Department of Ecology, Massey University, Private Bag 11-222, Palmerston North, New Zealand.
[1] Present address: Department of Conservation, P.O. Box 3016, Wanganui, New Zealand.
[2] Corresponding author

THE FORAGING ECOLOGY OF FERAL GOATS *CAPRA HIRCUS* IN THE MAHOENUI GIANT WETA RESERVE, SOUTHERN KING COUNTRY, NEW ZEALAND

Summary: Feral goats (*Capra hircus*) were studied in the Mahoenui giant weta reserve, southern King Country, New Zealand, from March 1992 to February 1993. The reserve supports the main population of the undescribed Mahoenui giant weta (*Deinacrida* sp.). Gorse (*Ulex europaeus*) is the dominant woody browse plant in the reserve and provides protection, shelter and food for weta. The activities, foraging behaviour and diet of feral goats within the reserve were measured by direct observation and analysis of rumen contents. Measures of nutrient levels indicate that gorse is adequate for goat growth only during late spring/summer, and becomes a maintenance food at other times of the year. Feeding (grazing and browsing) was the dominant activity of adult feral goats in the reserve. Females spent more time feeding than males. Grazing and browsing changed seasonally for both sexes, with grazing generally decreasing from autumn to summer, and browsing increasing from summer to spring. In every season females spent more time grazing than males, but males browsed more than females. Greater use of browse by males may be an effect of the presence of females. Browsing of gorse by goats may not be an important influence on weta survival.

Keywords: Feral goats; *Capra hircus*; diet; giant weta; *Deinacrida* sp.; gorse; *Ulex europaeus*; activity budget.

Introduction

Feral goats *Capra hircus* L. are resident throughout the year in the the Mahoenui giant weta reserve 40 km south of Te Kuiti in southern King Country, North Island. The reserve was established to protect an undescribed giant weta (*Deinacrida* sp. Orthoptera; Stenopelmatidae) which has colonized scrub dominated by gorse (*Ulex europaeus* L.). The weta is no longer found in adjoining remnant stands of native forest where it is presumed to have once lived. Gorse appears to provide protection, shelter and food, making it an ideal habitat for giant weta (Sherley and Hayes, 1993).

Previous research in the reserve (C. Jowett, unpublished MS; Sherley and Hayes, 1993; Richards, 1994) has paid little attention to feral goats even though it was believed that goat activity was important in maintaining weta habitat (Sherley and Hayes, 1993). Goats browse the gorse, but the extent of browsing was unknown. Work elsewhere on consumption by goats of coarse woody plants such as gorse has focused mainly on the agricultural applications of this behaviour under artificial conditions of set stocking rates, set grazing areas, and use of wethers (Rolston, Clark and Lambert, 1983; Radcliffe, 1986), or under laboratory situations (Howe, Barry and Popay, 1988; Lambert *et al*., 1989). Furthermore, most studies of feral goat diet have not explored differences between the sexes. This study was, therefore, aimed at better understanding the ecology of feral goats in the reserve. Here we describe the foraging activity of the goats; including dietary differences between the sexes, especially in relation to the amount of gorse browsed. Also, we describe the abundance of different growth forms of gorse and assess the nutrient content of gorse in summer and winter.

Study Area and Methods

The study was conducted at the Mahoenui giant weta reserve (38°35'S 174°50'E, NZMS 260, R17) on the property of Mr N. Rauputu. The 192 ha gorse-covered reserve lies 2 km north of the village of Mahoenui, between 40-140 m a.s.l.. The reserve occupies rolling hill-country formed from the underlying Mahoenui mudstone (22.5 million years.b.p.) which slumps readily because of its high clay content (Thornton, 1985). Over the study area soils are recent, with poorly drained alluvium (C. Jowett, unpublished MS). The reserve is bordered on three sides by private farmland and on the fourth by the Mokau River.

During monthly visits of 5-10 days between March 1992 and February 1993 goat activities were scored every five minutes by recording the behaviour of each visible animal. The observations from 12 scans per hour were pooled, and for each month data from different days were combined for successive hours after sunrise. Following Alley (1991), observed behaviour was classified as follows: Grazing (stationary and moving); Browsing; Resting (lying and sitting); Standing; Walking (not associated with feeding); Maintenance Behaviour (mutual grooming, self grooming or grooming against inanimate objects, urination not associated with sexual activity); Agonism; and Other (including nursing and sexual behaviour). Goats were shot, and rumen contents analysed following Mitchell, Fordham and John (1987a), in July 1992 and February 1993 for a broad comparison with observed feeding behaviour. In all 29 goats were collected; 4 males and 11 females in winter, and 6 males and 8 females in summer.

Plant cover was assessed by means of eight 100 m transects with stations at 2 m intervals. Transects were widely spaced to sample the large area where most goats were observed, and at each sample point the vegetation type was recorded as either pasture or gorse. Gorse bushes were assigned to one of four browse types according to the size and shape resulting from goat browsing (Fig. 1). Gorse foliage was collected in winter and summer to measure nutrient levels. The samples were taken within goat browse range (up to 1.5 m), and frozen. The material was then oven-dried, and ground in a Glen Creston micro-hammer mill. Analyses were carried out by R.J. Hill Laboratories in Hamilton. Nitrogen concentration was determined by the Kjedahl method. The remaining 11 elements tested were determined from nitric-perchloric acid digestion (R.J. Hill *pers. comm.*)

Individuals in the goat herd were not individually marked and it was impossible to record the identity of individuals, many of which were white males, during behavioural observations. For this reason we do not report any hypothesis tests regarding differences in behaviour between different categories of individuals. Where possible, we report standard errors and these may be used to compare means, e.g. Figs. 4 and 5.

Results

Activities

A total of 31,735 goat observations were made, 15,859 for males and 15,876 for females. Overall feeding (grazing and browsing) was the dominant activity (48.5%) (Table 1) with females spending significantly more time feeding than males (53% and 44%, respectively). Resting was the second most common activity after feeding and, when combined with standing, males spent more time in these activities than females. There was little or no difference between the sexes in the remaining activity classes (Table 1).

Grazing and browsing

For male goats 31% of their activity involved grazing, with marked differences between seasons. Grazing was most frequent in autumn, then declined steadily

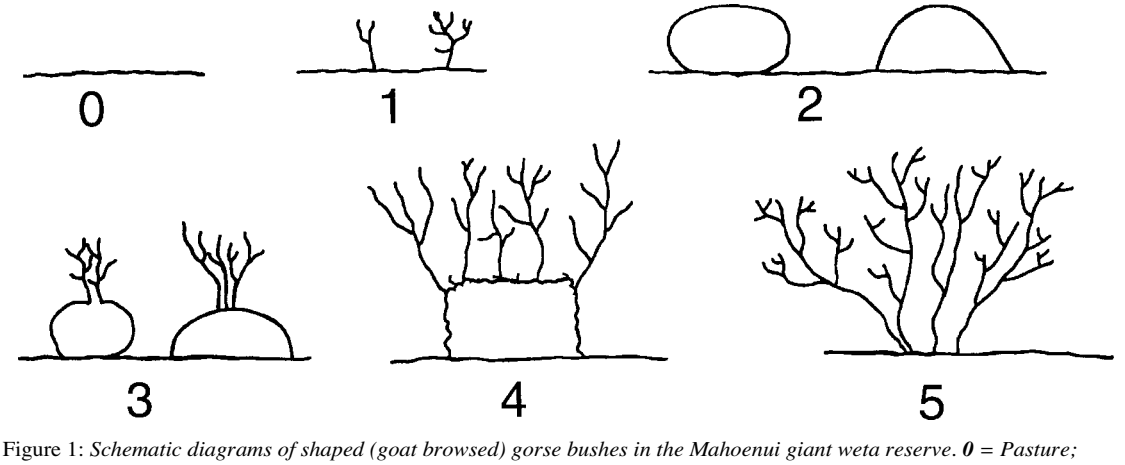

Figure 1: *Schematic diagrams of shaped (goat browsed) gorse bushes in the Mahoenui giant weta reserve.* ***0*** *= Pasture;* ***1*** *= Small unshaped;* ***2*** *= Low dense bush, shaped strongly, no top;* ***3*** *= Low dense bush, shaped strongly with top;* ***4*** *= Large open bush with base slightly shaped and with top;* ***5*** *= Very large open unshaped bush. Not drawn to scale.*

Table 1: *Percentage of time spent in each activity by male and female goats from March 1992 to February 1993 in the Mahoenui giant weta reserve (males, n = 15859; females n = 15876.*

Activity	Male	Female	Average Total
Feeding	44.0	53.0	48.5
Resting	28.0	25.5	26.8
Standing	15.5	10.0	12.8
Walking	8.5	8.0	8.2
Maintenance	2.7	2.7	2.7
Agonism	0.8	0.3	0.5
Other	0.5	0.5	0.5
TOTAL	100.0	100.0	100.0

through winter and spring to a low in summer (Fig. 2). From autumn to spring grazing activity was bimodal, with peaks mid morning and mid afternoon. During summer, however, grazing increased throughout the day to a single peak in mid/late afternoon (Stronge, 1993). For females nearly half of all activity was grazing. The occurrence of grazing was steady during autumn and winter but decreased before levelling out again in spring and summer (Fig. 2). The daily pattern of grazing by females resembled that of males, but the mid morning and mid afternoon peaks from autumn to spring were more distinct. Overall males spent 13% of their time browsing, which increased in frequency from autumn through winter to a high in spring before declining in summer (Fig. 2). Females spent little time browsing (6%) but followed the same seasonal pattern as males, with a peak in spring (Fig. 2).

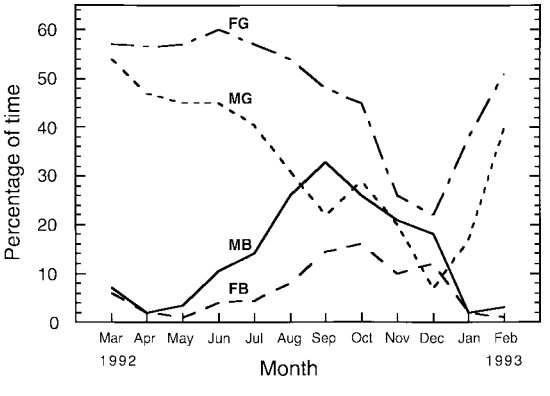

Figure 2: *Seasonal proportion of grazing and browsing by male and female feral goats (March 1992 - February 1993) in the Mahoenui giant weta reserve. MG = male grazing, FG = female grazing, MB = male browsing, FB = female browsing.*

Resting and Standing

For males resting was the most frequent activity after feeding, comprising 28% of all observations over the year (Table 1). From autumn to spring males rested most frequently in the middle of the day, and again just before dusk (when grazing and browsing were uncommon). During summer, however, resting was the dominant activity for males in the first four to five hours of the morning, and the last two to three hours before dusk (Stronge, 1993). Female goats spent 25.5% of their time resting and, as for males, this was their second most common activity. Female resting followed the same pattern as males over the twelve-month study period. For both males and females the occurrence of resting and grazing was complementary, despite the increase in browsing during spring (Fig. 2). Resting was most common during summer for both sexes when feeding was at its lowest (Fig. 3). Males and females stood (looking down or around) 12.8% of the time during autumn, spring and summer (Table 1), and most often in the early morning and late afternoon. In winter, however, standing occurred evenly through the day.

Vegetation transects

Gorse, the major scrub species, occurred at 58% of sample points on transects. Of the 213 gorse bushes recorded in types 1+5, 54% showed obvious signs of goat browsing. The majority of gorse bushes (44%) recorded were types five and four (Fig. 1) with fewer of types three and two. Type one occurred least often (Fig. 4). The relative frequency of each bush type, and the amount of pasture, varied between the eight transects, but in each, types five and four were most common.

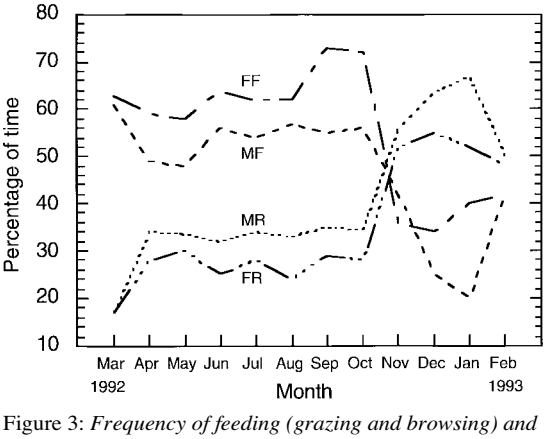

Figure 3: *Frequency of feeding (grazing and browsing) and resting by feral goats (March 1992 - February 1993) in the Mahoenui giant weta reserve. MF = male feeding, FF = female feeding, MR = male resting, FR = female resting.*

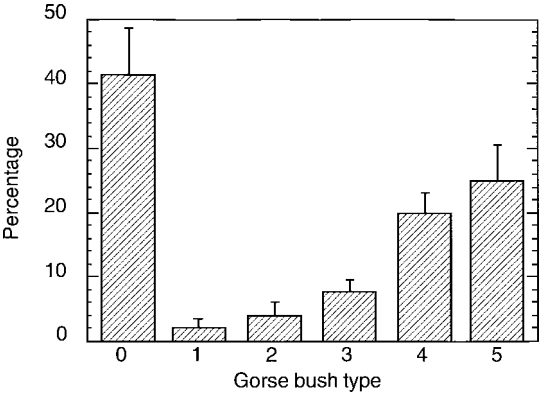

Figure 4: *Mean percentage of each gorse bush type (types 1-5) and pasture type (type 0) for the eight vegetation transects combined. See Fig. 1 for vegetation types.*

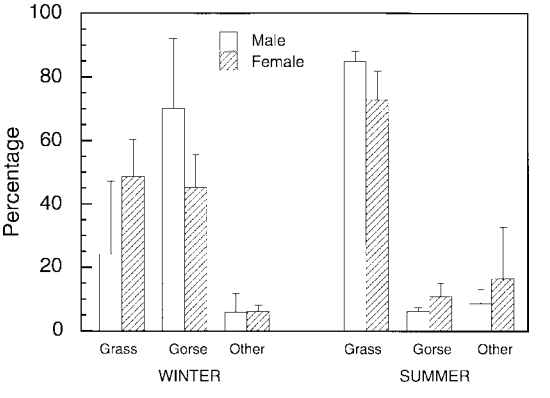

Figure 5: *Mean percentage of grass, gorse and other browse in the rumens of male and female goats autopsied at the Mahoenui giant weta reserve during winter (female n = 11; male n = 4) and summer (female n = 8; male n = 6). Bars show the standard error.*

Nutrient content

Gorse in the Mahoenui reserve had higher concentrations of all chemicals, except Fe and Mn, in summer than in winter (Tables 2 and 3). This pattern is consistent with other studies.

Rumen contents

Rumen contents differed significantly between winter and summer (Fig. 5). Grass made up a large proportion of the diet in summer, but relatively more gorse was eaten in winter. There was no significant difference between males and females in the amounts of grass and gorse in the diet over these seasons. Appendix 1 shows the reproductive status and age class of animals.

Discussion

Activity

Diurnal foraging

Most grazing ungulates feed more in the early morning and the late afternoon than at other times of day (Lickliter, 1987). Even though goats do not

Table 2: *Macro-element chemical composition of gorse in the Mahoenui giant weta reserve in winter (June 1992) and summer (February 1993) compared with other studies. Units are parts per hundred by weight of dry matter.*

Source	N	P	K	S	Ca	Mg	Na
Egunjobi (1971)[1]	1.6	0.07	0.7	0.14	0.34	0.22	0.13
Radcliffe (1986)							
winter[2]	1.74	0.06	0.65	0.09	0.26	0.14	-
summer	2.7	0.12	1.0	0.14	0.6	0.26	-
Howe *et al.* (1988)							
winter	4.0	0.17	1.7	0.25	0.74	0.34	0.34
summer	4.8	0.32	3.1	0.24	0.69	0.48	0.5
Lambert *et al.* (1989)[3]	1.8	0.1	1.0	0.13	0.31	0.13	0.26
This study							
winter	1.7	0.11	0.8	0.12	0.34	0.22	0.14
summer	3.1	0.3	1.8	0.18	0.51	0.3	0.24
Recommended[4]	1.7	0.18	0.4	0.13	0.17	0.1	0.05

[1]Values are means across all seasons
[2]Values are means over two years
[3]Values are means across three seasons
[4]Recommended level for adequate diet for lactating ewe with a single lamb (Grace 1983, in Lambert *et al.* 1989)

Table 3: *Micro-element chemical composition of gorse in the Mahoenui giant weta reserve in winter (June 1992) and summer (February 1993) compared with other studies. Units are parts per million by weight of dry matter.*

Source	Cu	Fe	Mn	Zn	B
Howe *et al.* (1988)					
winter	5	174	90	34	-
summer	6	62	84	36	-
Lambert *et al.* (1989)[1]	4	89	59	44	-
This study					
winter	5	67	124	26	8
summer	8	59	71	44	14
Recommended[2]	4.4	30	25	24	-

[1]Values are means across three seasons
[2]Recommended level for adequate diet for lactating ewe with a single lamb (Grace 1983, in Lambert *et al.*, 1989)

graze or browse exclusively (Lu, 1988), bimodal peaks of foraging have been identified by Kilgour and Ross (1980) and Alley (1991), and occurred at Mahoenui in all seasons except summer (Stronge, 1993). Bimodal foraging was, however, more sharply defined in females than in males. Females usually left overnight bedding sites first to begin feeding, which might be explained by the nutritional demands of gestation and lactation (Flowerdew, 1987).

Seasonal foraging

Seasonal patterns of foraging in males and females were different. Females grazed more than males in every season, but males browsed more than females. Differences between the sexes in both the species composition of the diet, and in its quality, have been reported for a number of ungulate species (Putman, Cuplin and Thirgood, 1993). For Rocky Mountain sheep, Shank (1982) reported differences in the quality of foods consumed by males and females, concluding that they did not arise from "preference", but because rams and non-rams (ewes, lambs and yearlings) self-segregated onto portions of the range containing distinct forage plants. Staines, Crisp and Parish (1982) found that sexual dietary differences in red deer were even maintained in populations where males and females occurred together. Males and females also ate different proportions of the same plants, for instance females took more grasses than did males. However, most authors have not discussed any differences for goats (Riney and Caughley, 1959; Atkinson, 1964; Bullock, 1985; Alley, 1991; Brockie, 1992; Genin and Pijoan, 1993). On Mt Taranaki Mitchell *et al.* (1987a) found that the diet in forest did not vary with sex, but Clark (1974) inferred from gut nematodes in autopsied goats that females spent more time grazing than males, a conclusion borne out by this study.

At Mahoenui, males and females occupy overlapping home ranges which may account for some differences in their foraging — specifically, the greater use of gorse browse by males compared to females.

Differences in diet are most pronounced in dimorphic ungulates. New Zealand feral male goats weigh 1.3 to 1.85 times more than females (Rudge, 1990). Illius and Gordon (1987) showed that, other things being equal, weight differences greater than 20% between males and females would be expected to lead to exclusion of the larger animals from swards where grazing pressure had reduced sward height to some critical level. Females, therefore, would be able to graze more economically on swards with a low standing crop, where larger males would be unable to gather enough food for their nutritional requirements. Because of the allometric relations of bite size and metabolic requirements to body size, small animals are able to subsist on shorter swards than large animals (Illius and Gordon, 1987). This causes the larger males to turn to other foods in order to obtain sufficient nourishment.

New Zealand feral goats eat many kinds of plants. Goats sampled at least 120 plant species in the Rimutaka Ranges (Rudge, 1990); 42 species on Raoul Island (Parkes, 1984); and over 68 species on Mt Taranaki (Mitchell *et al.*, 1987a). On Great Island in the Three Kings group, rumens contained mostly grasses, sedges and herbs, suggesting that the goats had been grazing (Turbott, 1948). However, palatable trees and shrubs on the island were also eaten to a high browse line implying that the goats had little choice other than to graze. At Mahoenui Reserve the high proportion of gorse and grass in the diet reflects the lack of variety in available food. Very few native tree species occur in areas where the goats were shot. Those trees that did occur are mature and well above the goats' browse range. Rumen analyses are supported by direct observations, showing that grass comprised most of the diet for both sexes during summer, with gorse being a minor constituent. During winter, however, the percentage of gorse in the diet increased considerably for both sexes.

Resting/Standing

Mahoenui goats showed little difference in the amount of time males and females spent resting. However, when combined with standing, males spent relatively more time throughout the year in these activities. This is consistent with the consumption by males of lower quality forage, and their probable need, therefore, to spend more time ruminating than females taking higher quality pasture.

Effects of cattle on goat feeding

Approximately 105 head of domestic cattle (in-calf Angus and Hereford/Angus crosses) were introduced to the reserve in August 1992 from a neighbouring farm, and stayed there with their calves until January 1993. Initially the cattle grazed near the reserve gate, but over several weeks they moved slowly down the fire breaks towards the river, and finally into the bottoms of the valleys (N. Rauputu, *pers. comm.*). Cattle may benefit feeding goats by breaking down gorse and forcing tracks through it en-route to grazing. By doing this they improve the access for goats to gorse bushes, and increase the penetration of light to lower levels, stimulating new green growth. Thus cattle enable goats to better exploit gorse bushes (Sherley, 1992) and improve pasture by reducing weeds (Anon, 1989).

Nutritional Value of Gorse

Gorse collected during winter was hard and sharp with little or no new growth, but during early summer when new terminal spines were being formed the foliage was soft and pliable. In summer gorse is most digestible and nutritious (Radcliffe, 1986).

In the Manawatu, gorse harvested during early summer has mineral concentrations likely to be adequate for the requirements of growing goats and sheep (Howe *et al.,* 1988). However, as the gorse matures, concentrations of P, N and S may fall below the level necessary to sustain growth in goats. Levels of N, Ca and Mo in gorse were sufficient for goat nutrition in Canterbury (Radcliffe, 1986), but levels of S, K, Cu, Mg and particularly P were low. The nitrogen in mature foliage was adequate to maintain goat condition, but levels sufficient for goat growth occurred only in spring and early summer. In the Manawatu Lambert *et al.* (1989) found that concentrations of minerals, especially P, were low in gorse and concluded that gorse was no more than a maintenance food for goats. In practice the low phosphorus content of gorse at Mahoenui may not be a problem because animals would be able to supplement gorse browse with pasture containing higher levels of P. Knowledge of the requirements of goats for major minerals and trace elements is fragmentary (Kessler, 1991), but Mitchell, Grace and Fordham (1987b) assumed that goats have similar requirements to sheep. If this is so, levels of P at Mahoenui were lower in winter than those recommended for sheep, and the levels of S were marginally deficient for animal production.

Because gorse starts growing later than pasture plants, and finishes earlier (Anon, 1989) gorse is unsuitable food for reproductive goats. Females in late pregnancy or early lactation have high nutritional requirements, as do growing kids. Poor kidding percentages are inevitable if females have a diet consisting mainly of weeds during mating and pregnancy. Also, young kids will grow slowly due to poor milk production by their mothers (Ministry of Agriculture and Fisheries, 1988).

At Mahoenui most female goats are pregnant and lactating in autumn and winter (Appendix 1) when gorse is not very nutritious and is essentially a maintenance food. Accordingly, any females depending mainly on gorse at this time would not be expected to do well. Macferson (1993) noted, however, that protein (or N) in pasture is higher than that required by lactating females during autumn, winter and spring. Therefore, in order to meet their reproductive demands during pregnancy and lactation, female goats at Mahoenui would need to consume pasture in preference to gorse. Male goats stepped up their consumption of gorse during winter and early spring when nutritionally it is poorest. They were, however, often observed to take gorse flowers which have higher mineral concentrations than the green foliage (Radcliffe, 1986). Giant weta also feed on the gorse foliage and flowers (Sherley and Hayes, 1993). There is, therefore, a clear dietary overlap between weta and goats, but nocturnal foraging by weta and essentially daylight foraging by goats minimises the possible interaction.

Goats are more selective feeders than cattle and sheep, tending to select a higher proportion of green leaves and a lower proportion of stem and dead materials (Flachowsky and Tiroke, 1993). Goats also show a superior utilisation of low quality forage than other ruminants such as sheep (Alam, Poppi and Sykes, 1985). Even so, gorse could be considered adequate for goat growth at Mahoenui only during late spring / early summer when new plant growth occurs.

Vegetation transects

Prior to the study we suspected that goats were important in maintaining weta habitat by browsing gorse into dense bushes which gave weta protection from predators such as rats. However, few of the gorse bushes in the reserve were severely modified by goat browsing. Although goats do shape gorse into small, dense, spherical bushes, the frequency of such bushes is low. Most of the gorse in the reserve consists of large open bushes (type 5). Richards (1994) found that the average number of giant weta in gorse decreased from type 5 to type 2 bushes, indicating that the gorse itself is important to weta, not the extent to which gorse is modified by goat browsing.

Acknowledgements

We would like to thank the New Zealand Department of Conservation for their general support. Doug Taucher, Roger Lentle, Grace Richards, and Ngatai Rauputu all provided valuable assistance in the field. Murray Potter commented most helpfully on the manuscript and Petra van Kan and Erica Reid patiently typed the drafts. Two anonymous referees made constructive comments on the manuscript.

References

Alam, M.R.; Poppi, D.P.; Sykes, A.R. 1985. Comparative intake of digestible organic matter and water by sheep and goats. *Proceedings of the New Zealand Society of Animal Production. 45:* 107-111.

Alley, J.C. 1991 (unpublished). *Aspects of the behavioural ecology of captive feral goats with emphasis on mother-kid relationships*. M.Sc. Thesis, Massey University, Palmerston North, N. Z. 123 pp.

Anon. 1989. Weeds controlled. *New Zealand Farmer 111:* 14.

Atkinson, I.A.E. 1964. Relations between feral goats and vegetation in New Zealand. *Proceedings of the New Zealand Ecological Society 11:* 39-44.

Brockie, R. 1992. *A Living New Zealand Forest*. David Bateman, Auckland, N.Z.. 172 pp.

Bullock, D.J. 1985. Annual diets of hill sheep and feral goats in southern Scotland. *Journal of Applied Ecology 22:* 423-433.

Clark, J.M. 1974 (unpublished). *Ecology of feral goats (Capra hircus L.) in the southern King Country New Zealand*. M.Sc. Thesis. University of Canterbury, Christchurch, N.Z.. 116 pp.

Egunjobi, J.K. 1971. Ecosystem processes in a stand of *Ulex europaeus* L. II. The cycling of chemical elements in the ecosystem. *Journal of Ecology 59:* 669-678.

Flachowsky, G.; Tiroke, K. 1993. Influence of type of feeding and rumen incubation time on in sacco dry matter degradability of ryegrass, straw and concentrate in sheep and goats. *Small Ruminant Research 9:* 321-330.

Flowerdew, J.R. 1987. *Mammals : Their reproductive biology and population ecology*. Edward Arnold Publications, London, U.K. 241 pp.

Genin, D.; Pijoan, A.P. 1993. Seasonality of goat diet and plant acceptabilities in the coastal scrub of Baja California, Mexico. *Small Ruminant Research 10:* 1-11.

Holst, P.J.; Denny, G.D. 1980. The value of dentition for determining the age of goats. *International Goat Sheep Research 1:* 41-47.

Howe, J.C.; Barry, T.N.; Popay, A.I. 1988. Voluntary intake and digestion of *gorse (Ulex europaeus*) by goats and sheep. *Journal of Agricultural Science (Cambridge) 111:* 107-114.

Illius, A.W.; Gordon, I.J. 1987. The allometry of food intake in grazing ruminants. *Journal of Animal Ecology 56:* 989-999.

Kessler, J. 1991. Mineral nutrition of goats. In: Morand-Fehr, P. (Editor), *Goat nutrition*, pp. 104-119. *European Association for Animal Production Publication no. 46*. Pudoc, Wageningen, The Netherlands. 308 pp.

Kilgour, R. and Ross, D.J. 1980. Feral goat behaviour - a management guide. *New Zealand Journal of Agriculture 141(5):* 15-20.

Lambert, M.G.; Jung, G.A.; Harpster, H.W.; Lee, J. 1989. Forage shrubs in North Island hill country 4: Chemical composition and conclusions. *New Zealand Journal of Agricultural Research 32:* 499-506.

Lickliter, R.E. 1987. Activity patterns and companion preferences of domestic goat kids. *Applied Animal Behaviour Science 19:* 137-145.

Lu, C.D. 1988. Grazing behavior and diet selection of goats. *Small Ruminant Research 1:* 205-216.

Macferson, H. 1993. Mid summer grass. *Dairy Goat News. February:* 13-14.

Ministry of Agriculture and Fisheries. 1988. Goat management for weed control. *Goat Health and Production 2:* 216-217.

Mitchell, R.J.; Fordham, R.A. and John, A. 1987a. The annual diet of feral goats (*Capra hircus* L.) in lowland rimu-rata-kamahi forest on eastern Mount Taranaki (Mount Egmont). *New Zealand Journal of Zoology 14:* 179-192.

Mitchell, R.J.; Grace, N.D.; Fordham, R.A. 1987b. The nitrogen and mineral content of seven native plant species preferred by feral goats (*Capra hircus* L.) in lowland rimu-rata-kamahi forest on eastern Mount Taranaki (Mt. Egmont). *New Zealand Journal of Zoology 14:* 193-196.

Parkes, J.P. 1984. Feral goats on Raoul Island II. Diet and notes on the flora. *New Zealand Journal of Ecology 7:* 95-101.

Putman, R.J.; Culpin, S. and Thirgood, S.J. 1993. Dietary differences between male and female fallow deer in sympatry and in allopatry. *Journal of Zoology (Lond). 229:* 267-275.

Radcliffe, J. 1986. Gorse - a resource for goats? *New Zealand Journal Experimental Agriculture 14:* 399-410.

Richards, G. 1994 (unpublished). *Behaviour and movement of the Mahoenui giant weta*

Deinacrida *sp*. M.Sc. Thesis, Massey University, Palmerston North, N.Z. 184 pp.

Riney, T.; Caughley, G. 1959. A study of home range in a feral goat herd. *New Zealand Journal of Science 2:* 157-170.

Rolston, M.P.; Clark, D.A.; Lambert, M.G. 1983. Scrub and coarse weed control by goats and sheep: Ballantrae trial. *Proceedings of the Ruakura Farmers Conference* pp 26-36. Ministry of Agriculture and Fisheries, Wellington, N.Z.

Rudge, M.R. 1990. Feral Goat. *In:* King, C.M. (Editor). *The Handbook of New Zealand Mammals*. pp 406-423. Oxford University Press, Auckland, N.Z. 600 pp.

Shank, C.C. 1982. Age-sex differences in the diets of wintering Rocky Mountain bighorn sheep. *Ecology 63:* 627-633.

Sherley, G.H. 1992. Gorse and goats : Are pest species necessary for the conservation of a new giant weta (*Deinacrida* sp.) at Mahoenui, King Country? *Proceedings of the Entomological Society New Zealand 41st Annual Conference* , 26-36.

Sherley, G.H.; Hayes, L.M. 1993. The conservation of a giant weta (*Deinacrida* n. sp. Orthoptera: Stenopelmatidae) at Mahoenui, King Country : habitat use, and other aspects of its ecology. *New Zealand Entomologist 16:* 55-68.

Staines, B.W.; Crisp, J.M.; Parish, T. 1982. Differences in the quality of food eaten by red deer (*Cervus elaphus*) stags and hinds in winter. *Journal of Applied Ecology. 19:* 65-77.

Stronge. D.C. 1993 (unpublished). *Aspects of the ecology of feral goats (*Capra hircus *L.) in the Mahoenui giant weta reserve*. M.Sc. Thesis. Massey University, Palmerston North, New Zealand. 85 pp.

Thornton, J. 1985. *Field guide to New Zealand geology*. Heinemann Reed, Auckland, N.Z. 226 pp.

Turbott, E.G. 1948. Effect of goats on Great Island, Three Kings, with descriptions of vegetation quadrats. *Records of the Auckland Institute and Museum 3:* 253-272.

Appendix 1: *Age data and female reproductive status of feral goats shot in winter 1992 and summer 1993 in the Mahoenui giant weta reserve. Aging was by tooth eruption sequence (Holst and Denny, 1980; Rudge, 1990).*

Age class (years)	Winter	Summer
0 - 1	3	5
>1 - 2	2	1
>2 - 3	6	5
>3	8	3
Female status	**Winter (n = 16)**	**Summer (n = 8)**
Lactating	9	2
Pregnant	2*	0

* Both pregnancies were single conceptions