THE DIET OF FERAL GOATS (*Capra hircus* L.)

IN THE RIMU-RATA-KAMAHI FOREST OF MOUNT EGMONT

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fulfilment of the requirements
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FRONT PIECE

The lowland forest of the study area on Mt Egmont in January 1984; looking from the north-east.

ABSTRACT

The diet of the feral goat (*Capra hircus*) in rimu-rata-kamahi forest on Mount Egmont was examined by sorting monthly rumen samples for one year. Seasonal changes in diet, relative plant palatabilities, differential fragmentation and digestion rates of plant species, nitrogen and mineral levels in principal foods, and several aspects of population biology were measured.

Results show that individual goats contain at least 19 plant species on average and some more than 30. Presumably, they eat about this number daily. However, just two species (*Asplenium bulbiferum* and *Ripogonum scandens*) make up 44.8% of the total amount eaten over the year.

There are significant seasonal changes in the amounts eaten for *Coprosma grandifolius*, *Coprosma tenuifolia*, *Griselinia littoralis*, *Melicytus ramiflorus*, *Ripogonum scandens* (fruit and vine) and *Weinmannia racemosa*.

Goats clearly select or reject different plant species. Thus use of species is largely independent of availability. The most preferred foods are probably *Schefflera digitata* and *Ripogonum scandens* fruit and vine. In contrast the very abundant *Microlaena* spp., *Uncinia* spp., moss, *Alsophila smithii* and especially *Blechnum fluviatile* are among the most unpalatable.

The low and probably variable availability of many species within the study area obscures their seasonal trends and palatability ratings.

Asplenium bulbiferum, and probably *Melicytus ramiflorus*, are underestimated in the diet, whereas *Ripogonum scandens* vine may be overestimated. However, the magnitude of error is not sufficient to be a problem in this study.

There is no obvious correlation between diet selection and the levels in plants of N, K, Ca, Mg, P, S, Cu, Zn, Fe and Mn. Only Na is deficient enough to possibly be selected for and highest levels occur in the very palatable *Schefflera digitata*.

Age structure, body condition and reproductive data suggest a predominantly young, healthy population that is reproducing rapidly.

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CHAPTER 1

INTRODUCTION AND AIMS

1.1 GENERAL EATING HABITS OF GOATS

Throughout the world goats (Capra hircus L.) are valued because they continue to be productive in range conditions where other domestic herbivores cannot (Campbell et al 1962, Devendra 1978, Huston 1978) or because they largely eat weeds or plants that other stock do not want (Rolston et al 1981, 1983, Clark et al 1982, McKinnon 1982, Wilson 1982). On the other hand goats are often disliked because they deplete vegetation and promote erosion in areas too infertile to carry domestic stock (Campbell et al 1962, Huston 1978).

The tenacity of goats, compared to other domestic or feral ruminants, is probably associated with their eating habits, described by Huston (1978) as being different from sheep and cattle, but similar to deer. Major factors which probably contribute to these differences are:

1) Acceptance of a wide variety of feeds, especially browse (Campbell et al 1962, Coblentz 1977,1978, Devendra 1978, Huston 1978 and Devendra and McLeroy 1982).
2) The ability to digest tough feeds (Devendra 1978, Huston 1978, Devendra and McLeroy 1982, D.Dellow pers.comm.).
3) Energetic and versatile food gathering habits (Huston 1978) including limited tree climbing ability (Atkinson 1964, Sykes 1969). They are much more inquisitive than other ruminants and will walk long distances in search of food. This behaviour helps them meet their nutrient requirements (Devendra and McLeroy 1982).
4) A mobile upper lip, allowing closer feeding and better selection of the palatable plant parts (Campbell et al 1962, Atkinson 1964, Huston 1978).
5) A high tolerance of bitter tastes (Bell 1959, Devendra and McLeroy 1982).

Although goats occupy a wide variety of habitats in tropical to temperate climates. they perform best in the dry tropics (as opposed to wet humid areas). This is because of their resistance to

dehydration, preference for browse and wide ranging feeding habits which may include poorer feeds (Devendra and McLeroy 1982).

1.2 NEW ZEALAND STUDIES REFERING TO FERAL GOAT DIET

The destructive influence of feral goats on New Zealand's native flora has caused a number of biologists to comment on goat dietary habits. Most of these works have been based on observation of goat browse sign (Turbott 1948, Atkinson 1964, Sykes 1969, Rudge and Campbell 1977, Russell 1981, Parkes 1982, 1983a, 1984b); or changes in the composition of plant associations within goat inhabited areas in comparison with uninhabited areas (Atkinson 1964). In some cases stomach contents were examined (Laing 1947 in Asher 1979, Turbott 1948, Asher 1979, Parkes 1983a, 1984b). The two studies that actually quantified the intake of plant species by goats were by Rudge and Campbell (1977) using faecal analysis, and Parkes (1983, 1984b) using macro-rumen analysis. However, neither of these studies considered seasonal changes in diet or measured palatability by comparing plant use with plant availability. Also both were on outlying islands. Hence there is no accurate description of seasonal diet or preference for feral goats in New Zealand. All the studies were on islands except for Atkinson (1964), Asher (1979) and Russell (1981), but most of the islands' floras were broadly similar to the mainland and thus carried implications about goat diet in New Zealand.

The above studies are briefly described below in chronological order. In the main, only common, widely distributed plant species will be mentioned.

1) Turbott (1948) commented on diet while describing the impact of goats over a sixty year period on Great Island, Three Kings. He observed browse sign and the browse induced plant communities compared with earlier descriptions and goat inaccessible areas. He made several rumen examinations and found they were full of grasses, sedges and herbs, i.e. the goats had been grazing. However palatable tree and shrubs were eaten to a high browse line implying goats had little choice except to graze. Seemingly more palatable species included *Metrosideros excelsa*, *Melicytus ramiflorus*, *Paratrophis smithii* and native grasses. Species which were hardly eaten or avoided, included *Leptospermum scoparium*, *L.ericoides*, *Myoporum laetum*, *Coprosma*

rhamnoides and various grasses and sedges.

2) Atkinson (1964) presented lists of low preference species and unpalatable species based on comparisons of goat inhabited versus uninhabited areas and browse sign from various regions in New Zealand. He found that goats browsed many species but only barked a few in any one area. On Cuvier Island seaward slopes were modified more than anywhere else. Zotov (1949 in Atkinson 1964), mentioned this phenomenon occuring in parts of the Tararua and Rimutaka Ranges. In each case aspect did not seem important and Atkinson thought perhaps foliage bearing wind-carried salt was being sought after.

Common species of apparently low palatability included Blechnum fluviatile, Alsophila smittii, Leptospermum scoparium and Leptospermum ericoides, Gaultheria antipoda, Uncinia spp. and Microlaena spp.. His proposed unpalatable species included Cardiomanes reniforme, Hebe odora, Histiopteris incisa, Hymenophyllum spp. and Pseudowintera colorata. He also implied Griselinia littoralis, Weinmannia racemosa, Coprosma tenuifolia, Coprosma robusta and some Blechnum spp. were palatable to goats on Mt Egmont.

3) Sykes (1969) visited the Kermadec Islands to assess the impact of goats on the vegetation. Like Turbott (1948) he looked at browse and regeneration and compared earlier descriptions with the present state of the vegetation. Sykes noted goat browse sign up to 10m above the ground on trees with leaning trunks. Similarly Atkinson (1964) concluded that Mt Egmont goats climbed into scrub and ate the crowns.

Although Sykes did not aim to describe goat diet he suggested the following species were palatable: Pittosporum eugenioides and Kermadec varieties of Pseudopanax arboreus, Metrosideros (Similar to M.excelsa) and Coriaria arborea. Two species which had increased and therefore were probably unpalatable were Ascarina lucida var.lanceolata and Myrsine kermadecensis.

4) Parkes (1983a, 1984b) measured goat diet on Raoul Island as part of an experiment on the application of 1080 poison gel to standing plants. A random 200ml rumen sample was collected from each of 103 goats shot in June - December 1982 and April - December 1983. Particles catching on a 4mm sieve were macroscopically sorted to species or type (e.g. grasses). The rumen samples, and to some degree permanent vegetation plots, gave indications of which species were

palatable. Parkes (1984b) suggested that the goats were selective feeders, although without measurements of plant availability he could not assign palatabilities to plant species. However, the fungus Auricularia sp. was obviously preferred because of its low abundance and high use. Seven species made up 89% of the diet. Parkes (1983a) thought most of these species were probably palatable, although he felt the high proportion of ferns in the diet (18%) may have reflected a lack of choice. The seven foods included Kermadec varieties of Metrosideros (Similar to M.excelsa), Coriaria arborea, Melicytus ramiflorus and Rhopalostylis, and a number of grasses and sedges. Other palatables listed by Parkes (1984) included Alsophila sp., Pseudopanax arboreus var.kermadecense, Coprosma sp., and Melicope ternata which was considered only slightly palatable by Turbott (1948) and Sykes (1969). Unpalatables included the two species listed by Sykes (above).

5) Rudge and Campbell (1977) looked at the impact of feral goats and pigs on the largest of the Auckland Islands. The harsh environment appeared to have restricted goat distribution and therefore diet selection since goats used but few of the plant communities rich in palatable species. Rudge and Campbell determined an approximate scale of palatability by measuring browse sign within a range of plant communities. Also diet was measured more precisely by analysing faecal samples collected in different plant communities. The following species were eaten out below the browse line of 1.25m and were likely to have been highly palatable: Blechnum durum, Asplenuim oblongifolium and Phymatosorus diversifolium. Pseudopanax simplex var.simplex had 79% of tufts browsed, Polystichum vestitum 79%, Metrosideros umbellata 38% and Coprosma foetidissimma 37%, suggesting that they were fairly palatable. Blechnum procerum, Uncinia spp. and Histiopteris incisa were never recorded as browsed and were probably unpalatable.

6) Asher (1979) roughly sorted the contents of 69 rumen samples from one island and 11 mainland populations. Different areas would have varied in species abundance, therefore species which were consistently eaten in many different areas were probably palatable. Asher found that goats ate large proportions of exotic grasses when available and suggested that goats are predominantly grazers, as did Riney and Caughley (1959), Atkinson (1964), Malechek and Leinweber (1972) and Coblenty (1977). In contrast other researchers suggest that

goats are mainly browsers, e.g. Campbell et al (1962), Yocom (1967), Devendra (1978), Rudge (1979), Sidahmed et al (1981), Clark et al (1982) and Devendra and McLeroy (1982). More recently goats have been classified as adaptive mixed feeders (Sidahmed et al 1983).

In two of Asher's study areas that were eaten out to the browse line, over 50% of the diet was Griselinia littoralis litter. The leaves "had the appearance of decomposing litter" (Asher 1979). Similarly Turbott (1948) found two goats contained large amounts of palatable browse (Melicytus ramiflorus, Metrosideros excelsa and lichens), only after strong winds had blown it to the ground. Laing (1947 in Asher 1979) found dead leaves of Fuchsia excorticata in the rumen of Mt Egmont goats. Rumen samples collected by Asher were dominated firstly by exotic pasture grasses and secondly by Chionochloa and Poa species. However, the dominant trees and shrubs were similar to those in other studies and were as follows: Griselinia littoralis, Coprosma spp., Melicytus ramiflorus and Pseudopanax spp..

7) Russell (1981) described the state of the Mount Egmont vegetation in relation to goats and possums. The browse index of Wardle et al (1971) was used to calculate the percentage contribution of each species to the diet. Unfortunately the browse index does not take into account availability and therefore did not measure palatability. The five most important species in the diet according to the browse data were Asplenium bulbiferum 35%, Astelia fragrans 21%, Blechnum discolor 5%, Griselinia littoralis 3% and Microlaena spp.3%.

The above studies did not consider seasonal changes in intake or provide any clear indications about species palatabilites, because they did not measure plant availability. However, they probably represented a large range of availabilities for many species. Therefore species which consistently made up large proportions of the diet were probably palatable (preferred). On this basis a minimum list of suspected palatable species is extracted.

Griselinia littoralis
Melicytus ramiflorus,
Metrosideros excelsa
Pseudopanax spp. (five-fingers)

1.3 THE MODIFICATION OF HABITATS BY GOATS

The destructive impact of goats, especially on the vegetation of islands, has frequently necessitated their being controlled or exterminated. Goats are probably more destructive than other feral herbivores (Roots 1976) because they continue to thrive in habitats with little remaining vegetation (Campbell et al 1962, Devendra 1978 and Huston 1978).

Wallace (1911) and Roots (1976) briefly described the devastation of vegetation and fauna by goats on St Helena and the Galapogas Islands respectively. Within the Hawaiian Halekala National Park, feral goats caused some plant species to vanish, many to change in distribution and abundance and promoted the establishment of exotic herbs that no longer prevented erosion (Yucom 1967). Research by Coblentz (1977) compared habitat modification by goats with that due to deer, bison and sheep combined, on Santa Catalina Island. Goats degraded their habitat when compared with the other animals because of their tendency to eat plants to ground level, or to pull them out of the ground.

Mainland and island studies from New Zealand recorded similar devastation. Goats were barely exterminated in time to save the few climax forest remnants on Great Island, Three Kings (Turbott 1948). Merton (1970) wrote of "spectacular regeneration of forest species" on Cuvier Island once sheep, cattle and especially goats were gone. Regeneration of many plant species, including the dominant canopy species Metrosideros sp. (similar to M.excelsa) was prevented by goats on Raoul Island (Sykes 1969). Now that most, if not all of the goats are gone (J.Parkes pers.comm.) many once declining species are regenerating well (Parkes 1984b). On mainland New Zealand only a few high priority feral goat populations are controlled (Parkes 1982). Most populations continue to modify their habitats by eating palatable species leading to the dominance of unpalatables. They eventually open up the understory and prevent canopy regeneration which enables a dense ground cover of harsh grasses and sedges to develop (Atkinson 1964).

1.4 GOAT CONTROL IN NEW ZEALAND, PAST AND PRESENT

Traditionally, goats have been controlled by foot hunting with or without dogs. The Department of Internal Affairs first began large scale and systematic feral goat control in 1937 after an already long

period of damage by goats in New Zealand. This government control was subsidized by bounty payments and free ammunition to encourage private hunters to kill feral goats. Responsibility for goat control was taken over by the New Zealand Forest Service in the 1960s. Rudge (1979) stated that despite about a million goats having been shot in New Zealand to date, their mainland distribution had not altered much in the last 30 years. However, some populations have been greatly reduced (Parkes 1982).

Goat control by foot hunting is a continual and expensive process with a few top priority areas exhausting the available money and man power; so many areas remain unmanaged. Hence there is a very real need to establish more cost-efficient methods of control.

1.5 UNDERSTANDING GOAT DIET COULD HELP CONTROL GOATS

A method of feral goat control showing considerable promise is the application of 1080 gel to the underside of leaves of palatable food species. The method probably has the greatest potential in densely populated areas with a shortage of preferred species within the browse range. Branches of highly preferred species can be bent down to within reach of goats and poisoned with 1080 gel. Thus goats will concentrate their feeding on poisoned plants.

So far the method has been tried on feral goats in the Raukumara Ranges (Parkes 1982, 1983b), on Raoul Island (Parkes 1983a), and also on white-tailed deer on Stewart Island (Challies and Burrows 1984). On Raoul Island the abundance of palatables and the effects of high humidity on the 1080 gel meant the time was best spent hunting (Parkes 1983a). In contrast, the Raukumara trial produced an estimated 97.5% reduction in goat numbers with poisoning in one area and a 94.5% reduction by hunting in another similar area for much the same effort. This was despite a lot of the poison gel probably being ineffectively applied to non-preferred species or laid in low use areas. Also the gel was phyto-toxic and quickly caused browning or abscission which reduced bait life from many weeks down to a matter of days. Parkes (1982) concluded by saying "where suitable these preliminary trials suggest that very encouraging results can be obtained for less effort than traditional methods." Challies and Burrows obtained similarly favourable results for white-tailed deer, with pellet density counts indicating a 90% kill.

It appears that poisoning natural vegetation can be a "useful alternative or addition to hunting as a goat control method" (Parkes 1983b). However, an obvious step to improve the method is to obtain more precise knowledge of goat dietary preferences through the year. This could also help in assessing which plant species and communities are at risk and how they might be modified by feral goats.

1.6 AIMS OF THE STUDY

1.6.1 Diet

The method of controlling goats by applying 1080 poison to the underside of edible foliage (see problems found by Parkes 1982 in Section 1.5) cannot be most efficiently applied without a good knowledge of goat dietary habits. Thus the principal aim of this study was to gain a greater understanding of goat diet within a typical New Zealand goat habitat.

1.6.1.1 Seasonal Changes in Diet

As the season changes, so may the foods selected by goats (Cory and Fraps 1940 in Huston 1978, Malechek and Leinweber 1972, Devendra 1978, Devendra and McLeroy 1982 and Sidahmed *et al* 1983). Diet studies of large herbivorous mammals suggest that seasonal variation in diet occurs because of changes in availability (McCaffery *et al* 1974, Ellis *et al* 1977, Sexson *et al* 1981 and Baranga 1983) or because of changes in plant quality including digestibility (Drozdz 1979, Schwartz and Ellis 1981), the levels of nutrients in the plants (Mills and Mark 1977, Leader-Williams *et al* 1981, Baranga 1983 and Pellew 1984) and levels of secondary compounds on the plants (Freeland and Janzen 1974, Bryant and Kuropat 1980 and Pellew 1984). Also the needs of the animal may change seasonally, causing it to favour different foods (Pellew 1984). Hence the second important objective was to describe seasonal changes in diet.

1.6.1.2 Variation in Diet with Sex, Age, and Time

The plant species eaten by a herbivore may vary according to sex (Dzieciolowski 1970, Leader-Williams *et al* 1981, Staines *et al* 1982, Pellew 1984); age (Dzieciolowski 1970, Leader-Williams *et al* 1981, Kossak 1981) and time of day (Gaare 1977, Leader-Williams *et al* 1981,

Savory 1983). The third aim of this study was to test whether goat diet varied with any of the above factors. Also the effects of altitude and area (locality) (see Figure 2.1) on diet (probably through changes in availability) were examined to enable more accurate interpretation of the results.

1.6.1.3 Preference :The Use of Plant Species in Relation to their Availability

The palatability or preference rating of a plant species cannot be established on the basis of how much of it is eaten. Large amounts of a species in the diet may simply result from lack of choice, as was possibly the case for ferns on Raoul Island (Parkes 1983a). It is usual to have measurements of both species use (in the diet) and availability in the field to show selection for particular species (Crawley 1983). The fourth aim of the study involved estimating the relative standing crop of each plant species within the browse range and relating this to the average amount of each species eaten, using an appropriate preference index.

1.6.2 Differential Fragmentation and Digestion

Previous diet studies indicated that the proportions of plant species found in the rumen of a herbivore may not accurately reflect the proportions of those species eaten (Bergerud and Russell 1964, Staines 1976, Gaare *et al* 1977, Owaga 1978). Plant species probably fragment and digest at different rates so that some disappear faster than others from the rumen. A fifth aim of this study was to briefly examine the effects of goat chewing and digestion on some principal dietary species to detect any gross differences in species breakdown rates. This would allow more accurate interpretation of the rumen results.

1.6.3 Nitrogen and Mineral Levels in Principal Dietary Species

Many studies of herbivore diet and nutrition suggest that the animals adapt their food preferences in response to food quality (nutrient levels, digestability and levels of secondary plant compounds; for references see Section 1.6.1.1).

A sixth aim of this study was to discover any correlations between

the use of species and their nitrogen and mineral levels.

1.6.4 Population Biology

The seventh and final aim of the study was to briefly describe population parameters including age structure, reproduction and body condition. These measurements may be informative with respect to the type of pressures influencing the population and may imply something about the diet in terms of food quality and abundance.

1.6.5 Summary of the Aims

1) The overall aim of the study was to describe feral goat diet in a native forest, in order to improve efficiency of goat control by applying poison to edible natural vegetation.
2) To describe seasonal changes in the use of plant species.
3) To describe how diet varies with sex, age and time of day.
4) To establish relative palatability ratings (seasonal if possible) for plant species
5) To see whether principal dietary species fragment and/or digest at different rates.
6) To find any correlations between plant species use and plant nitrogen and mineral levels.
7) To describe population parameters including age structure, sex ratios, reproduction and body condition.

CHAPTER 2

STUDY AREA

2.1 CHOOSING A STUDY AREA

The study area described below was selected on the following criteria:

1) It consisted of a single forest type, containing plant species in fairly uniform proportions throughout.
2) It contained sufficient goats to sustain the removal of at least 20 animals per month over one year.
3) It was regularly hunted year round by New Zealand Forest Service (NZFS) shooters who could collect the samples.
4) It had easy vehicle access.
5) It was reasonably close to Palmerston North.

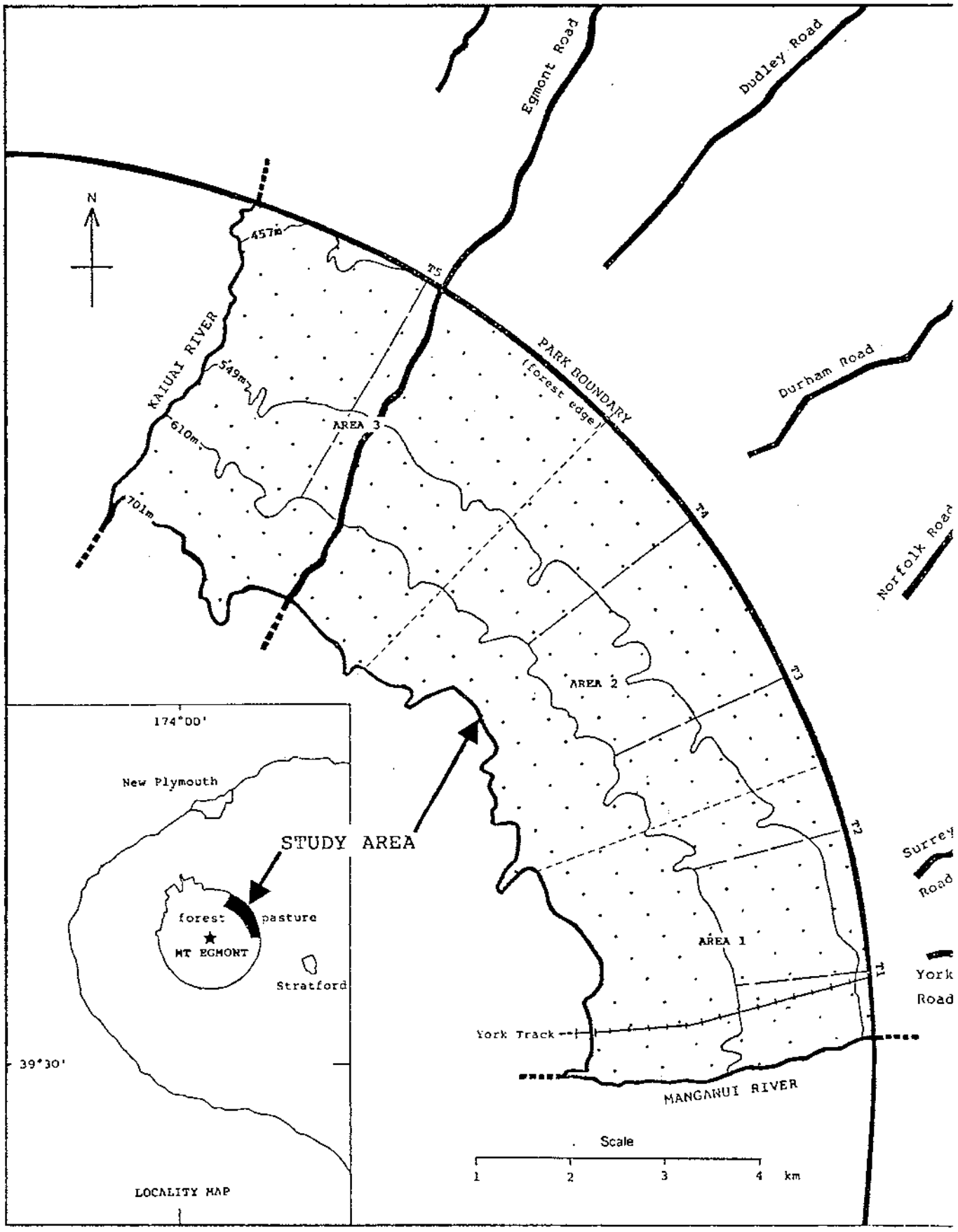
The large block of lowland rimu-rata-kamahi forest on the lower eastern slopes of Mount Egmont was chosen (see Figure 2.1 and Section 2.1.2) and subsequently provided the samples on which this study was based.

2.2 DESCRIPTION OF THE STUDY AREA

Russell (1981) described the rimu-rata-kamahi belt as running from the Waingongoro River in the south to the Kaiauai Stream in the north and climbing from about 450m a.s.l. (boundary fence) to around 760m a.s.l. where the transitional kamahi forest type dominates. However south of the Manganui River the forest is broken by frequent clearings, thus the Manganui River became the southern boundary. The study area was gently sloping (<10 degrees), about 3.5km wide by 10km long and of fairly uniform species proportions. It has good road access to several points along its edge including a good walking track traversing the southern end (York Track) and a road penetrating the northern end (Egmont Road).

FIGURE 2.1: THE STUDY AREA

T1 to T5 indicate plant availability transects.
Dotted lines delineate AREAs 1 to 3.


Egmont Road
Dudley Road
Durham Road
Norfolk Road
Surrey Road
York Road
N
457m
549m
610m
701m
KAIURI RIVER
T5
T4
T3
T2
T1
PARK BOUNDARY
(forest edge)
AREA 3
AREA 2
AREA 1
York Track
MANGANUI RIVER
Scale
1
2
3
4
km
174°00'
39°30'
New Plymouth
STUDY AREA
forest
pasture
MT EGMONT
Stratford
LOCALITY MAP

2.2.1 Climate (adapted from Coulter 1976).

Although the study area is 2000m below the summit of Mt Egmont, it is still sufficiently high to experience much wetter, windier, colder and more changeable weather than the Taranaki Province in general.

Rainfall is high throughout the study area and reaches 6000mm p.a. near its upper boundary. Late autumn through to mid-spring (May to October) receives 50% more rain than early summer through to early autumn (December to March).

Average seasonal temperatures recorded at the Stratford Mountain House (848m a.s.l.) are 12-13C in summer and 3-4C in winter. Temperatures below zero have occurred in all months except January with an average of 43 days per year. In the study area (450 to 700m a.s.l.) temperatures probably reflect those at the Mountain House but may be slightly warmer and probably increase with decreasing altitude.

Although wind strength increases with altitude the tall dense bush within the study area means that all but strong winds are barely noticable on the forest floor.

In general the study area climate can be described as damp, cool and of low to moderate light intensity with little wind disturbance on the forest floor.

2.2.2 Geology and Soils (adapted from Neall 1976).

A long history of volcanic eruptions and floods formed the topography, geology and soils of Mount Egmont and its older neighbouring Pouakai and Kaitake cones. Each cone is surrounded by a large "apron" of airfall ash and pumice with laval flows only covering relatively small areas. Pumice in the forks of living trees and buried Maori artifacts reveal the recent nature of numerous volcanic eruptions (from 1500 A.D).

The soils within the study area are basically of two types, Burrell and Patua (V.Neall pers.comm.). The Burrell soil (lapilli) is about 7.5 cm thick near the Maketawa River. It becomes thicker to the south and thins out to the north where Patua soil predominates. Burrell soils are described as friable, weakly structured and containing very hard pumice lapilli. They tend to be shallow, have low nutrient status, coarse texture, low soil-temperatures and impeded drainage (Aitken et al 1978). Patua soils on the other hand are well drained, strongly leached soils (generally derived from deep volcanic ash) with top soils which are often coarse from the addition of recent

coarse ash and lapilli (Palmer et al 1981).

2.2.3 Vegetation (adapted from Russell 1981).

The vegetation of Mount Egmont is quite distinctive due to its isolation, varying climate and volcanic history. The vegetation changes gradually with altitude forming four major associations with species compositions that vary quite markedly at different regions around the mountain. The four major associations are:

1) Low-land forest (the eastern block of which formed the study area).
2) Transitional kamahi (Weinmannia racemosa) forest.
3) Upland forest.
4) Sub-alpine forest.

2.2.3.1 The Vegetation of the Study Area

The study area was the eastern block of lowland rimu-rata-kamahi forest (see Figure 2.1 and Plates 2.1 to 2.4). The lowland forest belt gradually merges into the transitional Weinmannia racemosa association at around 760m a.s.l. where emergent podocarp species decline in comparision with the lowland forest belt. The canopy of Weinmannia racemosa is lower and the understory is more sparse. Also Pseudowintera colorata is more common and may form locally dense thickets.

The lowland forest has a reasonably dense canopy of Weinmannia racemosa about 5 to 20m high with Dacrydium cupressinum and Metrosideros robusta forming scattered emergents in excess of 30m. Melicytus ramiflorus dominates the sub-canopy although Weinmannia racemosa is still a major component. Other sub-canopy species include Myrsine salicina, Carpodetus serratus, Hedycarya arborea and Beilschmiedia tawa. As well as shrub species, a good representation of canopy and sub-canopy species can be found in the shrub tier (30cm to 5m in height). Dominant taller shrubs include Coprosma grandifolius, Coprosma tenuifolia, Schefflera digitata, Geniostoma ligustrifolium, Pseudowintera colorata and two tree-fern species Alsophila smithii and Dicksonia squarrosa. Below these Astelia spp. are common and in places there are Alseuosmia macrophylla and Griselinia littoralis. The ground cover is generally thick, and especially dense where the canopy is broken (see Plates 2.2 and 2.3). Asplenium bulbiferum, Microlaena

spp., Uncinia spp., Blechnum fluviatile and in some places Blechnum discolor dominate the ground cover, the grasses and sedges being most dominant in larger canopy gaps. Again there is a reasonable representation of tree and shrubs species, except for Weinmannia racemosa, which begins life as an epiphyte. Similarly Coprosma lucida and Pseudopanax arboreus are largely restricted to an epiphytic existence. Some fairly common epiphytes are Phymatosorus diversifolium, Asplenium flaccidum, Earina spp. and Dendrobium cunninghamii.

Ripogonum scandens forms a dense belt for several hundred metres near the bush edge (see Plate 2.1) and bush lawyer is also fairly common, extending to beyond the Ripogonum scandens belt.

Rivers and larger streams in the area are often narrowly bordered by quite different species associations from that of the general forest. River bank vegetation has higher densities of certain species which are also in the forest, especially Griselinia littoralis, Coprosma lucida and Myrsine salicina. Some alpine species such as Hebe stricta and Gaultheria antipoda and also exotic grasses and herbs (especially Lotus pedunculatus) are present. However this river bank vegetation only accounts for a very small proportion of the total area.

2.2.4 Introduced Mammals

1) Feral Goats (Capra hircus): Goat densities in the study area were described as moderate by Russell (1981). However, just prior to the study several hundred goats were shot there, markedly reducing the number of animals (D.Clark pers.comm.). Russell (1981) suggests goats in the lowland forest probably do not migrate into the upland forests and that they tend to concentrate in the Ripogonum scandens belt where hunting is less intense. The NZFS shooter on the project suggested goats concentrated in dry sheltered areas in winter and were more evenly dispersed in summer months.

Goats first arrived in Taranaki in 1910 when 250 pairs were brought to Inglewood for weed control. Some escaped from adjacent farmland into the 33,000 ha Mt Egmont National Park. By 1925 large feral herds within the park had caused sufficient damage to stimulate the instigation of control operations. However lack of appreciation of the seriousness of the problem and restricted finance resulted in only one ranger being appointed for goat as well as possum control. Control was rather intermittent until 1943 although some 10,000 goats were shot

(Parkes 1983c). After 1943 effort was increased by the Park Board. In 1950 a bounty was introduced which nearly eliminated goats from all the farmland around the park. In 1961 the NZFS took over goat control from the Park Board and now have several full time shooters operating. On the basis of annual kills per unit effort recorded since 1961, the goat population was estimated to be 1672 goats in 1982 (Parkes 1983c). This was an immense reduction from a few decades earlier when goats were so dense that the keeper of Stratford Mountain House regularly shot several goats while driving the four kilometres from the park boundary to the Mountain House. Parkes concludes the population is still being reduced although for increasingly greater effort.

2) Brush-tailed Possums (Trichosurus vulpecula): Liberations of possums into the park began in 1900. Populations peaked about 1950 and their present density is generally moderate throughout the park. Possum density is particularly high within the study area and could be contributing to the deterioration of the Weinmannia racemosa canopy (Russell 1981). Russell suggested that goats may be encouraging possums by improving nesting conditions and accessibility of feeding sites. At present there is probably very little direct competition between goats and possums because they attack plants at different stages of maturity.

3) Cattle (Bos taurus): For several decades either side of the turn of the century, cattle in the park were a considerable problem because of incomplete boundary fences (Russell 1981). The problem is now much reduced although cattle faeces and tracks were seen occasionally during the study.

4) Other Species: Hares (Lepus europaeus) are present above and below the bushline. Rabbits (Oryctolagus cunniculus) live on the farmland adjacent to the park. However neither utilize the forest.

Stoats (Mustela erminea), ship rats (Rattus rattus) and feral cats (Felis domestica) are all present in the park. Presumably they largely account for the scarcity of native birds.

PLATE 2.1: A TYPICAL FOREST SCENE

A Weinmannia racemosa tree covered in lichen and filmy fern dominates the centre right of the photo, where the ground cover is dense due to the fairly open canopy. Ground cover is much sparser beneath the tree ferns.

PLATE 2.2: THE SUPPLE JACK BELT

This liane (Ripogonum scandens) typically forms a dense belt for several hundred metres starting at the lower forest edge. It impedes human access, and goats may use it more when hunting pressure is heavy (Russell 1981). The palatable foliage is mainly in the canopy, except for juvenile plants and where the adult vines have collapsed. The soft young vine and ripe fruits are particularly favoured.

PLATE 2.3: FOREST CLEARINGS

As is typical of larger canopy gaps, grasses and ground ferns grow profusely. Here Microlaena spp. and to a lesser degree Asplenium bulbiferum are dominant. In other clearings, sedges (largely Uncinia spp.) and Blechnum fluviatile may be dominant species.

PLATE 2.4: FOREST STREAMS

Vegetation along small forest streams is very similar to the surrounding forest although a few species are more common such as Blechnum capense and B.pattersonii. In contrast the flora of the large open river beds may vary markedly from that of the surrounding forest.

CHAPTER 3

METHODS AND MATERIALS

3.1 DIET STUDY

Before starting to collect goat rumens, two trips were made to Mount Egmont in order to compile a reference collection of pickled and pressed plants. The shooter who was to collect samples for the project was accompanied over several days to review the autopsy procedure. Samples were taken from two goats for trial dietary analysis.

3.1.1 Collecting and Autopsying Goats

The New Zealand Forest Service shooter based in Stratford shot or dogged approximately 20 goats per month over the period July 1983 to June 1984 (the winter sample therefore comprised July and August 1983 and June 1984).

Each autopsy involved:

1) Recording the following details on a numbered card: date, time of death, estimated altitude (using a topographical map), locality within the study area, jaw tag number and sex.
2) One half of the lower jaw was removed and tagged so that it could be aged by tooth eruption patterns (Habermahl 1961).
3) The abdomen was cut open and the rumen removed by cutting it free at the oesophagus and omasum. The rumen was then massaged and compressed so as to mix its contents. After cutting it open (see Plate 3.1), at least ten spoon-fulls of contents from different regions of the rumen were put into a numbered 500ml plastic jar containing 50ml of 100% formalin.
4) Lactation in females was determined by squeezing or cutting the mammary glands. The uterus was examined and any foetuses were measured from the tip of the nose to the base of the tail so that they could be aged according to Eaton (1952).
5) Kidney fat (Riney 1955) was measured using a 200g spring balance.

At the end of each month the 20 preserved rumen samples, data cards and jaws were sent back to Massey University for analysis.

3.1.2 Processing the Rumen Samples

Samples were processed in the following manner:

1) Standardising Samples: Each sample was reduced to a standardized 300mls. Material was removed from down the side of the jar to avoid biases due to settling of plant fragments.

2) Sieving and Washing Samples: A sieving machine (Turner and Newall, Asbestos Fibre Classifier) was used to wash and sieve each sample into >4mm fractions and >2mm (i.e. <4mm but >2mm) fractions for identification. Initially, material was quickly hand sieved into a bucket with an 8mm sieve to remove the coarse material which choked the 4mm sieve. This coarse material was later recombined with material catching on the 4mm sieve producing the >8+4mm (identified) fraction. All the material passing through the 8mm sieve was then placed onto the sieving machine. The machine was used because it allowed sieving to be standardized with respect to time and the rate of stirring and water flow. However the great variability in mean particle size for different samples meant that some samples needed longer than the standard four minutes. Filter paper lined vacuum flasks were used to remove excess water from the sieve fractions prior to species composition analysis.

3) Sorting and Species Identification: The >8+4mm (identified) fraction was soaked in one litre of water for several hours to remove formalin. The sample was placed in about 10mm of water in an opaque perspex tray (30x20x5cm) to diffuse and partly suspend the plant fragments. The tray was placed over a light box to highlight leaf fragment characteristics such as veins, margins, mid-ribs, petioles and colour differences (see Plate 3.2). Fragments were then sorted into species using tweezers and if necessary a dissecting microscope. Material which had transparent regions and looked old due to digestive processes was classed as "residual" and was not included in the measurements. The >2mm fraction was visually scanned for several minutes to see if it contained any species or plant parts not found in the sorted fraction. Any new finds in the >2mm fraction were recorded as a trace.

4) Volumetric Measurement of Species: Sorted plant fragments from the >8+4mm fraction were spread out over tissue paper and blotted to remove surface moisture. The volume of each species was measured by

water displacement in a volumetric flask. It took about four to six hours per sample to reach this stage.

These species volumes were converted into percentages of the total amount of identified material in the sample. This weighted each sample equally, which was important because the volume of identified material varied considerably between samples.

NOTE: All statistical analyses were considered significant where $P < 0.05$ unless otherwise stated.

For an explanation as to how the above diet analysis procedure was chosen, refer to Appendix 2.

3.1.3 Seasonal Changes in Diet

Seasonal mean percentage volumes in the diet (M%Vol) with 95% confidence limits were calculated for each species (i.e. the average amount of each species eaten in each season). Similarly seasonal percentage frequencies (%Freq), (the proportion of goats containing each species in each season) were calculated. Despite the skewed distribution of the diet data, the large sample sizes meant that a reasonable prediction of the population mean and its confidence intervals were obtained for frequently eaten species (central limit theorem). However results were poor for less frequently eaten species where the confidence intervals often approached zero. Transformations such as arc-sine would not have helped (T.Hassard pers.comm.).

3.1.4 Variation in Diet in Relation to Season, Sex, Age, Time of Day, Altitude and Area

Diet (M%Vol) was examined to see whether it changed in relation to season, sex, age, time of day, altitude and area. Each rumen sample was catergorised according to season, sex and the following:

Age: 0-1yrs, >1-2yrs, >2-3yrs and >3yrs age classes.

Time of day: goats sampled prior to 1200 hours or between 1200 and 1700 hours. i.e. morning or afternoon.

Area: goats killed in areas 1, 2 or 3 as defined in Figure 2.1.

Altitude: goats killed between the park boundary and 549m, or 550m to 610m, or 611m to 701m. See Figure 2.1.

For the sake of statistical strength only species which occurred frequently (>70%) in large amounts over the year were used for these analyses; they were Asplenium bulbiferum, Astelia spp., Coprosma

grandifolius, Griselinia littoralis, Melicytus ramiflorus, Ripogonum scandens, and Weinmannia racemosa. One-way ANOVA was used to determine whether the volume of different species varied significantly ($p < 0.05$) with any of these factors (independent variables).

Whenever a plant species varied significantly with more than one factor, the situation was further examined to see whether the variation due to one factor was still significant after the variation due to the other factor was gone. This was done using the "GLIM" statistical package.

Seasonal effects were examined using ANOVA as well as by fitting confidence limits (see Section 3.1.3) because ANOVA was better able to handle the skewed nature of the diet data. (Anova is robust enough to handle even U shaped distributions as long as the ratio between the smallest and largest sample variance is no greater than about 20:1, the ratio between the smallest and largest sample size is no greater than about 4:1, the total degrees of freedom for the error term is >10 and two tailed tests of significance are used, Harris 1975).

3.1.5 Preference:The Use of Plant Species in Relation to their Availability

3.1.5.1 Relative Preference Index

The "forage ratio index" (Tochle and Rittenhouse 1982) was used to establish an index of preference (selection) for plant species eaten by the goats.

$$Pi = Di/Ai \quad \text{where:}$$

Pi = relative preference or (selection) for species i.
Di = mean % volume in the diet for species i.
Ai = mean % availability of species i in the field.

If the value of P is close to one, use approximates availability. The greater the value of P the more preferred (selected) that species is and conversely the closer P is to zero the less preferred (selected) it is.

Time restraints on the study meant that the vegetation availability survey produced an index of relative plant availability as

opposed to an accurate measure. To calculate accurate confidence intervals for "Preference" Pi, the denominator Ai needs to have a low coefficient of variance (S.E./mean). The availability survey only met this criterion for some more highly available species. Another area of imprecision was that the availability survey method only measured leaf surface area as opposed to volume or biomass. Thus it was probably more realistic not to present confidence limits for Pi. For an explanation on how the above "forage ratio index" was selected for this study see Appendix 2.

3.1.5.2 Establishing an Index of Plant Availability

The survey of relative plant availability was carried out over a 10 day period from mid-January 1983. Plant availability should have been at a maximum for most species, and long days and fine weather were expected.

Touches of edible plant parts against a thin rod were counted at 200 sample sites along each of five transects in the following manner:

1) Transects: Five transects ran from the bush edge to 610m a.s.l. following a compass bearing towards the mountain's peak. The four most southern transects were positioned to give good coverage of the region from which most goats came. The most northerly transect was to make the survey more representative of the entire study area (see Figure 2.1). Random transect positions were not used as such a small number of transects might have limited their representativeness of the area. Also many of the river beds were surrounded by high cliffs making it impossible to remain on a straight course, so these were avoided. Although river bank vegetation was different from the forest vegetation (see end of Section 2.2.3) it only covered a very small proportion of the total area and therefore probably had little effect on the availability of most species. The park boundary climbed in altitude from north (460m a.s.l.) to south (540m a.s.l.), consequently transect length decreased from north to south.

2) Sample Site Location: Two hundred equally spaced sample sites were used per transect. Spacing was calculated by dividing the transect length into 200 intervals. Hence spacing decreased from north to south. However sample sites were never less than 8m apart, therefore cover, interplant grouping and exclusion should not have been

problems. Spacing was paced (rather than measured precisely) for the sake of speed and ease in the tangled growth (see Plate 2.1).

3) Measurements taken at each Sample Site: The frequency with which edible plant parts of each species touched a vertical rod was recorded at five positions for each sample site. The fine rod (6mm diameter) projected 1.25m above the ground, thus measuring within the goat's normal browse range (M.Rudge pers.comm.). While facing along the compass bearing, touches on the rod were recorded at a forearm's length in front, fully extended arm in front, behind, to the left and right of the recorder's position at each sample site.

A criticism of this method is that it measured leaf surface area as apposed to biomass or volume. However, most species' leaves were of reasonabably similar thickness and the aim was to apply an index of relative availability as opposed to a precise measure. Also the very large differences in availability for many species helped overcome such problems.

Transects ended at 610m a.s.l. as opposed to 700m so that sampling was concentrated within a more important region from which 90% of the goats were collected. Also some species appeared to become scarce above 610m such as Ripogonum scandens and Schefflera digitata. Furthermore there was less risk of being stranded out overnight by using the shorter transects.

Ideally, seasonal measurements of availability should have been taken. However, this would have required a more sensitive and thorough method which was beyond the time limitations of this study. The fact that most species had a similar growing season, were perennial and evergreen and had a fairly low utilization by goats suggested that seasonal changes in relative availability would not have been very significant anyway. Thus they were assumed to be negligible for most foods.

Once the survey was completed, it was found that the availability of especially more palatable species was much greater along the most northern transect (T5 see Figure 2.1). This was probably due to the accessibility of the area via Egmont Road and the Waiwhakaiho River making goat control easy and effective. This transect did not seem representative of the rest of the study area and very few goats came from around it, thus it was not included in the availability estimates.

For an explanation of how the above vegetation availability

methodology was chosen see Appendix 2.

3.2 DIFFERENTIAL FRAGMENTATION AND DIGESTION

In order to reveal differences between plant species in the rates of fragmentation and digestion the following experiments were carried out. Experiments 2) and 3) below used the seven dominant dietary species in the July sample which were Asplenium bulbiferum, Coprosma grandifolius, Coprosma lucida, Melicytus ramiflorus, Ripogonum scandens, Schefflera digitata and Weinmannia racemosa.

1) Proportions in Sieve Fractions:

The proportion of each species remaining within different sieve fractions was examined for Mt Egmont rumen samples. Two rumen samples each month were sieved into >8mm, >4mm, >2mm and >1mm fractions which were individually sorted into species. Since too much of the finest fractions proved to be unidentifiable, it was decided to compare species proportions in the other three. The entire 8mm and 4mm fractions were sorted but the 2mm fraction was too fine to sort in entirety, therefore a well mixed watchglass full was identified. Analysis took about eight hours per sample.

2) Chewed Bolus Trial:

Four oesophageal fistulated goats (first cross or feral) were fed palatable native plants to examine the effects of chewing on the rates of breakdown of different plant species. This was because chewing is probably the major factor causing the disappearance of plant material from the rumen. The four goats were allowed two weeks to settle into their paddock and holding pen area after having ranged freely on a hill country farm. For another two weeks they were fed sheep nuts and watered twice daily. During the last week fresh handfuls of the native species were also offered. In the few days prior to the experiment the goats were penned up and hand fed the native plants. Also cannulae (plugs) were removed and dummy collection bags fitted over the fistulae. The above familiarization process made the goats quiet and cooperative for the experiment. However, the lowest ranking goat did not settle down sufficiently to be used.

For the experiment about 200g of edible plant parts of each species was prepared for each goat. Goats were penned individually,

their cannulae removed, a collecting bag attached (see Plate 3.4) and then fed one plant species. The throat was cleared and a new bag attached for successive plant species. Each chewed bolus sample was sieved into >8mm, >4mm, >2mm and >1mm fractions and dry weighed to find out the proportions in different fractions for each species. Also some unsieved sample was dry weighed from all samples so that the proportion of the sample passing through the 1mm sieve could be calculated by subtraction.

3) Incubation Trial:

The seven plant species were digested in vivo to look for relative differences in their rates of digestion. No rumen fistulated goats were available. Therefore two rumen fistulated sheep being fed on suitably low digestability diets were used. They had gradually increasing amounts of the seven species placed within their rumens over several days. This encouraged the development of rumen microbial populations which could digest the native plants. Using sheep was probably appropriate, because relative as apposed to absolute rates of digestion were being examined. Also various studies suggest different ruminant species can be substituted for this sort of work (Crawford 1982). Foliage was prepared in two ways:

a) Harsh Treatment: Leaves were patted and lightly rasped with a wire brush just sufficiently to perforate the leaf epidermis. Leaves were then cut into 0.5 to 1 cm wide strips. This treatment was intended to simulate severe cuticlular damage as probably occurs in real mastication.

b) Mild Treatment: Leaves were simply cut into 0.5 to 1cm wide strips.

Known weights of each species for both treatments were placed in small nylon bags (that only allowed the passage of dissolved matter) and placed in two sheep (one for each treatment). Differences between sheep were assumed to be minimal because they were both given the same feeds which was probably the more important factor (A.John pers.comm.). After 12 hours the bags were removed and examined. The residual percentage dry matters (% d.wt.) were calculated for all species in both treatments so that differences in the amounts digested between species and treatments could be examined. The amount digested was calculated by subtracting the % d.wt. of treated material from the % d.wt. of untreated material for individual species.

3.3 NITROGEN AND MINERAL LEVELS IN PRINCIPAL DIETARY SPECIES

The nitrogen and mineral levels in seven principal dietary species were compared to the levels probably required by goats to see if there was any correlation between species use and nutrient status. The species examined were Asplenium bulbiferum, Coprosma grandifolius, Coprosma lucida, Melicytus ramiflorus, Ripogonum scandens, Schefflera digitata and Weinmannia racemosa. They were the dominant food items of the first month's sample (July).

1) Collection of Samples: Seasonal collections of foliage from the seven plant species were made from two transects on Mount Egmont. Collection began in spring 1983 and subsequent collections were made in the middle of each season. Transects were positioned along the edge of York Track in the south and Egmont Road in the north respectively. Transects were sampled at three points equidistant with respect to altitude. The first being approximately 200m inside the bush edge and the last around 610m a.s.l.. Transects ended at 610m because Ripogonum scandens and Schefflera digitata were very scarce on the York transect above that altitude and particularly because 90% of all the goats were collected below that level. Thus the York Transect was sampled at 560m, 590m, 620m a.s.l.and Egmont Transect at 490, 550m, 610m a.s.l.. Samples were collected at 30 to 40m in from the track or road. At each altitude the equivalent of about six medium sized Melicytus ramiflorus leaves were collected from each of three plants, for all species. Thus the equivalent of 54 leaves were collected for each species per transect. Samples were chilled, sealed in an airtight bag and frozen within 12 to 24 hours.

2) Chemical Analysis of Samples: Once all seasons were sampled, samples were oven dried at 98C for 36 hours. Replicated, approximately 0.5g sub-samples were removed and placed in labelled preweighed digestion flasks. They were then redried to remove the 5 to 8% moisture regained from the atmosphere. Samples were weighed immediately on cooling and 10ml of concentrated nitric acid (70% W/W) was added to begin digestion. Flasks were stoppered with a glass funnel which had a reflexing effect, allowing expansion and contraction while minimizing aerosol losses during subsequent heating. After 24 hours in the acid to remove more reactive substances (thus reducing the chance of boiling over) the flasks were gradually heated. The

temperatures used were 50 to 60C for about six hours and 90C for 12 hours, i.e. temperature was gradually increased as more reactive organic matter was digested. The samples turned clear once all the organic matter dissolved; then the nitric acid was boiled off at 120C. On drying, samples were immediately removed. Next, 10ml of 2 molar HCl was added to make each sample the correct dilution. An internal standard of 5ppm of Ni was added to enable corrections for drift in the readings on the Inductively Coupled Argon Plasma Emission Spectrometer (ICAP/ES). Finally concentrations for the following minerals were measured on the ICAP/ES and the results for each pair of replicates averaged.

a) Major elements: Na, K, P, Ca, S, Mg.

b) Trace elements: Zn, Mn, Cu, Fe.

Also each sample was analysed for nitrogen concentration by the standard Kjedahl method.

Thus for the seven plant species there was a sample from each transect for all seasons. For each sample concentrations of nitrogen, six major elements and four trace elements were measured. Three important trace elements (Co, Se and I) and the major element Cl were not measured because of time restraints.

3.4 POPULATION BIOLOGY

The following data were collected for each animal from which a rumen sample was removed: sex, female reproductive status, foetal length, half a lower jaw for aging and the kidney fat index measurements (KFI), (see Section 3.1.1.2). Conception and birth dates were estimated using foetal age and the known gestation period of five months (Luisi 1979).

PLATE 3.1: RUMEN CONTENTS OF A FRESHLY KILLED GOAT

This photograph of the rumen contents was taken moments after the goat's capture in dense forest (1700 hours, May 1983). Note the very coarse and fresh appearence of the plant material. The goat was probably nearing the end of its afternoon feed. Most of the visible leaf fragments are Schefflera digitata. The photograph is about two thirds life size.

PLATE 3.2: A RUMEN SAMPLE READY FOR SORTING

The >8+4mm (identified) fraction of a rumen sample is shown in the light box ready to be sorted into species. Numbered fragments are named below:

1. Coprosma lucida
2. Ripogonum scandens fruit, other fruits have lost the red flesh.
3. Elaeocarpus dentatus
4. Weinmannia racemosa
5. Phymatosorus diversifolium
6. Asplenium bulbiferum
7. Ripogonum scandens foliage

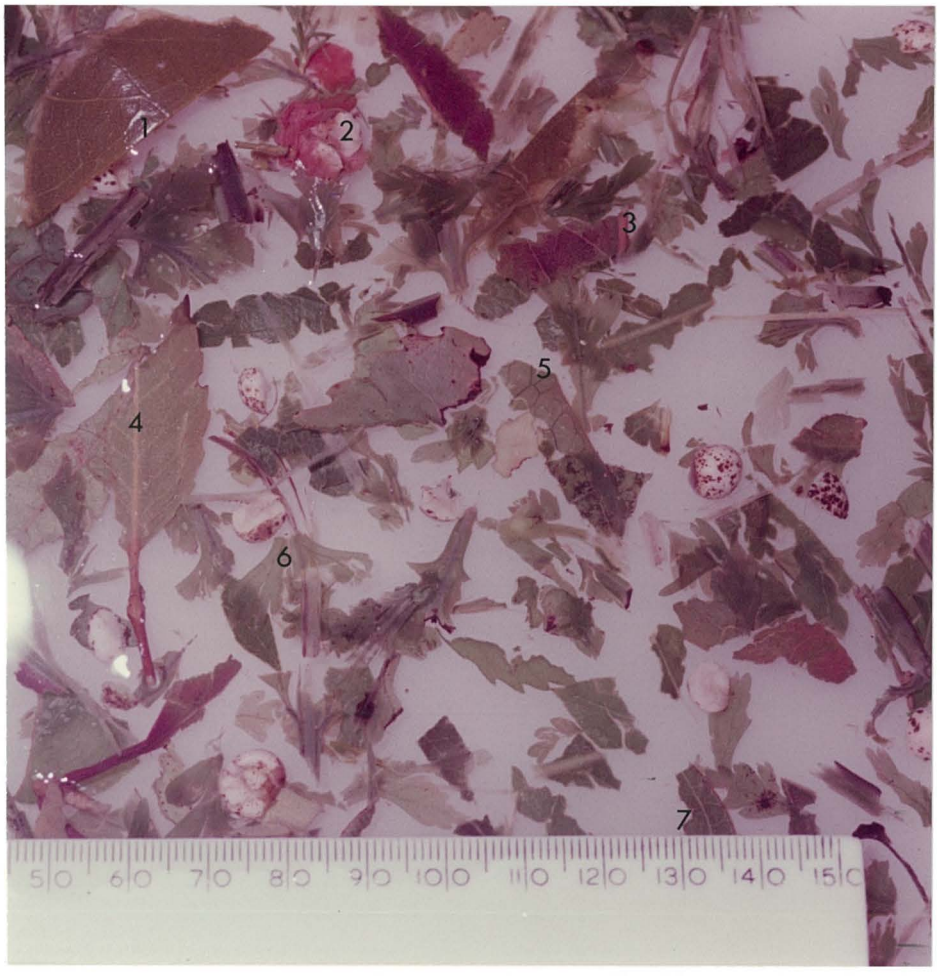

1
2
3
4
5
6
7

PLATE 3.3: A FISTULATED GOAT EATING

Note how in biting off a group of Weinmannia racemosa leaves in one mouthful, only coarse twigs were left behind. Fine Weinmannia racemosa twigs (occasionally other species) were fairly common in Mt Egmont rumen samples. Sometimes small clusters of leaves were ingested intact. (Photograph by R.A.Fordham.)

PLATE 3.4: COLLECTING CHEWED BOLUS SAMPLES

The goat is about to ingest and chew several Ripogonum scandens leaves. Chewed bolus material can be seen passing through the fistula into the collecting bag.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CHAPTER 4

RESULTS

4.1 DIET

The rumen contents of 227 goats were analysed. The consistency of the rumen contents was highly variable. Most samples had the appearance of green or brownish chunky "coleslaw" mixed with peat (see Plate 3.1), while others looked like vomit. Average particle size was variable so the proportion of each sample remaining in the >8+4mm (identified) fraction varied. Most of the material in the >8+4mm fraction had a fresh appearance with the original leaf colour and characteristics well preserved. However Weinmannia racemosa and Geniostoma ligustrifolium were often discoloured. Small amounts (about 1-5%) of the >8+4mm fraction were classed as "residual", because they showed obvious signs of digestion.

The ingested material comprised leaf blades, petioles, some finer twigs and occasionally fruit from species such as Griselinia littoralis, Carpodetus serratus, Pennantia corymbosa, Hedycarya arborea and Coprosma lucida. Fruits of Astelia spp. were eaten in moderate to large amounts by about 20% of goats in November and occurred at no other time. Piles of Astelia leaves with chewed off bases were seen on several occasions in the study area. These white leaf bases were not uncommon in the rumen samples. Ripogonum scandens fruit and vine (as well as foliage) were eaten over the whole year (see Section 4.1.1.1). A lot of the fern that was eaten carried masses of spores e.g. Alsophila smithii, Asplenium bulbiferum, Asplenium flaccidum, Asplenium polypodon , and Phymatosorus diversifolium. Some bark was eaten; it was probably Coprosma grandifolius as no other species was seen barked within the study area.

4.1.1 Seasonal Changes in Diet

The numbers of rumen samples collected each season were: winter (n=52), spring (n=58), summer (n=59) and autumn (n=58).

Seasonal changes in principal dietary species (i.e. species making up 1.5% or more of the annual (pooled over seasons) diet) are presented

in Figures 4.1 and 4.2. They are described in terms of: a) the amounts eaten, measured as the mean percentage volume in the diet (M%Vol). b) the proportion of the goats eating a species which is the percentage freguency in the diet (%Freq). These 10 species made up 81.5% of the annual diet by volume.

The seasonal trends for each species were as follows: (species are presented in order of decreasing annual M%Vol).

1) Asplenium bulbiferum was eaten by about 90 to 100% of goats and made up about 30% of the diet (M%Vol) in each season. The significant dip in M%Vol in summer was the result of most of the February sample coming from high up in a large river bed where there was little Asplenium bulbiferum (i.e. it is misleading).

2) Ripogonum scandens (foliage, fruit and vine) was eaten by about 70 to 85% of goats and made up about 15% of the M%Vol in each season except for spring (7.5%) which was just significantly less than autumn (16.6%), (see Section 4.1.1.1 for more detail).

3) Weinmannia racemosa was eaten by about 85 to 95% of the goats in all seasons except when significantly fewer goats (64%) ate it in spring (X^2=24.26,DF=3,P<0.005). It made up 10 to 13% of the M%Vol in all seasons except spring, which was significantly lower at 4.4%.

4) Schefflera digitata was eaten by about 40 to 60% of goats and made up about 3 to 7% of the M%Vol in each season, there being no significant seasonal changes.

5) Griselinia littoralis was eaten by about 90% of goats in winter and spring and 70% in summer and autumn (X^2=10.10,DF=3,p<0.025). It made up about 3 to 5% of the M%Vol except in spring where it is significantly higher (see ANOVA results below) at 8.1%.

6) Coprosma grandifolius was eaten by 80 to 90% of goats in all seasons. It made up about 3-5% of the M%Vol in each season except for a peak of 8.2% in autumn which was significantly higher than winter and spring.

7) Melicytus ramiflorus was eaten by 80 to 90% of the goats seasonally. The M%Vol in autumn (2.6%) was significantly lower than in summer (5.7%).

8) Astelia spp. were eaten by about 85 to 100% (X^2=8.54,DF=3,p<0.05) of goats and made up about 4% of the M%Vol seasonally.The M%Vol of 5% in spring corresponded with the large amounts of fruit in the November goats.

9) Coprosma tenuifolia was eaten by about 55 to 60% of goats in each season except summer which was 80% (X^2=10.53,DF=3,p<0.005). It

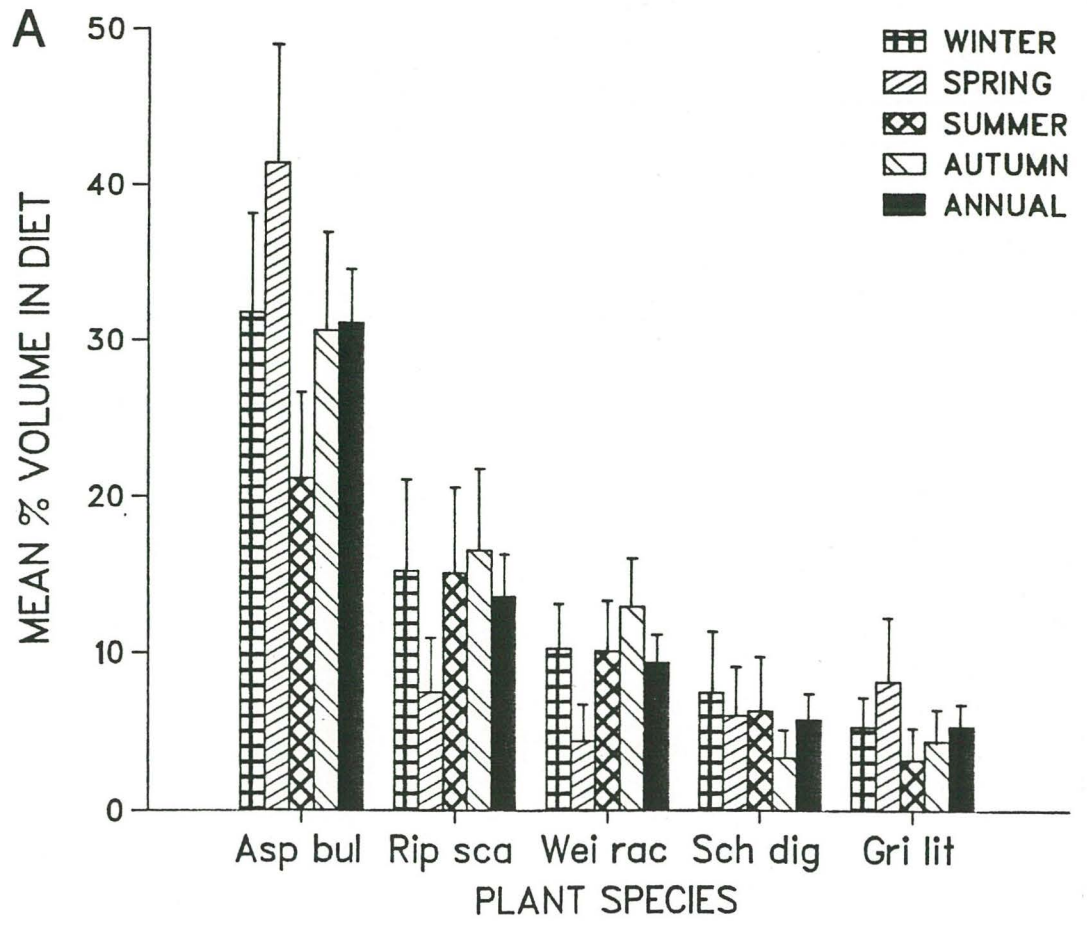
FIGURE 4.1

A. SEASONAL MEAN PERCENTAGE VOLUMES OF PRINCIPAL DIETARY SPECIES EATEN BY GOATS (M%Vol).

Species are given in order of decreasing annual M%Vol (all exceed 5%) and 95% confidence limits are fitted.

Asp bul = *Asplenium bulbiferum*
Rip sca = *Ripogonum scandens*
Wei rac = *Weinmannia racemosa*
Sch dig = *Schefflera digitata*
Gri lit = *Griselinia littoralis*

B. SEASONAL PERCENTAGES OF GOATS EATING PRINCIPAL DIETARY SPECIES (%Freq).


A
MEAN % VOLUME IN DIET
50
40
30
20
10
0
WINTER
SPRING
SUMMER
AUTUMN
ANNUAL
Asp bul
Rip sca
Wei rac
Sch dig
Gri lit
PLANT SPECIES

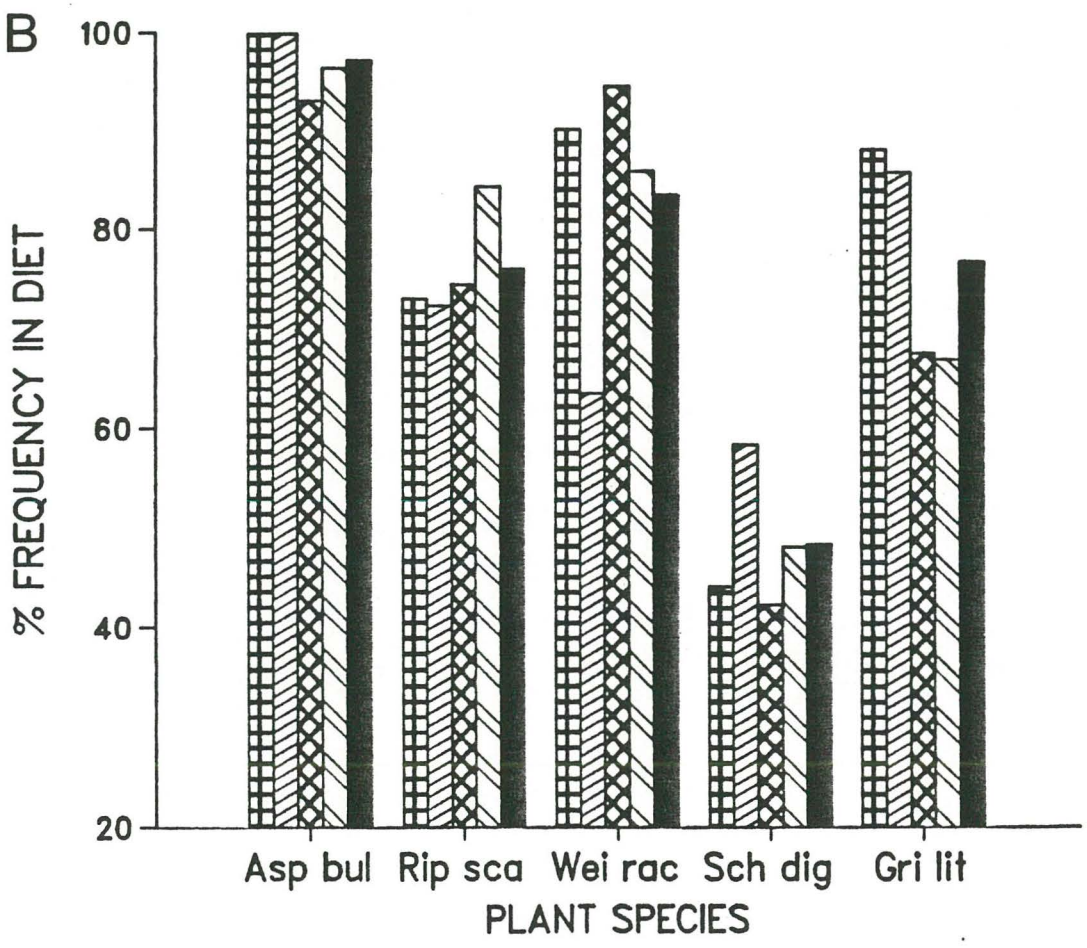

B
% FREQUENCY IN DIET
100
80
60
40
20
Asp bul
Rip sca
Wei rac
Sch dig
Gri lit
PLANT SPECIES

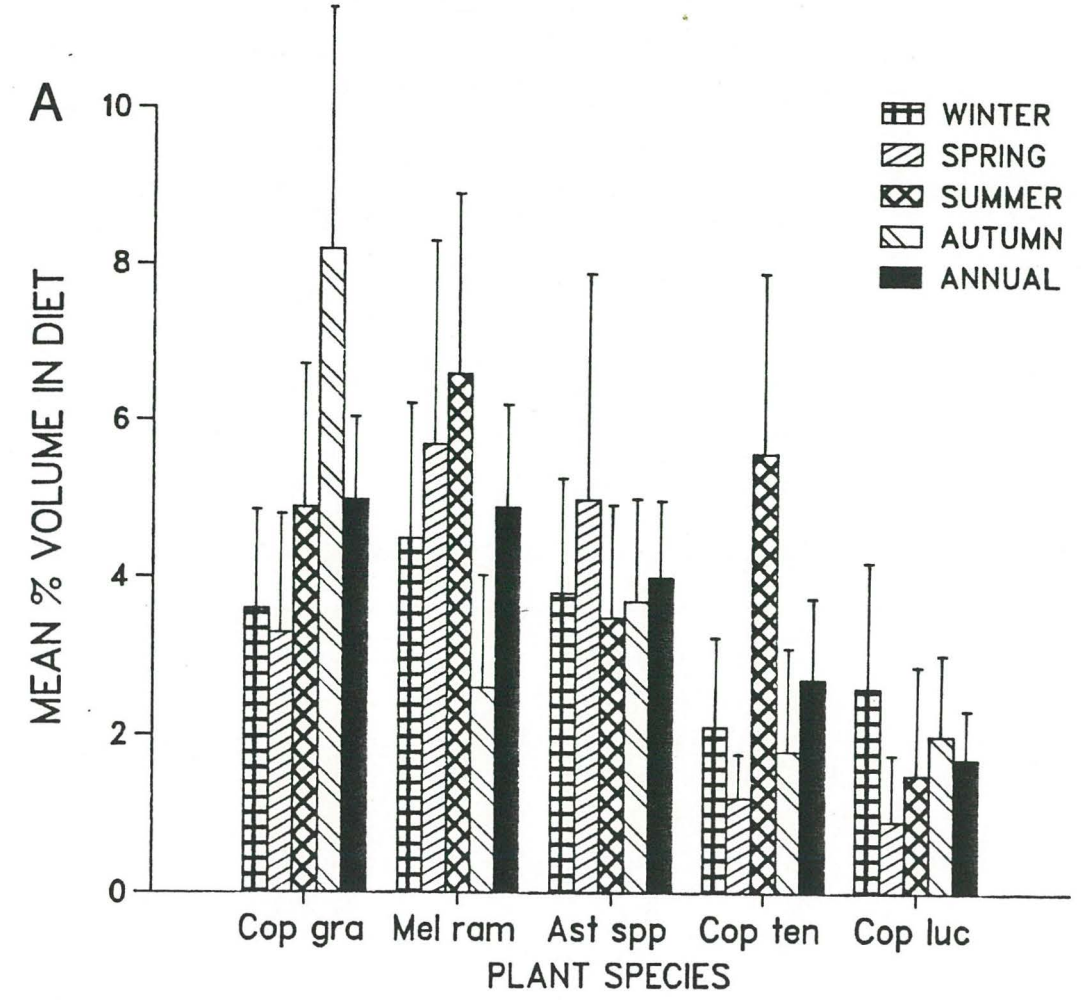
FIGURE 4.2

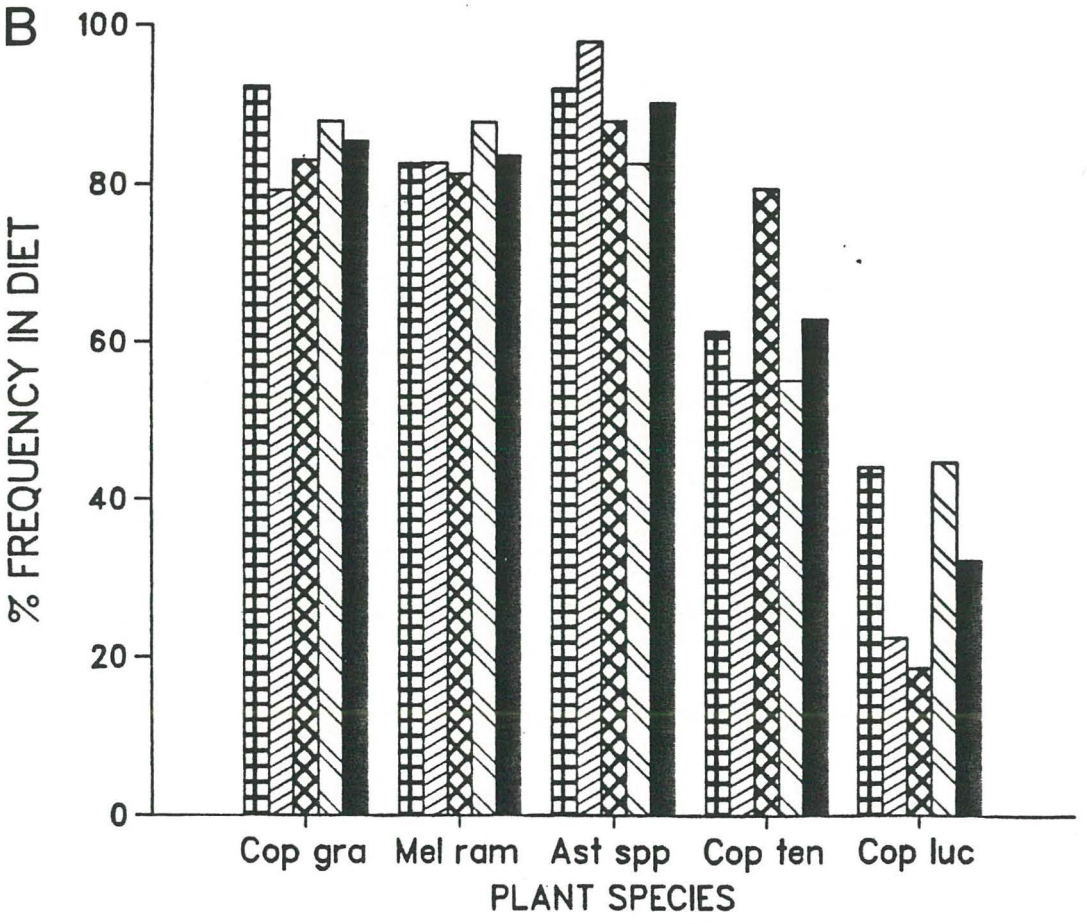
A. SEASONAL MEAN PERCENTAGE VOLUMES OF PRINCIPAL DIETARY SPECIES EATEN BY GOATS (M%Vol).

Species are given in order of decreasing annual M%Vol (all less than 5%). 95% confidence intervals are fitted.

Cop gra = Coprosma grandifolius
Mel ram = Melicytus ramiflorus
Ast spp = Astelia spp.
Cop ten = Coprosma tenuifolia
Cop luc = Coprosma lucida

B. SEASONAL PERCENTAGES OF GOATS EATING PRINCIPAL DIETARY SPECIES (%Freq).


A
MEAN % VOLUME IN DIET
0
2
4
6
8
10
WINTER
SPRING
SUMMER
AUTUMN
ANNUAL
Cop gra
Mel ram
Ast spp
Cop ten
Cop luc
PLANT SPECIES


B
% FREQUENCY IN DIET
0
20
40
60
80
100
Cop gra
Mel ram
Ast spp
Cop ten
Cop luc
PLANT SPECIES

made up about 1 to 2% of the diet seasonally except for summer (5.6%) which was significantly greater than other seasons.

10) Coprosma lucida was eaten by about 20% of goats in spring and summer and about 45% on winter and autumn. The amount eaten was about about 1 to 2.5% of the total seasonal M%Vol.

11) Species of smaller dietary proportions: About another dozen species each made up more than 0.5% of the annual M%Vol, however there were no significant seasonal differences, except in the case of Dicksonia squarrosa which was eaten most in summer. Seasonal M%Vol and %Freq values are presented for all species in Appendices 4 and 5.

4.1.1.1 Seasonal Changes in Consumption of Ripogonun scandens Plant Parts

All Ripogonum scandens plant parts were principal components of the diet. Seasonal M%Vols and %Freqs are presented in Figure 4.3.

1) Foliage: About 70 to 80% of goats ate the foliage in each season and it made up 2 to 4% of the M%Vol seasonally.

2) Vine: The number of goats eating vine changed significantly from a low in spring of 27.6% to a peak in autumn of 75.9% (X^2=35.42,DF=3,$p<0.001$). Simlarly the M%Vol climbed from a low in spring (0.87%) to significantly higher values in summer (10.92%) and autumn (13.19%).

3) Berry: Seasonal changes in frequency and amount of berry eaten followed an opposite trend to that of vine. Frequency decreased from a winter peak of 38.5% to a summer and autumn low of about 17% (X^2=9.07,DF=3,$p<0.05$). The M%Vol declined from a winter peak of 6.6% to an autumn low of 0.2%. Autumn was significantly lower than the winter and spring (4.2%) values.

4.1.2 Changes in Diet in Relation to Season, Sex, Age, Time of Day, Altitude and Area

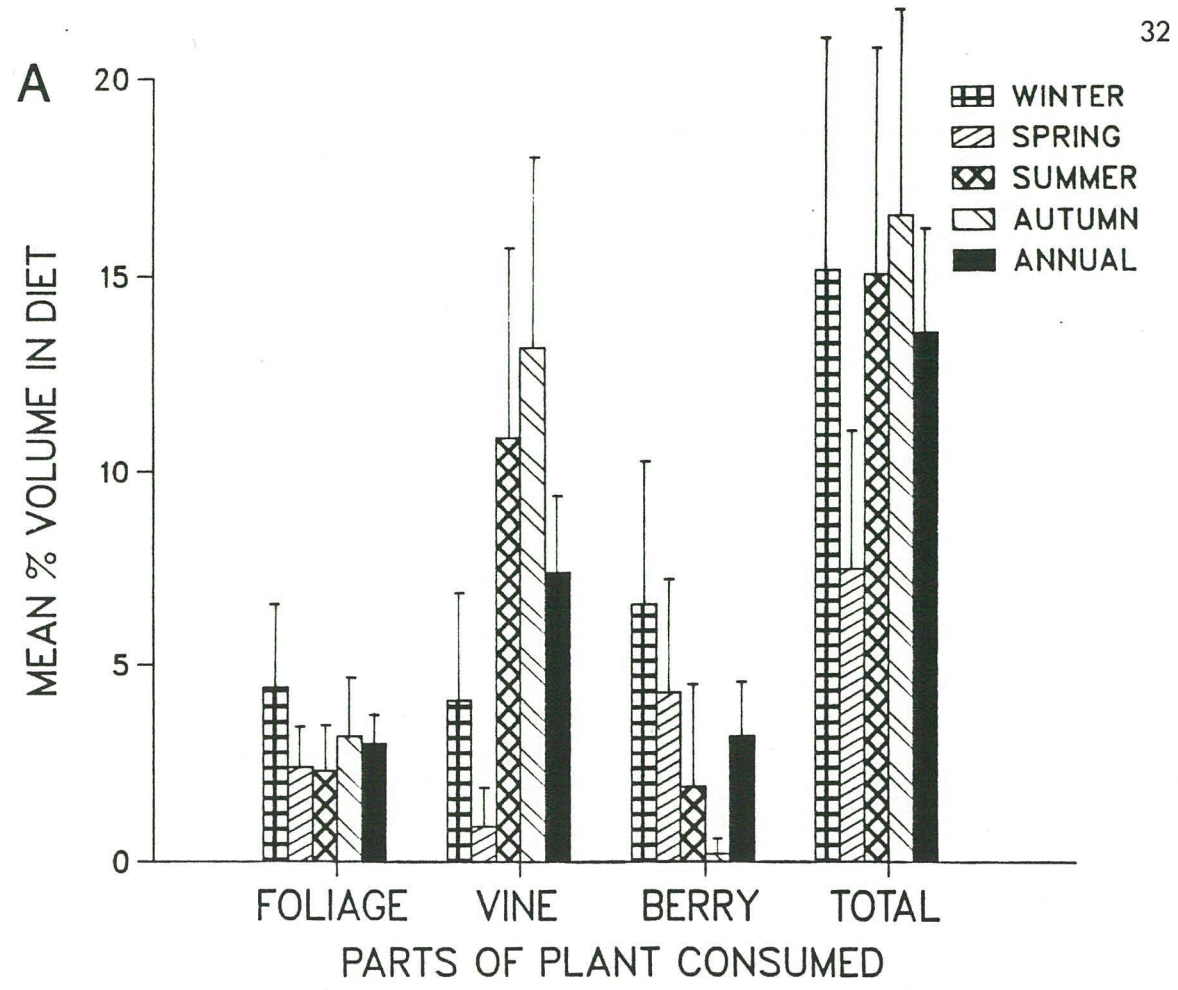
4.1.2.1 Variation in the Volumes of Species Eaten with Season, Sex, Age, Time of Day, Altitude and Area

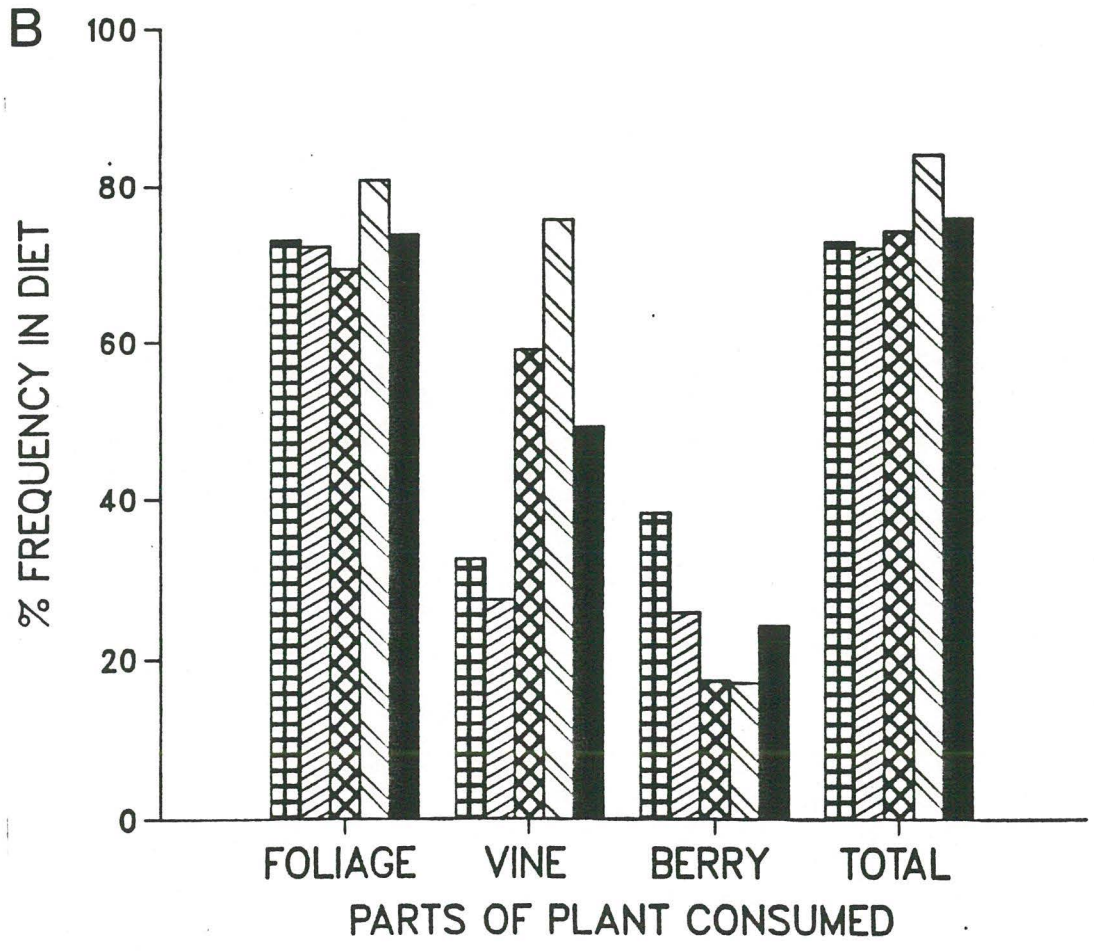
Table 4.1 gives ANOVA results where the volumes of principal species in the diet vary significantly with season, sex, age, time of

FIGURE 4.3

A. SEASONAL MEAN PERCENTAGE VOLUMES OF Ripogonum scandens PLANT PARTS EATEN BY GOATS (M%Vol). 95% confidence intervals are fitted.

B. SEASONAL PERCENTAGES OF GOATS EATING Ripogonum scandens PLANT PARTS (%Freq).


A
MEAN % VOLUME IN DIET
20
15
10
5
0
WINTER
SPRING
SUMMER
AUTUMN
ANNUAL
FOLIAGE
VINE
BERRY
TOTAL
PARTS OF PLANT CONSUMED


B
% FREQUENCY IN DIET
100
80
60
40
20
0
FOLIAGE
VINE
BERRY
TOTAL
PARTS OF PLANT CONSUMED

day, altitude, or area.

Table 4.1 FACTORS AFFECTING THE VOLUMES OF PRINCIPAL DIETARY SPECIES EATEN BY MOUNT EGMONT GOATS (ANOVA OF SPECIES VERSUS FACTOR)

Species	Season	Sex	Age	Time	Altitude	Area
Asplenium bulbiferum	0.000	0.044				0.000
Astelia spp.					0.005	
Coprosma grandifolius	0.003					0.000
Griselinia littoralis	0.033		0.046		0.001	
Melicytus ramiflorus	0.037			0.007		
Ripogonum scandens	0.052		0.035			0.033
Weinmannia racemosa	0.000					0.010

Following are the results using the computer package "GLIM", used to examine whether variation was independent or overlapped between factors (e.g. season and sex). It was hoped that this would expose whenever seasonal variation was an artifact of seasonal samples being unbalanced with respect to some other significant factor.

1) *Asplenium bulbiferum*: The volumes of *Asplenium bulbiferum* eaten varied significantly with season, sex and area. a) Seasonal variation was still significant ($p<0.001$) after sexual variation was removed and was independent from variation with area. b) Variation due to area was still highly significant after sexual variation was removed. c) Sexual variation was no longer significant ($p>0.05$) after seasonal variation was removed, but remained significant ($p<0.05$) after variation with area was removed. Therefore the amount of *Asplenium bulbiferum* in the diet varied significantly with season and area which were independent. However, seasonal variation was due to a mis-representative dietary sample in February (see 1) in Section 4.1.1).

2) *Ripogonum scandens*: Volumes of *Ripogonum scandens* (foliage, fruit and vine combined) in the diet varied significantly with age and area. Also season was tested against the other two factors because it was almost significant with $p=0.052$. a) Age was not significant after variation due to area ($p>0.05$) and season ($p>0.05$) had been removed. b) Area was not significant after variation due to season ($p >0.05$) and age (>0.1) had been removed.

3) Use of the other species varied significantly with each factor

after variation due to other significant factors was removed.

4.1.2.2 Variation in Dietary Diversity with Season, Sex, Age and Time of Day.

The number of species eaten by goats in relation to season, sex, age and time of day are given below.

1) Season: There was no significant difference in the number of species eaten in each season.

Season	winter	spring	summer	autumn.
Mean No of Spp	18.4	18.3	19.0	19.0
± 2S.E.	1.1	1.2	0.9	1.0
n	52.0	58.0	59.0	58.0

2) Sex: There was no significant difference in the number of species eaten by the sexes.

Sex	Male	Female
Mean No of Spp	18.5	19.0
± 2S.E.	0.6	0.9
n	154.0	72.0

3) Age: The number of species eaten by goats from 0-1 years old was significantly greater than for older goats, except for those in the >2-3 year old class where the 95% confidence limits overlapped slightly.

Age (years)	0-1	>1-2	>2-3	>3
Mean No of Spp	19.9	17.7	18.0	17.6
± 2S.E.	0.8	1.1	1.4	0.9
n	94.0	51.0	34.0	47.0

4) Time of Day: There was no difference in the number of species found in samples collected in the morning (0800 to 11 59 hours) and afternoon (1200 to 1700 hours).

Time	Morning	Afternoon
Mean No of Spp	18.9	18.8
± 2S.E.	0.8	0.7
n	83.0	136.0

4.1.3 Rankings of Dominant Items in the Diet

Ranked annual M%Vols of each species in the diet showed that only a few species were regularly the dominant dietary item. Percentage frequencies for the first (most dominant), second and third ranks for ten species in order of decreasing frequency in the first rank are presented in Table 4.2.

TABLE 4.2 RANKINGS OF DOMINANT ITEMS IN THE DIET

Species	1st Rank	2nd Rank	3rd Rank
Asplenium bulbiferum	49.8%	13.7%	5.3%
Ripogonum scandens	15.9%	14.1%	11.0%
Schefflera digitata	6.6%	8.4%	8.4%
Weinmannia racemosa	6.2%	21.6%	11.5%
Lotus pedunculatus	4.0%	1.8%	2.2%
Griselinia littoralis	3.1%	5.7%	8.8%
Coprosma grandifolius	2.6%	6.2%	10.6%
Melicytus ramiflorus	2.6%	6.6%	11.9%
Astelia spp.	2.2%	4.4%	7.0%
Coprosma tenuifolia	1.3%	3.1%	3.5%
Other species	each <1%		

The first two species alone made up the principal dietary component in 65.7% of the total 227 goats over the year.

4.1.4 Preference: The Use of Plant Species in Relation to their Availability

1) Species of Higher Availability within the Study Area:

Preference ratings were calculated for species which occurred more than 10 times in the plant availability survey. Figure 4.4 shows mean % availability values, annual M%Vol values, and annual relative preference ratings (PR). Of the 13 species with availabilities greater than 1% (upper bar chart) none were "highly preferred" species (PR>5); Asplenium bulbiferum (1.67) and Ripogonum scandens foliage (2.52) were "preferred" species (5≥PR>1.5) and only Carpodetus serratus (0.82) was an "equilibrium" species (1.5≥PR≥0.7). Astelia spp. (0.50) and Dicksonia squarrosa (0.27) were "rejected" species (0.7>PR≥0.2) and the remaining eight species were "highly rejected" (PR<0.2). They included Microlaena spp. (0.003), Uncinia spp. (0.003), Alsophila smithii (0.005), Blechnum fluviatile (0.000), Metrosideros diffusa (0.06), Blechnum discolor (0.12), Pseudowintera colorata (0.11) and filmy ferns (0.08). Three decimal places are presented for some species to show that they were actually eaten. Blechnum fluviatile was the only abundant species that was never seen in the diet. Although several other uncommon species also never occurred.

Five of the 13 species with availabilities less than 1% were "highly preferred": Griselinia littoralis, (5.78); Weinmannia racemosa (10.71), Melicytus ramiflorus (10.61), Coprosma grandifolius (12.55) and Schefflera digitata (27.36), in order of decreasing availability. Two species Coprosma tenuifolia (3.14) and Pseudopanax crassifolius (2.01) were "preferred" and Hedycarya arborea (0.70) and Pennantia corymbosa (0.71) were "equilibrium". Podocarpus ferrugineus (0.42) and Alseuosmia macrophylla (0.28) were "rejected" species and the remaining two species Beilschmiedia tawa (0.16) and Nestegis cunninghamii (0.11) were "highly rejected".

Many species of lower availability are not presented and although Schefflera digitata occurred only eight times (i.e. less than 10) in the availability survey, it was included here because it was so highly palatable.

Of the five "highly preferred" species, all had lower availabilities (less than 1%). Of the 10 "highly rejected" species, eight had high availabilities (greater than 1%). Therefore species use was largely independent of species availability.

"Highly preferred" species ranked from highest to lowest were: Schefflera digitata, Coprosma grandifolius, Weinmannia racemosa,

Melicytus ramiflorus and Griselinia littoralis. However, Schefflera digitata (PR=27) was much higher and Griselinia littoralis (PR=6) was much lower than the others which had similar "PR"s of about 10 to 12. Together these "highly preferred" species made up a very large 44% of the annual M%Vol and yet accounted for only 4% of what was available. "Preferred" species made up 34.5% of the annual M%Vol and 20% of what was available; they included Coprosma tenuifolia, Pseudopanax crassifolius and Asplenium bulbiferum. Asplenium bulbiferum alone accounted for 31% of the diet by volume. "Equilibrium" species, Carpodetus serratus, Hedycarya arborea and Pennantia corymbosa made up about 7% of the annual M%Vol and had a combined availability of about 10%. "Rejected" species: Astelia spp., Dicksonia squarrosa and Podocarpus ferrugineus made up about 4.7% of the annual M%Vol and had an availability of about 10.5%. The "highly rejected" species: Microlaena spp., Uncinia spp., Alsophila smithii, Blechnum fluviatile, Metrosideros diffusa, Blechnum discolor, Pseudowintera colorata, filmy fern, Beilschmiedia tawa and Nestegis cunninghamii made up a tiny 1.3% of the annual M%Vol and yet accounted for a huge 48.4% of what was available. Thus the ratio of use:availability was about 11:1 for high preference species and 1:37 for rejected species i.e. both strong selection and rejection was evident for different species.

In the case of Ripogonum scandens, only foliage was encountered in the availability survey yet most of what was eaten was vine or berry. This implied that the vine and berry were "highly preferred" whereas the foliage was only "preferred".

2) Species of Lower Availability:

Species which occurred less than 10 times in the survey of vegetation availability were given a subjective preference rating in Appendix 3. Some uncommon species were not rated because as availability declined so did one's ability to measure relative abundance and to account for the uniformity of the species distribution throughout the study area.

3) Seasonal Changes in Species Preference:

Seasonal changes in relative plant availability were assumed to be negligible for the foliage of most species (see Section 3.1.5.2). Therefore plant species foliage which showed seasonal use was likely to have been seasonally preferred. Thus it is proposed that goat's preference for Coprosma grandifolius, Melicytus ramiflorus, Coprosma

FIGURE 4.4: ANNUAL PREFERENCE RATINGS FOR PLANT SPECIES

Only species occurring more than 10 times in the plant availability survey are presented.They are given in order of decreasing availability.

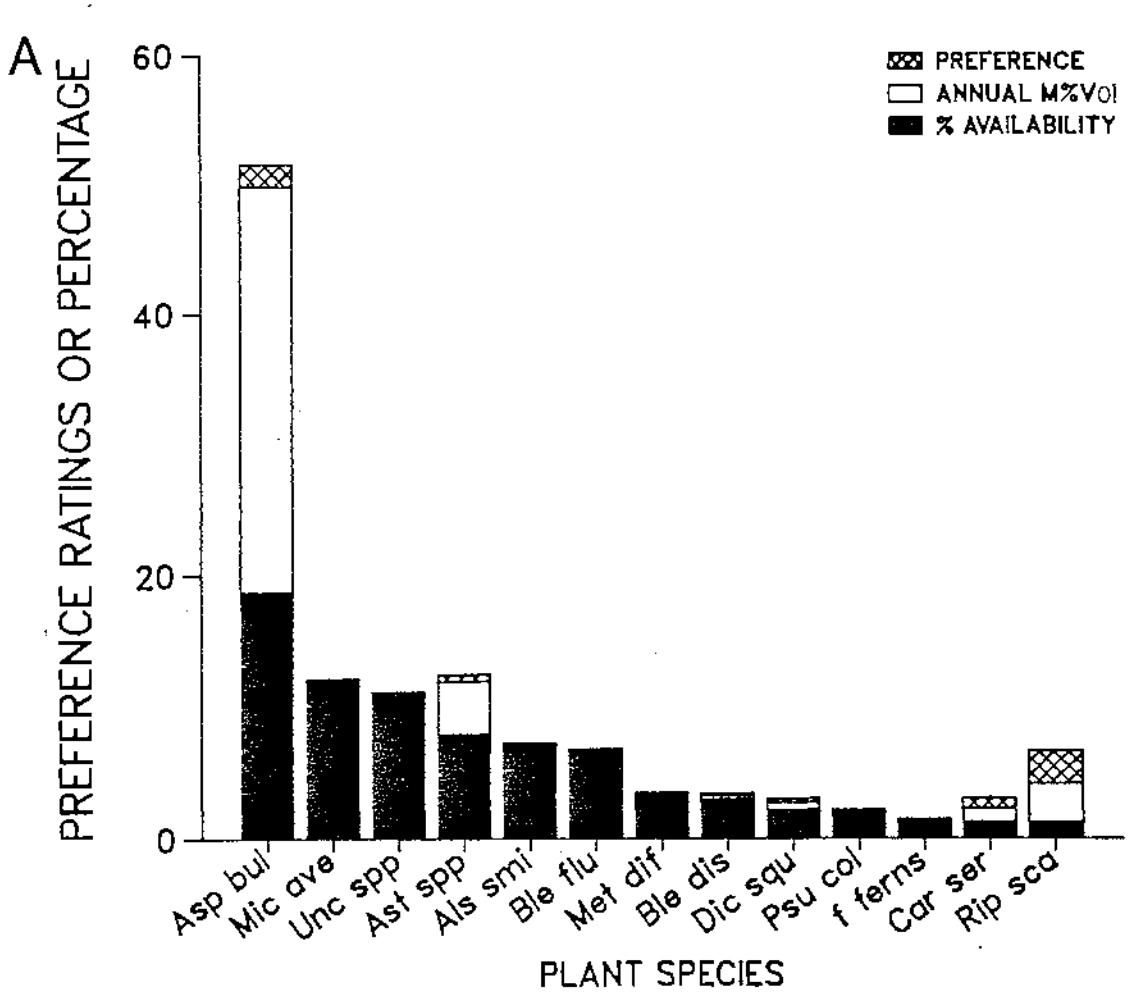
A. Species of availability >1%.

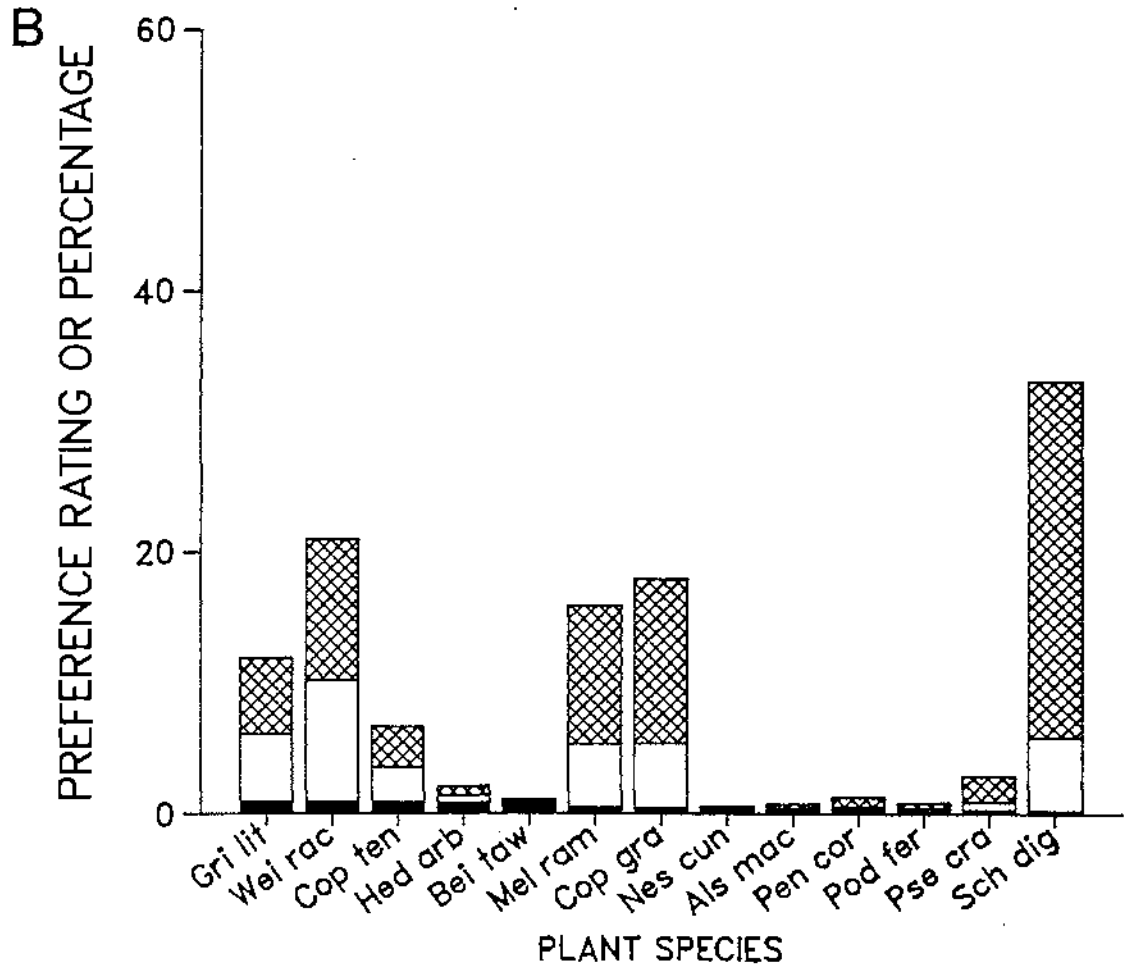
Asp bul=*Asplenium bulbiferum*
Mic ave=*Microlaena* spp.
Unc spp=*Uncinia* spp.
Ast spp=*Astelia* spp.
Als smi=*Alsophila smithii*
Ble flu=*Blechnum fluviatile*
Met dif=*Metrosideros diffusa*
Ble dis=*Blechnum discolor*
Dic squ=*Dicksonia squarrosa*
Psu col=*Pseudowintera colorata*
f ferns=filmy fern
Car ser=*Carpodetus serratus*
Rip sca=*Ripogonum scandens**

*(foliage only)

B. Species of availability <1%.

Gri lit=*Griselinia littoralis*
Wei rac=*Weinmannia racemosa*
Cop ten=*Coprosma tenuifolia*
Hed arb=*Hedycarya arborea*
Bei taw=*Beilschmiedia tawa*
Mel ram=*Melicytus ramiflorus*
Cop gra=*Coprosma grandifolius*
Nes cun=*Nestegis cunninghamii*
Als mac=*Alseuosmia macrophylla*
Pen cor=*Pennantia corymbosa*
Pod fer=*Podocarpus ferrugineus*
Pse cra=*Pseudopanax crassifolius*
Sch dig=*Schefflera digitata*


A
PREFERENCE
ANNUAL M%VOL
% AVAILABILITY
PREFERENCE RATINGS OR PERCENTAGE
60
40
20
0
Asp bul
Mic ave
Unc spp
Ast spp
Als smi
Ble flu
Met dif
Ble dis
Dic squ
Psu col
f ferns
Car ser
Rip sca
PLANT SPECIES


B
PREFERENCE RATING OR PERCENTAGE
60
40
20
0
Gri lit
Wei rac
Cop ten
Hed arb
Bei taw
Mel ram
Cop gra
Nes cun
Als mac
Pen cor
Pod fer
Pse cra
Sch dig
PLANT SPECIES

tenuifolia, Weinmannia racemosa and Griselinia littoralis changed seasonally. Both the seasonal diet and the plant species availability measurements gave at best fairly approximate results. Therefore calculating seasonal preference ratings could have been misleading. It was simply assumed that increasing use reflected increasing preference.

4.2 DIFFERENTIAL FRAGMENTATION AND DIGESTION

1) Proportions in the Sieve Fractions

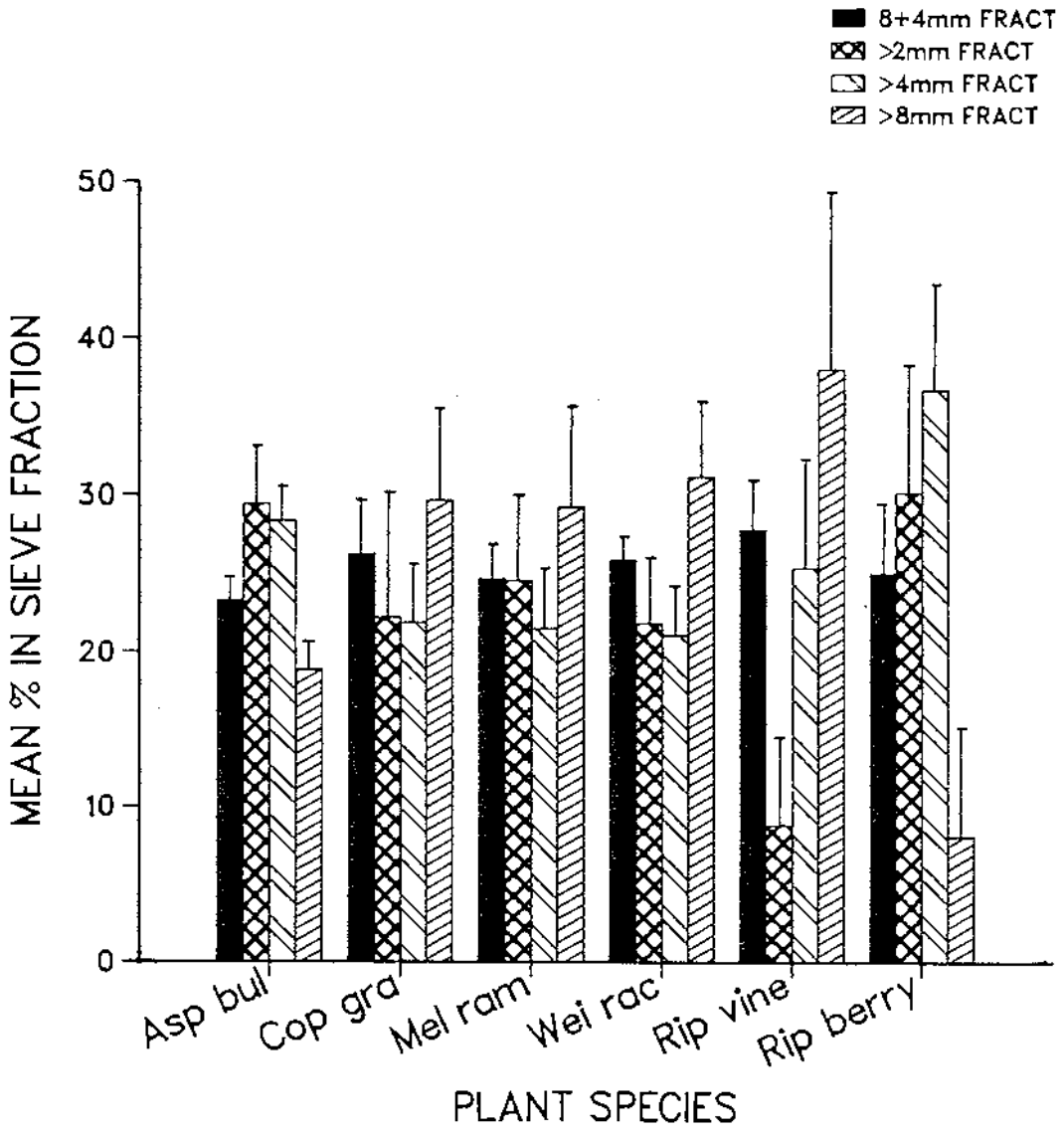
The mean proportions of several principal dietary species found in the >8mm, >4mm, >2mm and >8+4mm (>8mm and >4mm combined) sieve fractions are presented in Figure 4.5. The following plant species were found in large amounts (>3% of the >8+4mm fraction by volume) fairly frequently (about 10 or more times) from among the 24 animals examined. The species and corresponding number of animals were Asplenium bulbiferum (n=16), Coprosma grandifolius (n=9), Melicytus ramiflorus (n=12),Weinmannia racemosa (n=12) and Ripogonum scandens vine (n=7) and berry (n=6). In this study the main concern was whether the species proportions in the sorted fraction (>8+4mm) were similar to the species proportions in the finer, unsorted fractions. For dicotyledonous foliage it appeared that the proportion in the >8+4mm fraction was not significantly different from that in the >2mm fraction. This suggested that the sorted fraction was representative of the next finer fraction and therefore possibly the whole sample for those species. In Asplenium bulbiferum the >8+4mm proportion was significantly smaller than the >2mm unlike any of the dicotyledons. This implied that the fern (Asplenium bulbiferum) broke down more rapidly. Among the dicotyledons the smallest >8+4mm proportion relative to the >2mm proportion was for Melicytus ramiflorus although there was no significant difference.

The Ripogonum scandens vine and fruit showed how very differently non-foliar plant parts may behave. The vine made up a very large proportion of the >8+4mm fraction, about three times as large as in the >2mm fraction. The berries behaved in a completely different way because of their size and different structure. They nearly all passed through the >8mm fraction and caught predominantly in the >4mm fraction and to a slightly lesser degree in the >2mm fraction. Overall, the sorted fraction was representative of the >2mm fraction for the berry, but very poorly representative for Ripogonum scandens vine.

FIGURE 4.5: THE MEAN PERCENTAGE VOLUME OF PLANT SPECIES REMAINING IN DIFFERENT SIZED SIEVES (using rumen samples from Mt Egmont).

Note the differences between the >8+4mm and >2mm fractions within plant species (the >8+4mm fraction = sorted and identified fraction).

Asp bul = Asplenium bulbiferum
Cop gra = Coprosma grandifolius
Mel ram = Melicytus ramiflorus
Wei rac = Weinmannia racemosa
Rip vine = Ripogonum scandens vine
Rip fruit = Ripogonum scandens fruit


8+4mm FRACT
>2mm FRACT
>4mm FRACT
>8mm FRACT
MEAN % IN SIEVE FRACTION
50
40
30
20
10
0
Asp bul
Cop gra
Mel ram
Wei rac
Rip vine
Rip berry
PLANT SPECIES

2) Chewed Bolus Trial

The proportions of individual plant species remaining on each sieve after being chewed by one of three goats (G1,G2,G3) are described below. Goats G1 and G3 appeared to be more similar than G2 in their fragmentation of plants (see Figure 4.6).

In this study only the two coarser fractions (>8mm and >4mm) were combined (into the >8+4mm fraction) and measured together. The proportion of each species in this identified fraction was fairly similar for most of the species examined. The fern Asplenium bulbiferum and possibly Melicytus ramiflorus fragmented slightly more than the rest.

Angiosperms had the following mean percentages (averaged over the three goats) in the identified fraction: Coprosma grandifolius (30%), Coprosma lucida (35.3%), Ripogonum scandens (28.7%), Schefflera digitata (44%), Weinmannia racemosa (42.3%) and a slightly lower mean for Melicytus ramiflorus (23.3%). The fern Asplenium bulbiferum fragmented much more than the other species and only a comparatively small proportion (10.5%) remained in the identified fraction. The three goats appeared to vary individually in how much they fragmented a given species. However on average most species seemed to be fragmented to a similar degree. Thus similar proportions of their total remained in the identified fraction.

3) Incubation Trials

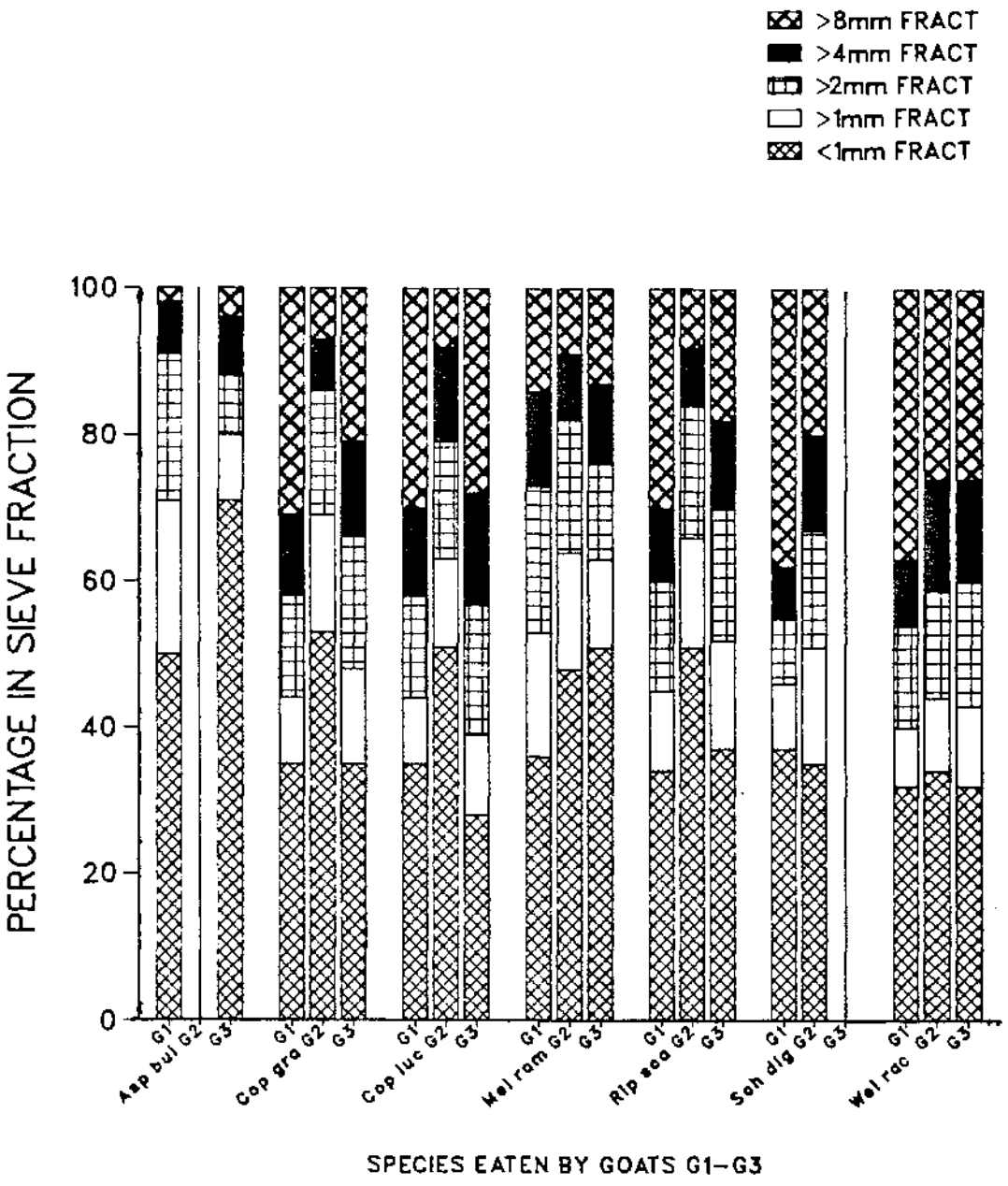
The degree to which the seven principal July dietary plant species were digested by 12 hours in vivo incubation is presented in Table 4.3. In the harsh treatment the degree of digestion varied from as little as 16.4% for Asplenium bulbiferum to as much as 40.9% for Schefflera digitata, a difference of 24.5%. For the light treatment, the range was from 10.7% for Asplenium bulbiferum to 40.9% for Schefflera digitata, a difference of 30.2%.

Despite the measurable dry weight losses the plant material looked reasonably undamaged for most species. After digestion, the plant material was a bit softer and more fragile, yet volume was probably much the same. Species recognition was affected very little. Only Melicytus ramiflorus showed obvious visual signs of digestion and then only in the harsh treatment. It showed some degree of clearing in small areas of up to several square millimetres. This suggested Melicytus ramiflorus would have become part of the "residual" fraction

FIGURE 4.6: THE PROPORTION OF MONOSPECIFIC CHEWED BOLUS SAMPLES IN DIFFERENT SIZED SIEVES

The sets of three stacked bars show how the three oesophageal fistulated goats fragmented each plant species into the five sieve fractions. A line indicates refusal of a sample.

Asp bul = Asplenium bulbiferum
Cop gra = Coprosma grandifolius
Cop luc = Coprosma lucida
Mel ram = Melicytus ramiflorus
Rip sca = Ripogonum scandens
Sch dig = Schefflera digitata
Wei rac = Weinmannia racemosa


>8mm FRACT
>4mm FRACT
>2mm FRACT
>1mm FRACT
<1mm FRACT
PERCENTAGE IN SIEVE FRACTION
100
80
60
40
20
0
G1
G2
G3
Asp bul
Cop gra
Cop luc
Mel ram
Rip sea
Soh dig
Wel rac
SPECIES EATEN BY GOATS G1–G3

(which was not included in the volumetric measurements, see Section 3.1.2) to a greater degree than the other species tested. The plant material illustrated in Plate 4.2 (see caption) also strongly supports this idea. Thus Melicytus ramiflorus may have been slightly underestimated in the diet.

Table 4.3: THE PERCENTAGE OF EACH SPECIES DIGESTED BY EACH TREATMENT.

Species	Light T	Harsh T	Difference
Asplenium bulbiferum	10.7	16.4	5.7
Coprosma grandifolius	14.4	25.4	11.0
Weinmannia racemosa	20.7	28.4	7.7
Ripogonum scandens	18.8	31.2	12.4
Melicytus ramiflorus	22.8	33.5	10.7
Coprosma lucida	31.7	38.7	7.0
Schefflera digitata	40.9	40.9	0.0

4.3 NITROGEN AND MINERAL LEVELS IN PRINCIPAL DIETARY SPECIES

Mean nitrogen and mineral levels (data pooled over four seasons) for seven principal food species collected along two transects are presented in Table 4.4. The mean nitrogen and mineral levels in the plants were very similar between transects. Seasonal trends of the nitrogen and minerals within a species appeared similar between transects although the actual seasonal values appeared to be more variable. Seasonal nitrogen and mineral levels are presented in Appendix 6.

Little is known about the nitrogen and mineral requirements of goats, but for the present they are probably best considered as being similar to sheep (Grace 1983b). Assuming this is so, sheep mineral requirements (taken from Grace 1983a) are used as a guideline (see Table 4.4). One can probably assume adequate dry matter intake (Grace pers.comm.) as the goats generally seemed to be in good condition and there appeared to adequate palatable food available.

NB: All values referred to are mean values (pooled) unless specified as seasonal.

TABLE 4.4 MEAN CONCENTRATIONS OF NITROGEN AND MINERALS IN PRINCIPAL DIETARY SPECIES AND ASSUMED GOAT REQUIREMENTS (GOAT RQ)

A. Mean Concentrations of Nitrogen

	N		
	T1	T2	
Asp bul	2.8	2.5	(Asplenium bulbiferum)
Cop gra	1.6	1.8	(Coprosma grandifolius)
Cop luc	1.3	1.4	(Coprosma lucida)
Mel ram	2.4	2.4	(Melicytus ramiflorus)
Rip sca	1.8	1.9	(Ripogonum scandens)
Sch dig	2.1	2.4	(Schefflera digitata)
Wei rac	0.9	1.0	(Weinmannia racemosa)
GOAT RQ	1.6		

T1 = York Transect
T2 = Egmont Transect

units=g/kg

B. Mean Concentrations of Major Elements

	Na		K		Ca		Mg		P		S	
	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2
Asp bul	0.4	0.5	38.2	35.0	10.4	11.8	5.4	6.3	3.0	2.8	2.2	2.0
Cop gra	0.6	0.5	20.7	24.9	17.8	18.4	5.6	5.0	1.8	2.1	1.8	1.9
Cop luc	0.4	0.4	12.8	11.7	14.5	13.9	4.4	5.1	1.3	1.5	1.8	2.3
Mel ram	1.6	1.3	25.9	25.9	14.9	14.9	5.1	5.1	2.7	2.8	3.4	3.2
Rip sca	1.0	0.8	18.6	21.8	11.0	7.1	2.4	2.1	1.4	1.8	1.9	2.0
Sch dig	2.9	3.4	23.3	25.4	17.2	14.2	3.9	3.6	2.3	2.7	3.6	2.8
Wei ram	1.4	1.5	5.7	8.3	7.7	7.8	2.7	2.5	0.8	1.1	1.4	1.7
GOAT RQ	0.9		3.6		2.9		1.2		2.0		1.5	

units=g/kg

C. Mean Concentrations of Trace Elements

	Cu		Zn		Fe		Mn	
	T1	T2	T1	T2	T1	T2	T1	T2
Asp bul	13.4	10.1	35.0	31.6	45.9	54.5	96.8	109.9
Cop gra	6.8	8.1	36.3	42.3	42.4	47.0	623.4	614.0
Cop luc	5.6	5.4	49.3	62.7	41.5	40.8	1129.3	1181.7
Mel ram	7.5	7.1	33.5	34.7	51.4	48.6	183.8	157.3
Rip sca	8.5	12.7	25.5	27.2	45.0	46.7	536.5	314.1
Sch dig	10.5	10.9	44.8	39.4	63.4	59.9	309.3	223.5
Wei ram	5.1	7.6	16.5	18.2	26.1	26.9	344.5	388.8
GOAT RQ	5.0		25.0		30.0		25.0	

units=mg/kg

1) Nitrogen:

Mean levels of N ranged from 1.0g/kg for Weinmannia racemosa up to 2.6g/kg for Asplenium bulbiferum. Goat requirements of 1.6g/kg were met or exceeded by most species. Coprosma lucida was marginal at 1.4g/kg and Weinmannia racemosa was lower at 1.0/g/kg. Both species were low in all seasons except for winter when Coprosma lucida approximated requirements. All other species met requirements in all seasons.

2) Major Elements:

a) Sodium: Levels of Na ranged from 0.4g/kg in Asplenium bulbiferum and Coprosma lucida to 3.0g/kg in Schefflera digitata. The other four species were between 0.5 and 1.5g/kg. Goats require 0.9g/kg, therefore Asplenium bulbiferum, Coprosma grandifolius and Coprosma lucida contained inadequate levels although Coprosma grandifolius may have met requirements in winter. All other species met or exceeded requirements, although Ripogonum scandens was inadequate in summer.

b) Potassium: Mean levels of K range from 7g/kg in Weinmannia racemosa up to 37g/kg in Asplenium bulbiferum with most species at around 20g/kg. Most species had five to 10 times goat requirements of 3.6g/kg, although Weinmannia racemosa was only twice that level. No seasonal value was ever below goat requirements.

c) Calcium: Mean levels of Ca ranged from 8g/kg in Weinmannia racemosa up to 18g/kg in Coprosma grandifolius, with most species having about 10 to 15g/kg. Most species had Ca concentrations several times that of goat requirements (2.9g/kg), even the relatively low levels in Weinmannia racemosa were 2.5 times above those needed. All seasonal values were at least twice requirement levels.

d) Magnesium: Mean levels of Mg ranged from 2g/kg in Ripogonum scandens up to 5 or 6g/kg in Asplenium bulbiferum, Coprosma grandifolius and Melicytus ramiflorus. Most species had about 3 to 5g/kg of Mg. All species met the 1.2g/kg requirements of goats. Even Weinmannia racemosa, which had the second lowest mean levels, was twice that needed. No species in any season was below 1.2g/kg.

e) Phosphorus: Mean levels of P ranged from 0.9g/kg in Weinmannia racemosa up to about 3g/kg in Asplenium bulbiferum and Melicytus ramiflorus. Three species (Asplenium bulbiferum, Melicytus ramiflorus and Schefflera digitata) exceeded goat requirements of 2g/kg by about 1 to 5 times and Coprosma grandifolius just met requirements. Ripogonum

scandens was marginally low. Coprosma lucida and Weinmannia racemosa were inadequate. However the winter level in Coprosma lucida was probably sufficient as was the summer level for Ripogonum scandens. In Weinmannia racemosa all seasonal levels were probably about half that required . Also levels in Coprosma grandifolius were marginal in summer and autumn.

f) Sulphur: Mean levels of S ranged from 1.5g/kg in Weinmannia racemosa up to 3.3g/kg in Melicytus ramiflorus and Schefflera digitata. Sulphur did not peak regularly in any particular season. Goat requirements of 1.5 g/kg were met or slightly exceeded by all species; Melicytus ramiflorus and Schefflera digitata had twice this level. All species had sufficiently high levels over all seasons although Weinmannia racemosa was fractionally low in winter, summer and autumn on the York Track Transect.

3) Trace Elements:

a) Copper: Mean levels of Cu ranged from about 5 or 6mg/kg in Coprosma lucida and Weinmannia racemosa up to about 10-13mg/kg in Asplenium bulbiferum, Ripogonum scandens and Schefflera digitata. Levels of Cu in Coprosma lucida and Weinmannia racemosa met goat requirements of 5mg/kg and all other species exceeded it by 1.5 to 2 times. All species at least met requirements in all seasons.

b) Zinc: Mean levels of Zn ranged from 17mg/kg in Weinmannia racemosa up to 55mg/kg in Coprosma lucida, the other species lay between 25 to 45mg/kg. Only Weinmannia racemosa was below goat requirements of 25mg/kg and did not reach more than 20mg/kg in any season. Also Ripogonum scandens was marginally low in winter on the York Track transect.

c) Iron: Mean levels of Fe ranged from 26mg/kg in Weinmannia racemosa to about 61mg/kg in Schefflera digitata with all other species lying between approximately 40 to 50mg/kg. Goats require 30mg/kg of Fe and all species exceeded this by 1.5 to 2 times, except for Weinmannia racemosa which was marginally low at 26mg/kg on average, although it met requirements in winter. All other species met requirements in all seasons.

d) Manganese: Mean levels of Mn ranged from 100mg/kg in Asplenium bulbiferum up to c 1100mg/kg in Coprosma lucida. Other species were about 250 to 600mg/kg. Even Asplenium bulbiferum which had the lowest levels of Mn had three to four times goat requirements of 25mg/kg. Coprosma lucida was over 40 times requirements on average.

In summary all species exceeded or at least met assumed goat requirements for K, Ca, Mg, Cu and Mn for all seasons. Only Weinmannia racemosa was below requirements in some seasons for S, Zn and Fe and had the lowest levels of most nutrients. Mean levels of Na, P and N were inadequate in several species and generally not high in the other species. Three species, Asplenium bulbiferum, Coprosma grandifolius and Coprosma lucida had about half the required levels of Na, which tended to be low in spring and summer for most species. Coprosma grandifolius, Coprosma lucida and Weinmannia racemosa were too low in P especially Weinmannia racemosa which was about 50% of the required level. Both Coprosma lucida and especially Weinmannia racemosa were sub-requirement levels for N in all seasons with of Coprosma lucida in winter.

4.4 POPULATION BIOLOGY

1) Age Structure

The age structure for goats sampled in each season is presented in Figure 4.7. Age structure appeared most similar between spring, summer and autumn. The proportion of the 227 goats in successive age classes declined markedly. There were 41.6% 0-1years old, 22.3% >1-2years old, 15.67% >2-3 years old and only 20% in the >3 years old age class.

2) Reproduction

Of the 227 goats sampled, only 72 were female. Hence reproductive data were scarce. Only 54 of the 72 females were older than six months and therefore likely to be fecund. However four of the 18 females less than six months old were pregnant. These were included with the greater than six month old females. Of these 58 females, 14 (24%) were pregnant, 15 (26%) were lactating and eight (14%) were both pregnant and lactating; i.e. 37 or 63.8% were fecund. Of the 22 pregnancies, five (22.7%) were single conceptions, 16 (72.7%) were twins and one (4.5%) comprised triplets; i.e. 77.2% of conceptions were multiple. Eight or 36.4% of pregnant females were also lactating. Figure 4.8 shows approximate seasonal percentages of lactating females and estimated births and conceptions. Most births occurred autumn through to spring. Conceptions were year round but peaked over summer and autumn.

3) Condition

a) Sexual Differences in Condition: There was very little difference in the proportions of male and female goats with a kidney fat index (KFI) below 180 (see Figure 4.10). However there was a significant difference in condition between the sexes (X^2=8.177 DF=3, P<0.04) because there were relatively more females with a KFI of 180-260 (see below). The male:female ratio of the overall sample was 2.1:1, whereas for animals with a KFI greater than 180 the ratio was 1:2.3.

SEXUAL DIFFERENCES IN CONDITION

KFI	0-60	61-120	121-180	>180	Total
Males(observed)	87	47	11	3	148
" (expected)	81.1	48	12.2	6.8	
Females(observed)	33	24	7	7	71
Expected	38.9	23	5.8	1	
Total	120	71	18	10	219

NB: KFI measurements were not obtained for eight goats.

b) Maturational Differences in Condition: There were no significant differences in KFI for different age classes: 0-1 years, >1-2 years, >2-3 years and >3 years. (X^2=11.64, DF=9, P>0.23).

c) Seasonal Differences in Condition: Seasonal mean KFIs and 95% confidence limits are given for both sexes in Figure 4.10. Seasonal means for KFI were highly correlated between the sexes (r=0.892). KFI did not change significantly with season for either sex. Sexes were not significantly different in any particular season.

FIGURE 4.7: THE AGE DISTRIBUTION OF GOATS IN EACH SEASONAL SAMPLE

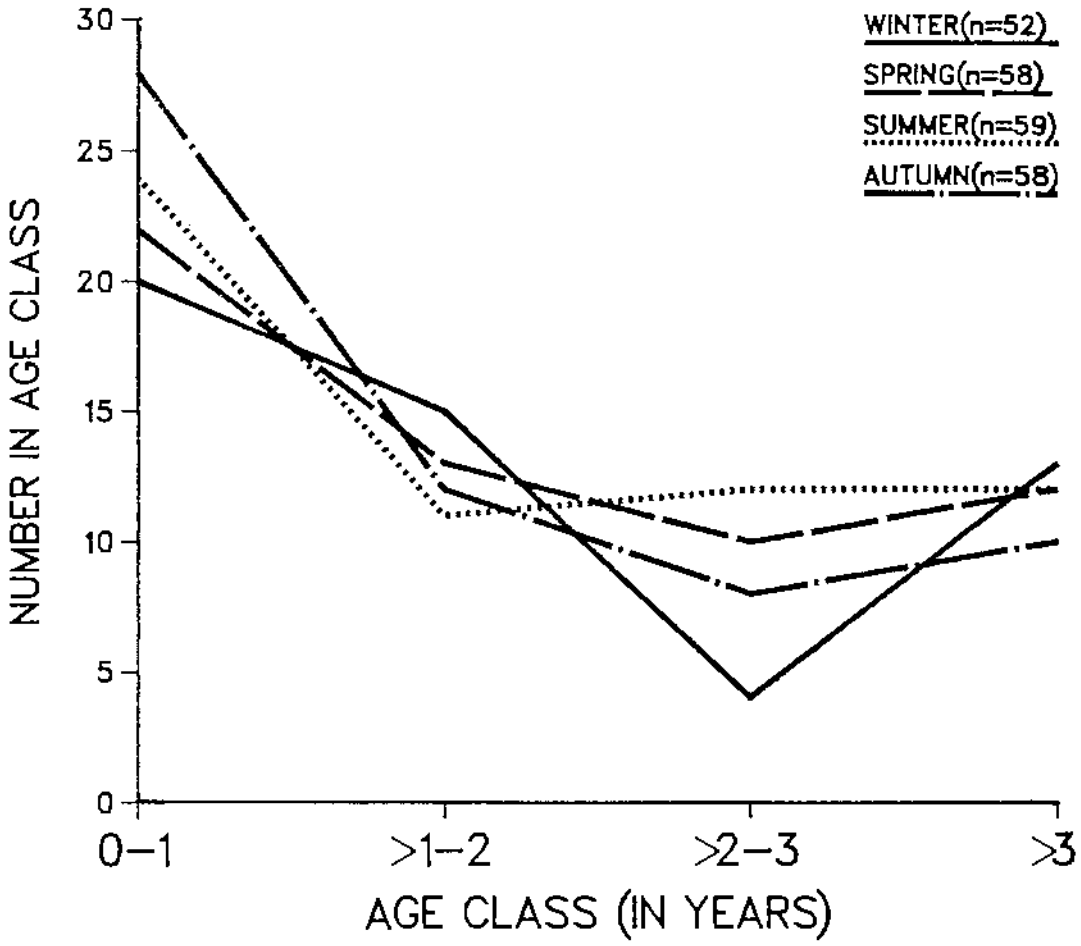
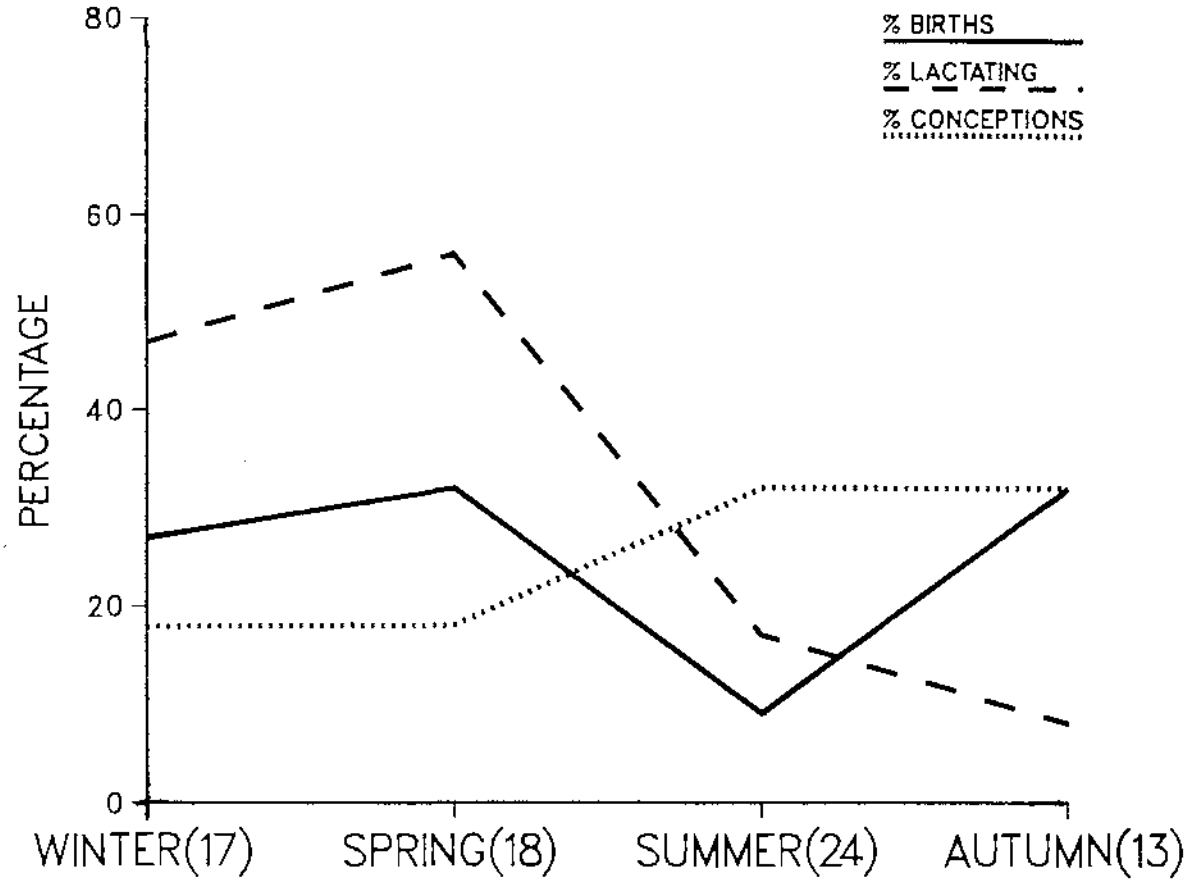

WINTER(n=52)
SPRING(n=58)
SUMMER(n=59)
AUTUMN(n=58)
NUMBER IN AGE CLASS
30
25
20
15
10
5
0
0–1
>1–2
>2–3
>3
AGE CLASS (IN YEARS)

FIGURE 4.8: THE PERCENTAGE OF ESTIMATED BIRTHS, CONCEPTIONS AND LACTATIONS IN EACH SEASON



(n)=No of Females sampled.

FIGURE 4.9: SEASONAL VARIATION IN BODILY CONDITION OF MALE AND FEMALE GOATS (using the kidney fat index).

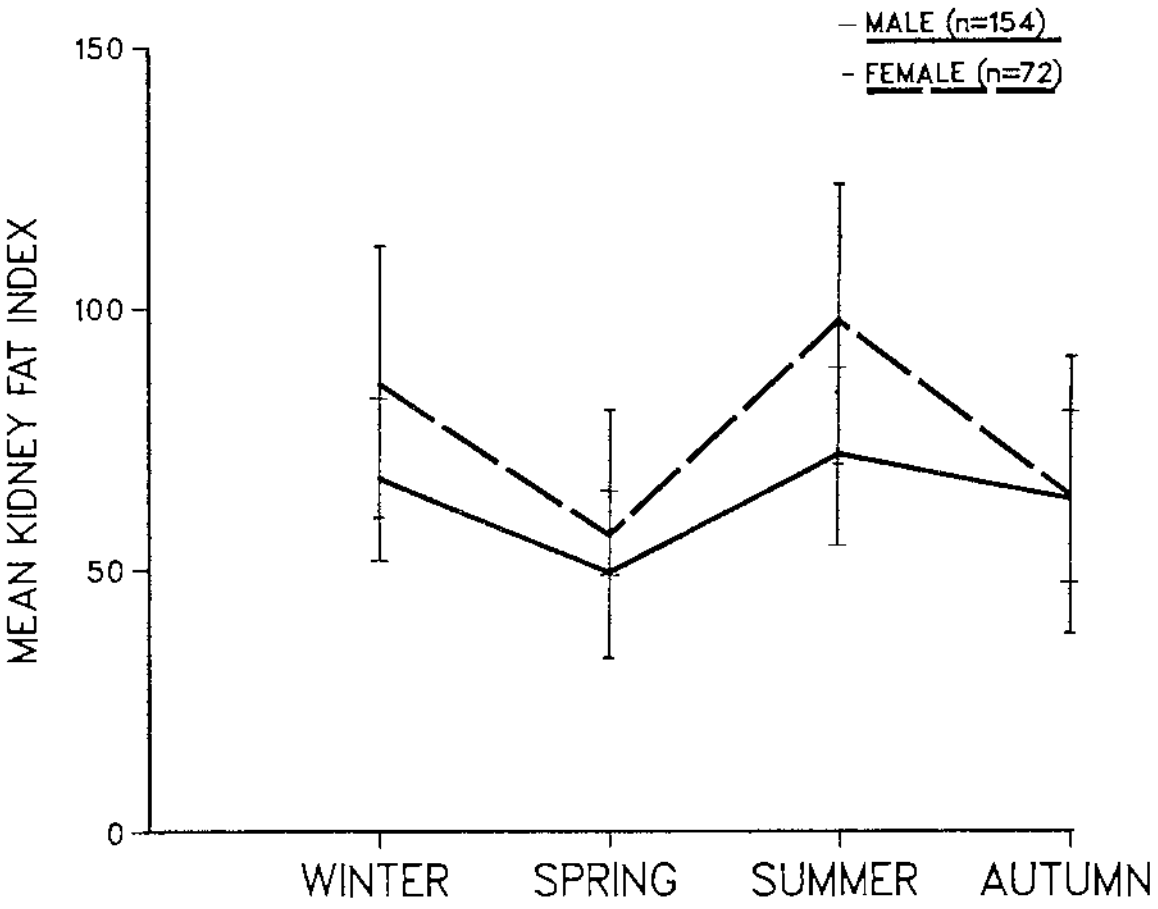

– MALE (n=154)
- FEMALE (n=72)
MEAN KIDNEY FAT INDEX
150
100
50
0
WINTER
SPRING
SUMMER
AUTUMN

PLATE 4.1: DIFFERENT STAGES OF BREAKDOWN IN TWO PRINCIPAL DIETARY SPECIES

From the left the four groups of plant material are:

1. Fresh foliage.
2. Chewed bolus, i.e. chewed only once, on ingestion.
3. Incubated chewed bolus, i.e. as for 2) but incubated *in vivo* for 12 hours.
4. Fragments from the identified fraction of Mt Egmont rumen samples.

A. *Melicytus ramiflorus*: Note how the *Melicytus ramiflorus* incubated chewed bolus had digested markedly compared with *Schefflera digitata* incubated chewed bolus which was little different from the chewed bolus.

B. *Schefflera digitata*


1
2
3
4

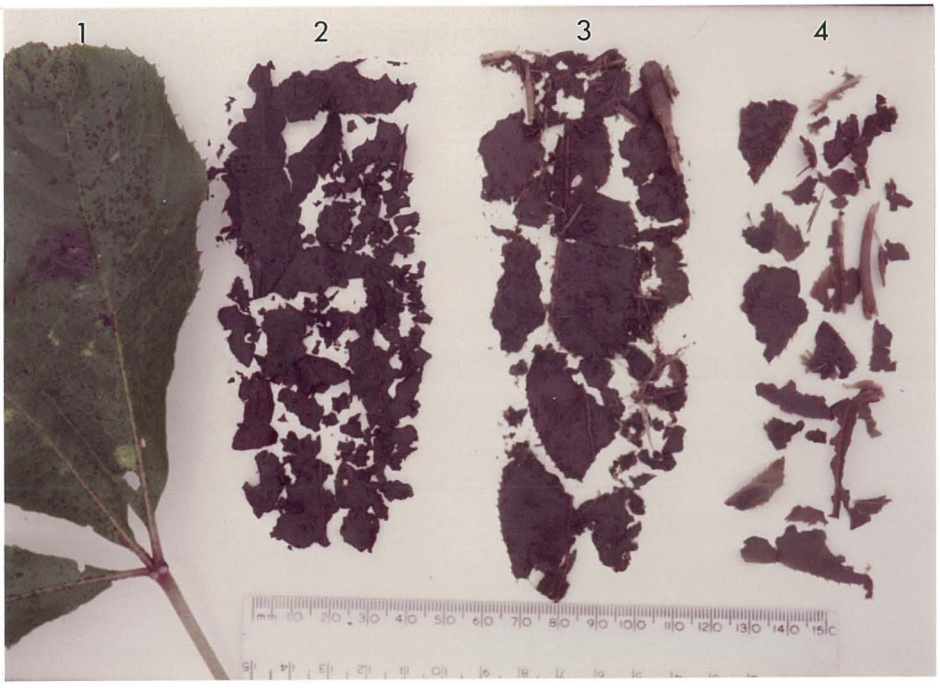

1
2
3
4

PLATE 4.2: DIFFERENTIAL DIGESTION

Handfuls of leaves had been placed within a sheep's rumen to encourage the development of suitable rumen micro-flora for the differential digestion experiment. The pictured material was removed via the rumen fistula after about 24 hours incubation. Note how Melicytus ramiflorus has digested a lot more than any other species and how Ripogonum scandens has slight clearing along the lines where it has been chewed. From left to right the plant species are as follows:

1. Asplenium bulbiferum
2. Coprosma lucida
3. Melicytus ramiflorus
4. Ripogonum scandens
5. Weinmannia racemosa


1
2
3
4
5

CHAPTER 5

DISCUSSION

5.1 DIET

5.1.1 Seasonal Changes in Diet

1) Interpretive Problems:

A major factor determining species use is species availability. The availability of some species varied considerably within the study area, i.e. with area, altitude and habitat type (forest or river bank vegetation). It was not possible to measure this variation let alone account for its effect on diet. Variation in diet with area and altitude (assumed to reflect species availability) was examined. However, the way that area and altitude were defined probably did not relate to the plant species' actual distrubtions. Also the lack of visible landmarks within the forest meant the hunter's estimate of area and altitude for many rumen samples was little better than a guess (E.Clince pers.comm.). Therefore it probably did not help account for variation in diet due to changing availability. The 60 animals sampled per season were probably representative of seasonal use for more uniformly distributed species. Seasonal samples did not necessarily represent (come from) the same regions and/or habitat types (river banks versus forest). Therefore the seasonal use of species with highly variable density throughout the study area probably were not very accurately represented in the diet results. With this in mind, seasonal diet is discussed.

2) Principal Dietary Species:

a) Species Showing No Seasonal Variation in the Diet: No significant seasonal changes in M%Vol were evident for *Asplenium bulbiferum*, *Ripogonum scandens* (foliage), *Schefflera digitata*, *Astelia* spp. and *Coprosma lucida*. Of these species *Asplenium bulbiferum* and *Ripogonum scandens* had reasonably uniform distributions throughout the study area suggesting that the results were reliable. In contrast *Schefflera digitata* and especially *Coprosma lucida* (which was most dense along river banks) had more variable distributions implying that the results were less reliable.

b) Species Showing Seasonal Variation in the Diet: For two species: Coprosma grandifolius and Melicytus ramiflorus corresponding M%Vol and %Freq values indicated that a similar proportion of the goat population ate different amounts seasonally. Because these common species had reasonably uniform distributions throughout the study area the results may be taken as reliable. Seasonal use of Ripogonum scandens vine and berry changed markedly. As the amounts eaten declined so did the proportion of goats eating them. It is likely that use of ripe fruits and possibly the soft young vine at least partially reflected seasonal availability. Seasonal use of Weinmannia racemosa, Coprosma tenuifolia and Griselinia littoralis changed significantly both in terms of the amounts eaten and (as for Ripogonum scandens fruit and vine and unlike the other two dicotyledons) the proportion of goats eating it also varied seasonally. Similar to Coprosma lucida, Griselinia littoralis was most abundant along river banks, suggesting that the result may not be accurately representative of it's seasonal use.

3) Species of Smaller Dietary Proportions:

Nearly all species of smaller dietary proportions (annual M%Vol<1.5%) were eaten in such variable amounts by different individuals that no significant seasonal changes in use were apparent. Little was known about the distribution of most of these lower availability species. Consequently it was not possible to determine how much varying availability affected their use. On the contrary, the abundant Dicksonia squarrosa was eaten most during summer when goats appeared to be eating young fronds and crowns which may not have been as abundant at other times of the year.

In summary use of Ripogonum scandens fruit peaked in winter; use of Griselinia littoralis peaked in spring; use of Melicytus ramiflorus, Coprosma tenuifolia and Dicksonia squarrosa peaked in summer and use of Ripogonum scandens vine, Weinmannia racemosa and Coprosma grandifolius peaked in autumn.

Changing use was assumed to reflect changing palatability for the foliage of most species because variation in relative seasonal availability was thought to be minor.

Goats ate both mature and new seasons growth but there was no clear evidence as to which they prefered. However, the goat's ability

to digest tougher feeds, and avoidance of soft clover and grasses in preference of seed heads and browse in the pasture situation (Clark et al 1982) implies that they may generally prefer mature growth.

5.1.2 Plant Species Preference Ratings

1) Principal Dietary Species:

Goats clearly selected just a few species which formed the bulk of their diet, few of which were abundant. In contrast many of the very common species were almost entirely avoided. Thus species use was largely independent of availability. In light of their moderate abundance (compared to other principal foods) and high use, it is proposed that Schefflera digitata and probably Ripogonum scandens (vine and fruit) were the most highly preferred of the principal foods. Some other uncommon species may be as palatable (see 2) below). At the other extreme was the highly abundant Blechnum fluviatile which was never eaten.

Usually only two or three principal dietary species dominated each rumen sample. However, Mt Egmont goats ate at least 19 species on average and some individuals contained more than 30. Devendra and McLeroy (1982) stated that goats "relish variety in their feed and do not thrive well when kept on a single type of feed for any length of time". Also that "palatability appears not to be the overriding consideration. The most important factor affecting choice of feed is the availability of a variety of feeds." Asplenium bulbiferum was at least 20 times more abundant than any other "preferred" or "highly preferred" species. The need for variety may have resulted in goats eating less Asplenium bulbiferum in relation to its abundance than for other principal foods. Consequently it may have recieved a lower preference rating than if it had only been as abundant as other principal foods. This same principle may apply to other species e.g. Astelia spp. (also see other problems with assigning preference ratings discussed at the end of Appendix 2). Other factors possibly affecting Asplenium bulbiferum's preference rating are that it was often particularly dense in damp regions which goats may use less than drier areas (Darling 1937 and Atkinson 1964) and it was slightly underestimated in the diet due to rapid fragmentation. The super-abundance of Asplenium bulbiferum relative to other palatable species was probably the result of forest regeneration following the decline of the goat population (A. Druce pers.comm.). On the other

hand the palatability of Griselinia littoralis may have been over-rated because it was far more abundant along river banks than in the forest where the availability measurements were done.

2) Species of Smaller Dietary Proportions:

Although it was difficult to determine the palatability of many scarcer species, it was probably safe to assume that Pseudopanax arboreus and Pseudopanax colensoi were at least "preferred" species, because they had declined markedly in the presence of goats which barked and killed the trees (A. Druce pers.comm.) and ate the foliage (Atkinson 1964). Foliage of Metrosideros fulgens may also have been very palatable, as foliage within the reach of goats was rarely seen except for small amounts of leaf litter. Furthermore it was seldom eaten in very small amounts. Similarly the coastal relative Metrosiders excelsa is highly palatable to goats elsewhere (Section 1.2). In contrast, the abundant small-leaved rata, Metrosideros diffusa was "highly rejected."

It is concluded that the preference ratings calculated in this study give a reasonable guideline of goat preference for the different species within the study area except where species availability was low or very variable.

There are no other in-depth goat diet studies from mainland New Zealand with which to compare results. However earlier studies which give an indication of plant palatability generally agree with this low-land forest study (see references in Section 1.2).

5.1.3 Diet: Variation with Sex, Age and Time of Day

1) Sex:

Recent studies of large wild herbivores have demonstrated sexual differences in diet (Staines et al 1982, Pellew 1984). Sometimes for deer these differences are most apparent or only apparent during the rut (Dzieciolowski 1970, Moen 1973 and Leader-Williams et al 1981). During the breeding season stags eat less and fewer species. The diet of hinds may also change although to a lesser degree.

In this study there were no significant differences in the number of species or the amounts of the principal species eaten (only seven species were tested) between males and females when their annual diets were compared. It is not known whether the diets were different over the rut. However, this seems unlikely as the breeding season is not a

short, sharply defined period as for deer but probably runs throughout the year.

2) Age:

Young roe-deer (Capreolus capreolus) use sight, smell and taste when learning which plants are suitable for food (Kossak 1981). Learning appears to involve repeated trial and error and their diet is different from that of adults for a period of months. Hence one might expect young ungulates to have a more diverse diet, as Leader-Williams et al (1981) found for reindeer up to four months of age.

In this study, goats 0-1 years old ate on average two more species than older goats. However, there was no significant difference from those in the >2-3 year old group. Lack of significant difference may be attributable to the small sample size of animals >2-3 years old, and possibly more important, the inclusion of many animals probably old enough to have adult dietary habits and the exclusion of very young kids from the 0-1 year old group. Use of the principal dietary species did not vary with age in a meaningful way for any species.

3) Time of Day:

The sequential eating of different food species is common among wild reindeer (Rangifer tarandus) in Norway (Gaare et al 1977), but was undetermined for Mt Egmont goats. However, there was no difference in the number of species eaten in the morning and the afternoon suggesting that goats eat a full complement of foods in their morning feed (from sunrise to late morning, Rudge 1968, Askins and Turner 1972, Batten 1983). Therefore collecting samples during the mid to late morning should give representative results.

Morning goats contained significantly more Melicytus ramiflorus than afternoon goats (no other species varied significantly). This probably was not a result of changing intake over time but may have reflected a faster rate of breakdown (Section 5.2).

4) Area and Altitude:

Species availability and therefore the diet of individual goats probably varied considerably with area and altitude. Another likely source of variation was the effect of previous feeding experience on diet selection. When sheep were moved from one pasture type to another there were marked differences between the new arrivals and the original inhabitants that persisted for more than a year (Arnold and Maller

1977). Similarly Bartmann and Carpenter (1982) felt previous foraging experience was an important variable when using tame deer in feeding experiments. Thus if groups of goats from various habitats move into a new area with different vegetation there may be significant differences in their dietary preferences. Males tend to move about considerably at various times of the year whereas females are more stationary (Riney and Caughley 1959, McDougall 1975); hence female diet may be less variable. On Mt Egmont, such variation may have been important if a lot of goats had moved into the study area from adjacent vegetation types. However, such variation could not be accounted for in this study.

5.2 DIFFERENTIAL FRAGMENTATION AND DIGESTION

Differential digestion and especially fragmentation of plant species are potential sources of error when sorting rumen samples (Appendix 2). The usual method of looking for differential rates of breakdown has been to examine the proportions of species remaining in graded sieves. The need to establish the sieve sizes most appropriate for each diet study is evident from work on several African ungulates by Owaga (1978). Bergerud and Russell (1964) came to similar conclusions when studying caribou diet. Nugent (1983) suggested that some foods of white-tailed deer (*Odocoileus virginianus*) such as small-leaved *Coprosma* spp. and *Ripogonum scandens* berries were grossly underestimated in an 8mm sieve, but that a 4mm sieve gave similar results to the finer 2mm sieve for most foods.

Although the effects of differential fragmentation and digestion were not examined extensively for Mt Egmont goats, the results indicated general trends for different food types. The sieve fraction experiment showed that there was no significant difference in the breakdown rate of all the dicotyledons and the chewed bolus experiment gave similar results. However, the fern *Asplenium bulbiferum* broke down faster than the dicotyledons and therefore was probably underestimated in the diet, although not to the degree where it would have any major bearing on this study. Both experiments suggested *Melicytus ramiflorus* may break down faster than other dicotyledons although there were no significant differences. The lack of significance may have resulted from the small sample sizes and from insufficient mixing of the rumen prior to sampling causing large

variation between samples. Sufficient mixing is probably very important in such experiments as the rumen contents tend to be layered with respect to particle size (Gaare et al 1977, M. Ulyatt pers.comm.). Incubated Melicytus ramiflorus (see Plates 4.1 and 4.2) and the differential digestion experiment indicated that Melicytus ramiflorus breaks down to a "residual" state (see 3) in Section 3.1.2) more rapidly than other species. This may explain why there was significantly less Melicytus ramiflorus in goats sampled during the afternoon compared to the morning.

Not surprisingly, the fruit and vine of Ripogonum scandens fragmented differently from the foliage of other species. However, only vine showed a significant difference between the identified and >2mm fractions suggesting that it was considerably overestimated in the diet. On the other hand this soft fleshy tissue may have digested very rapidly once broken into smaller pieces due to the lack of strong cell wall material to protect cell contents. Thus it may disappear faster than foliage from the finer fractions. However, this needs further investigation and whatever the case vine was still a very important food item.

It is concluded that identifying material on a single 4mm sieve gave fairly representative results for the foliage of most species except some foods of a very different nature. Other exceptions probably included very small leaved species such as Metrosideros diffusa, most of which tended to pass through the coarser sieves. Thus where principal food items are very different it may be important to determine which sieve sizes give the most representative results.

5.2.1 Minimizing Error due to Differential Breakdown

Particle size determines when material leaves the rumen via the omasum (which acts as a sieve, Ulyatt et al 1984). It is primarily chewing, not microbial digestion, which reduces particle size to the threshold level of about 1mm (Ulyatt 1983 in Ulyatt et al 1984). Therefore the rate of fragmentation is most important in determining the rate of disappearance of most material from the rumen and hence the representativeness of the identified fraction. For example about 30 to 50% of most species were reduced to below 1mm on eating in the chewed bolus experiement, yet most species were little more than discoloured in appearance after 12 hours in vivo incubation. Ruminated material is a lot more fragmented than freshly ingested (unruminated) material (A. John pers.comm.) and therefore is more likely to be

unrepresentative. Recent work on sheep suggests they can clear the rumen of most of the previous day's feed during the night when peak rumination occurs (A. John pers.comm.) Goats (like sheep) are diurnal feeders with main feeding periods in the morning and afternoon (Rudge 1968, Askins and Turner 1972, Batten 1983) and probably have peaks of rumination during their mid-day rest and especially at night. If, like sheep, goats largely clear the rumen at night and do not ruminate heavily again until mid-day, samples collected in the mid to late morning may yield the best results. This is because a greater proportion of the rumen contents should be less fragmented (and digested) than at any other time of the day.

5.3 NITROGEN AND MINERAL LEVELS IN PRINCIPAL DIETARY SPECIES

1) Other Studies Indicating Nutritional Wisdom:

Moss (1972) proposed that selection for a particular nutrient (i.e. high quality food) would occur when the available feed was generally deficient in that nutrient. Although not all animal nutritionists accept the idea that animals can select what they need i.e. nutritional wisdom (G.Wilson pers.comm.), a number of diet studies do suggest that herbivores select plants that will best provide their particular nutrient requirements. Williams et al (1976) found that the basal portions of certain tussock species eaten by takahe (Notornis mantelli) were richer in sugar, protein (N) and most major elements than other parts of the plant. Mills and Mark (1977) found that both takahe and red deer (Cervus elaphus) selected native tussock species that had high levels of P which was generally scarce in all plants. It appeared that takahe even selected particular individuals within species which were higher in P. Similarly Mark et al (1980) found the takahe's use of summer green fern (Hypolepis millefolium) coincided with increases in starch and slightly later, nitrogen. It seemed likely that the fern was one of the few plants cabable of supplying the bird's energy requirements during the sub-freezing mid-winter period. Leader-williams et al (1981) found rein-deer showed positive selection for N and P during summer months. Moss et al (1981) found hares (Lepus timidus) and red deer concentrated their feeding on patches of heather (Calluna vulgaris) rich in P and N, respectively. Fraser et al (1984) found moose (Alces alces) selected plant species with significantly

higher levels of Na than non-selected species. Levels of P and N may have also influenced selection. Savory (1983) demonstrated that red grouse (Lagopus lagopus scoticus) in poor condition selected heather containing higher levels of P and N, thus supporting earlier work by Moss (1972) and others that suggested red grouse could select heather on the basis of its nitrogen and mineral content.

2) Mt Egmont Plant Nutrient Levels:

Only N, P and Na are discussed because levels of all other minerals were obviously adequate. Two of the seven species tested from Egmont were below goat requirement levels for N. These species only made up a small proportion of the total available palatable species and it therefore seems unlikely that goats would have had to select for species high in N, especially when Asplenium bulbiferum, with twice the required levels of N, made up nearly 20% of the total available forage. This conclusion assumes that foliar nitrogen is available for the goats to metabolize.

Two species were slightly below goat P requirements and one was about half. The other four species met or exceeded requirements up to one and half times. Thus it seems unlikely that goats would need to select for P especially when the highly available Asplenium bulbiferum contained maximum P levels.

Asplenium bulbiferum, Coprosma grandifolius and Coprosma lucida had about half the required levels of Na. Especially because of Asplenium bulbiferum (which was 20 times as abundant as other very palatable foods) these species made up the dominant proportion of the available palatables. Therefore Mt Egmont goats may be under pressure to select for species containing high levels of Na such as the very highly selected Schefflera digitata that had three times goat requirements and twice what any other species had. McKenzie (1957) and Devendra and McLeroy (1982) stress the very high Na requirements of lactating goats. Also Zotov (1949) and Atkinson (1964) noted that goats preferred to feed on seaward facing slopes, possibly because of wind carried salt on the foliage. McKenzie (1957) claimed that not even wild goats could survive while lactating without access to raw salt because they secrete nearly 50% more salt than lactating dairy cows. Although goats possibly obtain adequate Na by eating a variety of plants, selection for Na may warrant further examination.

Of course only a few palatables and no unpalatables were examined. Also, other very important aspects of food quality not considered here

include energy content, vitamins, digestability and several minerals (especially Co, Se and I). Thus the chemical analyses are far from complete. However as most goats appeared to be in good condition one can probably assume the availability of other minerals and nutrients was adequate. Deficiency of iodine and cobalt for example would certainly have noticeable effects as goitre, or wasting, respectively.

Bryant and Kuropat (1980) examined the dietary preferences of several sub-artic browsers including ptarmigans, grouse (both are Lagopus spp.), moose and beaver (Castor sp.) and concluded that plant secondary compounds and not nutrient contents determined preference. This was not examined on Mt Egmont. Although it is suspected that various species were unpalatable because of their aromatic nature, for example Pseudowintera colorata and Pseudopanax edgerleyi. Palatable species do not appear to have such an obviously strong taste or smell.

Most species provided or exceeded requirement levels for all, or all except one nutrient. Melicytus ramiflorus and especially Schefflera digitata stood out as being particularly rich in all nutrients measured. On the other hand Coprosma lucida was below goat requirements for Na, P and N, which were generally not in high levels compared to other nutrients. Weinmannia racemosa alone was particularly low in nutrients. It was below goat requirements in P, N, Zn and Fe and was low compared to other species for all other nutrients except Na and Mn.

Manganese was the only mineral found in high levels likely to depress growth. Levels exceeding 400ug/kg have been found to decreased lamb development (Grace 1983a). Several species, Coprosma grandifolius, Ripogonum scandens and especially Coprosma lucida exceeded this level. However they were eaten along with plants of lower levels so were unlikely to harm the goats.

A lot more work on other aspects of native plant food quality and phenology as well as goats actual nutrient requirements and tolerences of plant secondary compounds is clearly necessary.

5.4 POPULATION BIOLOGY

1) Age Structure:

In five New Zealand populations mentioned by Asher (1979), 29 to 43% of goats were >3 years old while on Mt Egmont and the Hunuas (Clark 1974 in Asher 1979) the proportions were 20% and 13.5% respectively.

The proportion of goats <2 years old on Mt Egmont (64%) and Hunua (69%) were both higher than the 42% in the undisturbed population on Macauley Island (Williams and Rudge 1969). These differences probably reflected differences in hunting pressure. Also it is likely that very young animals were underrepresented for Mt Egmont, since dogs may have killed and left young goats before the hunter found them, also kids obviously containing a lot of milk were not sampled. These factors all point towards a population of predominantly young animals. Hunting pressure is the assumed cause.

Sex ratios are not discussed here because samples were biased towards males, which were easier to autopsy.

2) Reproduction:

The gestation period of goats is five months (Luisi 1979) and the ages of the foetuses recovered were expected to be spread equally over that period. However, half of them were five months old and only 14% (instead of the expected 40%) were less than two months old. This suggests many small foetuses were not detected and together with the low number of females sampled implied that reproductive data were imprecise. Notwithstanding, the dip in births over summer appeared similar to Rudge's (1969) observations. On Mt Egmont, lactation, birth and conception data suggested most births occured from autumn to spring, possibly with a peak in winter. Winter births are the norm for feral goats in New Zealand (Clark 1974 in Asher 1979). Conception dates suggested year round mating (breeding) with increased activity from summer through autumn, similar to Rimutaka goats (Rudge 1969) although there the peak activity was confined to early summer. In comparison with other populations a high proportion (77%) of Mt Egmont conceptions were multiple; c.f. the Rimutakas 52% (Rudge 1969), Macauley Island 31% (Williams and Rudge 1969) and the Hunua Ranges 41% (Clark 1976). This is assuming that multiple conceptions were not overestimated on Mt Egmont due to easier detection. The proportion of lactating goats also pregnant (hence possibly breeding twice annually, Rudge 1969 and Parkes 1984a) in the Mt Egmont sample (53%) was higher than in the Rimutaka sample (26%) and also the Raoul Island sample (34%). However, the Raoul Island sample was not collected over the entire year. The high proportion of multiple conceptions and of possible bi-annual parturition suggest a high rate of reproduction as might be expected under a regime of intense hunting. In support of this, Parkes (1983c) stated that the rate of increase on Mt Egmont had

risen since the early 1960s.

3) Condition:

Seasonal mean KFI levels for males and females were highly correlated suggesting seasonal trends existed, yet fluctuations between seasons or sexes were not significantly different. Therefore differences in KFI between seasons within each sex or between sexes within each season was uncertain.

The seasonal condition of several populations has been examined by Clark (1974 in Asher 1979) and Asher (1979). Both found the KFI peaked in late summer to early autumn and was minimal in late winter to early spring. This was not the case in the Mt Egmont population although highest values for Mt Egmont goats did occur in summer. Some species of deer lose condition around the rut (see 1) in Section 5.1.3) yet no such changes were apparent for the goats. Similarly the effects of oestrous, pregnancy, and lactation on female condition found by Clark (1974 in Asher 1979) could not be detected in the Mt Egmont data. Johns et al (1983) stated that when assessing condition by KFI it was important to compare animals of the same age and sex from the same locality. Asher (1979) used only goats older than two years of age to remove the artifacts of juvenile growth. However, to do this on Mt Egmont would have meant removing about 65% of the sample. In white-tailed deer (Odocoileus virginianus) the KFI has been misrepresentative of total fat reserve when the value is below 30 (Ransom 1965 in Asher 1979) and in red deer when it is below 50 (Suttie 1983). Over 60% of the Mt Egmont goats had KFI values below 50, hence this may have been an important source of error. Asher (1979) concluded for goats that KFI "is a grossly variable measure of fatness" and its ability to determine physical condition is questionable.

However, the high mean KFI of about 70 for Mt Egmont goats compared to a mean KFI of 30 to 50 from Asher's populations implied the Mt Egmont population was more healthy.

5.5 GENERAL DISCUSSION AND CONCLUSIONS

Seasonal changes in diet were apparent for several species. However, the low or variable availability of some species within the study area possibly confused the real seasonal trends for such species. By comparison, differential species breakdown did not appear to affect

the diet results to a large degree.

Species preference ratings do not strictly measure what an animal perceives as preferable. However, by pooling the diet results for all goats and comparing them with the average availability of species within the study area, it is probable that a reasonable index of species palatability was obtained, except for uncommon and/or irregularly distributed species.

Culling has been reducing the goat population on Mt Egmont for more than a couple decades (Parkes 1983c). Consequently the availability of palatables may have increased since former times when there were very high goat numbers. This was suggested by the abundance of Asplenium bulbiferum (A. Druce pers.comm.), the adequate stockings of seedlings to replace forest cover (Russell 1981) and simply the visible quantities of what are commnly considered to be palatable species (to introduced ungulates) within the browse range. The population appeared to be healthy and reproducing rapidly and it may be reasonable to suggest that this was as a result of a good supply of palalatable and apparently nutritious foods.

Plant palatabilities are always relative to the available quantities of other species. However, many common species in this study are common elements in other New Zealand forests. It is suggested that the approximate palatabilities calculated for the Mt Egmont situation may have relevance to understanding goat diet, and in application to goat control operations elsewhere when using poisoned natural vegetation.

In future studies of seasonal diet and species preference it is recommended that the homogeneity of plant species within the study area be examined carefully if accurate, quantitative results are wanted. In the habitats of many New Zealand ungulates, the diversity of plant communities growing in close proximity (e.g. river flats, lowland forest, upland forest, sub-alpine scrub, alpine tussock and alpine herb gardens) and the variability within communities of the same type could make such diet studies difficult. Best results may be obtained by using a reasonable number of tame, oesophageal-fistulated animals, caught and raised in the study area. By controlling their movement it would be possible to measure species availability more precisely (including seasonal variation). Also correction factors for differential species breakdown could be easily established (even for individual animals) and the effects of previous experience accounted for.

CHAPTER 6

SUMMARY

1) Measuring the use and availability of less common and/or less uniformly distributed species was the main difficulty in this study.

2) Individual Goats ate a reasonable variety of species (at least 19 on average). However, only a few species were eaten regularly in large amounts. Asplenium bulbiferum alone was the dominant species in 50% of all rumen samples and 10 principal species made up 81.5% of the total amount eaten over the year.

3) The use of seven principal foods: Coprosma grandifolius, Coprosma tenuifolia, Melicytus ramiflorus, Ripogonum scandens (fruit and vine), Weinmannia racemosa and Griselinia littoralis probably varied seasonally. Other principal foods which probably did not change seasonally included Asplenium bulbiferum, Ripogonum scandens foliage and Astelia spp.. For many species the situation was unclear.

4) Plant species preference ratings, although approximate, showed that a number of foods were strongly selected for by goats. Such "highly preferred" and "preferred" species included Schefflera digitata, Ripogonum scandens (fruit, vine and foliage), Coprosma lucida, Melicytus ramiflorus, Weinmannia racemosa, Griselinia littoralis, Coprosma tenuifolia and Asplenium bulbiferum. In contrast most of the extremely abundant species were very seldom eaten, notably Microlaena spp., Uncinia spp., moss, Alsophila smithii and especially Blechnum fluviatile.

5) Very young goats probably ate a more diverse diet than adult animals. On the other hand diet did not appear to vary with sex or time of day.

6) The foliage of most large leaved species broke down at similar rates in the rumen. However, the fern Asplenium bulbiferum and probably the dicotyledon Melicytus ramiflorus were slightly underestimated in the diet. The vine of Ripogonum scandens was

possibly overestimated. Hence where principal food items are very diverse, differential breakdown should be examined, although it was not an large problem in this study.

7) The goat's diet contained adequate or more than adequate levels of nitrogen and the minerals K,Ca,Mg,P,S,Cu,Zn,Fe and Mn. Levels of Na were marginal suggesting that they may be selected for. Na levels were considerably higher in the extremely palatable Schefflera digitata than any other species examined.

8) Mating appeared to be year-round but peaked over summer and autumn with most births occurring between autumn and spring.

9) Goats in the lowland forest of Mt Egmont probably represented a healthy population that was reproducing rapidly in response to their low density and good food supply.

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APPENDIX 1

ADDITIONAL EXPLORATORY AND DESCRIPTIVE STATISTICS APPLIED IN ANALYSING THE DIET:

INTRODUCTION

1) Principal Components Analysis (PCA): Blackieth and Reyment (1971) state: "PCA is suitable for the analysis of the structure of multivariate observations, particularly from the stand point of investigating the dependence structure occurring in a suite of observations, particularly when no a priori patterns of interrelationship can be suggested or are suspected." PCA can be used "to reduce the dimensionality of a set of variables, that is, to describe the subjects in terms of their scores on a much smaller number of variables with as little loss of information as possible. If this effort is successful, then the new variables (components, factors) can be considered as providing a description of the "structure" of the original set of variables" (Harris 1975). Further, PCA is an appropriate exploratory analysis technique for this study that has no limiting assumptions about the data being examined (T. Hassard, pers, comm.). Accordingly PCA was used early on in the statistical analyses to look for relationships between the seven principal dietary species (see beginning of Section 3.1.4 for a definition of these principal dietary species).

2) Discriminant Function Analyses (DFA): DFA is a descriptive modification of MANOVA. It plots axes through successively smaller independent linear combinations of the dependent variables; the first axis (function) always describing the greatest amount of variation with respect to levels of the independent variable. It shows the amount of variation caused by each dependent variable for seperate functions and defines how much of the variation due to each dependent variable occurs at each level of the independent variable. Thus it defines the magnitudes of the dependent variables which best describe or catergorize levels of the independent variable. (T .Hassard pers.comm.). Where differences are sufficient individuals can be categorized into levels of the independent variable on the basis of their combinations of the dependent variables. DFA was used in this

study to see if there were particular combinations of species typical of goats coming from certain seasons, sexes, ages, times of the day, altitudes and areas.

The above two analytical procedures were carried out using the SPSS computer package described in Nie et al (1975).

RESULTS OF PCA AND DFA.

1) PCA showed there was no meaningful relationship between the seven principal dietary species tested. If there was perfect independence between species (factors) all the eigenvalues would have equaled one. On the other hand if several species were strongly associated a large proportion of the variation would have been explained by the first few factors and there would have been large differences in size between the first few eigenvalues and later ones. In this study each factor explained a similar amount of variation, hence variation was probably random. Jeffers (1967) gives a case where 74% of the variance was explained by four factors out of a total of 10 and states that such results mean there is a relationship between certain of the independent variables. Thus Mt Egmont goats appeared to eat these seven principal species independently of each other.

2) DFA was used to see how diet varied with different independent variables, the results of which are briefly summarized below. The first case (season and diet) is described more fully.

a) Were there particular combinations of plant species typical of the diet in certain seasons and could season of capture be determined by diet?

Of the three functions derived from the four seasons, only the first two were significant (refer Table A). The first function accounted for 61% of the total variance and the second function accounted for 36%. The greatest amount of variance in the first function was due to Coprosma grandifolius and Weinmannia racemosa which had much higher standardized coefficients relative to other species. The same is true for Asplenium bulbiferum in the second function (though see Section 4.1.1). Group means of function one show that autumn is characterized by high levels of Coprosma grandifolius and Weinmannia racemosa, spring has low levels of both whereas winter and

summer have intermediate levels. Group means of function two show that spring and autumn had high levels of Asplenium bulbiferum, summer was very low and winter was intermediate. Thus goats were assigned to predicted group (seasonal) membership. Spring (60.3%) and autumn (56.9%) were the best predicted because they were fairly distinct with respect to the main discriminating species for both functions. Winter (19.2%) was poorly discriminated as it had intermediate levels of the discriminating species for both functions. Summer (35.6%) was slightly better as it had low levels of Asplenium bulbiferum (function two). Thus predictive powers were better than guessing for all seasons except winter but a high proportion of individuals were catergorized incorrectly.

Table A.

Function	Eigenvalue	% of Variance	Chi-square	D.F	Significance
1	0.274	61.12	89.070	21	0.000
2	0.161	36.12	35.794	12	0.000
3	0.012	2.76	2.708	5	0.744

Standardized Canonical Discriminant Function Coefficients

Species	Funct 1	Funct 2
Asplenium bulbiferum	0.016	1.109
Astelia spp.	-0.024	0.418
Coprosma grandifolius	0.724	0.529
Griselinia littoralis	-0.180	0.676
Melicytus ramiflorus	-0.216	-0.222
Ripogonum scandens	0.449	0.491
Weinmannia racemosa	0.756	0.310

Canonical Discriminant Functions evaluated at Group Means

Season	Funct 1	Funct 2
Winter	-0.028	-0.009
Spring	-0.741	0.292
Summer	0.059	-0.632
Autumn	0.706	0.360

b) Were there particular species combinations typical of each sex? Only 53.9% of males and 56.6% of females could be catergorized on the basis of diet. Asplenium bulbiferum was the main discriminating species and was higher in males than females, but function one was not statistically significant (X^2=5.530,DF=7,P>0.5), and grouping by diet was little better than guessing.

c) Were there particular combinations of species typical of different age groups?

The percentages of goats which could be grouped according to age by DFA was: 0-1 years (51.6%), >1-2 years (37.3%), >2-3 years (35.3%) and > 3 years (34%). This was slighty better than random, but shows that many animals cannot be catergorized by diet. Only the first of the three functions was significant in discriminating age (X^2=38.692,DF=21,P<0.02) and explained 69.34% of the variance. The discriminating species were Griselinia littoralis and Ripogonum scandens. However use of these species did not show a meaningful trend in relation to goat age.

d) Were there particular combinations of species typical of goats shot at different times of the day?

Goats were grouped into those shot prior to 1200 hours and after 1200 and before 1700 hours i.e. morning and afternoon. The percentages of goats catergorized correctly were morning goats (59%) and afternoon goats (72.1%) with a total of 67.1% of goats grouped correctly by DFA. Only one function was almost significant (X^2=1.3.852, DF=7,P=0.054) and Melicytus ramiflorus explained most of the variance. Morning goats contained more Melicytus ramiflorus than afternoon goats. (see discussion, Section 5.2).

e) Were there particular species combinations typical of goats coming from different altitudes?

The percentages of goats that could be catergorized according to altitude were: park boundary to 548m (46.6%); >548m to 610m (51.1%); and >610m to 692m (53.3%). Only the first function which described 87.67% of the variation was significant (X^2=34.805,DF=14, P=.002). The species which explained most of the variation in function one were Astelia spp. and especially Griselinia littoralis. Whether this was meaningful or not was hard to say as the upper altitude sample size was very small (15, which was about 1/8 of the size of others), hence the level of siginificance may have been considerably lower than it

appeared. As well as the small sample size, most of the 15 individiuals came from only three groups or mobs and thus may not have been very representative of diet in the higher altitudinal belt (also see Section 5.1).

f) Were there particular species combinations typical of goats from different areas?

The percentages of goats that could be catergorized according to area were: area one (48.2%), area two (50%) and area three (55.6%). Both the first function which explained 65.6% of the variation and the second function which explained 34.4% of the variation were significant; (X^2=53.631,DF=14, P<0.0001) and (X^2=18.895, DF=6, P<0.01), respectively. Asplenium bulbiferum, Coprosma grandifolius and to a lesser degree Ripogonum scandens accounted for most of the variation in the first function. The variation was more evenly spread for the second function and otherwise fairly similar to the first function. Area one and especially area three had low levels of Asplenium bulbiferum, Coprosma grandifolius and Ripogonum scandens compared to area two. However, see Section 5.1.

APPENDIX 2

CHOOSING METHODOLOGY FOR THE STUDY

Different methods of establishing:

- the diet of a mammal herbivore,
- the availability of plants for food and
- relative preference ratings for food plants,

are discussed below and a choice of the most appropriate ones for this study explained.

DIET ANALYSIS

A number of options are open when studying the diet of large herbivores, each tending to be suited to particular situations. Only macro-rumen analysis and micro-faecal analysis were really suitable for this study and are discussed after other alternatives have been briefly considered.

1) Utilization Techniques: Establishing exclosure plots and measuring differences in non-exclosure plots would not have been suitable on Mount Egmont because of low goat numbers and the time constraints in which to measure seasonal changes in diet.

2) Direct Observation: Direct observation of goats to count bites or minutes spent feeding on each species would have proved very difficult because goats were difficult to find, let alone get close to for long periods of time.

3) Oesophageal Fistulae: This technique can give samples which are very representative of what is eaten (Holechek unpublished in Holechek *et al* 1982). However, to catch sufficient goats from Mt Egmont, fistulate, train and maintain them *in situ* or transport them back and forth between Massey University and Mt Egmont would have been practically impossible with the time and resources available for this study. Fistulated animals from other areas would not have helped, since they may have had different food preferences (Arnold and Maller 1977 and Bartmann and Carpenter 1982). The oesophagael fistulae method is probably more accurate than any other (McInnes 1976 in Kessler *et al* 1981) but requires a large number of animals for precision (Holechek *et al* 1982).

4) Micro-Histological Techniques: The use of this method involves collecting rumen or faecal samples, grinding them to a uniform size, identifying and counting the cuticular fragments. Faecal analysis has been the most popular method for studying range herbivore diet over the last decade (Holechek et al 1982). It has a number of advantages over rumen analysis methods including:

a) The subject animals need not be killed or even disturbed.
b) Collection of a large number of samples from diverse habitats is fast and cheap.
c) Samples cover a longer period of feeding and may therefore be more representative of the diet than equal numbers of rumen samples (Antony and Smith 1974).

Disadvantages shared by faecal analysis and microhistological rumen analysis include:

a) Differential fragmentation and/or digestion of different species may cause errors in diet estimation (Antony and Smith 1974, Dearden et al 1975, Westoby et al 1976, Fitzgerald and Wadington 1979, Smith and Shandruk 1979 and Kessler et al 1981).
b) Different plant species have different amounts of cuticle in relation to their biomass or volume, hence cuticle counts may poorly reflect the relative proportions of species actually eaten (Westoby et al 1976).
c) The cuticles of some species are much easier to identify than others and these tend to be over estimated (Dearden et al 1975, Westoby et al 1976, Saunders et al 1980 and Kessler et al 1981).
d) Some species do not survive the digestive process (more relevant to faecal analysis) and others do not survive the preparatory techniques (Johnson and Pearson 1981).
e) Not all plant parts can be identified by cuticle analysis.
f) A long period of time is needed to learn how to identify cuticle fragments (Westoby et al 1976, Saunders et al 1980). Johnson and Pearson 1981) spent about 6 months. Also it takes a lot of work to prepare a reference collection, especially as dietary diversity increases.
g) A very large number of slides and observations per slide are necessary for quantitative estimates of anything other than very dominant dietary species (Holechek and Vavra 1981).

Of the two micro-histological techniques, faecal analysis is probably the most useful because of the advantages it has over all

rumen analysis techniques. Whereas micro-histological rumen analysis has nearly all the disadvantages of faecal analysis as well as the difficulty of collecting rumen samples.

5) Macro-Analysis Techniques: These methods are restricted to rumen samples, usually from killed animals. Samples are wash-seived to remove fine unidentifiable material. They can then be sorted, or point sampled after Chamrad and Box (1964). Point sampling involves measuring the frequency with which species are encountered at fixed, or ideally random points on a grid when spread out in a thin layer of water in a tray. The frequency of encounter reflects the relative surface areas of species. Eastman (1974 in Nuegent 1983) found it underestimated the number of species eaten and Robel and Watt (1970) found it was generally less accurate than sorting. The method is potentially a lot faster than sorting, but in practice it is likely to be slower because of the large number of identifications needed to get accurate quantitative estimates of even major species (Nugent 1983). The problem intensifies as species decrease in importance. This method, which has much the same potential for error as sorting (see below), also seems inferior and more complex in other respects. Sorting is simply dissecting samples into species or types and measuring them by dry weight or volumetrically. Of the methods covered so far, faecal analysis and sorting rumen contents seem most appropriate.

Following are the likely advantages of sorting rumens:

a) Once collected, samples are easier to prepare and may be faster to analyse depending on the aims of the study. For example a five man team processed up to 100 deer in a day (Puglisi et al 1978) on the assumption that processing a large number of samples was more informative than fewer, more detailed examinations.
b) Species identification of fragments is usually fairly easy and requires a lot less training and practice than faecal analysis (Nugent 1983).
c) The identified fraction is the larger more freshly ingested material and therefore differential digestion should have less effect (Jackson 1977, Nugent 1983, A.Johns pers.comm.).
d) The proportion of unidentifiable material is lower than for faecal analysis (Nugent 1983).

Disadvantages of sorting include:

a) Sorting can be very time consuming depending on sample size and the smallest sieve size used, e.g. Dzieciolowski (1970) took 50

hours per sample.

b) Differential fragmentation of plant species may be a source of considerable error. Therefore different sized sieve fractions should be examined to see if the different food species are found in similar proportions in each sieve (Dirschl 1962, Bergerud and Russell 1964, Gaare et al 1977, Owaga 1978 and Kessler et al 1981).

Kessler et al (1981) found faecal analysis detected a higher number of species than rumen analysis in pronghorn antelope and concluded it was just as reliable as rumen analysis. The higher number of species detected could have been due to the longer feeding period represented by faecal analysis (Antony and Smith 1974) and the small number of samples used. Johnson and Pearson (1981) compared faecal and oesophagael fistulae samples from cattle grazing grasslands and found a few species did not survive digestion. But overall, they too concluded that faecal analysis was an "accurate and efficient" method. Dearden et al (1976) used correction factors for the effects of differential digestion on the discernability of plant cuticle. However, Westoby et al (1976) studied black-tailed jackrabbit (Lepus californicus) diet with micro-rumen analysis (the principles of which are the same as faecal analysis). Ease of species identification varied so much for the desert plant species that it caused considerable error. Species present in small amounts were often missed or underestimated, while common species were overestimated. The ratio of epidermis to other material varied greatly for different species. Westoby suggested the method was best when plants of very similar makeup were involved. Smith and Shandruk (1979) reached a similar conclusion. They found sorting rumen contents more suitable for pronghorn antelope (Antilocapra americana) diet. Nugent (1983) reviewed diet study literature to determine the best method of assessing the diet of wild deer in New Zealand and chose sorting of rumen contents.

In light of the readily available rumen samples, time constraints, the simplicity of sorting rumens and the greater potential for error with faecal analysis, it was decided to use sorting of rumen contents to study the diet of feral goats.

PLANT AVAILABILITY

Plant species availability should be quantified in terms of the biomass of edible plant parts within the browse range. For their study of goat diet in the Orongoranga Valley. M. Rudge and J. Campbell (pers.comm.) used a pole and cord to delineate a cylindrical volume within which they removed and weighed the foliage of each species. The browse zone was substantially eaten out so the method was reasonably fast to apply. Most diet preference studies have involved grasslands and have used standard agronomic methods such as point frames or quadrats and herbage dissection (Everitt and Alaniz 1980 and Sexson et al 1981). Such methods were not suitable for the forest situation. In view of the available time and personnel it was only realistic (M.Rudge pers.comm.,C.Jenkins pers.comm.) to aim for an index of species availability as opposed to a precise measure. The method needed to be fast to apply so as to allow the sampling of a high number of sample sites throughout the large study area and thus produce representative results. Owing to the size of the study area and the very dense vegetation, Rudge and Campbell's method would have taken too long. Ellis et al (1977) dropped a rod into the ground at intervals along a transect and counted touches of plant species against it. This method allowed rapid sampling and hence was adopted for this study. A criticism is that it measures plant surface area and not biomass or volume. However, almost all of what was being measured was foliage, most of the species were of fairly similar thickness and there were time restraints which meant that more precise methods were not feasible.

RELATIVE PREFERENCE INDICES

1) Alternatives:

A number of forage preference indices were assessed by Krueger (1972); Krueger's indices along with others were tested using cattle and sheep on pasture by Toehle and Rittenhouse (1982). Toehle and Rittenhouse found no clear advantages in any one index over another. The very simple "forage ratio" index was chosen for this study as it gave results second only to a much more complex index.

2) Problems with Assigning Preference Ratings:

Assigning plant palatability requires an accurate measure of species use in relation to availability. Achieving such measurements for wild herbivores could prove very difficult especially if the plant species density and distributions are highly variable across the animal's range which is likely. Next, a suitable preference index relating diet and availability is necessary. Even in closely controlled agricultural experiments, Tochle and Rittenhouse (1982) expressed dissatisfaction with all the preference indices they tested. They concluded that "sampling problems combine with inadequacies of the preference indices to prevent accurate representation of the concept of diet preference" and "further investigations into animal behaviour are needed to determine variables which affect what the animal percieves as being desirable in relation to what is available". Even if diet and availability were accurately measured, the resultant preference ratings would only be a guideline as to what the herbivore actually prefers. Crawley (1983) says "true feeding preferences can only be determined under the very strictest controlled environmental conditions, when all differences in availability between the different foods are eliminated" i.e. by means of "cafeteria trials." However, such experiments are very difficult to run and especially difficult to interpret (Crawley 1983). But then how does one relate preference ratings where availability was equal for all species to those in the field where it is possible to measure relative species biomass but not the true availability from the animal's point of view? And the accessibility of food will probably have a large affect on how much it is used and hence preferred.

It is concluded that the difficulties associated with quantifying diet (above), measuring the amounts of each species available (above) and then relating use and availability to oneanother in an appropriate manner are considerable.

APPENDIX 3

The annual mean % volumes (M%V) in the diet, % availabilities (%AV) and preference ratings for all species found in the diet are presented. Subjective preference ratings are given for all species which occurred less than 10 times in the availability survey where:

P = Preferred
E = Equilibrium (i.e. not obviously preferred or rejected)
R = Rejected
? = Unclear (usually because species was uncommon)
(Numberss are calculated preference ratings)

Plant Species	Annual M%V	2S.E	%Av	2S.E	Pref Rating
Alseuosmia macrophylla	0.095	0.058	0.34	0.37	0.279
Alseuosmia pusilla	0.011	0.010	0.11	0.21	?
Alsophila smithii	0.036	0.020	7.28	1.67	0.005
Anarthropteris lanceolata	0.003	0.006	0.00	0.00	?
Aristotelia serrata	0.033	0.024	0.05	0.14	?
Asplenium bulbiferum	31.244	3.350	18.70	2.50	1.671
Asplenium flaccidum	0.599	0.206	0.00	0.00	P
Asplenium oblongifolium	0.058	0.060	0.00	0.00	P
Asplenium polypodon	0.042	0.022	0.05	0.14	?
Astelia spp.	3.981	0.948	8.00	1.74	0.498
bark	1.010	0.590	0.00	0.00	?
Beilschmiedia tawa	0.119	0.052	0.75	0.55	0.159
Blechnum discolor	0.350	0.152	2.98	1.09	0.117
Blechnum fluviatile	0.000	0.000	6.88	0.00	0.000
Brachyglottis repanda	0.001	0.000	0.00	0.00	?
Cardiomanes reniforme	0.051	0.032	0.24	0.31	E
Carmichaelia egmontiana	0.606	0.526	0.00	0.00	P
Carpodetus serratus	1.035	0.486	1.26	0.71	0.821
Clematis paniculata	0.670	0.444	0.16	0.25	P
Coprosma grandifolius	5.020	1.052	0.40	0.40	12.550
Coprosma lucida	1.719	0.612	0.03	0.11	P
Coprosma tenuifolia	2.704	0.740	0.86	0.59	3.144
Cordyline indivisa	0.038	0.070	0.00	0.00	?
Coriaria arborea	0.077	0.096	0.00	0.00	?
Cyathodes fasciculata	0.003	0.004	0.00	0.00	?
Dacrydium cupressinum	0.092	0.044	0.08	0.18	?
Dicksonia squarrosa	0.585	0.194	2.18	0.93	0.268
Elaeocarpus dentatus	0.511	0.264	0.00	0.00	E
filmy fern	0.099	0.036	1.26	0.71	0.079
Freycinetia banksii	0.003	0.006	0.21	0.29	?
Fuchsia excorticata	0.007	0.008	0.00	0.00	?
fungi	0.007	0.008	0.00	0.00	?
Gaultheria antipoda	0.147	0.116	0.00	0.00	E
Geniostoma ligustrifolium	0.834	0.484	0.08	0.18	P
Grammitis billardieri	0.001	0.002	0.00	0.00	?
exotic grass	0.147	0.112	0.00	0.00	?
Griselinia littoralis	5.250	1.256	0.91	0.61	5.769
Hebe stricta	0.873	0.552	0.00	0.00	P
Hedycarya arborea	0.557	0.234	0.81	0.57	0.688
Lotus pedunculatus	2.869	1.518	0.00	0.00	P
Libocedrus bidwillii	0.002	0.002	0.00	0.00	?
lichen	0.017	0.012	0.30	0.35	0.057
Melicytus lanceolatus	0.002	0.004	0.00	0.00	?
Melicytus ramiflorus	4.879	1.030	0.46	0.43	10.607
Metrosideros diffusa	0.184	0.044	3.28	1.14	0.056
Metrosideros fulgens	0.925	0.474	0.00	0.00	P
Metrosideros robusta	0.189	0.114	0.00	0.00	P
Microlaena spp.	0.040	0.074	12.14	2.09	0.003
moss	0.022	0.006	11.42	2.04	0.002
Myrsine salicina	0.166	0.150	0.00	0.00	R
Nestegis cunninghamii	0.042	0.034	0.40	0.40	0.105
orchid species	0.161	0.124	0.05	0.14	P
Parsonsia capsularis	0.006	0.006	0.03	0.11	?
Pennantia corymbosa	0.228	0.110	0.32	0.36	0.713
Phymatosorus diversifolium	1.232	0.290	0.03	0.11	P
Podocarpus ferrugineus	0.134	0.074	0.32	0.36	0.419
Podocarpus totara	0.020	0.022	0.13	0.23	?

Plant Species	Annual M%Vol	2S.E	%Av	2S.E	Pref Rating
Pseudopanax anomalus	0.001	0.002	0.00	0.00	?
Pseudopanax arboreus	0.257	0.194	0.00	0.00	P
Pseudopanax crassifolius	0.602	0.534	0.30	0.35	2.007
Pseudowintera colorata	0.207	0.096	1.88	0.87	0.110
Ripogonum scandens foliage	3.024	0.742	1.20	0.70	2.520
vine	7.376	1.874	0.00	0.00	P
fruit	3.158	1.362	0.00	0.00	P
Rubus spp.	0.070	0.032	0.00	0.00	R
Rumohra adiantiformis	0.011	0.006	0.00	0.00	?
Rumohra hispida	0.002	0.004	0.32	0.36	0.006
Schefflera digitata	5.746	1.530	0.21	0.29	27.362
Tmesipteris tannensis	0.000	0.000	0.00	0.00	?
Uncinia spp.	0.029	0.028	11.20	2.02	0.003
Weinmannia racemosa	9.426	1.432	0.88	0.60	10.711

APPENDIX 4

Seasonal mean % volumes in the diet for all dietary species.

Plant Species	Seasonal M%Vs and 2S.E.s							
	Winter	2S.E	Spring	2S.E	Summer	2S.E	Autumn	2S.E
Alseuosmia macrophylla	0.078	0.078	0.127	0.172	0.113	0.112	0.060	0.058
Alseuosmia pusilla	0.000	0.000	0.000	0.000	0.019	0.028	0.022	0.030
Alsophila smithii	0.030	0.028	0.011	0.010	0.014	0.008	0.089	0.072
Anarthropteris lanceolata	0.000	0.000	0.001	0.002	0.000	0.000	0.012	0.024
Aristotelia serrata	0.029	0.052	0.051	0.062	0.042	0.048	0.012	0.022
Asplenium bulbiferum	31.813	6.276	41.520	7.680	21.213	5.482	30.663	6.148
Asplenium flaccidum	0.636	0.418	1.163	0.602	0.210	0.162	0.395	0.300
Asplenium oblongifolium	0.003	0.004	0.080	0.138	0.098	0.182	0.045	0.064
Asplenium polypodon	0.052	0.058	0.040	0.028	0.044	0.028	0.034	0.060
Astelia spp.	3.766	1.392	4.969	2.914	3.472	1.424	3.704	1.310
bark	0.000	0.000	2.268	1.942	0.883	0.938	0.786	0.724
Beilschmiedia tawa	0.190	0.182	0.114	0.072	0.058	0.042	0.122	0.090
Blechnum discolor	0.446	0.374	0.560	0.370	0.049	0.026	0.360	0.314
Blechnum fluviatile	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Brachyglottis repanda	0.003	0.004	0.000	0.000	0.000	0.000	0.000	0.000
Cardiomanes reniforme	0.082	0.068	0.016	0.018	0.054	0.048	0.053	0.094
Carmichaelia egmontiana	0.009	0.018	1.675	1.634	0.049	0.096	0.640	1.224
Carpodetus serratus	2.280	1.778	0.274	0.276	1.225	0.852	0.487	0.360
Clematis paniculata	1.239	1.734	0.475	0.664	0.622	0.258	0.404	0.310
Coprosma grandifolius	3.551	1.234	3.294	1.468	4.887	1.778	8.199	3.074
Coprosma lucida	2.640	1.574	0.878	0.802	1.497	1.408	1.962	1.004
Coprosma tenuifolia	2.064	1.100	1.240	0.596	5.570	2.284	1.826	0.984
Cordyline indivisa	0.000	0.000	0.147	0.278	0.003	0.006	0.001	0.002
Coriaria arborea	0.000	0.000	0.010	0.020	0.275	0.364	0.011	0.022
Cyathodes fasciculata	0.000	0.000	0.008	0.016	0.005	0.006	0.000	0.000
Dacrydium cupressinum	0.104	0.092	0.137	0.114	0.083	0.092	0.046	0.042
Dicksonia squarrosa	0.056	0.064	0.226	0.220	1.760	0.602	0.222	0.152
Elaeocarpus dentatus	0.905	0.934	0.351	0.448	0.236	0.242	0.600	0.320
filmy fern	0.046	0.030	0.158	0.108	0.125	0.072	0.060	0.028
Freycinetia banksii	0.000	0.000	0.000	0.000	0.000	0.000	0.010	0.020
Fuchsia excorticata	0.002	0.004	0.005	0.008	0.015	0.030	0.008	0.016
fungi	0.011	0.020	0.005	0.006	0.013	0.026	0.000	0.000
Gaultheria antipoda	0.055	0.056	0.129	0.180	0.300	0.392	0.091	0.100
Geniostoma ligustrifolium	0.909	0.970	0.994	1.410	0.371	0.510	1.078	0.786
Grammitis billardieri	0.005	0.010	0.000	0.000	0.000	0.000	0.000	0.000
exotic grass	0.000	0.000	0.265	0.288	0.289	0.324	0.015	0.018
Griselinia littoralis	5.271	1.840	8.151	3.992	3.230	1.450	4.385	1.642
Hebe stricta	0.009	0.012	2.262	1.860	1.032	1.002	0.098	0.098
Hedycarya arborea	0.592	0.366	0.832	0.784	0.409	0.262	0.402	0.208
Lotus pedunculatus	0.000	0.000	0.318	0.554	8.537	5.272	2.227	1.842
Libocedrus bidwillii	0.000	0.000	0.006	0.012	0.000	0.000	0.000	0.000
lichen	0.012	0.016	0.007	0.006	0.042	0.046	0.004	0.006
Melicytus lanceolatus	0.000	0.000	0.000	0.000	0.010	0.020	0.000	0.000
Melicytus ramiflorus	4.529	1.740	5.716	2.452	6.567	2.288	2.639	1.422
Metrosideros diffusa	0.159	0.080	0.183	0.082	0.161	0.084	0.231	0.108
Metrosideros fulgens	1.297	1.262	0.045	0.090	0.544	0.414	1.857	1.376
Metrosideros robusta	0.120	0.158	0.264	0.236	0.244	0.326	0.121	0.112
Microlaena spp.	0.000	0.000	0.011	0.016	0.141	0.282	0.000	0.000
moss	0.014	0.008	0.034	0.016	0.020	0.014	0.019	0.012
Myrsine salicina	0.127	0.114	0.105	0.158	0.018	0.024	0.412	0.558
Nestegis cunninghamii	0.002	0.004	0.079	0.112	0.040	0.046	0.044	0.046
orchid species	0.166	0.230	0.010	0.012	0.090	0.122	0.380	0.414
Parsonsia capsularis	0.005	0.010	0.011	0.016	0.008	0.012	0.001	0.002
Pennantia corymbosa	0.044	0.034	0.293	0.208	0.497	0.350	0.055	0.058
Phymatosorus diversifolium	1.205	0.552	1.328	0.558	1.626	0.782	0.760	0.296
Podocarpus ferrugineus	0.083	0.070	0.123	0.126	0.267	0.242	0.057	0.042
Podocarpus totara	0.001	0.002	0.076	0.082	0.001	0.002	0.000	0.000
Pseudopanax anomalus	0.001	0.002	0.000	0.000	0.003	0.004	0.000	0.000
Pseudopanax arboreus	0.033	0.064	0.237	0.252	0.186	0.144	0.551	0.698
Pseudopanax crassifolius	1.580	2.242	0.295	0.338	0.301	0.272	0.337	0.356
Pseudowintera colorata	0.269	0.224	0.136	0.086	0.199	0.146	0.233	0.268
Ripogonum scandens foliage	4.443	2.206	2.359	0.960	2.251	1.052	3.204	1.530
vine	4.116	2.766	0.872	0.966	10.924	4.361	13.194	4.830
fruit	6.635	3.836	4.268	2.856	1.910	2.634	0.200	0.230
total	15.194	5.888	7.499	3.520	15.085	5.734	16.598	5.194
Rubus spp.	0.040	0.040	0.078	0.092	0.042	0.038	0.117	0.070
Rumohra adiantiformis	0.003	0.004	0.013	0.020	0.012	0.012	0.017	0.010
Rumohra hispida	0.000	0.000	0.001	0.002	0.008	0.016	0.000	0.000
Schefflera digitata	7.515	3.854	5.995	3.008	6.301	3.366	3.348	1.736
Tmesipteris tannensis	0.000	0.000	0.000	0.000	0.002	0.004	0.000	0.000
Uncinia spp.	0.002	0.002	0.063	0.086	0.038	0.066	0.008	0.006
Weinmannia racemosa	10.265	2.728	4.441	1.914	10.111	3.054	12.962	3.132

APPENDIX 5

The % of goats eating each plant species seasonally (%Freq).

Plant Species	Winter	Spring	Summer	Autumn	Annual
Alseuosmia macrophylla	21.154	8.621	20.339	17.241	16.740
Alseuosmia pusilla	0.000	0.000	3.390	5.172	2.203
Alsophila smithii	21.154	17.241	23.729	29.310	22.908
Anarthropteris lanceolata	0.000	3.448	0.000	1.724	1.322
Aristotelia serrata	5.769	12.069	8.475	3.448	7.489
Asplenium bulbiferum	100.000	100.000	93.220	96.552	97.357
Asplenium flaccidum	55.769	60.345	37.288	41.379	48.458
Asplenium oblongifolium	3.846	5.172	5.085	3.448	4.405
Asplenium polypodon	11.538	20.690	23.729	12.069	17.181
Astelia spp.	92.308	98.276	88.136	82.759	90.308
bark	0.000	25.862	15.254	12.069	13.656
Beilschmiedia tawa	36.538	24.138	22.034	24.138	26.432
Blechnum discolor	46.154	44.828	33.898	31.034	38.767
Blechnum fluviatile	0.000	0.000	0.000	0.000	0.000
Brachyglottis repanda	3.846	0.000	0.000	0.000	0.881
Cardiomanes reniforme	32.692	8.621	22.034	13.793	18.943
Carmichaelia egmontiana	1.923	12.069	3.390	6.897	6.167
Carpodetus serratus	53.846	36.207	69.492	48.276	51.982
Clematis paniculata	32.692	34.483	59.322	34.483	40.529
Coprosma grandifolius	92.308	79.310	83.051	87.931	85.463
Coprosma lucida	44.231	22.414	18.644	44.828	32.159
Coprosma tenuifolia	57.692	55.172	79.661	55.172	62.115
Cordyline indivisa	0.000	3.448	1.695	1.724	1.762
Coriaria arborea	0.000	1.724	5.085	1.724	2.203
Cyathodes fasciculata	0.000	1.724	5.085	0.000	1.762
Dacrydium cupressinum	32.692	29.310	25.424	25.862	28.194
Dicksonia squarrosa	15.385	25.862	76.271	55.172	44.053
Elaeocarpus dentatus	42.308	29.310	25.424	43.103	34.802
filmy fern	50.000	60.345	62.712	63.793	59.471
Freycinetia banksii	0.000	0.000	0.000	1.724	0.441
Fuchsia excorticata	1.923	3.448	1.695	1.724	2.203
fungi	5.769	8.621	1.695	0.000	3.965
Gaultheria antipoda	11.538	15.517	10.169	17.241	13.656
Geniostoma ligustrifolium	25.000	22.414	11.864	34.483	23.348
Grammitis billardieri	1.923	0.000	0.000	0.000	0.441
exotic grass	3.846	10.345	13.559	8.621	9.251
Griselinia littoralis	84.615	86.207	67.797	67.241	76.211
Hebe stricta	7.692	22.414	18.644	10.345	14.978
Hedycarya arborea	51.923	34.483	30.508	48.276	40.969
Lotus pedunculatus	0.000	5.172	20.339	22.414	12.335
Libocedrus bidwillii	0.000	3.448	0.000	0.000	0.881
lichen	7.692	10.345	18.644	5.172	10.573
Melicytus lanceolatus	0.000	0.000	1.695	0.000	0.441
Melicytus ramiflorus	86.538	82.759	81.356	87.931	84.582
Metrosideros diffusa	59.615	56.897	45.763	56.897	54.626
Metrosideros fulgens	26.923	1.724	16.949	25.862	17.621
Metrosideros robusta	13.462	18.966	6.780	17.241	14.097
Microlaena spp.	0.000	5.172	1.695	0.000	1.762
moss	26.923	46.552	20.339	25.862	29.956
Myrsine salicina	19.231	5.172	5.085	18.966	11.894
Nestegis cunninghamii	1.923	12.069	15.254	6.897	9.251
orchid species	28.846	6.897	10.169	13.793	14.537
Parsonsia capsularis	1.923	6.897	3.390	3.448	3.965
Pennantia corymbosa	21.154	41.379	32.203	13.793	27.313
Phymatosorus diversifolium	80.769	79.310	76.271	82.759	79.736
Podocarpus ferrugineus	28.846	24.138	30.508	32.759	29.075
Podocarpus totara	3.846	6.897	1.695	0.000	3.084
Pseudopanax anomalus	1.923	0.000	3.390	0.000	1.322
Pseudopanax arboreus	3.846	15.517	20.339	25.862	16.740
Pseudopanax crassifolius	17.308	10.345	28.814	22.414	19.824
Pseudowintera colorata	36.538	34.483	35.593	18.966	31.278
Ripogonum scandensfoliage	73.100	72.400	69.500	81.500	74.000
vine	32.700	27.600	59.300	75.900	49.300
fruit	38.500	25.900	17.400	17.200	24.200
total	73.100	72.400	74.600	84.500	76.200
Rubus spp.	11.538	15.517	18.644	32.759	19.824
Rumohra adiantiformis	5.769	6.897	13.559	22.414	12.335
Rumohra hispida	0.000	1.724	3.390	0.000	1.322
Schefflera digitata	44.231	58.621	42.373	48.276	48.458
Tmesipteris tannensis	0.000	0.000	1.695	0.000	0.441
Uncinia spp.	9.615	8.621	10.169	12.069	10.132
Weinmannia racemosa	90.385	63.793	94.915	86.207	83.700

APPENDIX 6

Seasonal levels of nitrogen and minerals in seven principal dietary species. Species, nutrients and seasons are abbreviated. * = samples that were damaged.

York Road Transect

Species	Na	K	Ca	Mg	P	S	N	Cu	Zn	Fe	Mn
	g/kg							mg/kg			
Asp bul W	*	*	*	*	*	*	2.8	*	*	*	*
Asp bul Sp	0.5	38.2	8.1	5.0	3.0	2.0	2.9	13.9	33.8	40.9	75.8
Asp bul S	0.4	41.8	11.2	5.6	3.3	2.2	2.8	14.2	36.9	46.6	94.8
Asp bul A	0.2	34.3	11.8	5.4	2.5	2.1	2.6	11.9	34.3	50.1	119.8
Cop gra W	1.0	18.8	17.0	5.5	2.1	1.9	1.6	6.6	36.7	40.6	833.5
Cop gra Sp	0.2	21.4	16.4	4.9	1.9	1.6	1.7	7.1	35.4	41.0	489.1
Cop gra S	0.3	24.5	17.8	5.8	1.5	1.5	1.5	6.7	36.1	44.9	481.1
Cop gra A	0.7	17.9	20.0	6.2	1.5	2.1	1.5	6.6	36.6	43.0	689.9
Cop luc W	0.4	11.1	13.6	3.9	1.7	1.8	1.5	6.0	56.3	37.2	1385.2
Cop luc Sp	0.3	14.6	14.0	4.2	1.2	1.6	1.3	6.0	49.4	36.0	1115.4
Cop luc S	0.2	14.9	13.2	5.0	1.2	1.8	1.3	5.1	45.0	40.7	820.8
Cop luc A	0.4	10.3	16.7	4.5	1.0	1.8	1.1	5.0	46.3	51.8	1195.4
Mel ram W	2.7	24.6	11.2	4.3	3.1	3.3	2.6	9.4	35.5	50.1	168.2
Mel ram Sp	1.1	28.8	15.2	5.3	2.8	3.8	2.3	7.8	35.8	51.7	206.9
Mel ram S	1.1	29.9	14.4	5.1	2.6	3.1	2.4	6.9	26.9	54.0	180.7
Mel ram A	1.4	20.2	18.8	5.4	2.1	3.2	2.0	5.8	35.7	49.7	179.1
Rip sca W	0.9	13.6	14.5	2.9	1.1	1.5	1.8	6.3	22.3	40.8	644.4
Rip sca Sp	1.4	21.6	11.2	2.6	1.4	2.1	1.8	8.1	29.0	56.0	710.8
Rip sca S	0.3	20.5	7.6	1.7	1.8	1.8	1.8	12.0	26.0	38.6	339.3
Rip sca A	1.0	18.5	10.3	2.2	1.2	2.0	1.7	7.6	24.6	44.2	451.4
Sch dig W	3.2	16.2	20.6	4.6	2.5	4.2	2.2	10.9	59.5	64.4	411.3
Sch dig Sp	2.1	30.6	12.6	2.9	2.3	3.0	2.0	10.0	39.2	51.1	288.9
Sch dig S	2.9	26.1	16.1	3.8	2.5	3.1	2.1	10.7	36.4	49.9	322.1
Sch dig A	3.1	20.0	19.2	4.1	1.9	3.8	1.9	10.0	43.9	87.8	214.9
Wei rac W	2.1	5.5	7.6	2.8	0.7	1.3	0.9	5.5	19.3	38.6	480.6
Wei rac Sp	1.2	6.8	6.9	2.4	0.9	1.5	0.9	5.0	16.0	22.9	361.1
Wei rac S	0.9	5.2	8.0	2.8	0.8	1.3	0.9	5.0	15.6	21.9	287.5
Wei rac A	1.1	5.0	8.0	2.7	0.6	1.2	0.8	4.6	14.9	20.9	248.4

Egmont Road Transect

Species	Na	K	Ca	Mg	P	S	N	Cu	Zn	Fe	Mn
	g/kg							mg/kg			
Asp bul W	*	30.0	12.4	7.2	2.5	2.6	2.7	9.4	34.9	68.1	126.6
Asp bul Sp	0.3	35.5	9.4	5.7	2.8	1.9	2.5	9.8	30.0	54.1	89.4
Asp bul S	0.4	38.5	12.1	5.9	3.0	1.9	2.4	11.2	31.5	45.8	95.2
Asp bul A	0.4	35.0	13.3	6.3	2.6	2.0	2.5	9.7	29.7	49.9	128.5
Cop gra W	0.7	20.9	17.9	5.1	2.3	2.2	1.8	8.4	40.2	54.1	688.8
Cop gra Sp	0.3	31.5	14.8	5.0	2.5	1.8	2.0	9.9	44.3	49.4	442.9
Cop gra S	0.3	23.9	19.8	4.7	1.8	1.8	1.6	6.9	37.7	39.3	671.6
Cop gra A	0.6	23.1	20.9	5.2	1.8	1.7	1.6	7.1	46.8	44.9	652.5
Cop luc W	0.2	11.2	12.7	4.2	1.9	2.4	1.7	6.5	74.1	48.8	1227.0
Cop luc Sp	0.5	13.5	13.8	4.9	1.3	1.8	1.2	5.4	51.9	35.3	1120.4
Cop luc S	0.5	11.1	15.2	5.7	1.3	2.4	1.1	4.5	82.3	42.6	1389.9
Cop luc A	0.3	11.0	13.7	5.3	1.2	2.6	1.1	5.1	42.4	36.5	989.2
Mel ram W	1.4	24.2	14.9	4.7	3.1	3.7	2.5	7.3	43.3	59.2	222.1
Mel ram Sp	0.9	32.1	14.2	4.7	3.1	2.9	2.8	9.1	34.0	51.1	121.4
Mel ram S	0.9	25.8	14.3	4.9	2.3	2.2	2.1	5.9	29.1	40.7	128.4
Mel ram A	1.9	21.4	15.9	5.8	2.5	3.7	2.1	5.7	32.5	43.1	157.2
Rip sca W	1.1	18.5	7.0	2.2	1.1	1.7	1.6	8.1	25.5	46.7	281.6
Rip sca Sp	1.1	24.2	7.3	1.9	1.8	2.1	1.9	13.9	27.9	52.8	360.4
Rip sca S	0.4	25.5	5.7	1.9	2.3	2.2	2.0	17.5	30.6	46.6	269.7
Rip sca A	0.7	18.9	8.2	2.3	1.7	1.8	1.8	11.3	24.5	40.6	344.3
Sch dig W	3.4	22.3	13.4	3.8	3.9	3.6	2.9	13.3	46.4	64.1	219.8
Sch dig Sp	2.3	28.2	12.5	3.1	2.4	2.3	2.3	10.3	35.1	64.3	212.3
Sch dig S	3.2	24.8	15.6	3.7	2.2	2.3	2.1	9.2	42.4	54.0	246.6
Sch dig A	4.5	26.2	15.1	3.6	1.9	3.0	2.1	10.6	33.6	57.0	214.9
Wei rac W	1.6	6.4	8.4	2.7	1.0	1.6	0.9	5.8	17.6	33.3	612.7
Wei rac Sp	0.7	8.2	5.4	2.0	1.3	1.5	1.1	9.3	17.6	22.8	289.5
Wei rac S	1.0	6.5	9.0	2.6	0.9	1.6	0.9	5.8	17.1	22.9	317.7
Wei rac A	2.5	11.8	8.2	2.5	1.0	2.0	0.9	9.4	20.1	28.2	335.1