumption of P.colensoi increased greatly in autumn at the lower altitudes (below 1400 m). It was, however, not a major dietary species in other seasons.

This probably again reflects its availability. In the Cupola Basin where P.colensoi is the major dietary component during the summer, it is also one of the more abundant species, (Gibb and Flux 1973).

Composite average area (A) results indicated that C.spectabilis and P.colensoi fragments generally had the largest area (0.82 - 1.22 mm^2), C.rubra and S.bidwillii fragments were generally slightly smaller (0.41 - 0.82 mm^2) with moss fragments being smallest ($>$ 0.41 mm^2). Volumetric measurements could not be determined from these estimates of area, however they do aid in the determination of quantities consumed. For example, although P.colensoi made up a lower percent frequency composition in the diet than C.rubra, the P.colensoi fragments occurring in the faeces were larger. Any future dietary studies should include a volumetric analysis on dietary components.

Only five species comprised the bulk of the hares diet. This limited diet has also been noted by several other authors: Sparks (1968) and Flinders and Hansen (1972) observed that two species; western wheatgrass (Agropyron smithii) and alfalfa (Medicago-Melilotus), comprised the major portion of the diet of both L.californicus and L.alleni. Similarly Flux (1962), Hewson (1962) and Walker and Fairley (1968), found that a single species Calluna vulgaris comprised at least 50% of the annual diet of L.timidus. Although heather was the dominant vegetation below 1100 m on the Chateau site, only traces were observed during dietary analysis during my study. This observation, that L.europaeus does not prefer heather is supported by work of Fargher (1977) who found that although heather constituted 60% of the diet of L.timidus, monocotyledons constituted 99% of the diet of L.europaeus on the Isle of Man.

Summing up, results of cuticle analysis reveal that both season and altitude affect the diet of hares and consumption of preferred species reflected their general availability.

5.1.2. Feeding Trials.

Results from the three feeding trials undertaken (see Section 4.1.2.) indicate Aciphylla squarrosa, Chionochloa rubra and Calluna vulgaris, were preferred species. With the exception of C. rubra, however, these species were insignificant components of the natural diet (see Section 4.1.1.). As Flux (1967 (b)) points out the preferences of penned animals can not be assumed to be those of the wild state. In his study three captive hares avidly ate mountain beech, but it was almost completely ignored by wild hares in Cupola Basin. Currie and Goodwin (1966) made similar deductions when they could not explain the heavy use of salt sage by L. californicus during clipped foliage trials, which was the opposite pattern to that found in field pen trials.

When discussing the results of her study on number and weight of faecal pellets produced by opossums (Trichosurus vulpecula), Fitzgerald (1976) noted that the food intake of opossums was related to season and so it is possible that feeding trials held in different months may produce different results.

Feeding trials in my study were carried out during February and March, preferred species were collected from areas outside the study area and the captive hares were obtained from farmland in the Wairarapa. These factors either acting singly or combined probably have an affect on results and thus may help explain differences between the diet of captives and that of the field situation.

In Feeding Trials 1 and 2 considerably greater amounts of food were consumed on the first day of each trial. This phenomenon was also observed by Currie and Goodwin (1966) but remains unexplained.

It was perhaps unfortunate that rabbit pellets were fed during the feeding trials, but it was feared that without this supplement, the hares might die.

Food consumption totals (in grams wet weight) during the three feeding trials were 94.3 g/hare/day, 197.2 g/hare/day and 219.0 g/hare/day. At the close of the study the average weight of the hares used in Trials 1 and 2 was 2.6 kg and in Trial 3 1.4 kg. Other authors have recorded food consumption by various methods. Arnold and Reynolds (1943) cite consumption per day in grams dry weight for L. californicus as 0.32 ± 0.3 lbs. (141.7 g) and 0.39 ± 0.02 lbs. (170.1 g) for L.alleni. Average weights of L.californicus and L.alleni were 4.3 lb. (1.9 kg) and 6.0 lbs. (2.7 kg) respectively. Haskell and Reynolds (1947) estimated that L.californicus required an average daily consumption of 0.27 lbs. (113.4 g) air dry weight of native forage. The average weight of hares was 2.3 kg. Another estimate for L. californicus was made by Currie and Goodwin (1966) who determined an average consumption of 105 g/day dry weight. They noted that rabbits fed clipped material utilised about one-half as much as rabbits on field trials. This suggests that the animals in the field nipped off and wasted an amount of herbage about equal to that actually consumed. Bear and Hansen (1966) found that L.townsendii consumed 0.19 lbs. (85 g) of alfalfa and rolled barley per rabbit per day. The average weight of rabbits recorded was 7.3 lbs. (3.2 kg). Food consumption of L.europaeus was studied under laboratory conditions by Pilarska (1969). From the results of hares of the same weight as used in my study (ie. 2.6 kg) the daily calorific value of food consumed was 219 kcal.

Mean dry weights of pellets produced during Feeding Trials 1 and 2 were 24.9 g/hare/day and 26.9 g/hare/day respectively. When average daily weight of pellets voided was expressed as a percentage of average daily weight of forage consumed, it was calculated that 26.4% and 13.6% of forage injested was voided for Trials 1 and 2 respectively. Arnold and Reynolds (1943) gave figures for dry weight of pellets produced per hare per day as 0.18 ± 0.02 lbs. (85.1 g) for L.californicus and 0.22 ± 0.01 lbs. (113.4 g) for L.alleni. They calculated that 55% of native forage ration consumed was voided by both species. Bear and Hansen (1966) indicated that 28%

of the forage consumed by L.townsendii was voided as solid wastes so there was a weak positive correlation between the amount of forage eaten and the air dry weight of pellets. L.europaeus kept under laboratory conditions produced 43 k cal/day of faeces, that is 19.6% of food consumed was voided per day. (Pilarska 1969).

The average pellet number and weight was not affected by the age of mature animals in the study by Arnold and Reynolds (1943). The fact that large animals do not drop a larger number of pellets is explained by the lack of relationship between live weight and amount of food consumed. That is, mature animals tend to consume a constant amount of forage irrespective of size. Results of their study also indicated that pellet weight was affected greatly by the character of the food and reflected the digestibility of the food consumed. The consumption of both species on dry and green native forage was similar but a greater weight of material was voided when on dry feed.

The mean dry weight of one fresh pellet (N = 100) collected at 1100 m during my study, was $0.27 \pm .03$ g. When this figure is multiplied by the average number of pellets produced per day (see Section 4.1.3.): 0.27 x 409 = 111.8 g/day. A much larger figure than that estimated from the feeding trials is obtained. Although no measurements of length and width of pellets from feeding trials were made, pellets collected from the field appeared to be larger in size. It was observed that leverets produced very small pellets which became larger as the animals matured. From results of Pilarska (1969) it would seem that L.europaeus reaches a constant weight (3.1 kg) at between 7 and 9 months of age. The hares in my study weighed only 2.6 kg and were probably 4 to 5 months old. Hence food consumption and weights of faecal pellets produced during my study were probably less than would have resulted from using more mature hares.

5.1.3. Field Observations.

Plants observed with distinctive signs of hare browsing were:

Aciphylla squarrosa
Celmisia spectabilis
Schoenus pauciflorus
Chionochloa rubra
Poa colensoi

Analogous observations were made by Flux (1967 (b)) who recorded the numbers of hare bites on plant species in the Cupola Basin. Species preferred in his study were:

Celmisia allanii
Celmisia coriacea
Schoenus pauciflorus
Chionochloa flavescens
Chionochloa pallens
Chionochloa rubra
Poa colensoi

Only small quantities of *Aciphylla colensoi* and *Celmisia spectabilis* were observed showing hare browsing signs. As Flux (1967 (b)) points out, palatability to grazing mammals varies with a host of factors, and it is unlikely that the list for Cupola Basin is valid for other areas, or even for the same area with hares at different densities, or in different years.

Casual observation of plants eaten by hares may give a misleading impression of their relative dietary importance. In my study *A.squarrosa* was found to be very palatable (see Section 4.1.2.), and in the field it shows marked browsing signs (Plate 4), yet it is not a major dietary component (see Section 4.1.1.). An explanation may be that it shows bite marks readily, or that it recovers slowly from hare damage.

5.1.4. Samples From Other Areas.

The aims of this section were firstly to determine whether pellets found in bush were composed of bush species, and secondly, whether the same species were being eaten throughout the Park.

Tables 8 (a), (b) and (d) indicate that in general the composition of those pellets collected within the bush was similar to that of pellets found adjacent to transects at equivalent altitudes. Results however in Table 8 (b) for pellets collected in June and September indicate a high composition of unidentified species. These pellets were collected after heavy snowfalls when branches had been brought down to snow level. Thus it is likely that the hares were able to eat a species normally unavailable to them. Conversely other food sources may have been rendered unavailable by the snow cover, and the hares were forced to eat a less palatable bush species.

Results of collections made from other areas, Tables 8 (c), (e), (f) and (g), indicate that plant species eaten followed similar trends to those found adjacent to transects. However, results of analyses from the Tukino Road on the Eastern slopes, Table 8 (h), reveal slightly different trends in diet. No pellet samples were found between 1500 m and 1700 m a.s.l. and vegetation at these altitudes was very sparse. Amounts of Chionochloa rubra consumed at 1300 m and 1400 m are similar to those consumed at the same altitudes on the transects, but amounts at 1100 m and 1200 m are considerably lower. Vegetation in the whole of this area (ie. the Rangipo Desert) is very sparse compared with that of the study areas. Analysis of photographs taken of this desert area at collection points, reveals less C.rubra at 1100 m and 1200 m than at 1300 m and 1400 m. Unidentified species comprise 20% and 50% of composition at 1100 m and 1200 m respectively, thus it would appear that some palatable species unavailable in the study areas is available to hares in this area.

Altitudinal trends found from transect pellet analysis are followed by results in Table 8 (i). Greater amounts of moss were eaten with increasing altitude, and only small amounts of C.rubra appear in the diet. Although there was only sparse snow lying, very little vegetation was observed, with amounts progressively lessening with increasing altitude. Numbers of pellets found also became less with increasing altitude. At 2200 m permanent snow was reached, and no pellets were found.

5.2. VEGETATION ANALYSIS.

5.2.1. Seasonal and Altitudinal Availability of Vegetation.

The sole seasonal variation in availability of vegetation that could be observed from results of Section 4.2.1. was due to snow cover during winter and spring. On snow covered transects the only species available to hares were those tall enough to penetrate the snow, and those which grew on exposed ridges where snow cover was thinner. Consequently available species were:- moss, Gaultheria colensoi, Dracophyllum recurvum, Senecio bidwillii, Hebe tetragona, and Chionochloa rubra. Of these, moss, S.bidwillii and C.rubra were found in the hares' diet. (See Section 4.1.1.).

Marked variations in the altitudinal availability of plant species were recorded. Of those species comprising the hares' diet, moss was found throughout the altitudinal range, but was more abundant above 1500 m; Celmesia spectabilis was spread evenly over all altitudes, S.bidwillii occurred mainly above 1500 m, while C.rubra was found predominantly below 1400 m. Small amounts of Poa colensoi grew at lower altitudes with considerable amounts around 1600 m. These findings of altitudinal availability of plant species are analogous to those of Gibbs (1966), although his was a more detailed study.

To determine whether seasonal trends in availability occur, it is suggested that either more point analysis samples at each altitude would need to be taken or recordings taken more frequently. Work by Sparks (1968), using a similar method of 100 point analyses for each area for each season also fails to identify any significant differences in seasonal botanical composition. It is felt, however, that for the purpose of the author's study the results in this section are adequate, but that any future work should be undertaken in greater detail.

5.2.2. Chemical Composition of Important Dietary Plants.

Chemical composition may be summarised similarly for all species by ranking the elements in order of concentration: K > Ca > Mg > Na > Fe > Zn. A similar order was found by Williams et al (1977).

Seasonal effects on element concentration were significant for all elements except Zn on the Chateau site (Table 10) and Na on the Ohakune site (Table 11). Concentrations of K and Mg were higher during spring and summer, Ca amounts lowest in autumn, and levels of Na showing no marked fluctuations (Tables 12 and 13). However results conflict somewhat with those of Williams et al (1977) who found that slight seasonal differences in plant chemistry occurred in Chionochloa rubra taken from the Kaweka Ranges. Concentrations of Mg were lower in autumn than in spring, conversely levels of K, Ca, and Na were higher in autumn.

Significant interspecific differences in concentrations of elements, especially K, Ca and Mg were found. This was also noted by Conner et al (1970). Aciphylla squarrosa, Celmisia spectabilis and Senecio bidwillii clearly contained higher concentrations of all six elements (Tables 14 and 15). The effects of altitude on element concentration were also significant for Na, K, Fe and Zn on the Chateau site and for Na, Mg and Fe on the Ohakune site (Tables 10 and 11). No trends, however, are observable in Tables 16 and 17.

Several authors have noted that preferences of animals are related to the nutritive value of dietary species. Grouse, hares and rabbits have a shown preference for food species with a high content of N, P and sugar. (Radwan and Campbell (1967), Miller (1968) and Moss (1968). Conversely, Hewson (1974) found that L.timidus showed no preference for heather (Calluna vulgaris) on the basis of its N or P content. In a later paper Hewson (1976) suggests that height of vegetation may be more important with respect to preferences than composition, as grazing on shorter heather precludes a preditor approaching unnoticed.

Lindloff *et al* (1974) found birch, willow, and blueberry were preferred foods of *L.timidus* and correlated this preference with crude protein and P content. Contrary to the work of Radwan and Campbell (1967) no correlation between sugar content and food preference was found in this study.

Recent New Zealand dietary studies of Takahe (*Notornis mantelli*) revealed that the butt portion of the tussock tiller (*Chionochloa spp*) eaten, contains the highest concentrations of sugars, amino acids and most major nutrients in the plant. (Williams *et al* 1976 (a)). Furthermore, the general order of consumption of leaf bases of the tussock species eaten by takahe correspond with the relative amounts of major nutrients and sugars contained. Deer also showed a similar preference for tussocks with the highest nutrient levels. (Mills and Mark 1977).

Results of my study indicate that hares select a variety of plant species, not necessarily determined by nutrient content. The most nutritious plants were *A.squarrosa*, *S.bidwillii*, and *C.spectabilis*; yet cuticle analysis (see Section 4.1.1.) indicates that *A.squarrosa* is but a minor component of the diet. Conversely, *C.rubra* and *P.colensoi* which were comparatively less nutritious, composed major portions of the diet. Similarly, the seasonal dietary changes observed, could not be related to element composition of dietary species. Further studies of data collected are needed to fully expand all aspects of hare selectivity for particular plant species. Nevertheless, a conclusion compariable to that drawn by Holter *et al* (1974) and Lindloff *et al* (1974) is reached; in that several plant species are required in the daily diet to provide the minimum requirements of energy, protein and other nutrients.

5.3. HARE ABUNDANCE.

5.3.1. Pellet Density.

Population density of hares varied from 0.15 to 36.57 hares/hectare (Table 20). No seasonal trends can be determined from results. Estimates were expected to be lowest during winter and spring at the higher altitudes as these areas were snow covered during sampling from June to September; consequently only those pellets lying on top of the snow could be recorded and a lower pellet density estimated. The highest densities however of hares at 1600 m and 1500 m were recorded during winter and spring.

Flux (1962) defines a high density as one hare per 10 acres (4.1 hectares) and in his 1967 study estimates there to be 8 hares in the 300 acre Cupola Basin study area (ie. 1 hare per 15 hectares). Webb (1942) cites a density of 268 hares/square mile (1.0 hares/hectare) for L.americanus in Minnesota, USA and Lechleitner (1958) estimated a density of 1 hare/acre (2.5 hares/hectare) for L.californicus in California, USA. Peak densities of 50 hares/100 hectares are cited by Pielowski (1972) for L.europaeus in Poland. Using aerial counts from a helicopter Windberge and Keith (1977) found a peak density of 17.6 hares per hectare (L.americanus) in Alberta, Canada.

From casual observations, highest pellet densities occurred at 1400 and 1300 m and lowest densities at 1600 and 1500 m. These observational estimates coincide with trends of calculated estimates (Table 18), however, when pellet density is converted to hare density the figures become unrealistic. Analysis of results indicates that the greatest error in density determination may arise from the estimation of faecal decay rates. Comparison with other work (Flux 1967 (b)) implies that rates estimated may be too rapid, this being the case, the high densities obtained are not completely unexplained. In any future studies it would be advisable to use another method of density estimation so that a comparison of results could be made.

5.3.2. Faecal Decay Rates.

Factors known to affect decay rate include altitude, type of food eaten, location in the field, climate, amount of trampling, and breakdown agents such as invertebrates, bacteria or fungi. (Flux 1967 (b)).

Faecal pellet decay rate decreased with increasing altitude. These findings concur with those of Flux (1967 (b)), who found in the Cupola Basin that pellets at 4,200 ft. (1300 m) took 1.5 years for half to decay, and greater than 2.5 years at 4,800 ft. (1500 m). Decay rates in Tongariro National Park were, however, much faster: 50% of pellets being decayed in 1.5 months at 1300 m, and 4.5 months at 1500 m (Fig. 6(a)). Bear and Hansen (1966) also observed the effects of altitude. Jackrabbit faecal pellets on meadows completely disintegrated in less than one year, while pellets in upland areas showed only slight signs of weathering in the period.

Taylor and Williams (1956) in their study of pellet counts for estimating rabbit numbers, found that faecal decay rates varied considerably with the type of food eaten by rabbits, and the locations of pellets in the field. The highest decay rate occurred under bush and thick scrub, or in tall grass, and pellets on short grass or bare earth had the lowest decay rate. Analogous results were obtained by Cochran and Stains (1961) in their studies of cottontail faecal pellet decomposition. In my study all pellets in both decay rate experiments were placed in similar situations; however the vegetation adjacent to those pellets placed at 1300 m and 1200m was much taller than at the other altitudes. Pellets at these altitudes showed the fastest decay rates (Figs. 6 (a) and (b)). Thus it would seem that vegetation hight was excerting an affect on decomposition rate.

Pellets at 1200 m showed dramatic decomposition -

all pellets being decomposed within 4 months (Fig. 6 (a)) and 2 months (Fig. 6 (b)). These pellets tended to 'splatter' completely during this short time, whereas pellets from other altitudes tended to become gradually reduced in size. Flux (pers. comm.) suggests that pellets with a high composition of the pubescent leaves of Celmisia spectabilis break down after the first rain, as the hairy leaf surfaces readily absorb moisture and the pellet 'explodes'. Pellets which consist principally of tussock species have a high silica content and are more resistant to moisture, especially if their mucous coating has dried hard before they are wetted; such pellets tend to erode away only gradually.

Rainfall, temperature, humidity and snow cover were measured to deduce their effect on faecal pellet decomposition rates. The average annual rainfall at the Chateau site was 2450 mm, almost twice the figure recorded at the Ohakune site, 1322 mm. Mean temperatures were 12.0^{o}C. (max.) and 3.1^{o}C. (min.) for the Chateau site, and 15.4^{o}C. (max.) and 5.2^{o}C. (min.) for the Ohakune site. Average humidity was 84.9% at the Chateau site and 90.8% on the Ohakune site. Snow levels were generally lower and snow persisted longer at lower altitudes on the southern slopes of the Ohakune site.

Results of Experiment two (Fig. 6 (b)) indicate that decay rates were slower on the Ohakune site; at 1500 m 50% of pellets still remained after 7 months, whereas at the close of the study on the Chateau site 50% of pellets at 1500 m had decayed in 3.5 months. These results seem to indicate that lower rainfall has a greater affect on the decay rates than the higher temperatures and humidity of the Ohakune site. (Snow only covered this area between June and October).

In the second experiment, begun in mid-spring (Fig. 6 (b)) pellets decayed at a faster rate than those in the first experiment begun in late autumn (Fig. 6 (a)). Temperatures experienced during the second experiment were warmer and humidities higher than those experienced at the beginning of the first experiment (Table 23). Pellets at the higher altitudes were covered in snow for varying periods from June to October, and all pellets were snow covered during a heavy snow fall in September.

In Experiment one (Fig. 6 (a)) pellets decayed fastest during the periods June - July, September - October and November - December. These periods coincide with the months of highest rainfall (Table 23). Similar results were found in experiment two where greatest rates of decay were recorded during October - November and November - December, and again these were the months of greatest rainfall (Table 23). These results concur with those of Wallmo et al (1962).

Mean reductions in weight, length and width of pellets (Fig. 7 (a), (b) and (c)) reveal fluctuating results. It is apparent that to obtain consistent results a larger sample size is required.

The effects of trampling on pellet decomposition are not known, and for the purposes of this study it was assumed that the effects were similar over all altitudes.

White (1960) working with sheep on the Pennine Moorland reported that the removal of dung in winter was largely effected by wind, rain, snow and ice, for climatic conditions in the area were sufficiently severe to reduce animal activity to a minimum at this time. It is assumed that bacterial and fungal decomposition of pellets would be greatest at higher temperatures and humidities hence at lower altitudes and during the warmer months of the year.

From the results obtained it would seem that all the factors listed by Flux (1967 (b)) do have an effect on pellet decomposition, with rainfall having the greatest effect. Altitude with correspondingly lower temperatures at higher altitudes would also seem to be an important factor affecting rates of decay.

Observational estimates of decay rates may not be totally reliable, as estimates depend solely on the disgression of the observer. Decay rates in this study were approximately 10 times more rapid than in the Cupola Basin. (Flux 1967 (b)). Both areas experience similar rainfalls, temperatures, periods of snow cover and have comparable vegetation types. Soils within Tongariro National Park are younger and more acidic, thus less microbial and fungal breakdown would be expected. It is possible that a higher composition of C.spectabilis occurs in pellets from the Tongariro National Park, but this factor alone can not explain such rapid decomposition. In future studies a more reliable estimate of decay rate, such as measurements of reductions in weight and size of pellets should be used in conjunction with visual observations.

5.3.3. Defecation Rates of Captives.

An average defecation rate of 409 pellets/hare/day (maximum 458, minimum 352) is similar to that determined by Flux (1967). Over 24 days with two captive hares, each averaged 388 pellets daily (extremes 157 and 603) on a natural diet supplemented with rabbit food. In addition, five hares were tracked in snow over their whole one night's travels, and their number of pellets counted. The average per hare was 434 (with extremes of 296 and 671). Consequently, all told, the best estimate was 410 pellets/hare/day. This estimate is the only one recorded for L.europaeus.

Defecation rates of Arizona jackrabbits (L. californicus), and Antelope jackrabbits (L.alleni), were found to be 545 ± 42, and 522 ± 35 pellets/hare/day respectively by Arnold and Reynolds (1943).

The difference between pellet counts of the two species was not statistically significant. Accordingly, the data from both species was grouped, to give an average daily pellet count of 531 ± 27. This was considered to be valid for all jackrabbits irrespective of age, sex, size or species. Bear and Hansen (1966) however, reported that white-tailed jackrabbits (L.townsenii) voided from 146 to 440 pellets/day, with a mean of 277. Similar variation was observed by Adams (1959) with two penned snowshoe hares (L.americanus); averages were 216± 53.6 and 233± 38.6 pellets/day over six days. Using two field methods, Adams made much higher estimates of 554 pellets/hare/day with the calendar-graph method, and 481 pellets/hare/day with the recapture method. He concluded that pellet production in the field was at a rate somewhere between the mean of 225 per day found in the penned studies, and the 480 found in the field studies. An average rate of 208 pellets/hare/day (extremes 33 and 450) was estimated by Flux (1962) for L.timidus.

Research by Cochran and Stains (1961) on Sylvilagus floridanus revealed that daily deposition of pellets varied considerably from rabbit to rabbit (0 to 687 pellets), from food to food, and from time to time, with the same rabbit on the same food. High variability was also observed by Fitzgerald (1977) with the brush-tailed opossum (Trichosurus vulpecula) and she concluded that the nature, amount and nutritive value, as well as the mix of foods eaten, appeared to influence the number and weight of faecal pellets voided. In Fitzgerald's experiments, small numbers and weight of droppings reflected low food intake.

5.3.4. Weather Data.

Total rainfall, recorded at the Chateau during the study was approximately 50 mm less than the average. When compared with values from Table 1 which summarises climaticological observations from 1930 to 1970, May and October 1977 and January, February and March 1978 were drier than normal, while June and September 1977 and May 1978 were wetter. The percent humidity was slightly higher; an average of 84.9% was recorded during the study compared to a normal of 80%. Average maximum and minimum temperatures were also slightly higher than normal; an average maximum of 12°C and minimum of 3.1°C were recorded during the study compared to normal values of 11.3^{o}C and 2.9^{o}C.

No record summary was available for data from the Ohakune Junction Meteorological Station, however means were determined by the author from data recorded for 1971 to 1976. Total rainfall was again approximately 50 mm less than average; 1322 mm being recorded during the study compared with an average of 1397 mm. Percent humidity and average maximum temperatures were also slightly higher; mean percent humidity was 90.8 during the study compared to a normal value of 85 and mean maximum temperature of 15.4^{o}C compared with 14.7^{o}C. The average minimum temperature recorded was equivalent to the normal being 5.2^{o}C.

5.3.5. Questionnaires.

Results of questionnaires placed in Park Headquarters at the Chateau and Ohakune were disappointing. It had been hoped that these replies would back up results of population density estimates by pellet census (see Section 4.3.1.). However apart from indicating that hares range to high altitudes even during the winter months, the results are misleading. For example, the observation of 21 hares between 1100 m and 1200 m a.s.l. on the northern slopes; there were probably only two or three hares in the area, and these were observed more frequently as this was the area in which most Park Staff spent much of their time. The same applies to the records of six hares seen between 600 m and 700 m a.s.l. the area adjacent to the Ohakune Ranger Station. Accordingly no valid conclusions could be drawn regarding seasonal or altitudinal ranges of hares.

CHAPTER 6: GENERAL DISCUSSION AND CONCLUSIONS.

The aims of this study were to investigate the effects of season and altitude on diet and abundance of hares in Tongariro National Park. The study was divided into three sections: analysis of hare diet, analysis of vegetation available to hares and determination of hare density within the study area.

Cuticle analysis of faecal pellets revealed that five species: Celmisia spectabilis, Senecio bidwillii, Chionochloa rubra, Poa colensoi and moss, comprised the major portion of the diet and that season and altitude did affect species consumed. Generally, those plants which showed signs of hare browsing in the field were preferred by captive hares. These same plants, with the exception of C.rubra, were however, not necessarily those observed in faecal pellets. C.spectabilis, Schoenus pauciflorus and P.colensoi all showed browsing signs and were consumed in varying quantities by both captive and wild hares. Aciphylla squarrosa showed browsing signs was a favoured species of the captives but was an insignificant dietary component in the wild. Calluna vulgaris was also a species preferred by the captives, however, no feeding signs were observed in the field and only traces observed in the diet. It appears therefore, that field observations of browsed plants and the preferences of captives may give a misleading impression of the relative importance of a plant species in the natural diet. Distinct trends regarding consumption of the major dietary species were observed: consumption of C.rubra decreases with increasing altitude, conversely consumption of C.spectabilis, S.bidwillii, P.colensoi and moss increase with increasing altitude.

Samples collected from other areas within the Park indicate that throughout a generally similar diet is consumed. Altitudinal trends continue with moss becoming the major dietary component above 1600 m.

It is interesting to note that except during periods of heavy snowfall, hares do not browse on native forest species, although pellets were found within forested areas. Pellets collected from forest areas, during periods without snow cover, were not fresh and probably dropped during the winter. Most pellets occurred beside patches of introduced grasses or in clearings. Pellets were collected along the grass edges of the Ohakune Mountain Road, but none were found within the bush. It is suggested that the forest is used as shelter during periods of stormy weather or simply as a route from one grassland area to another.

The plant species eaten, with the exception of certain aromatic species, usually reflected their availability. C.rubra was the dominant species consumed below 1400 m for up to this altitude C.rubra was more abundant. Also during the months when there was extensive snow cover at the higher altitudes and C.rubra became the dominant species available, greater amounts were consumed. C. spectabilis, S.bidwillii and moss were all more abundant at the higher altitudes (above 1400 m) and consumption of these species was greater at these altitudes. Most P. colensoi was consumed during autumn when seed heads had matured, and consumption peaked at 1400 m.

Food consumption totals (in grams wet weight) could not be directly compared with those of other authors as measurements were expressed in different units. Several authors have shown that plant chemistry is an important factor in dietary preference. However, selectivity could not be related to plant chemistry from results of this study. It appears that a variety of plant species, some more nutritious than others, are required in the hares' diet. Likewise, seasonal dietary changes could not be related to seasonal changes in plant chemistry.

Pellet density estimates by computer analysis, coincided with casual field observations of pellet concentration. However, when pellet numbers were extropolated to hare abundance figures, numbers became unrealistic. It is postulated that pellet decay rate extimates were too rapid.

The most important factors determining decay rate were rainfall and altitude. Rates of decay were faster at equivalent altitudes on the Chateau site, where twice as much rain fell as on the Ohakune site; while rates were markedly slower at high altitudes. Flux (1967 (b)) noted much slower rates of decay, working in a similar mountain area.

Defecation rates correspond with the only other estimate for L.europaeus, calculated by Flux (1967 (b)). It is realised, however, that figures may be vastly different in the field situation. High variability has been recorded by several authors, and it has been noted that many factors such as the nature of the food, the individual animal and the season affect results.

Future work should include a more reliable method of density estimation. The questionnaires which were designed to complement computer density estimates in this study unfortunately proved unsatisfactory.

In conclusion, the single most important factor affecting the diet of hares in Tongariro National Park was the availability of plant species. Both seasonal and altitudinal variations in the diet reflect plant availability. Preference for particular dietary species could not be related to plant chemistry, nor could seasonal and altitudinal changes in availability of macroelements be related to dietary changes. It appears that a combination of plant species is required by hares for a balanced diet.

No conclusions could be drawn concerning the seasonal or altitudinal abundance of hares. It should be pointed out that no faecal pellets were found below 1100 m on the Chateau site (where Calluna vulgaris and Gleichenia/Empodisma swamp were the dominant vegetation) nor above 2,200 m (where vegetation was very sparse). Apparently hares do not travel far in search of food, even during periods of heavy snowfall.

It was estimated that one hare consumes on average 170 g/day of vegetation, hence a total of 62 kg of vegetation per year is consumed by each hare within the

70,100 ha of Tongariro National Park. Even though hares may not be sufficiently abundant to cause substantial permanent damage to vegetation, their presence alone is exerting an effect on indigenous vegetation. Signs of hare browsing were ubiquitous on preferred species and changes occassioned by the loss of the more palatable species from the plant community is probably occurring. As the hare is an introduced mammal, population numbers are not fully regulated as they would be by preditors when in an indigenous situation. Hence population numbers are probably increasing and unless alternative regulatory measures are undertaken damage to vegetation within the Park will increase.

APPENDIX 1: COMPLETE SPECIES LIST OF PLANTS COLLECTED WITHIN STUDY AREA.

LICHENS.

Cladia retipora

Cladonia mitis

Hypogymnia enteromorpha

MOSSES.

Rhacomitrium lanuginosum

FERNS.

Lycopodium australianum

Gleichenia circinata

Polystichum vestitum

GYMNOSPERMAE.

Podacarpus nivalis

Dacrydium bidwillii

Dacrydium laxifolium

Phyllocladus alpinus

ANGIOSPEMAE - DICOTYLEDONES.

Pimelea buxifolia

Pimelea prostrata

Coriaria plumosa

Leptospermum scoparium

Nothofagus solandri var *cliffortioides*

Aciphylla squarrosa

Anistome aromatica

Gaultheria colensoi

Pentachondra pumila

Cyathodes juniperina

Cyathodes fraseri

Epacris alpina

Dracophyllum filifolium

Dracophyllum recurvum

Coprosma cheesemanii

Celmisia incana

Celmisia glandulosa

Celmisia spectabilis

Celmisia gracilenta

Olearia nummularifolia

Raoulia australis

Helichrysum bellidioides
Craspedia spp
Cassinia vauvilliersii
Senecio bidwillii
Gentiana bellidifolia
Wahlenbergia pygmaea
Forstera bidwillii
Euphrasia cuneata
Ourisia vulcanica
Hebe stricta
Hebe odora
Hebe tetragona
MONOCOTYLEDONES.
Phormium tenax
Juncus gregiflorus
Luzula campestris
Empodisma minus
Schoenus pauciflorus
Oreobolus pectinatus
Carpha alpina
Hierochloe redolens
Chionochloa rubra
Notodonthonia setifolia
Poa colensoi
Cortaderia fylvida
INTRODUCED SPECIES.
Calluna vulgaris
Erica spp.

APPENDIX 11: COMPLETE ANALYSIS OF VARIENCE TABLES.

Na Chateau.

Source of Variation	SS	DF	MS	F	P
Season	1.261	3	0.420	8.255	0.001
Plant	2.190	6	0.365	7.170	0.001
Altitude	2.901	12	0.242	4.748	0.001
S x P	0.762	14	0.054	1.069	0.388
S x A	1.966	21	0.094	1.838	0.017
P x A	1.760	31	0.057	1.115	0.320
S x P x A	2.411	31	0.078	1.528	0.045

K Chateau.

Source of Variation	SS	DF	MS	F	P
Season	111.442	3	37.147	12.967	0.001
Plant	3338.383	6	556.397	194.225	0.001
Altitude	55.937	12	4.661	1.627	0.084
S x P	185.019	16	11.564	4.037	0.001
S x A	137.668	31	4.441	1.550	0.037
P x A	238.392	35	6.811	2.378	0.001
S x P x A	249.104	52	4.790	1.672	0.005

Ca Chateau.

Source of Variation	SS	DF	MS	F	P
Season	58.036	3	19.345	4.741	0.003
Plant	4512.747	6	752.124	184.332	0.001
Altitude	60.967	12	5.081	1.245	0.252
S x P	65.392	16	4.087	1.002	0.455
S x A	223.081	31	7.196	1.764	0.010
P x A	288.000	35	8.229	2.017	0.001
S x P x A	186.463	52	3.586	0.879	0.999

Mg Chateau.

Source of Variation	SS	DF	MS	F	P
Season	6.258	3	2.086	22.442	0.001
Plant	133.341	6	22.223	239.085	0.001
Altitude	9.171	12	0.764	8.222	0.001
S x P	14.725	16	0.920	9.901	0.001
S x A	7.748	31	0.250	2.689	0.001
P x A	17.499	35	0.500	5.379	0.001
S x P x A	13.317	52	0.256	2.755	0.001

Fe Chateau.

Source of Variation	SS	DF	MS	F	P
Season	0.240	3	0.080	4.200	0.006
Plant	2.469	6	0.411	21.602	0.001
Altitude	0.975	12	0.081	4.265	0.001
S x P	0.479	16	0.030	1.571	0.076
S x A	1.834	31	0.059	3.105	0.001
P x A	0.923	35	0.026	1.385	0.082
S x P x A	2.133	52	0.041	2.154	0.001

Zn Chateau.

Source of Variation	SS	DF	MS	F	P
Season	0.001	3	0.000	0.303	0.999
Plant	0.028	6	0.005	3.597	0.002
Altitude	0.012	12	0.001	0.805	0.999
S x P	0.023	16	0.001	1.100	0.355
S x A	0.039	31	0.001	0.993	0.999
P x A	0.041	35	0.001	0.911	0.999
S x P x A	0.055	52	0.001	0.823	0.999

Na Ohakune.

Source of Variation	SS	DF	MS	F	P
Season	0.057	3	0.019	1.130	0.342
Plant	0.571	4	0.143	8.569	0.001
Altitude	0.254	3	0.085	5.075	0.003
S x P	0.293	11	0.027	1.595	0.015
S x A	0.370	9	0.041	2.467	0.015
P x A	0.088	6	0.015	0.877	0.999
S x P x A	0.290	11	0.026	1.579	0.120

K Ohakune.

Source of Variation	SS	DF	MS	F	P
Season	111.987	3	37.329	22.053	0.001
Plant	752.339	4	188.085	111.116	0.001
Altitude	26.569	3	8.856	5.232	0.002
S x P	57.684	11	5.244	3.098	0.002
S x A	36.593	9	4.066	2.402	0.018
P x A	22.791	6	3.799	2.244	0.046
S x P x A	103.871	11	9.443	5.579	0.001

Ca Ohakune.

Source of Variation	SS	DF	MS	F	P
Season	20.776	3	6.925	4.658	0.005
Plant	743.294	4	185.824	124.987	0.001
Altitude	2.114	3	0.705	0.474	0.999
S x P	69.444	11	6.313	4.246	0.001
S x A	17.426	9	1.936	1.302	0.248
P x A	7.047	6	1.175	0.790	0.999
S x P x A	76.547	11	6.959	4.681	0.001

Mg Ohakune.

Source of Variation	SS	DF	MS	F	P
Season	2.627	3	0.876	2.594	0.057
Plant	15.508	4	3.877	11.488	0.001
Altitude	1.294	3	0.431	1.278	0.287
S x P	3.976	11	0.361	1.071	0.394
S x A	3.954	9	0.439	1.302	0.248
P x A	5.026	6	0.838	2.482	0.029
S x P x A	5.085	11	0.462	1.370	0.202

Fe Ohakune.

Source of Variation	SS	DF	MS	F	P
Season	0.257	3	0.086	9.732	0.001
Plant	0.371	4	0.093	10.538	0.001
Altitude	0.104	3	0.035	3.949	0.011
S x P	0.141	11	0.013	1.455	0.164
S x A	0.064	9	0.007	0.807	0.999
P x A	0.075	6	0.013	1.430	0.212
S x P x A	0.076	11	0.007	0.781	0.999

Zn Ohakune.

Source of Variation	SS	DF	MS	F	P
Season	0.003	3	0.001	12.801	0.001
Plant	0.004	4	0.001	12.879	0.001
Altitude	0.001	3	0.000	2.942	0.037
S x P	0.003	11	0.000	3.167	0.001
S x A	0.000	9	0.000	0.452	0.999
P x A	0.000	6	0.000	0.578	0.999
S x P x A	0.001	11	0.000	1.474	0.156

APPENDIX 111: COMPLETE MULTIPLE CLASSIFICATION ANALYSIS TABLES.

Na Chateau.

Grand Mean = 0.35

Category	N	Unadjusted Deviation	Adjusted For Independents Deviation
Winter	67	-0.06	-0.01
Spring	26	0.21	0.09
Summer	110	-0.09	0.08
Autumn	112	0.08	0.06
C.spectabilis	89	0.04	0.03
C.rubra	84	-0.12	-0.08
S.bidwillii	23	0.38	0.29
S.pauciflorus	36	-0.04	0.01
P.colensoi	58	0.05	-0.02
C.vulgaris	20	-0.15	-0.09
A.squarrosa	5	-0.01	0.03
900 m	11	-0.17	-0.08
1000 m	25	-0.13	-0.06
1100 m	36	-0.05	0.00
1200 m	23	-0.05	-0.03
1265 m	15	-0.08	-0.06
1300 m - 1	25	-0.14	-0.12
1300 m - 2	16	-0.10	-0.07
1400 m lt	22	0.02	-0.01
1400 m rt	26	-0.06	-0.03
1500 m lt	40	0.08	0.06
1500 m rt	11	0.33	0.33
1600 m lt	23	0.36	0.23
1600 m rt	42	0.00	-0.06

K Chateau.

Grand Mean = 4.98

Category	N	Unadjusted Deviation	Adjusted For Independents Deviation
Winter	68	-1.33	-1.08
Spring	125	0.75	0.49
Summer	110	0.16	0.29
Autumn	111	-0.18	-0.17
C.spectabilis	117	2.21	2.18
C.rubra	113	-0.97	-0.92
S.bidwillii	34	5.44	5.18
S.pauciflorus	44	-1.94	-1.97
P.colensoi	71	-3.08	-3.03
C.vulgaris	29	-3.41	-3.33
A.squarrosa	6	11.59	11.86
900 m	17	-2.14	-0.38
1000 m	34	-1.01	0.07
1100 m	45	0.85	0.10
1200 m	31	-0.03	0.52
1265 m	23	0.25	0.54
1300 m - 1	35	-0.76	-0.07
1300 m - 2	24	-0.75	-0.74
1400 m lt	34	0.57	-0.22
1400 m rt	39	-0.51	-0.27
1500 m lt	48	0.40	0.36
1500 m rt	19	-0.58	-0.83
1600 m lt	23	1.56	0.32
1600 m rt	42	0.68	0.02

Ca Chateau.

Grand Mean = 3.21

Category	N	Unadjusted Deviation	Adjusted For Independents Deviation
Winter	68	-0.04	0.43
Spring	125	0.93	0.35
Summer	110	-0.45	-0.12
Autumn	111	-0.57	-0.53
C.spectabilis	117	1.69	1.70
C.rubra	113	-2.74	-2.70
S.bidwillii	34	8.84	8.77
S.pauciflorus	44	-2.29	-2.34
P.colensoi	71	-2.45	-2.48
C.vulgaris	29	1.18	1.19
A.squarrosa	6	8.53	8.76
900 m	17	-0.95	0.47
1000 m	34	-0.44	-0.36
1100 m	45	0.36	-0.46
1200 m	31	-0.18	0.49
1265 m	23	-1.29	-0.26
1300 m - 1	35	-1.78	-0.31
1300 m - 2	24	-1.61	-0.50
1400 m lt	34	0.82	0.23
1400 m rt	39	-0.13	0.19
1500 m lt	48	0.55	0.37
1500 m rt	19	1.34	0.92
1600 m lt	23	1.98	-0.14
1600 m rt	42	0.74	-0.20

Mg Chateau.

Grand Mean = 0.71

Category	N	Unadjusted Deviation	Adjusted For Independents Deviation
Winter	67	-0.16	-0.15
Spring	125	0.18	0.10
Summer	110	0.08	0.12
Autumn	112	-0.18	-0.14
C.spectabilis	117	0.15	0.15
C.rubra	113	-0.47	-0.47
S.bidwillii	34	1.42	1.49
S.pauciflorus	44	-0.26	-0.30
P.colensoi	71	-0.46	-0.41
C.vulgaris	29	0.67	0.64
A.squarrosa	6	1.92	1.59
900 m	17	-0.15	0.01
1000 m	34	-0.11	-0.21
1100 m	45	0.54	0.35
1200 m	31	-0.08	0.08
1265 m	24	-0.03	0.13
1300 m - 1	35	-0.23	0.03
1300 m - 2	24	-0.27	-0.07
1400 m lt	34	0.20	0.07
1400 m rt	38	-0.14	-0.02
1500 m lt	48	-0.05	-0.03
1500 m rt	19	-0.02	-0.07
1600 m lt	23	0.16	-0.19
1600 m rt	42	-0.17	-0.19

Fe Chateau.

Grand Mean = 0.11

Category	N	Unadjusted Deviation	Adjusted For Independents Deviation
Winter	68	0.02	0.04
Spring	125	0.01	0.01
Summer	110	-0.05	-0.04
Autumn	111	0.02	0.01
C.spectabilis	117	-0.01	-0.01
C.rubra	113	-0.09	-0.08
S.bidwillii	34	0.04	0.01
S.pauciflorus	44	-0.05	-0.03
P.colensoi	71	0.20	0.17
C.vulgaris	29	-0.06	-0.02
A.squarrosa	6	-0.08	-0.02
900 m	17	-0.07	-0.01
1000 m	34	-0.09	-0.05
1100 m	45	-0.08	-0.06
1200 m	31	-0.09	-0.06
1265 m	24	0.05	0.04
1300 m - 1	34	-0.04	-0.02
1300 m - 2	24	-0.07	-0.06
1400 m lt	34	-0.02	0.01
1400 m rt	39	0.13	0.10
1500 m lt	48	0.07	0.06
1500 m rt	19	0.08	0.01
1600 m lt	23	0.11	0.05
1600 m rt	42	0.00	-0.02

Zn Chateau.

Grand Mean = 0.02

Category	N	Unadjusted Deviation	Adjusted For Independents Deviation
Winter	68	-0.01	-0.00
Spring	125	0.00	-0.00
Summer	110	0.00	0.00
Autumn	112	0.00	-0.00
C.spectabilis	118	0.00	-0.00
C.rubra	113	-0.01	-0.01
S.bidwillii	34	0.03	0.03
S.pauciflorus	44	-0.00	-0.00
P.colensoi	71	0.01	0.01
C.vulgaris	29	-0.01	-0.00
A.squarrosa	6	-0.00	0.00
900 m	17	-0.01	-0.00
1000 m	34	-0.01	-0.00
1100 m	45	-0.01	-0.00
1200 m	31	0.00	0.01
1265 m	24	-0.00	-0.00
1300 m - 1	35	-0.01	-0.00
1300 m - 2	24	-0.01	-0.00
1400 m lt	34	0.01	0.01
1400 m rt	39	-0.00	-0.00
1500 m lt	48	0.00	-0.00
1500 m rt	19	0.02	0.02
1600 m lt	23	0.01	0.00
1600 m rt	42	-0.00	-0.01

Na Ohakune.

Grand Mean = 0.25

Category	N	Unadjusted Deviation	Adjusted For Independents Deviation
Winter	30	-0.04	-0.02
Spring	36	0.04	0.03
Summer	31	-0.02	-0.02
Autumn	35	0.00	0.00
C.spectabilis	33	0.02	0.03
C.rubra	45	-0.06	-0.07
S.bidwillii	11	0.21	0.17
S.pauciflorus	29	-0.06	-0.04
P.colensoi	14	0.10	0.07
1500 m	50	0.08	0.05
1400 m	36	-0.04	-0.04
1300 m	35	-0.06	-0.05
1200 m	11	-0.01	0.05

K Ohakune.

Grand Mean = 4.50

Category	N	Unadjusted Deviation	Adjusted For Independents Deviation
Winter	30	-0.18	-1.00
Spring	36	0.74	0.00
Summer	31	1.44	1.56
Autumn	35	-0.48	-0.53
C.spectabilis	33	1.50	1.61
C.rubra	45	-0.62	-0.93
S.bidwillii	11	6.82	6.89
S.pauciflorus	29	-2.17	-2.09
P.colensoi	14	-2.42	-1.90
1500 m	50	0.27	-0.25
1400 m	36	0.09	-0.11
1300 m	35	-0.73	-0.04
1200 m	11	0.79	1.62

Ca Ohakune.

Grand Mean = 2.25

Category	N	Unadjusted Deviation	Adjusted For Independents Deviation
Winter	30	-0.50	0.26
Spring	36	0.72	0.04
Summer	31	0.29	0.41
Autumn	35	-0.57	-0.62
C.spectabilis	33	1.25	1.24
C.rubra	45	-1.83	-1.77
S.bidwillii	11	7.36	7.38
S.pauciflorus	29	-0.69	-0.71
P.colensoi	14	-1.41	-1.57
1500 m	50	0.69	0.12
1400 m	36	0.08	-0.13
1300 m	35	-0.41	0.06
1200 m	11	-2.08	-0.31

Mg Ohakune.

Grand Mean = 0.59

Category	N	Unadjusted Deviation	Adjusted For Independents Deviation
Winter	30	-0.20	-0.10
Spring	36	0.30	0.24
Summer	31	-0.08	-0.08
Autumn	35	-0.07	-0.08
C.spectabilis	33	0.34	0.36
C.rubra	45	-0.33	-0.33
S.bidwillii	11	0.96	0.80
S.pauciflorus	29	-0.11	-0.06
P.colensoi	14	-0.24	-0.30
1500 m	50	0.17	0.13
1400 m	36	-0.04	-0.11
1300 m	35	-0.11	-0.08
1200 m	11	-0.30	0.03

Fe Ohakune.

Grand Mean = 0.08

Category	N	Unadjusted Deviation	Adjusted For Independents Deviation
Winter	30	0.06	0.05
Spring	36	-0.07	-0.06
Summer	31	-0.02	-0.01
Autumn	35	0.03	0.03
C.spectabilis	33	0.03	0.03
C.rubra	45	-0.06	-0.05
S.bidwillii	11	-0.02	-0.02
S.pauciflorus	29	-0.02	-0.02
P.colensoi	14	0.16	0.14
1500 m	50	0.05	0.03
1400 m	36	-0.01	0.01
1300 m	35	-0.04	-0.05
1200 m	11	-0.07	-0.01

Zn Ohakune.

Grand Mean = 0.01

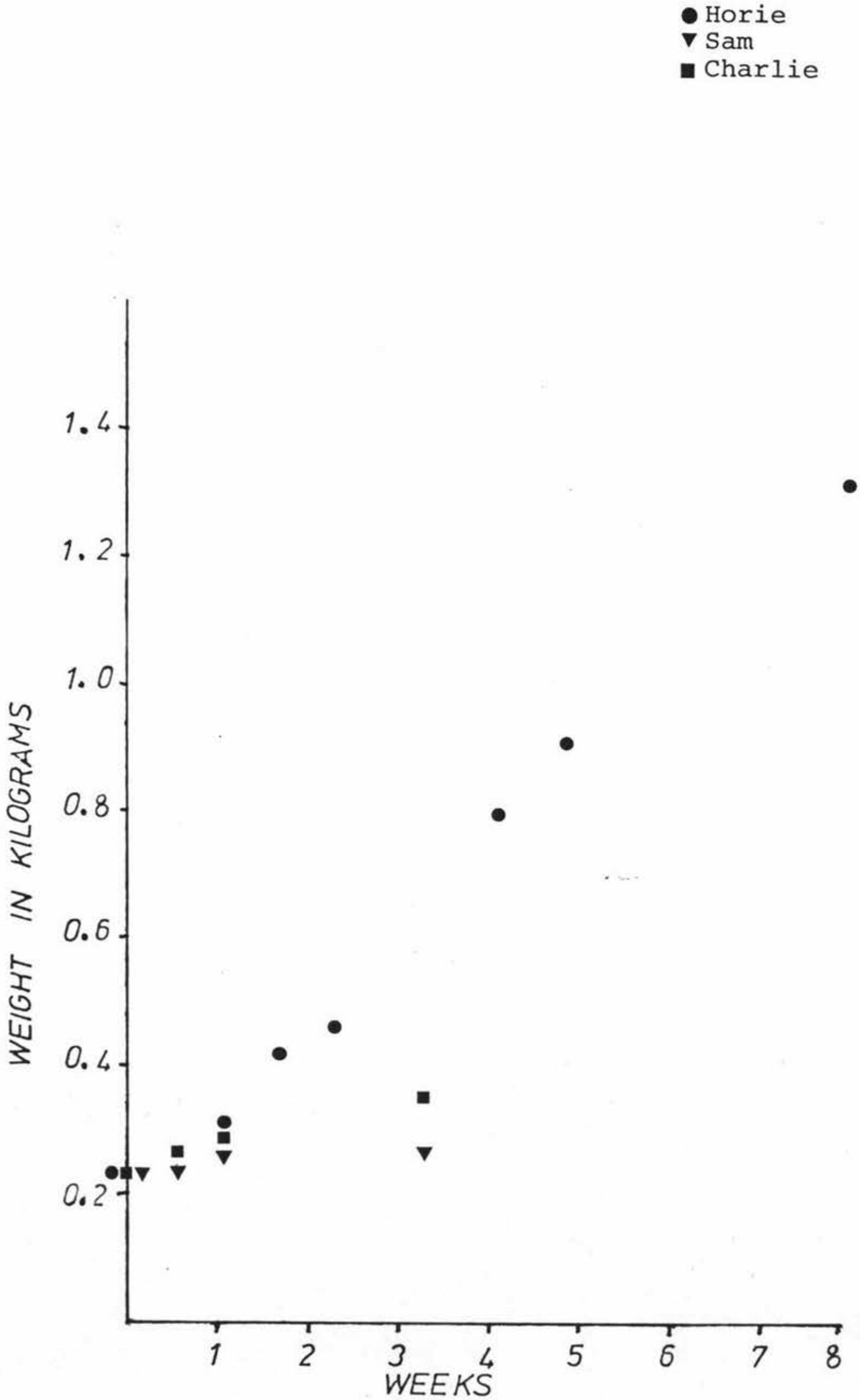
Category	N	Unadjusted Deviation	Adjusted For Independents Deviation
Winter	30	0.00	0.00
Spring	36	-0.01	-0.01
Summer	31	-0.00	-0.00
Autumn	35	0.01	0.01
C.spectabilis	33	0.00	0.00
C.rubra	45	-0.00	-0.00
S.bidwillii	11	0.02	0.02
S.pauciflorus	29	-0.00	-0.00
P.colensoi	14	-0.00	-0.01
1500 m	50	0.00	0.00
1400 m	36	-0.00	-0.00
1300 m	35	-0.00	-0.00
1200 m	11	-0.00	0.00

APPENDIX lV: GROWTH RATES OF SAM, CHARLIE AND HORIE.

Hare	Original wt. (g)	Final wt. (g)	Time Interval (days)	Growth Rate (g/day)
Sam	227	264	23	1.6
Charlie	227	347	23	5.2
Horie	227	1361	63	18.0

APPENDIX V

GROWTH CURVES FOR SAM, CHARLIE AND HORIE



APPENDIX V1: BODY MEASUREMENTS OF HARES SHOT WITHIN STUDY AREA.

Sex	Body wt. (kg)	Body Length (cm)	Hind-foot Length (cm)	Ear Length (cm)
M	3.5	43.5	13.4	11.2
M	3.4	44.5	14.5	11.9
M	3.2	46.0	14.0	12.0
M	2.4	38.5	13.8	10.5
M	3.4	45.0	14.7	11.2
M	3.6	48.0	15.2	12.4
M	3.6	37.0	13.6	11.7
M	3.8	47.0	14.1	11.9
M	3.4	41.0	14.1	10.7
M	3.3	42.0	14.3	11.0
F	1.3	29.0	12.5	8.5
F	2.8	44.5	13.8	10.5
F	2.9	42.7	14.8	11.0
F	3.3	42.5	13.7	10.8

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