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VEGETATION ON GOAT-FREE ISLANDS IN A LOW-ALPINE LAKE, PAPAROA RANGE, AND IMPLICATIONS FOR MONITORING GOAT CONTROL OPERATIONS

Summary: Pronounced differences between the vegetation of four islands in a low-alpine lake compared to an adjacent mainland site are attributed to browsing by feral goats. The herbs *Anisotome haastii* and *Ourisia macrocarpa* are significantly more abundant on the islands, where they form tall herbfields. The grass *Hierochloe recurvata* and the shrub *Gaultheria crassa* were also more common on the islands, and were absent at the mainland study site. It is suggested that these species may be useful indicators for assessing the success of feral goat control operations in low-alpine areas of the Paparoa Range.

Keywords: Feral goat; *Capra hircus*; impacts; low-alpine vegetation; indicator species.

Introduction

Feral goats (*Capra hircus*[1]) are patchily distributed in New Zealand (Rudge, 1990; Parkes, 1990), primarily on lands managed for nature conservation, and can occur at high densities locally. Goats are regarded as serious pests because of their impact on indigenous biota which is manifest through changes in the composition of shrubland and forest communities (Atkinson, 1964; Parkes, 1984, 1993; Campbell and Rudge, 1984; Mitchell, Fordham and John, 1987; Cochrane, 1994), the near extermination of insular endemics (Parkes, 1984), and competition with indigenous avifauna (Leathwick, Hay and Fitzgerald, 1983). Although most studies of goat impacts have been in forest and shrubland, goats also live above the tree line (Rudge, 1990; James, 1990) and can have a significant impact on alpine[2] vegetation (*pers. obs.*).

A substantial number of goats are present in the Paparoa Range, northwestern South Island (James, 1990), ranging from lowland forest to the low-alpine tops (exceeding 1400 m elevation). Much of the range is managed by the Department of Conservation, including Paparoa National Park. Concern about goat impacts has lead to a sustained control programme being undertaken within Paparoa National Park (James, 1990) with the objective being to reduce goat density to a level which allows an improvement in the condition of forest and alpine habitats. As an interim operational target, it is intended that within five years the goat population will be reduced to the point that, on average, less than one goat is killed per hunter-day (Terry Farrell, *pers. comm.*, Department of Conservation, Hokitika).

To assess whether this target will achieve the control objective, appropriate biotic indicators need to be chosen that are sensitive to a reduction in goat density. Indicator choice can be based on information on goat diet or from studies of goat impacts (e.g., through comparisons of vegetation in goat-infested and goat-free areas). However, there is no information on goat impacts in alpine environments, and assessment of both impact and vegetation recovery after goat control operations in the low-alpine zone of the Paparoa Range has been limited. (One exclosure plot has been established.)

The objective of this study was therefore to assess goat impacts on the low-alpine vegetation of the Paparoa Range through contrasting the vegetation of islands in a low-alpine lake that appeared unaffected by mammalian herbivores with an adjacent mainland area. Islands have proved useful for assessing herbivore impacts in other studies (e.g., James and Wallis, 1969, working in cool-temperate forests in Urewera National Park, North Island, New Zealand).

[1] Nomenclature follows King (1990) for mammals, and Allan (1961) and Moore and Edgar (1970) and changes suggested in Brownsey, Given and Lovis (1985) and Connor and Edgar (1987) for vascular plants unless otherwise stated.

[2] My use of ‘alpine’ follows Wilson (1993) who recognised a lower and upper alpine zone. The Paparoa Range tops lie within the low-alpine zone (equivalent to the penalpine zone of Wardle, 1991).

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Methods

Study site

A small lake (2-3 ha) on the north side of Mt Faraday (1485 m) contains five islands ranging in size from *c*. 12 m^2 to *c*. 220 m^2. This lake, known informally as Faraday tarn, formed the focus of this study and is located at the northern end of the Paparoa Range (42° 02’ S, 171° 33’ E) at an altitude of *c*. 1260 m and lies within the Atbara Ecological Area (Punakaiki Ecological District; McEwen, 1987). Geologically this part of the Paparoa Range is dominated by gneiss rocks of the Charleston Metamorphic Group (Dennis, 1981). These mountains have been glaciated in the past and the present topography reflects this; Faraday tarn lies in a depression created by a small cirque glacier.

The climate of the Paparoa Range is poorly known and the following summary is largely taken from Dennis (1981). Mean annual rainfall may reach 8000 mm and fall on up to 200 days a year along the crest of the Paparoa Range. Snow is common in winter, although does not lie to any great depth. Mean annual temperature at the study site is 6.2 °C, with January and June means of 10.6 °C and 1.6 °C respectively (based on equations in Norton, 1985). The prevailing wind is from the west.

Descriptions of the low-vegetation of the Paparoa Range are given by Townson (1906), Dennis (1981) and Norton and Lord (1989). On well drained sites, *Chionochloa pallens* grassland dominates, with scattered shrubs (*Coprosma*, *Dracophyllum*, *Olearia*) and various herbs (*Astelia*, *Celmisia*, *Craspedia*, *Forstera*, *Schoenus*) present. This tall tussock grassland is interspersed with mats of the turf forming tussock *Chionochloa australis* on less well drained sites, with *Astelia linearis* often locally abundant. On the most poorly drained sites, cushion bogs dominated by *Donatia novae-zelandiae*, *Phyllachne colensoi* and *Oreobolus* species occur, with *Carpha alpina* and *Drosera* species often common. At lower altitudes and in more bouldery areas, shrubs and *Phormium cookianum* are conspicuous.

The study area is not presently being subjected to feral goat control operations (Terry Farrell, *pers. comm.*). Goats appear common in the study area (*pers. obs.*) and seven goats were observed near the lake at the start of field work.

Sampling

In late December 1994, 134 0.25 m^2 sample plots were sited using a randomly located 2 m grid across four of the five islands and on the mainland near the lake outlet as an experimental control. The fifth island was not visited because of the depth of surrounding water. The mainland area had a similar physiography to the islands and was largely surrounded by water but was not isolated. Within each plot cover abundance of all vascular plant species, and rocks and bryophytes, was estimated using cover classes of <1, 1-5, 6-10, 11-25, 26-50, 51-75, and 76-100%. To assess the possible impacts of goats on the growth of individual plants, the heights of vegetative parts of all *Anisotome haastii* plants in sample plots were measured. *A. haastii* was chosen because its upright tufted growth form appeared particularly susceptible to goat browse and was readily measured. Because only a small number of *A. haastii* plants were included within the mainland study site sample plots, all *A. haastii* plants that could be located at this site were measured in order to increase the sample size. As well as quantitative vegetation measurements, the vascular flora of the four islands and the mainland area was documented.

Analysis

Detrended correspondence analysis (DCA) as implemented in CANOCO (version 3.12; ter Braak, 1987) was used to ordinate the cover abundance data in order to compare floristic composition between the island and mainland study sites. DCA summarises the variation across all species and plots into a smaller number of variables with the first few variables (or axes) explaining the majority of the variation in the original data set. Graphing the sample plot scores for the first two axes of the ordination provides a means of contrasting the floristic composition of the sample plots, as plots with similar floristic composition will occur close together. Default options were used in the analyses except that the percentage cover data were log transformed and rare species were down-weighted. Single factor analysis of variance (ANOVA) was used for comparing *Anisotome haastii* heights and cover abundance for selected species between islands and the mainland study site.

Results

The vegetation of the study sites comprised a mixture of cushion bog, *Chionochloa* grassland and turf, herbfield, and sparsely vegetated rocky areas often with abundant bryophytes. A total of 75 vascular plant species were recorded from the five study sites (Table 1). Similar numbers of such species were present at the mainland site and on islands A and B (61, 49 and 57 species respectively),

Table 1: *Vascular plant species present at the five Faraday tarn study sites. M, mainland, A-D, islands A-D.*

	M	A	B	C	D
Abrotanella linearis	*				
Actinotus novaezelandiae	*	*			
Anisotome haastii	*	*	*	*	
Anisotome imbricata var *prostrata*	*				
Aporostylis bifolia	*		*		
Astelia linearis	*		*		
Brachyglottis bellidioides	*	*	*	*	*
Brachyglottis bidwillii		*			
Caltha novae-zelandiae	*	*	*	*	
Carex sp.		*			
Carpha alpina	*	*	*		*
Celmisia alpina	*	*	*		*
Celmisia dallii	*	*	*	*	*
Celmisia du-rietzii	*	*	*	*	*
Celmisia incana	*	*	*		
Celmisia laricifolia	*		*		
Celmisia monroi	*	*	*		
Celmisia sessiliflora	*	*	*	*	*
Centrolepis ciliata	*	*			
Chionochloa australis (Buchanan) Zotov	*	*	*	*	*
Chionochloa flavescens Zotov	*	*	*		
Chionochloa pallens Zotov	*	*	*	*	*
Coprosma niphophila		*			
Coprosma sp. aff. *C. pseudocuneata*			*		
Craspedia sp.	*	*			
Cyathodes empetrifolia	*				
Donatia novae-zelandiae	*	*	*		*
Dracophyllum kirkii	*		*		
Dracophyllum longifolium			*		*
Dracophyllum pronum	*	*	*	*	*
Dracophyllum uniflorum	*	*	*	*	*
Drapetes dieffenbachii	*		*		
Drosera arcturi	*		*		
Drosera stenopetala	*	*	*		*
Epilobium glabellum		*			
Epilobium sp.			*		
Euphrasia sp.	*				
Forstera mackayi	*		*		
Forstera sp.	*	*	*		
Gaultheria crassa		*	*	*	*
Gaultheria depressa var. *depressa*			*	*	
Gaultheria sp. (*G. depressa* var. *novae-zelandiae*)		*	*	*	*
Gentiana grisebachii	*	*	*		
Gentiana sp.	*				
Geum uniflorum	*		*		
Gnaphalium sp.	*	*			
Grammitis billardierei		*			
Grammitis poeppigiana	*		*		
Hebe ciliolata	*	*			
Hierochloe recurvata (Cheeseman) Zotov		*	*		
Hymenophyllum multifidum	*	*	*	*	
Hymenophyllum villosum	*		*		
Leucogenes grandiceps	*	*	*		
Luzula crinita	*	*	*		
Lycopodium australianum	*	*	*		
Lycopodium fastigiatum			*		
Microlaena colensoi (Hook. f.) J.C. Smith	*	*	*	*	*
Mitrasacme novae-zelandiae	*	*			*
Myrsine nummularia	*		*		
Nertera balfouriana	*		*		
Olearia colensoi	*	*	*	*	
Oreobolus impar	*		*		
Oreobolus pectinatus	*	*	*	*	*
Ourisia macrocarpa	*	*	*		*
Ourisia sessilifolia	*		*	*	
Pentachondra pumila	*		*	*	*
Phyllachne colensoi	*	*	*		*
Plantago novae-zelandiae	*	*	*	*	*
Poa colensoi Hook. f.	*	*	*		*
Polystichum vestitum		*			
Ranunculus gracilipes	*	*	*	*	
Raoulia eximia	*	*	*		
Raoulia grandiflora	*	*	*		*
Schoenus pauciflorus	*	*	*	*	
Viola cunnunghamii	*				
Total number of species	61	49	57	22	24

but fewer species were present on the two smaller islands (22 and 24 species), and island area and species number were significantly correlated ($r^2 = 0.94$, *d.f.* = 3, $P < 0.001$). The smaller number of species on islands C and D reflects the limited range of habitats and thus of vegetation types present on these islands. For the mainland site and islands A and B, species similarities between each site pair ranged from 0.54 - 0.71 (total species for both areas/ species in common).

The first two axes of the ordination explained 22.4 % of the variance, with axis 1 explaining 14.7 % and axis 2 explaining 7.7 % (Fig. 1). There was considerable overlap in the spread of sample plot scores from each of the five study sites along the first two axes in the ordination diagram suggesting that these five sites were floristically similar. However, both islands A and B had several plots with higher scores on axis 1 than did the mainland site. These plots were characterised by species such as *Anisotome haastii*, *Epilobium glabellum*, *Gaultheria crassa*, *Hierochloe recurvata*, *Luzula crinita* and *Ourisia macrocarpa* which were uncommon or absent in the mainland study site.

Four species were noticeably more abundant on the islands than on the mainland (*Anisotome haastii*, *Gaultheria crassa*, *Hierochloe recurvata*, *Ourisia macrocarpa*; Table 2). These species were either absent from the mainland plots (*G. crassa*, *H. recurvata*) or were much less frequently encountered in mainland plots than in island plots (*A. haastii*, *O. macrocarpa*). Mean cover abundances of *A. haastii* and *O. macrocarpa* were also substantially higher on the islands than on the mainland (Table 2). For the mainland study site and islands A and B, this difference in cover was significant for *A. haastii* ($F = 3.153$, $P = 0.046$) but not-significant for

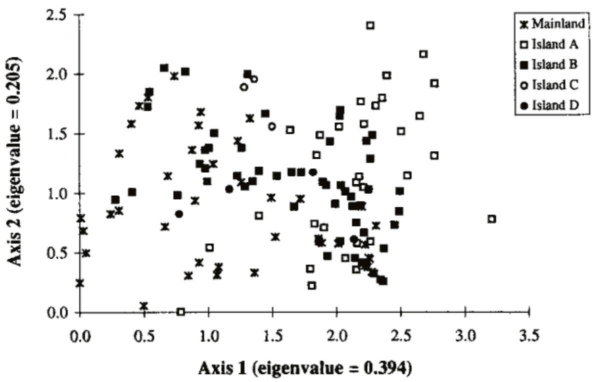

Figure 1: *Sample scores for the 134 study plots graphed against the first two axes of the detrended correspondence analysis ordination.*

Table 2: *Frequency (% of plots which species are present in) and mean cover abundance for species that appear more abundant on the islands compared with the mainland study site.*

		Mainland	Island A	Island B	Island C	Island D
Number of plots		42	32	53	3	4
Island area (m^2)			120	220	12	16
Anisotome	freq.	11.9	50.0	45.3	100.0	0.0
haastii	mean	0.2	2.3	2.3	28.3	0.0
Gaultheria	freq.	0.0	25.0	13.2	33.3	50.0
crassa	mean	0.0	3.4	2.1	5.8	1.5
Hierochloe	freq.	0.0	34.4	3.8	0.0	0.0
recurvata	mean	0.0	3.8	0.1	0.0	0.0
Ourisia	freq.	4.8	37.5	24.5	0.0	0.0
macrocarpa	mean	0.1	4.2	1.0	0.0	0.0

Table 3: Anisotome haastii *vegetative plant heights (cm). ANOVA results (excluding island D), $F = 10.21$, $P < 0.001$.*

	n	Height (cm) mean	Height (cm) variance
Mainland	28	4.8	3.82
Island A	30	9.3	27.26
Island B	40	10.7	27.92
Island C	13	11.6	41.42
Island D	0	-	-

O. macrocarpa ($F = 2.531$, $P = 0.084$). However, these comparisons are biased by the patchy distribution of these species, and the difference in cover between the islands and the mainland is substantially greater than the ANOVA results imply if only those plots with these species present are considered.

Not only are species such as *Anisotome haastii* and *Ourisia macrocarpa* more abundant on the islands than on the mainland, but in the case of *A. haastii*, individual plants are significantly larger on the islands (Table 3). No *A. haastii* plants were present on island 4. The variance was also considerable greater on the islands than on the mainland, suggesting a much greater range of plant heights at these sites.

Discussion

The results show marked floristic differences between the vegetation of the islands and the mainland study site. These differences could reflect differences in the physiography of the study sites or could be due to differences in herbivore activity (as is presumed here). Although it was not possible to precisely match sites, the mainland area chosen for comparison is geologically and topographically similar to the islands (including elevation and landforms) and was surrounded by water on three sides. It is thought to provide a realistic control. The overlap of plots from the different study sites in the ordination diagram (Fig. 1) also suggests that in terms of the overall flora, the islands and mainland study sites are comparable, and so the floristic differences observed are more likely to be due to the effects of introduced herbivores rather than to differences in physiography.

Goats were the only mammalian herbivore seen in the area, where there has been a long history of high numbers (Terry Farrell, *pers. comm.*). Hares (*Lepus europaeus occidentalis*), red deer (*Cervus elaphus scoticus*), fallow deer (*Dama dama dama*) chamois (*Rupicapra rupicapra rupicapra*) and possums (*Trichosurus vulpecula*) are known to occur in the Paparoa Range, but apart from an old cast antler, no sign of their presence at the study site was observed. Both red and fallow deer are thought to have never been present in high numbers in the Paparoa Range, possibly as a result of the early colonisation of the area by feral goats (1920s - 1940s; Terry Farrell, *pers. comm.*), and it would seem likely that their impact on the vegetation has been limited compared to that of feral goats.

The most obvious impact of feral goats is on the abundance and vigour of the large herbs *Anisotome haastii* and *Ourisia macrocarpa* which were particularly abundant on three of the four islands forming tall herbfields, and were flowering profusely during fieldwork (Fig. 2).

Figure 2: Anisotome haastii *and* Ourisia macrocarpa *growing amongst* Gaultheria crassa *and dense mats of* Hypnum cupressiforme *and* Racomitrium pruinosum *on Island B, Faraday tarn (1 January 1995).*

At the mainland study site these species were occasionally present but were not seen in flower; flowering plants elsewhere appeared confined to steep bluffs or in rock crevices, presumably sites largely free of goat browsing. The vulnerability of large herbs to introduced herbivores has been documented in several other studies. *A. haastii* and *O. macrocarpa* both showed significant increases in abundance after deer control in northern Fiordland (Rose and Platt, 1987) and Mark (1989) noted that palatable herbs including *A. haastii* and *O. macrophylla* increased after deer control in Mt Aspiring National Park. Similar increases in large herbs were also observed after sheep (*Ovis aries*) were removed from Campbell Island (Meurk, 1982).

Other species that were more abundant on the islands than at the mainland study site included *Hierochloe recurvata* and *Gaultheria crassa*. *H. recurvata* was only seen once elsewhere in the Mt Faraday area, growing amongst shrubs near the summit of Mt Faraday. On Campbell Island Meurk (1982) observed that *Hierochloe* spp. increased in abundance once sheep grazing was removed. *G. crassa* was also common on all four islands, but was not present at the mainland study site, and was only seen elsewhere on bluffs or amongst shrubland. *G. crassa* is highly palatable to thar (*Hemitragus jemlahicus*) and chamois (John Parkes, *pers. comm.*, Landcare Research, Lincoln) and it would seem likely that it is also palatable to goats. Mitchell *et al.* (1987) observed that goats browsed the related *G. antipoda* in lowland forest on Mt Taranaki.

General observations in the Mt Faraday area suggest that the distribution and abundance of several other plant species may also have been affected by goats, with these species being largely confined to bluff sites and other inaccessible locations. Species likely to be affected by goats include *Aciphylla* species, *Coprosma serrulata*, *Dolichoglottis lyallii*, *Geum cockaynea* (Bolle) Molloy et C.J. Webb and *Ranunculus insignis*. Norton and Lord (1989) noted that *R. insignis* and *R. verticillatus* were significantly less common than expected in the low-alpine vegetation of Paparoa National Park and attributed this to goat browse. James (1990) identified *Aciphylla* spp., *R. insignis* and *R. verticillatus* as being threatened by goats in the low-alpine grasslands of Paparoa National Park.

Other studies of herbivore impact in low-alpine grasslands and related communities have shown substantial changes in overall community composition as a result of grazing and browsing (e.g., Campbell and Rudge, 1984; Rose and Platt, 1987; Mark, 1989). In the study area, tall herbfields are virtually non-existent except on herbivore-free sites such as islands and steep bluffs. Tall herbs are also very uncommon in tall tussock grassland on the Paparoa, and it would seem likely that this scarcity is a direct result of herbivore pressure from feral goats. Comparable mainland areas to the tall herbfields of the study islands often support only bryophytes and a sparse cover of vascular plants (especially *Celmisia durietzii*), although even the bryophytes appeared more vigorous and form deeper and more extensive mats on the islands (especially *Hypnum cupressiforme* Hedw. and *Racomitrium pruinosum* (Hook. f. & Wils.) C. Mull.). The floristic differences observed here between the island and mainland study sites strongly suggest (as is supported by other studies) that long-term changes in the structure and distribution of alpine plant communities are occurring in the Paparoa Range as a result of feral goat browsing.

The results of this study highlight the vulnerability of a range of large herbs to browsing by feral goats and extend observations of introduced herbivore impacts on low-alpine vegetation to goats. These results suggest plant species that can be used to monitor the success of goat control operations in low-alpine areas of the Paparoa Range (c.f. James, 1990). For example, a reduction in goat numbers should result in an increased abundance of plants such as *Anisotome haastii*, *Gaultheria crassa*, *Hierachloe recurvata* and *Ourisia macrocarpa*. However, it is important to determine the threshold goat density below which these plants will increase in abundance. It may be that even very low goat densities are sufficient to continue to restrict the most preferred species to sites that goats cannot use or surviving goats do not use. Reducing goats to a density above this threshold level is therefore unlikely to have universal benefits for the long-term conservation of Paparoa low-alpine grasslands. However, the continued presence of palatable plants in small goat-free refuges suggests that if goat control is successful, the type of recover documented in low-alpine grasslands after deer control in southern South Island (Rose and Platt, 1987; Mark, 1989) may also occur in the Paparoa Range.

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