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FERAL GOATS ON RAOUL ISLAND
II. DIET AND NOTES ON THE FLORA

Summary: Feral goats *(Capra hircus)* have been hunted intensively every year since 1972 on the 2950 ha Raoul Island to protect the indigenous vegetation. Rumen samples taken from 103 goats shot in 1982-83 showed that a minimum of 48 species of vascular plants, mostly indigenous species, were eaten. Only seven foods - *Metrosideros kermadecensis, Coriaria arborea* var. *kermadecensis, Me/icytus ramillorus* spp. *ramiflorus, Rhopalostylis baueri* var. *cheesemanii,* various grasses and sedges, *Blechnum* spp., and the fungus *Auricularia* sp. - made up 89% of the diet by dry weight. The reduction in goat numbers has allowed most of the palatable species to regenerate, and rare, endangered plants such as *Hebe breviracemosa, Homalanthus polyandrus,* and *Boehmeria australis* var. *dealbata* are now increasing.

Keywords: Feral goats; Capra hircus; Bovidae; diet; Raoul Island; control; forest changes.

Introduction

Raoul Island (Fig. 1), 2950 ha in extent, is the largest island in the Kermadec group and is situated equidistant between the North Island of New Zealand and the Tongan Islands. The indigenous flora has some tropical elements but the dominant species are closely allied to the flora of New Zealand, the nearest large land mass. Forty ferns and 64 flowering plants are indigenous to Raoul Island, and four ferns and 17 flowering plants are endemic. One hundred and eighty-one species of introduced vascular plants have been recorded from Raoul Island, but only 53 species were recently considered to be widespread (Sykes, 1977).

Raoul island was gazetted a Flora and Fauna Reserve in 1934 and attempts have been made to control or exterminate such introduced biota as feral goats *(Capra hircus)* (Parkes, 1984), feral cats *(Felis catus),* and various introduced plants (Devine, 1977). Goats were liberated on the island before 1836 (Straubel, 1954) and in 1908, Oliver (1910) noted that they were damaging the vegetation by thinning the undergrowth, restricting the groWth of some terrestrial seedlings and barking some trees so that certain plants which had been once common were then restricted to inaccessible places. Several later visitors reiterated his concern (Merton, 1968; Sykes, 1969, 1977) and proposals were made to exterminate the herd. Government hunting campaigns began in 1937 and had reduced the herd from at least several thousand to the verge of extinction by 1983 (Parkes, 1984).

This paper records the diet of the goats during the final phase of the hunting campaign and reports some of the changes in the vegetation coincident with and induced by the reduction in browsing pressure.

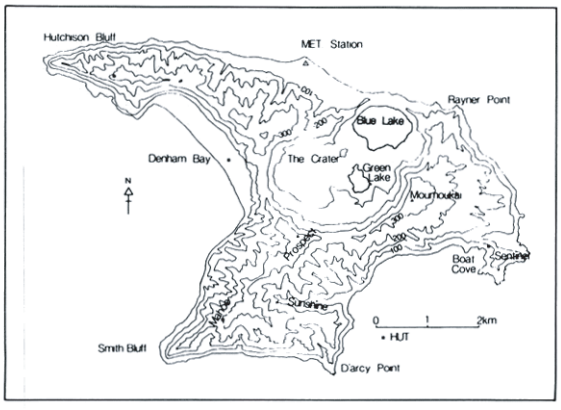

Figure 1: *Map of Raoul/sland showing topography and places mentioned in the text.*

Methods

Samples of rumen contents of 103 shot goats (70 F, 33 M) were collected by New Zealand Forest Service (NZFS) hunters during control operations on the island from June-December 1982 and from April-December 1983. These samples consisted of about 200 ml taken from one randomly chosen site in each rumen and preserved in 10% formalin. Each sample was washed through a 4 mm sieve; the larger fraction was sorted macroscopically, oven-dried at 70 ∞C for three days then weighed, and the smaller fraction was searched for additional species but not sorted or weighed. Nugent (1983), in evaluating various methods of deer diet analysis, recommended a 4 mm sieve for white-tailed deer *(Odocoileus virgineanus)* rumen samples. This sieve size allowed, in a reasonable time, most fragments to be identified and the composition

estimates were not grossly biased compared with smaller (2 mm) sieved samples. It was assumed therefore that a reasonable estimate of the composition of the goat's diet would be revealed by fragments greater than 4 mm. Because layering of the rumen contents is known to occur in some ungulates (Wilson, Hirst and Ellis, 1977) substantial biases may result from taking small samples from one site in the rumen. Therefore data from all rumens were pooled to reduce this potential bias.

Principal foods were defined arbitrarily as those contributing more than 2% by dry weight to the diet. Preferred foods were defined as those encountered more often in the diet than expected from their availability in the vegetation (Petrides, 1975).

During an eight day visit to Raoul Island in December 1982, I made qualitative descriptions of the forest vegetation. Rare species and those known to be eaten by goats were particularly noted. These notes, observations made in annual reports submitted by leaders of NZFS hunting expeditions, and previously published descriptions of the effect of goats on the flora are used to describe some of the more obvious changes induced by the reduction in goat numbers.

Botanical nomenclature follows Sykes (1977).

Results

Diet

Forry-eight species of plants were identified in the rumen samples with an average of 6.3± 0.4 (95% C.L.) in each sample (range 2-15).

Eighty-seven percent by dry weight of the samples were identified to at least generic level. Indigenous species comprised 99% of the identified material (by dry weight) and endemic taxa, 54%. Some known foods could not be identified past the generic level, e.g., the endemic *Coprosma* spp. (*C. acutifolia* and *C. petiolata),* the tWo endemic tree ferns *(Cyathea milnei* and C. *kermadecensis),* and the tWo *Blechnum* spp. (B. *procerum* and *B. norfolkianum)* were all eaten, but many fragments could not be assigned to specific level. The only grass separated was *Oplismenus imbecillis,* which has distinctive leaves. All other grasses and sedges were pooled, making up 10.5% by dry weight. *Digitaria pruriens, Stenotaphrum secundatum, Paspalum* sp., *Bromus* sp., and *Cyperus ustulatus* were sometimes identified from flowers and seed heads in this pooled fraction.

Eight foods were classed as principal foods and together made up 89% of the diet by dry weight (Table 1). Most of these are readily available to the goats.

Pohutukawa *(Metrosideros kermadecensis),* the dominant canopy tree, was eaten by most goats and formed 32% of their diet. In 1982, abundant epicormic shoots on leaning trunks, windfalls and in some areas, seedlings (Fig. 2) were accessible to goats. The second most important dietary item was the *Blechnum* ferns. Both B. *norfolkianum* and B. *procerum* are common terrestrial plants on the island and were freely available to goats. The endemic tutu *(Coriaria arborea* var. *kermadecensis)* is a widespread shrub on eroded and riparian sites. Its leaves are usually within browse range as new branches arise from the plant's base and older branches are often bent to ground level. Despite the toxicity of the genus to many other animals (Connor, 1977), it formed the third most iml'∞rtant item in the goat's diet.

Two main species from among the unsorted grasses and sedges were identified from seed heads. These were the grass *Digitaria pruriens* and the sedge *Cyperus ustulatus,* both of which were recorded by Sykes (1977) as common in open places, coastal talus slopes, and headlands. Although grasses and sedges were ranked fourth by dry weight, they occurred in 82% of the samples, second only to pohutukawa. Both the leaves and fruit of the Raoul Island nikau palm *(Rhopalostylis baueri* var. *cheesemanii)* were widely available to the goats. Dense standards of

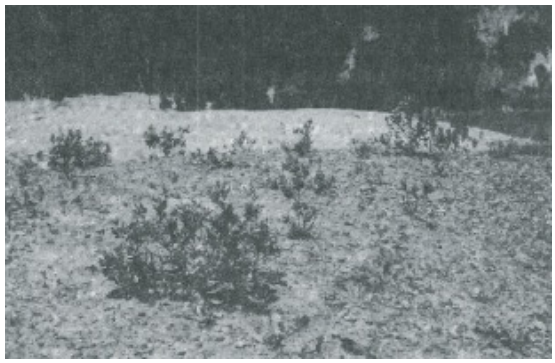

Figure 2: *Pohutukawa seedlings on pumice flats formed in the 1964 eruption, Raoul Island, 1982.*

Table 1: *Diet of 103 feral goats shot on Raoul Island, 1982-83. (• endemic to Raoul Island; * introduced to Raoul Island; (P) Principal food; trace items weighed less than 0.5g, but are included in total weights.)*

Species	Dried wt. (g)	% of total dried wt. (>1%)	% Occurrence	% Samples dominated
Metrosideros kermadecensis • (P)	15.9	31.7	90.3	35.0
Coriaria arborea var. *kermadecensis* • (P)	6.0	11.9	61.2	12.6
Melicytus r. spp. *ramiflorus* (P)	2.5	4.9	32.0	3.9
Coprosma spp. •	0.4		20.4	
Pseudopanax arboreus var. *kermadecensis* •	0.4		3.9	1.9
Melicope ternata	0.4		6.8	
Solanum nodiflorum	0.2		1.9	
Scaevola gracilis •	0.2		9.7	
Myrsine kermadecensis •	0.1		6.8	
*Leontodon taraxacoides**	0.1		5.8	
Corynocarpus laevigatus	0.1		3.9	
Anagal/is arvensis ssp. *arvensis**	trace		1.9	
*Sonchus oleraceus**	trace		1.9	
*Rumex brownii**	trace		1.0	
*Eurphorbia peplus**	trace		4.9	
*Veronica arvensis**	trace		1.0	
Myoporum obscurum •	trace		2.9	
Lepidium oleraceum var. *frondosum*	trace		1.0	
Macropiper excelsum var. *psittacorum*	trace		1.0	
Boehmeria australis var. *dealbata* •	trace		1.0	
*Bidens pilosa**	trace		1.9	
*Cirsium vulgare**[1]	trace		1.0	
Unknown Dicotyledonae	0.4		21.4	1.0
TOTAL DICOTYLEDONAE	26.7	53.2		
Grasses and sedges (P)	5.2	10.5	81.6	12.6
Rhopalostylis baueri var. *cheesemanii* (fruit) (P)	3.1	6.2	12.6	3.9
R. *baueri* var. *cheesemanii* (P)	1.1	2.2	13.6	1.0
*Oplismenus imbecillus**	0.3		3.9	
TOTAL MONCOTYLEDONAE	9.7	19.4		
Blechnum spp. (P)	7.2	14.3	79.6	20.4
Cyathea spp.	0.4		10.7	
Phymatosorus diversifolius	0.3			
Arachnoides aristata	0.3		16.5	
Adiantum sp.	0.2		13.6	
Pyrrosia serpens	0.1		4.9	
Doodia milnei •	0.1		4.9	
Asplenium flaccidum	0.1		14.6	
Hymenophyl/um demissum	0.1		12.6	
Asplenium obtusatum	0.1		1.0	1.0
Nephrolepis hirsutula	0.1		1.0	
Nephrolepis cordifolia	trace		1.9	
Hypolepis tenuifolia	trace		1.0	
Unidentified rachis	trace		1.0	
TOTAL FILICOPSIDA	9.0	17.9		
Auricularia sp. (P)	3.7	7.4	16.5	7.8
Lichen	0.1		10.7	
Moss	trace		2.9	
Unidentified scraps and stalks	1.0	2.0		
TOTAL PLANT	50.1			

young palms are widespread in the wetter forests (Fig. 3), and the ground beneath adult palms is often littered with fallen fruit. The importance of the nikau fruit as a food is over-estimated by dry weight measurements as a large part of the fruit is woody, and presumably indigestible, endosperm.

Mahoe *(Melicytus ramiflorus)* is a common sub-canopy forest tree on Raoul Island. In 1982 the trees were producing many epicormic shoots accessible to goats, although seedlings and saplings were rare.

The fungus *Auricularia* sp. was the final principal food item (Fig. 4). Unlike the other principal foods, it was also clearly a preferred food as it is not an abundant species. However it must be widespread on Raoul Island as the 17 goats that had eaten it were shot at widely sepaarated places.

The minor food items ranged from those eaten by many goats but rarely in quantity (e.g., *Coprosma* spp. *Phymatosorus diversifolius)* to those rarely eaten because either the species are unpalatable and/or only ingested accidentally (e.g., *Bidens pilosa* which occurred only as seeds), or are rare (e.g. *Boehmeria australis* var. *dealbata),* or are restricted to small areas on the island (e.g., *Macropiper excelsum* var. *psittacorum*).

Figure 3: *Dense standards of nikau palms, Raoul Island, 1982.*

Figure 4: Auricularia *sp. on mahoe, Raoul Island, 1983.*

Changes in the vegetation

The distribution of goats has been progressiveiy limited and their density progressively lowered since 1972 when annual hunting expeditions began (Parkes, 1984). This has reduced browsing pressure and has allowed many plant species to regenerate successfully.

Pohutukawa regeneration had been limited by 1966 so that Sykes (1969) reported seeing few or no young plants in most areas, and predicted the species eventual disappearance over large parts of the island. In 1982, terrestrial seedlings and young trees were common, particularly in the crater and on cliffs at Denham Bay, and epicormic shoots were abundant on most trunks (Fig. 5).

The other principal food tree species have also responded to lower browsing pressure. Tutu, for example, has formed tall stands on several eroded sites around the crater wall since 1981 (c. F. Buchanan, pers. comm.). In 1966, mahoe was climbed by goats and browsed to 10m or more above the ground (Sykes, 1969), but most trees in 1982 had many epicormic shoots available to goats at ground level.

The nikau palm has always been abundant despite goats. Oliver (1910) reported that only young palms were browsed, and Sykes (1969)

Figure 5: *Epicormic shoots on old windthrown pohutukawa, crater rim, Raoul Island 1982.*

claimed that goats could check the development of seedlings. In 1982, palms of all sizes were common, with impenetrable stands of young palms, usually without trunks in some areas (Fig. 3). Here, the palms were dense enough to suppress the usually ubiquitous introduced aroid lily *(Alocasia macrorrhiza).*

Oliver (1910) thought that *Pseudopanax arboreus* var. *kermadecensis* would become rare or even extinct because of browsing by goats. The species was described as uncommon in 1966 by Sykes (1969), although scattered adult trees were producing seedlings which were eaten by the goats. In 1982, many saplings and seedlings were growing along the Prospect-Mahoe ridge, particularly along south-facing slopes.

Coprosma acutifolia, a major sub-canopy species in 1908 (Oliver, 1910), was eaten out by goats so that Sykes (1969) described it as 'uncommon' but it is now plentiful, at least along the Denham Bay-Smith Bluff faces.

In 1908, young plants of the tree ferns *(Cyathea* spp.) were 'extremely rare' (Oliver, 1910), although mature plants were plentiful. In 1966, mature plants were becoming less common and regeneration was still 'virtually absent' (Sykes, 1969). Both authors blamed goats. Since the removal of most of these animals, the 1908 situation has reversed, so that in 1982 young ferns were plentiful but adults were rare.

The status of some rare species may also be improving in the absence of browsing by goats. The endemic *Hebe breviracemosa* was last seen by Oliver (1910) and was listed as 'presumed extinct' in the New Zealand Red Data Book (Williams and Given, 1981). A single young plant was discovered by R. Scrimgeour on Hutchinson's Peninsula in 1983 (Fig. 6). *Homalanthus polyandrus,* classed as 'vulnerable' in the Red Data Book, was reduced to a few trees in the early 1970's (Sykes, 1977), but now forms substantial groves, particularly along the Boat Cove road and in canopy gaps around the island.

The endemic tree *Boehmeria australis* var. *dealbata* was also reduced to a few widely scattered individuals by 1966 (Sykes, 1977). Adult trees are still rare, but seedlings and saplings are common in Sunshine Valley (W. Fleury, pers. comm.) and were seen in 1982 along the Prospect-Mahoe ridge.

Some other rare species - *Pisonia umbellifera, Pittosporum crassifolium* and *Asplenium*

Figure 6: Hebe breviracemosa, *Raoul Island, 1983.*

shuttleworthianum - are still rare and have not responded to the removal of most of the goats.

Discussion

This study did not measure the relative availability of the various plants so that, except in general terms, food preference ratings could not be assigned to species.

The only species in the goat's present diet that was both a principal and a preferred food was the fungus *Auricularia* sp. One of the reasons for my visit to Raoul Island was to assess the potential for using a natural vegetation - 1080 gel poisoning technique developed by J. A. Peters (Parkes, 1983) to kill goats. The present abundance of other principal foods ruled out their use as useful baits, but the fungus, being preferred, may be worthy of further investigation.

Three species *(Disphyma australe, Rhagodia triandra,* and *Homalanthus polyandrus)* noted by Sykes (1977) as being eaten by goats were not identified in the rumen samples despite being available to goats. There are three possible explanations for their absence. First they may have been mis-identified, although *Homalanthus* at least has a distinctive leaf and is unlikely to have been overlooked. Second, they are possibly seasonal foods so that the lack of samples over January-March may account for the absence. Third, they may be less preferred species which were eaten only when goats were more numerous and food less abundant. This latter explanation may also account for the scarcity of ngaio *(Myoporum obscurum)* in the rumen samples. Although Sykes (1969, 1977) claimed this species was being destroyed by goats, it was not a major item in the diet (Table 1) and no browse was seen on trees in 1982.

Only 1 % by dry weight of the identified material in the diet consisted of introduced species, of which the most widespread and common (e.g., *Alocasia macrorrhiza)* are unpalatable. Goats may have limited the spread of some plant introductions, *Citrus* for example. With the reduction of the herd, these and new introductions may spread more easily over the island.

Previous work on the diet of feral goats in New Zealand forests has been based on observations of their browse on understorey plants. Atkinson (1964) divided those plants exposed to browsing into "(a) high-preference species which include the majority of plants although there is considerable variation in the extent to which any particular species is browsed; (b) low-preference species (of which he listed 19); (c) unpalatable species" (of which he listed 12). Leathwick, Hay and Fitzgerald (1983) have used this as evidence of goats' "wide food preferences" and claim, less fairly, that they are "unselective" feeders.

Raoul Island goat's diet contained only 32 of the 104 available indigenous plants and although it is difficult to classify these 32 according to Atkinson's types, their diet is apparently not as wide as mainland herds, at least when the most preferred foods are freely available as at present. The few principal dietary food items show that Raoul Island goats are not unselective feeders, and nor, I suspect, are mainland goats. It is unlikely that many more species would be added to their listed diet on Raoul Island if samples were taken during January-March, or if the unknown fragments were identified, and it is improbable that any that were thus added would be principal foods.

Taylor (1968) cautioned against the automatic eradication of introduced mammals on modified islands with apparently balance ecosystems of indigenous survivors and new introductions, at least until the ecological implications of such actions were understood. The ecological implications of not controlling the goats on Raoul Island are not fully understood, but would clearly be inimicable to the management aim of maintaining a stable and diverse indigenous ecosystem. The goats destabilised the ecosystem, first by altering the understorey composition by decreasing palatable species such as *Cyathea* spp., *Pseudopanax arboreus* var. *kermadecensis, Melicytus r. ramiflorus, Coprosma* spp., and *Melicope ternata* which have been replaced by unpalatable species such as *Myrsine kermadecensis* and *Ascarina Lucida* var. *lanceolata,* and second by affecting the succession following the collapse of parts of the dominant pohutukawa forests during cyclones.

Once, presumably prior to the introduction of goats, windthrown pohutukawa could regenerate by producing new trunks from epicormic shoots on the fallen trees. Areas of mature trees along the ridges around the crater have developed in this way. However, more recent windthrown pohutukawa on ridges around Sunshine Valley have produced no large epicormic trunks and the vegetation has developed into dense standards of nikau palms or the tall fern *Pteris comans.*

The continued presence of goats would also

lead to a decrease in species diversity as such plants as *Hebe breviracemosa, Boehmeria australis* var. *dealbata* were eliminated.

The ecological implications of exterminating the goats are not necessarily simply the reverse of these changes, although their removal should permit the maintenance and regeneration of the dominant pohutukawa forest with a full complement of the indigenous plants.

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