little information on the relative abundance of these species in the past to compare with their present distribution and frequency. As in the comparison of botanical descriptions the obvious change is from a simple to a more detailed list of the species eaten.

These studies of diet form the first step in determining the effect of sheep on the tussock grasslands at the present time. The next step is to determine the effects of various levels and frequencies of defoliation on the plant, its rate of vegetative growth, flowering, seeding, and survival.

One important area for which little experimental evidence is available is the snowgrass country. There is a strong body of opinion that in the snowgrass the combined effects of fire and grazing have been responsible for deterioration in vegetative cover and stability. It seems likely that changes in the boundaries between the snowgrass and fescue communities have been due to, or aggravated by, the combined pressures of fire and sheep grazing. The snowgrass communities have been opened up during the time the land has been farmed and in the more stable localities there has been invasion of the inter-tussock area.

Finally, there have been visible changes in the tussock grasslands during their use for grazing by sheep. It is suggested that in some areas this is mainly a quantitative change in vegetative growth, often with changes in the balance between individual species within the community. In many areas the combined effects of fire and grazing have served to open up the community and allow the invasion by exotic species leading to a richer or more varied inter-tussock flora than the original.

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RELATIONS BETWEEN FERAL GOATS AND VEGETATION IN NEW ZEALAND

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This paper describes some relations between feral* goats and vegetation, and attempts to show how understanding their reciprocal nature may assist in improving methods of controlling goats. Examples are drawn from the Rimutaka Range where goats, red deer, pigs and opossums are present; Mt. Egmont and the adjacent Pouakai Range where goats and opossums are present; and Cuvier Island, 24 miles east of Cape Colville, where goats were the only browsing mammals prior to their extermination in 1961. Methods used in this study follow those described by Atkinson (1963).

* Feral animals are those that have reverted from the domestic to the wild state.

EFFECTS OF GOATS ON VEGETATION-SOIL PATTERNS

Compaction and slipping of soil

In the localities studied compaction is localized along tracks most of which follow contours. It seems doubtful whether this has resulted in increased run-off.

The statement that "goats induce slips" is open to doubt until more critical work is done. For example there are numerous slips in the goat-infested Pouakai Range but a photograph taken of the southern slopes by H. M. Skeet in 1898, some 10 years before the entry of goats, shows no major difference from the present pattern and number of slips. However, in the absence of unpalatable plants, continued browsing on slip faces may prevent an eroding catchment from regaining stability.

Return of plant nutrients to soil from dung and urine.

A search was made along tracks and at sheltering spots at Cuvier and Egmont but no stimulation of the vegetation from dung and urine was apparent.

Barking of trees and shrubs

In contrast to browsing, goats rarely bark more than two or three species in any one locality. In parts of the subalpine scrub on the western side of Egmont between 2500 and 3000 ft. over 60 per cent of those stems of mountain fivefinger (*Neopanax colensoi*) still alive, had been barked. At higher altitudes few were barked perhaps because thicker growths of epiphytic filmy ferns, mosses and liverworts covered the trunks. Browsed individuals of these plant groups were not seen. *Neopanax simplex* var. *sinclairii* with equally palatable foliage and growing alongside *N. colensoi* was unbarked.

Browsing of shrub and tree crowns

In subalpine scrub at Egmont there are several areas on ridges and in valleys between 3000 and 4000 ft. where the canopy has been completely killed by a combination of browsing and barking. Where the scrub is less than 5 ft. high goats have browsed crowns from the ground; where higher they have sometimes climbed into the shrubs. A one-acre area of scrub has been destroyed in less than four years. Opossums are present but do not appear primarily responsible. The destroyed areas vary in size from less that an acre to many acres usually with sharp boundaries between the dead and undamaged canopy. The factors responsible for such localized destruction are not clear although it has been suggested that regular patterns of shooting have concentrated animals in particular areas (G. G. Atkinson, pers. comm.).

At Cuvier the effect of goats on coastal scrub was catastrophic. Skeletal soils of northern off-shore islands exposed to wind-carried salt are normally covered with scrub dominated by various combinations of karo (*Pittosporum crassifolium*), houpara (*Pseudopanax lessonii*), *Hymenanthera novae-zelandiae*, taupata *(Coprosma repens)*, ngaio (*Myoporum laetum*), flax (*Phormium tenax*) and pohutukawa (*Metrosideros excelsa*), varying from 3 to 10 ft. in height. By 1960, after 70 years of goat influence, karo, hymenanthera, taupata and ngaio were practically restricted to an off-shore stack not reached by goats. The scrub itself, formerly occupying a zone from near sea-level to about 300 ft., had been replaced completely by grassland, herbfield and sedgeland.

Browsing of forest understorey

This is by far the most important effect of goats. Plants exposed to browsing may be classified as (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; (c) unpalatable species.

In forest on soils of moderate or high fertility four stages in a succession induced by goats may be distinguished.

1. A differentially browsed understorey with only one or two low-preference species unbrowsed. Effective regeneration of some canopy trees terminated.

2. Understorey dominated by low-preference species (Fig. 1a). Regeneration of most canopy trees terminated excepting those of low preference. Understorey rather open as a result of browsing and trampling. Goats appear to eat mainly the annual crop of seedlings and resprouts from trunks.

3. Canopy consists of a mixture of the original trees and low-preference species (Fig. 1b). Regeneration of all trees and shrubs retarded or terminated. Understorey very open below the browse line at 5 ft. Annual crop of seedlings reduced owing to diminishing seed sources.

TABLE 1. *Plants of low preference or unpala table to goats.*

Low-preference species	LOCALITY OF OBSERVATION
Agathis australis (kauri)	Hunua Range (W. B. Silvester, pers. comm.)
Blechnum fluviatile	Egmont, Rimutaka Range
Coprosma sp. (*parviflora* group)	Egmont
Cyathea smithii (soft tree-fern)	Egmont
Cyathodes fasciculata (mingimingi)	Egmont, Rimutaka Range
C. frazeri (patotara)	Cuvier, Egmont
Dysoxylum spectable (kohekohe)	Cuvier
Gahnia lacera	Cuvier
Gaultheria antipoda (snowberry)	Egmont
Leptospermum ericoides (kanuka)	Egmont, Great King Island (Turbott 1948)
L. scoparium (manuka)	Cuvier, Egmont
Mariscus ustulatus	Cuvier
Microlaena avenacea (bush rice-grass)	Egmont, Rimutaka Range, Moehau (Moore & Cranwell 1934)
Myrsine salicina (toro)	Egmont, Rimutaka Range
Phyllocladus trichomanoides (tanekaha)	Hunua Range (W. B. Silvester, pers. comm.)
Scirpus nodosus	Cuvier
Unsinia ferruginea	Egmont
Uncinia spp.	Cuvier
Uncinia uncinata	Egmont
Unpalatable species	
Acaena anserinifolia	Egmont
Blechnum mountain sp. (*capense* group)	Egmont
Cardiomancs reniforme (kidney fern)	Egmont
Cassinia leptophylla (tauhinu)	Rimutaka Range
C. retorta (tauhinu)	Cuvier
C. vauvilliersii (mountain tauhinu)	Egmont
Dracophyllum longifolium (inaka)	Egmont
Hebe odora	Egmont
Histiopteris incisa	Egmont, Rimutaka Range
Hymenophyllum spp.	Egmont
Hypolepis millefolium	Egmont
Pseudowintera colorata (red horopito)	Egmont, Rimutaka Range

NOTE. Manuka, kanuka and possibly red horopito are browsed as seedlings.

4. Death of canopy trees accompanied by increased cover of sedges and grasses. Replacement of forest by types of browse-stable vegetation often containing a high proportion of relatively unpalatable plants (Table 1).

Assuming a continuing intensive use of a forest by goats the rate of forest degradation apparently depends firstly on the natural life span of the canopy species and secondly on the frequency of local disturbances such as wind-throw or slips that may destroy the canopy.

At Te Moehau, Moore and Cranwell (1934) recognised three stages in replacement of a forest by a *Microlaena avenacea* grassland during 50 to 60 years influence of goats, pigs and cattle. From their account it appears that factors other than animals could have contributed to the destruction of the canopy, and for this reason their successional stages do not correspond with those outlined above.

On Cuvier Island, where in 1960 goats were present at a density of 0.8 per acre, the principal low-preference species was kohekohe (*Dysoxylum spectabile*) which dominated the understorey of both valleys and ridges. The forest itself was a mosaic of stages 2 to 4, with stage 4 concentrated on the lower seaward slopes. Here the vegetation consisted of mixtures of grasses, sedges and herbs with cocksfoot (*Dactylus glomerata*), prairie grass (*Ceratochloa unioloides*), *Uncinia* spp., *Scirpus nodosus*, *Mariscus ustulatus* and bur clover (*Medicago polymorpha*) prominent.

On Great King Island, shrublands of low-preference kanuka (*Leptospermum ericoides*) and grasslands of *Zoisia matrella* had developed during the 60 years of goat occupation (Turbott 1948).

At Egmont stage 2 appears to have been reached within 20 years of the entry of goats in 1910. Many parts of the forest are now passing into stage 3 although stage 4 has been

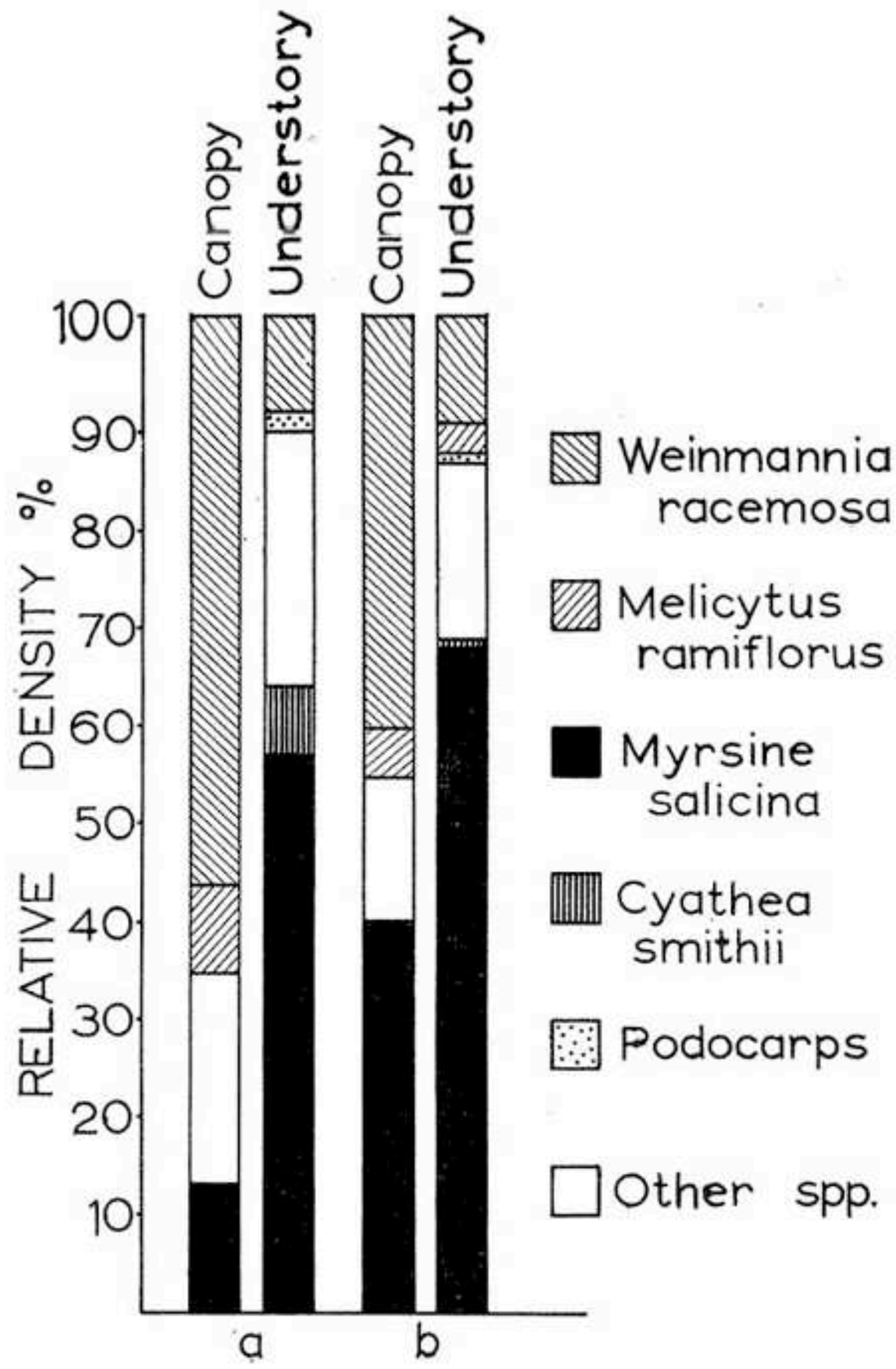

FIGURE 1. *Difference in the proportions of kamahi* (Weinmannia racemosa) *and toro* (Myrsine salicina) *between canopy and understorey (> ft.) layers of two forests at western Mt. Egmont: (a) kamahi forest at* 1600 *ft. (b) kamahi/toro forest at* 1300 *ft. Data obtained from two sets of* 10 *belt transects (25 × 2 yd.) each transect spaced along a compass line at* 100 *pace intervals (March* 1963).

reached locally where the canopy has been destroyed by other factors. In the kamahi forests of western Mt. Egmont from 1300 to 2400 ft. toro (*Myrsine salicina*) and *Cyathea smithii* are the main low-preference species. At higher altitudes these are replaced by red horopito (*Pseudowintera colorata*). Stage 4 vegetation includes sedgelands of *Uncinia uncinata* and *U. ferruginea* and in large canopy gaps, grasslands of *Microlaena avenacea*, Yorkshire fog (*Holcus lanatus*) along tracks; and fernlands and shrublands of *Histiopteris incisa*, *Hypolepis millefolium* and *Coprosma* sp. (*C. parviflora* group) in areas of subalpine scrub devastated by goats.

Thus the evidence suggests that with high densities of goats, forest on soils of moderate and high fertility is replaced by herbaceous or shrubby vegetation. Whether goats could maintain sufficient numbers to induce a similar change in forest on a low fertility soil is still an unanswered question.

EFFECTS OF VEGETATION-SOIL PATTERNS ON GOATS

Bogs

At Egmont bogs occur on easy slopes between 1500 and 3000 ft. Many palatable species such as *Blechnum* sp. (*B. capense* group), broadleaf (*Griselinia littoralis*), kamahi (*Weinmannia racemosa*), karamu (*Coprosma robusta*) and *Coprosma tenuifolia* are unbrowsed in these bogs, yet completely eliminated from the understorey of the surrounding forest. Fraser Darling (1937) records that wild goats on mountains in Scotland keep to well-drained ground above the peatline. Whether this behaviour is related to goats avoiding waterlogged soils or to differences in chemical composition and palatibility of bog plants is not known.

Areas of grass

Riney and Caughley (1959) found that goats fed chiefly on areas containing a large proportion of grasses. It seems worthwhile establishing how far goats will move towards such areas and whether they can maintain themselves on a forest diet alone.

Slopes exposed to wind-carried salt

Zotov (1949) noted that windward slopes, not necessarily 'sunny' faces, were most thoroughly denuded by goats in the Tararua Range. In the head of the Pakuratahi valley, Rimutaka Range, it was noticed in 1958 that goat browsing had been more severe on the windward slopes below canopies of silver beech (*Nothofagus menziesii*) furrowed and smoothed by wind-carried salt. Similar effects can be seen on some of the southern slopes of the Pouakai Range.

At Cuvier Island the maximum modification by goats took place on the seaward slopes, regardless of aspect. Apart from destruction of the coastal scrub on the lower seaward slopes, the remaining forest on the upper seaward

slopes was being used more intensively than that of the sheltered inner valleys. Fig. 2 illustrates the distribution of size classes of three populations of trees each showing fewer short or tall saplings on the seaward slopes than in the valleys. Population structures such as these do not occur on other islands without goats.

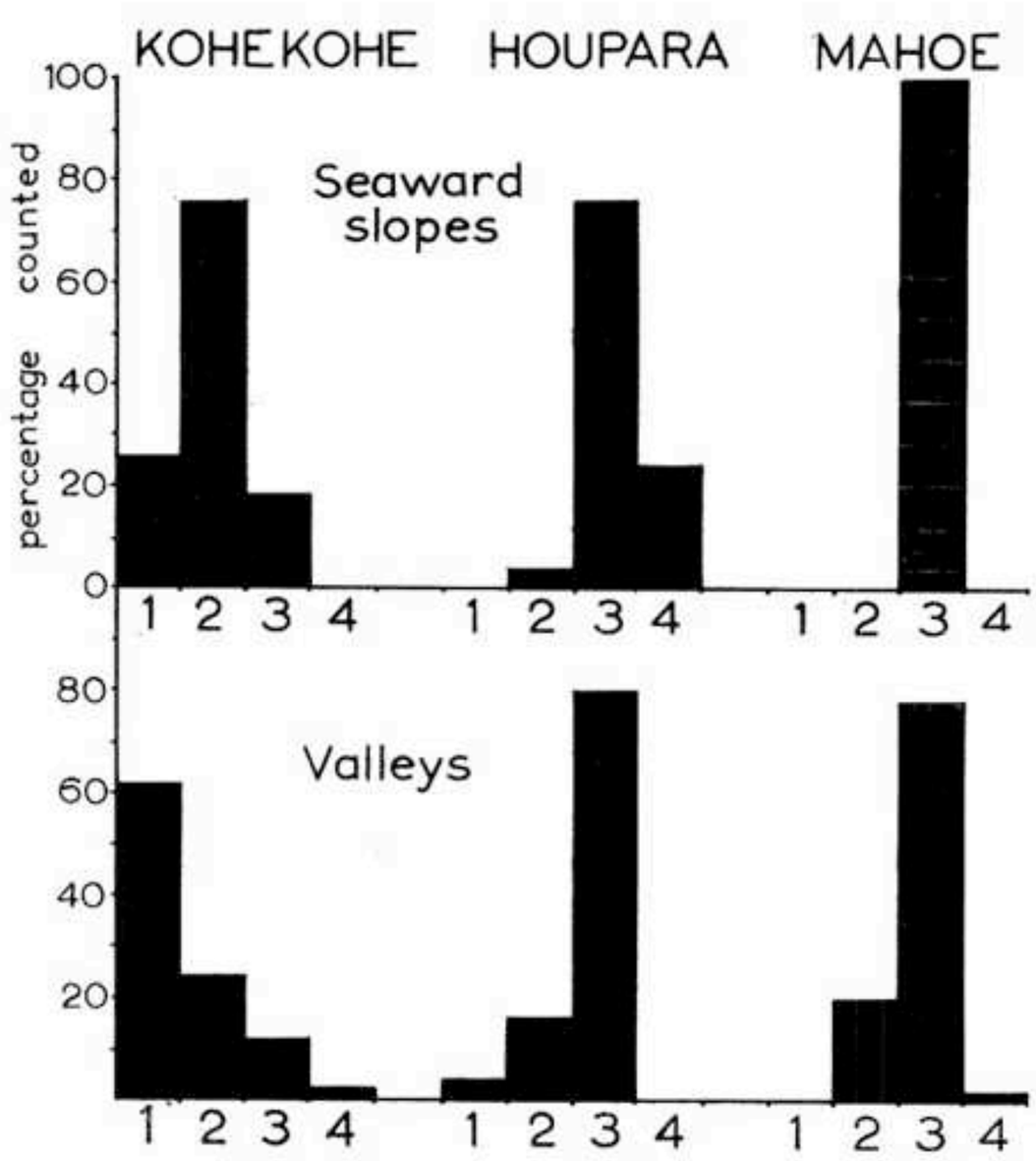

FIGURE 2. *Size class distributions of three trees at Cuvier Island in* 1960 *showing smaller proportions of saplings on seaward slopes: kohekohe* (Dysoxylum spectabile), *houpara* (Pseudopanax lessonii) *and mahoe* (Melicytus ramiflorus). *Size classes are* (1) *short saplings (*1-6 *ft. high); (2) tall saplings (>* 6 *ft. high to* 4 *in. d.b.h.); (3) small trees (>* 4-12 *in. d.b.h.); (4) trees >* 12 *in. d.b.h. Proportions based on counts of* 50 *plants made along contoured walks.*

The concentration of browsing may be because wind-carried salt makes the plants more attractive to goats. Further work is needed to test this hypothesis.

The Puniho Flat

On the western side of Mt. Egmont a large alluvial terrace ("Puniho Flat") lies parallel to the Stony River. From the lower forest edge to about $1\frac{1}{4}$ miles uphill the undergrowth is dense and unbrowsed by goats although a few have been shot on this flat (E. M. Atkinson, pers. comm.). This unbrowsed strip is 600 to 800 yards wide and extends from the Waiweranui Stream to the Stony River. In startling contrast the forest on the fan south of the Waiweranui, the forest above and west of the flat, and the forest on the north side of the Stony River are all extremely modified, many stands having reached stage 3 (see Fig. 3).

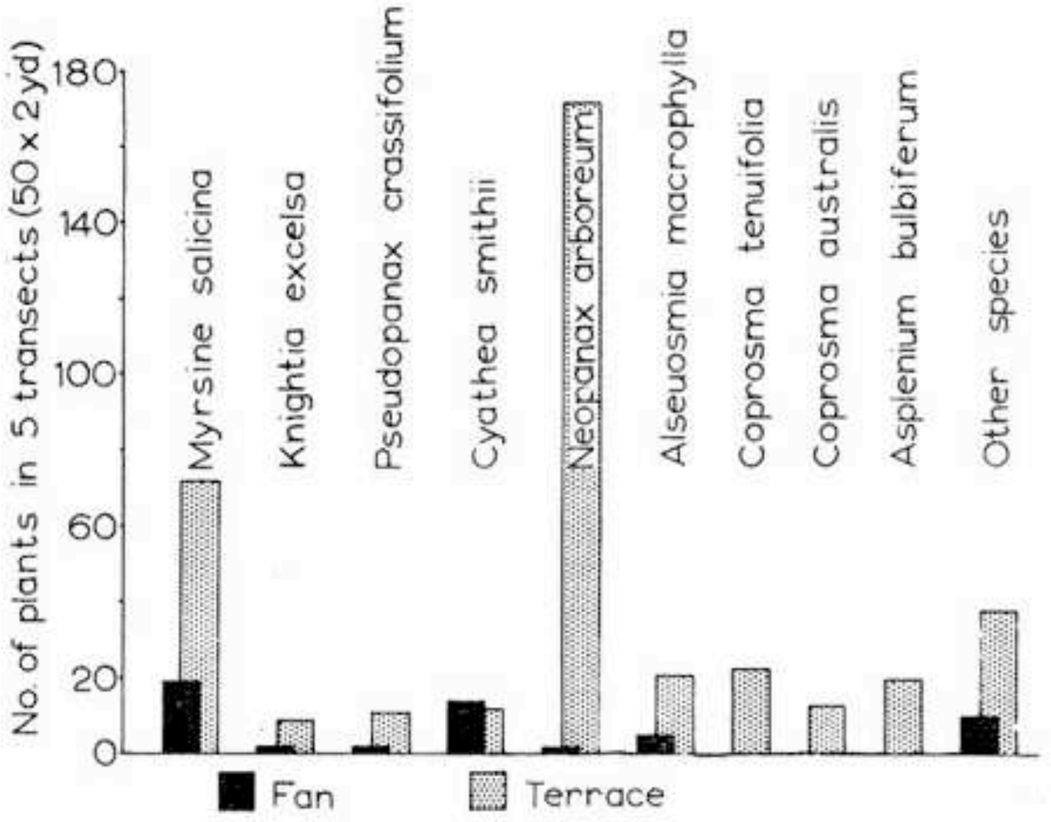

FIGURE 3. *Difference in the density of plants between the Puniho alluvial terrace and the adjacent alluvial fan (March* 1963).

Although recovery of vegetation alongside tracks regularly used by hunters can be seen in several places at Egmont, this is not an adequate explanation of the Puniho case. There is no gradational change in browsing as one moves southwards from the Puniho track, rather is there a sharp change where the Waiweranui separates the alluvial flat from the alluvial fan. Soil analyses carried out by the Soil Analysis Section of Soil Bureau, D.S.I.R., have not shown any differences which might explain this.

DISCUSSION

These observations emphasize the extreme effects that goats can have on vegetation and agree with earlier findings from New Zealand

and overseas. Because goats tend to concentrate locally even small numbers can retard regeneration.

The tendency to move in groups is an aspect of behaviour that could be exploited in control measures. Apart from the observation of Riney and Caughley (1959) that billies segregate from the nanny-kid herds during winter, there is little information on the movement patterns of goats. Of the many aspects of the ecology of this animal that could be studied, knowledge of movements in varying conditions of weather, topography, vegetation and population structure is of paramount importance if effective census and control measures are to be developed.

Investigation of the physiology and behaviour of goats, in particular their taste preferences, their possible dependence on salt, their inquisitive nature and their liking for high promontories or rocky outcrops might also lead to new methods of control. The present distribution of goats mapped by Wodzicki (1961) includes many areas where effective methods of control are urgently needed: National Parks, scenic reserves and potential coastline reserves as well as catchments considered critical from the point of view of soil erosion and river control.

SUMMARY OF CONCLUSIONS

1. The greatest effect of goats on vegetation is that due to browsing of the forest understorey. With high densities of goats forest on soils of moderate and high fertility is replaced by herbaceous or shrubby vegetation. On soils of low fertility the effect of goats on forest stability is not known.

2. Reciprocal effects of vegetation on goats are exemplified by the absence of significant browsing in bogs and on an alluvial terrace at Mt. Egmont, and the possible attraction to goats of vegetation containing large proportions of grass or vegetation exposed to wind-carried salt.

3. Study of the taste preferences of goats for foliage and bark may provide a biochemical basis for new methods of controlling goats.

4. Study of the daily and seasonal movements of goats in relation to weather, topography, vegetation, and population structure, appears essential for developing improved methods of census and control.

ACKNOWLEDGEMENTS

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INTERACTIONS BETWEEN MAN, DEER & VEGETATION IN MICHIGAN

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INTRODUCTION

Compared with New Zealand, ecological communities in North America are very complex. In the state of Michigan alone there are over 50 different species of mammals, about 300 of birds and perhaps 40 terrestial or partly terrestrial reptiles and amphibians. Many of

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