Impact of cattle on conservation land licensed for grazing in South Westland, New Zealand

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Abstract: Making use of existing fences as ready-made exclosures, this study aimed to assess the long-term effects of cattle grazing on forest margins. Results indicated: 1) that cattle browsing and trampling has an impact on vegetation species composition, structure and regeneration; 2) that the effects of a particular grazing regime may take many decades to dissipate; and 3) that the impacts of cattle change with stock intensity. Some plant species appeared to be highly palatable to cattle and only occurred on sites without cattle. Such species included pate (*Schefflera digitata*), broadleaf (*Griselinia littoralis*), pigeonwood (*Hedycarya arborea*), supplejack (*Ripogonum scandens*), mahoe (*Melicytus ramiflorus*), milk tree (*Streblus heterophyllus*), lancewood (*Pseudopanax crassifolius*) and hen and chickens fern (*Asplenium bulbiferum*). A small group of plants appeared to regenerate better under cattle than in their absence, particularly mountain horopito (*Pseudowintera colorata*) and prickly shield fern (*Polystichum vestitum*). A few species were encouraged by cattle at one site but suppressed by them at another: kahikatea (*Dacrycarpus dacrydioides*), wheki (*Dicksonia squarrosa*), *Coprosma rhamnoides* and *Blechnum fluviatile*. The impact of cattle on most other plant species was not discernible. The results of this study, while somewhat equivocal, indicate that future grazing licences in South Westland should restrict stock to low numbers and be confined to already modified sites where damage to conservation values would be minimal.

Keywords: browsing; cattle; conservation values; domestic stock; exclosures; grazing; grazing lease; grazing licence; impacts of stock; regeneration; South Westland.

Introduction

The region

South Westland extends 240 km north-south on the West Coast of the South Island of New Zealand, from the Waitaha River in the north to Big Bay in the south (Fig. 1). The region covers about 6000 sq km and encompasses 11 Ecological Districts (McEwen, 1987). Some 90% of the land is managed by the Department of Conservation (DOC); much of it is still covered in original native vegetation. Indeed, South Westland has the largest areas of lowland forest and wetland remaining in New Zealand (Wardle, 1977; Newsome, 1987). The main lowland forest types are: (1) podocarp with rimu (*Dacrydium cupressinum*), kahikatea (*Dacrycarpus dacrydioides*), miro (*Prumnopitys ferruginea*), matai (*P. taxifolia*), totara (*Podocarpus totara*); (2) podocarp/broadleaved forest comprising podocarps and kamahi (*Weinmannia racemosa*); (3) beech-podocarp with mainly silver beech (*Nothofagus menziesii*) and some red beech (*N. fusca*).

South Westland has a high annual rainfall, ranging from 3400–4900 mm in the lowlands to more than 10 000 mm in the mountains (Hessell, 1982). Along the many rivers, flooding and erosion have created open alluvial flats with correspondingly young soils (Mutch and McKellar, 1965; Warren, 1967; Tonkin *et al*., 1985). Some of these flats have no forest, for a variety of reasons including frost, cold air, very young soils, either too much or too little drainage; or changing river courses have recently removed forest cover. Farmers cleared some of the flats in the late 19th century or early 20th century. Left undisturbed, these cleared flats would usually be re-clothed in forest.

Today the majority of lowland valleys in South Westland have a history of use by domestic stock. Some have been used by cattle, and to a lesser extent sheep, since the 1870s or earlier, mostly under some form of Crown lease (Rosoman, 1990). Cattle graze the grasslands, browse the adjacent forest and also cause other ancillary damage by breaking vegetation and trampling. There are currently 122 grazing licences (issued to permit stock use of Crown land) administered by the Department of Conservation, plus a few administered by Knight Frank Group (a property company) and Land Information New Zealand, and one Maori lease. They comprise about 5% of the land area of South Westland (Department of Conservation, West Coast Conservancy data).

Stock mostly graze open river flats. Under grazing, the grassland there has become dominated by introduced pasture grasses and clovers, such as brown top (*Agrostis capillaris*), Chewings fescue (*Festuca rubra*), Yorkshire fog (*Holcus lanatus*) and especially lotus (*Lotus pedunculatus*). The few remaining native species are low-growing and unpalatable to stock (Buxton *et. al.*, 2001). While stock prefer the grassland, they can penetrate up to 100 m into adjacent wetlands and native forest (Riney, 1957; Rosoman, 1990). Thus today there are few truly unmodified forest margins left in South Westland because of burning, clearing, the presence of cattle and sheep, and also the high numbers of red deer (*Cervus elaphus*) in the past.

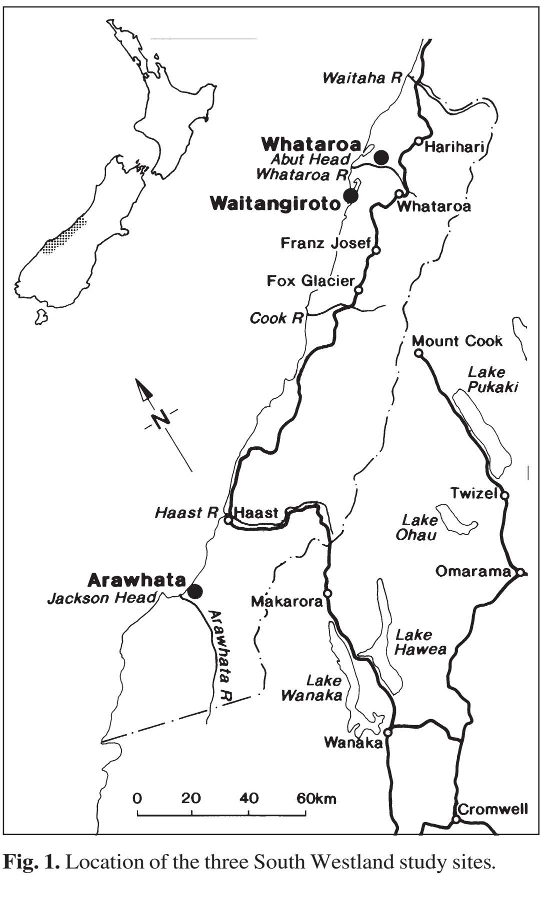

Fig. 1. Location of the three South Westland study sites.

The issue

The New Zealand Department of Conservation is subject to two opposing pressures with respect to continuation of the grazing licences. Some conservation interests call for DOC to revoke all licences on the assumption that the stock are harming natural ecosystems which DOC is obliged by legislation to protect (e.g. Robertson and Hackwell, 1995). Conversely, some local residents contend that grazing is not a significant disturbance factor, especially when compared with the damage caused by deer, possum (*Trichosurus vulpecula*), and the natural river building/erosion cycle (Rosoman, 1990). They suggest that most damage from stock would have occurred over 100 years ago and that continued use by stock will not cause further degradation.

Neither of these opposing views had been backed by comprehensive scientific study. In 1989, DOC set up research studies to assess the impact of domestic cattle on leasehold land (Wardle *et al.*, 1988). A long-term study, conducted by Landcare Research in association with DOC, is using exclosures to monitor the vegetation response to removal of cattle (Buxton *et al.*, 2001). Another study surveyed grazing regimes, investigating the extent to which cattle range across both leased and adjacent land areas and farmers' perceptions of the impacts of cattle on conservation values (Rosoman, 1990). A scale of ecological impact indicators was also developed. A third study, on vegetation response in areas where cattle have been excluded for 20 years, is the subject of this paper.

Studies on the impact of ungulates

The impact of ungulates on native vegetation has been a prevailing theme of ecological research in New Zealand (Wardle, 1991). Most studies have investigated the impact of several deer species on forest and shrubland (e.g. *Cervus* spp.; Wardle, 1984; Stewart *et al.*, 1987). Others have looked at species such as goats (*Capra hircus*; e.g. Atkinson, 1964; Parkes, 1984) and Himalayan thar (*Hemitragus jemlahicus*; e.g. Caughley, 1970; Tustin and Challies, 1978). Very few studies have been made on the effects of cattle and sheep.

In 1934 Moore and Cranwell observed that feral cattle could convert tawa (*Beilschmiedia tawa*)-kamahi forest to bush rice grass (*Microlaena avenacea*) swards. McKelvey (1963) observed that wild cattle browsed the lower story of the West Taupo forests. Wardle (1984) suggested that cattle are less selective browsers than deer and that they break branches and trample undergrowth. Harrison-Smith (1944) ventured that cattle browsing may allow regeneration of podocarps by exposing the soil and eliminating competing broadleaved shrubs. Beveridge (1973) made a similar observation. In contrast, McSweeney (1982) observed that matai especially, and kahikatea, were browsed by cattle in his South Westland exclosure study.

The more comprehensive literature on other ungulates has shown that while the pattern of browsing changes over time and with site and species composition, some species are consistently highly preferred. These include *Pseudopanax* spp., large-leaved *Coprosma* spp., pate (*Schefflera digitata*), broadleaf (*Griselinia littoralis*) and hen and chickens fern (*Asplenium bulbiferum*) (Wardle, 1984). In contrast, the abundance of some plant species increases in the presence of deer, e.g. crown fern (*Dicksonia lanata*) and especially mountain horopito (*Pseudowintera colorata*), hook sedges (*Uncinia* spp.), mat-forming smaller herbs and grasses. The latter can form a dense ground cover and, in turn, inhibit the establishment of most woody seedlings (Wardle, 1984). It is likely that some of the observations of the effect of deer on vegetation can be extrapolated to cattle (e.g. Rosoman 1990).

The approach

There are several sites in South Westland where fences have been erected to protect part of a forest stand from stock but the forest is still accessible to other browsing animals such as deer and possum. This study used three sites with these ready-made exclosures. I sampled the vegetation on both sides of the fence to gain a snapshot of the long-term effects of cattle presence and cattle removal.

Exclosure studies have some limitations (Allen *et al.*, 1984): (1) If animals are already present, the vegetation will already be modified and so the vegetation which regenerates may or may not resemble the original. Unfortunately there are no valleys in South Westland that have never had domestic stock so the original state is unclear. (2) Fencing removes the animals at a particular point in time. At another time a different combination of factors may prevail. This limits the applicability of the results to other sites or situations.

Although in this study the vegetation was not sampled prior to fencing, the aim was to get an indication of likely vegetation trends more quickly than would be obtained by setting up new exclosure studies. These areas would give an indication of the likely changes in vegetation that can be expected after cattle have been excluded for various periods up to 20 years. Thus, the objectives for this study were to assess: (1) the impact of cattle on native plant species in the presence of other ungulates and introduced animals; (2) whether cattle impair regeneration of major canopy and subcanopy components of native communities; (3) the impact of cattle on vegetation structure; and (4) whether any impacts are long term.

Methods

In September 1988 a pilot study at Waitangiroto was conducted as a trial of using existing fences. Forty 3 x 3 m paired plots were set up 3 m either side of the fence at 5 m intervals along its length. Within each plot, percentage values for ground (< 0.3 m in height) and understorey (≥ 0.3 m, < 2 m) cover were subjectively assessed and diameters at breast height (dbh) for all stems ≥ 2 m tall measured.

In June/July 1989, transect lines were established at Whataroa and Arawhata. Belt transects (50 x 4 m) were used because they are fast to record and information-rich (Atkinson 1985). Some of the transects ran parallel to, but 5 m away from, the fence to avoid disturbance effects. Further transects were located systematically to cover the range of variation in forest composition and perceived impact from stock. Transects inside the exclosure were selected for similar site and forest canopy characteristics to 'match' those on the cattle side.

The study sites

The sites had to be under an extensive grazing regime, like most of the grazing licences, be large enough to accommodate several transects and avoid edge effects, and have an adequate area of browsed forest comparable in forest composition and site characteristics to that part now fenced off. Most sites in South Westland where a part of a forest had been fenced did not comply with these criteria but extensive searching found three suitable sites (Fig. 1). The first was on conservation land, the other two were on private land with no formal protection status for the land fenced off from cattle.

Waitangiroto (NZMS 260 H34/865818)

Ten years before the sampling for this study, a fence was erected through a forest of kowhai (*Sophora microphylla*), *Coprosma rotundifolia* and kahikatea to protect it from cattle browsing. The forest is within the Waitangiroto Nature Reserve, 1214 ha, 23 km from Whataroa. This site was used as a pilot study for the rest of this study.

Whataroa (NZMS 260 I34/958 720)

This is a 0.8 ha block of totara-matai forest 3.5 km north of Whataroa township, accessible off Gunn Rd. The site is 100 m from the banks of the Waitangitaona River and 4 km from the Whataroa River and is probably occasionally affected by river flooding. The forest block straddles the boundary fence between two farms. One farmer fenced his part of the forest block to exclude stock 16 years before the survey. Prior to that stock had access to the whole of the forest block.

Arawhata (NZMS1 S97/534933)

This site is 3 km up river from the mouth of the Arawhata River, about 35 km south west of Haast township. It consists of a narrow strip of kahikatea-silver beech/kamahi forest (4.32 ha) lying on a low terrace of alluvial silt. The farmer fenced the area 11 years before the survey. The fence runs parallel to the river, leaving the part of the forest closest to the river still accessible to stock.

Field measurements

Transect data

Within each transect several measurements were made. The frequency of different species or cover types on the ground, was recorded based on point intercepts at one pace intervals along the transect. The height of all saplings ≥ 0.3 m and < 2 m tall and the diameter of all saplings ≥ 2 m tall and < 10 cm diameter at 1.4 m (dbh) was recorded for a 1 m strip either side of the transect line (2 x 50 m belt). The height of all tree ferns and the diameter of all trees ≥ 10 cm dbh were measured in a 2 m strip either side of the transect line (4 x 50 m belt). In addition, an assessment of the intensity of use of the site by cattle was made based on the presence of dung and evidence of trampling and damage to plants. The assessment was made in relation to the other transects in the study; overall, grazing in South Westland valleys is light.

For several additional 2-m wide transects either side of the fence, the number of individuals were counted by species for six size classes: short saplings class I (≥ 0.3 m,< 1 m tall), short saplings class II (≥ 1m,< 2 m tall), tall saplings class I (≥ 2 m tall,< 5 cm dbh), tall saplings class II (≥ 2 m tall, ≥ 5 cm but < 10 cm dbh), small trees (≥ 2 m tall, ≥ 10 cm, < 50 cm dbh), large trees (≥ 2 m tall, ≥ 50 cm dbh).

Six kahikatea seedlings/saplings ranging in height from 23 cm to 83 cm were removed from the non-cattle side of the fence at Whataroa and aged (Buxton 1994).

Data processing

For the Waitangiroto plots, the percentage cover values for the ground and mid layers, and basal area for each tree species, were used. Analyses used paired-comparison t-tests, as well as comparing average values for all cattle plots versus non-cattle plots using Kruskal-Wallis one-way non parametric analysis of variance. For the Whataroa and Arawhata data, a single basal area (BA) value was determined for each species in each transect. This involved summing BA for trees and saplings ≥ 2 m tall, tree ferns (which were given an arbitrary diameter of 10 cm), and saplings ≥ 0.3 m and < 2 m tall (which were given an arbitrary diameter of 1 cm).

The canopy, understorey and ground data were ordinated to see whether cattle plots could be separated from non-cattle plots using detrended correspondence analysis (DCA; Hill, 1979a; Hill and Gauch, 1980) as implemented in PC-ORD (McCune, 1991). A variety of data transformations, such as standardising and square root, were used. Two-way indicator species analysis (TWINSPAN; Hill, 1979b) was used to classify each of the data sets into groups of like plots and species. These groupings were compared with information on intensity of cattle use.

Subsequent analysis steps compared the cattle and non-cattle plot data, species by species. The transect data were summarised in the size class categories given above and combined with the supplementary data. The chi-square test was used to check for recruitment differences in the prominent species in the presence and absence of cattle. The mean basal area values for each understorey species in the transect data were compared using two-sample t-tests to test for significant differences in the species data between the cattle and non-cattle plots.

Results

Waitangiroto

There were no significant differences in the basal areas of the dominant trees in the cattle and non-cattle plots (Table 1). However, the following mid-tier species were significantly more abundant in the non-cattle plots than the cattle plots: hen and chickens fern, *Pneumatopteris pennigera*, mahoe (*Melicytus ramiflorus*), pate and pigeonwood (*Hedycarya arborea*) (Table 1). *Metrosideros diffusa* was common on both sides of the fence and kaikomako (*Pennantia corymbosa*) saplings were more abundant on the cattle side of the fence but the latter situation may just reflect the greater number of adult trees there.

In the ground layer, again the two ferns listed above as well as grasses such as bush rice grass were significantly more abundant in the non-cattle plots (Table 1). In contrast, the *Blechnum* ferns, especially *B. chambersii* and *B. fluviatile*, were more abundant in the cattle plots. Exotic herbs were also more common on the cattle side of the fence. Many of the cover types were not significantly different between cattle and non-cattle plots, with high and low cover values on both sides of the fence: bare ground, bryophytes, native herbs, hook sedges and woody plant seedlings (e.g. kahikatea seedlings). The results from the pilot study at Waitangiroto helped in the design and interpretation of the transects established at Whataroa and Arawhata.

Table 1. Abundance of selected canopy (C), mid tier (M) and ground layer (G) species at Waitangiroto site under cattle and non-cattle conditions; (SE = standard error). Species ordered within each tier from most abundant under non-cattle conditions to more abundant under cattle. Units are mean basal area (cm^2) per 200 m^2 plot for canopy, and mean % cover estimate for mid-tier and ground layer.

Species	Tier	Cattle mean	SE	Non-cattle mean	SE	Signif.
Weinmannia racemosa	C	339.0	(215.9)	732.4	(409.9)	ns
Dacrycarpus dacrydioides	C	504.8	(293.8)	605.7	(320.2)	ns
Carpodetus serratus	C	268.3	(52.0)	277.3	(62.6)	ns
Coprosma rotundifolia	C	65.9	(11.4)	54.7	(10.0)	ns
Dicksonia squarrosa	C	454.0	(135.2)	398.4	(99.1)	ns
Sophora microphylla	C	619.5	(198.6)	436.3	(59.1)	ns
Pennantia corymbosa	C	239.4	(74.7)	85.7	(39.7)	*
Pneumatopteris pennigera	M	0	(0)	15.6	(3.5)	***
Ferns	M	0.2	(0.04)	5.9	(1.2)	***
Asplenium bulbiferum	M	0	(0)	3.0	(1.7)	**
Coprosma rotundifolia	M	16.8	(2.0)	10.3	(2.3)	*
Dicksonia squarrosa	M	6.1	(1.9)	11.1	(3.1)	*
Hedycarya arborea	M	0	(0)	1.3	(0.7)	*
Melicytus ramiflorus	M	0	(0)	1.5	(0.5)	*
Schefflera digitata	M	0	(0)	0.6	(0.4)	*
Ripogonum scandens	M	0.1	(0.05)	0.5	(0.4)	*
Dacrycarpus dacrydioides	M	7.2	(2.0)	6.0	(1.5)	ns
Metrosideros diffusa	M	3.6	(1.4)	2.6	(0.8)	ns
Pennantia corymbosa	M	13.6	(2.6)	7.8	(1.8)	*
Pneumatopteris pennigera	G	1.5	(0.4)	9.1	(1.8)	***
Microlaena avenacea	G	3.2	(2.4)	8.1	(2.6)	*
Asplenium bulbiferum	G	0.01	(0.04)	2.7	(1.6)	*
Blechnum chambersii	G	3.2	(0.6)	2.1	(0.5)	*
Blechnum fluviatile	G	3.3	(0.6)	1.4	(0.8)	*
Ripogonum scandens	G	0.1	(0.0)	0.4	(0.1)	*
Griselinia littoralis	G	0.0	(0)	0.1	(0.04)	*
Bryophytes	G	9.2	(2.1)	11.6	(2.8)	ns
Dacrycarpus dacrydioides	G	0.9	(0.3)	1.2	(0.3)	ns
Uncinia spp.	G	3.7	(1.7)	4.3	(1.4)	ns
Dacrycarpus dacrydioides seedlings	G	15.3	(4.5)	15.1	(3.8)	ns
Native herbs	G	0.8	(0.2)	0.7	(0.2)	ns
Woody seedlings	G	0.7	(0.6)	0.7	(0.4)	ns
Bare ground	G	67.5	(3.9)	63.5	(2.9)	ns
Metrosideros diffusa	G	8.1	(1.8)	4.6	(1.3)	ns
Polystichum vestitum	G	1.0	(0.5)	0.3	(0.2)	ns
Exotic herbs	G	0.7	(0.3)	0.1	(0.0)	*

Significant differences (signif.) determined by Mann-Whitney test: * = $P < 0.05$, ** = $P < 0.01$, *** = $P < 0.001$, ns = not significant.

Ordination and classification

Trees

Whataroa: The ordination of Whataroa transects using tree basal area data showed no clear separation of cattle and non-cattle transects. However, the eigenvalue for the first two axes was a low 0.43. The rank order of transects on axis 2 in part reflected increasing abundance of wheki (*Dicksonia squarrosa*). The TWINSPAN classification and the presence/absence data also showed no simple distinction between cattle and non-cattle transects. Rather, at first division at least, the groupings seemed to relate to abundance of tree ferns in the canopy. However, again the eigenvalues were very low. On average, total basal areas and basal areas for totara and for wheki, were higher in the cattle than in the non-cattle transects.

Arawhata: The ordination of Arawhata tree data showed some partitioning of cattle and non-cattle transects, but the rank order of transects on axis 1 also related to increasing basal area of silver beech (eigenvalue for the first two axes 0.50). The classification showed no clear separation into cattle or non-cattle transects but rather seemed to relate to abundance of silver beech or kamahi. On average, the non-cattle transects had half as much kamahi and four times as much silver beech as the cattle transects.

Understorey

Whataroa: Ordination of the Whataroa understorey data showed a separation of cattle and non-cattle transects along axis 1 (eigenvalue of 0.666; Fig. 2). There was also some separation of stock pressure along axis 1, with the transect with the most pressure from cattle at the extreme right of axis 1 (Fig. 2).

The classification of transects produced similar results. By the second level of division the transects fell into 4 groups (Fig. 3): (A) cattle excluded; (B) lightly used by cattle; (C) mixture of use by cattle; (D) most use made by cattle. Pate was an important determinant of the classification; pate was recorded as present to very abundant in all the non-cattle transects, but absent or very limited in the cattle plots. Other species that were almost, or entirely, confined to non-cattle transects included hutu (*Ascarina lucida*), broadleaf, milk tree (*Streblus heterophyllus*), pigeonwood and supplejack. In contrast, prickly shield fern was four times more abundant in the cattle transects. Many of the other understorey species occurred throughout. The transects with higher light levels, either canopy gaps or edge sites, had higher total understorey basal area.

The species classification was consistent with the transect classification. The seven groups formed at the third division appeared to have some relationship to intensity of cattle use: (A+B) species more common in non-cattle transects; (C+D) infrequent but in both cattle and non-cattle transects; (E) species common throughout; (F) sparse, cattle transects only, predominately ferns; (G) low abundance, exclusive to cattle transects.

Arawhata: Ordination of Arawhata understorey data gave some separation of the cattle and non-cattle transects along axis 2; eigenvalues were 0.54 for axis 1 and 0.24 for axis 2. When the six kamahi transects were omitted, i.e., when the effect of different canopy composition was removed, the separation became very clear, with a cumulative eigenvalue for axis 1 and 2 of 0.76 (Fig. 4). The three outliers were a non-cattle transect in a clearing, one with a large canopy gap, and a cattle transect on the edge of the forest.

The classification of the Arawhata understorey data produced equivocal results with respect to separation of cattle and non-cattle transects. By the fourth division six groups had either purely transects where cattle were present or purely transects where cattle were excluded, but three other groups comprised a mixture of cattle use (Fig. 5). Nevertheless, three species were confined to non-cattle transects: broadleaf, pate, mahoe. Four other species were found mostly in non-cattle transects: lancewood (*Pseudopanax crassifolius*), pigeonwood, supplejack and hen and chickens fern. Species such as prickly shield fern and

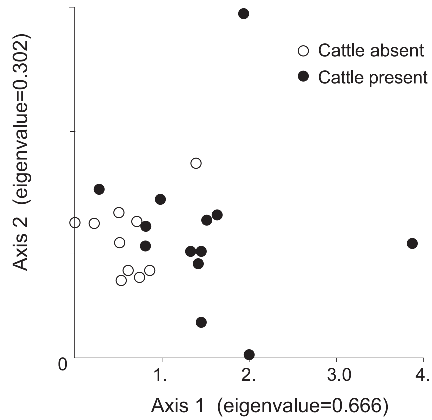

Fig. 2. Graph of site ordination from detrended correspondence analysis based on understorey basal area scores for the 25 samples at Whataroa.

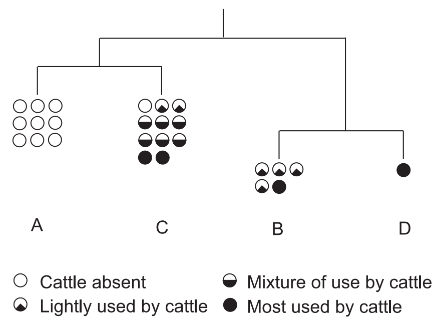

Fig. 3. Dendrogram of the 25 samples at Whataroa from TWINSPAN classification of the understorey basal area scores.

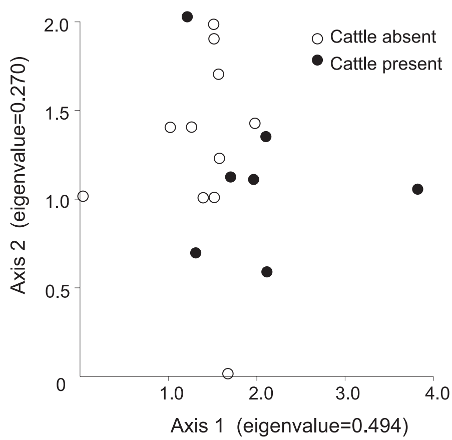

Fig. 4. Graph of site ordination from detrended correspondence analysis based on understorey basal area scores (square root transformed) for 18 samples (6 kamahi canopy samples omitted) at Arawhata.

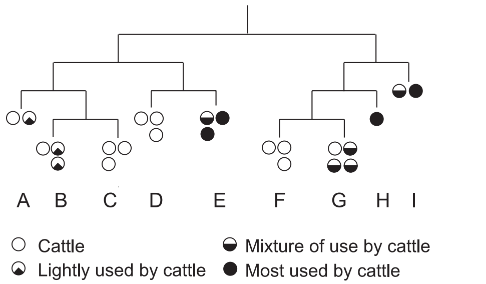

Fig. 5. Dendrogram of the 23 samples at Arawhata from TWINSPAN classification of the understorey basal area scores.

mountain horopito, which tend to be associated with browsing, were found throughout but in greater abundance in the cattle transects (three times in the case of horopito). Several other species were also found in all transects: miro, kahikatea, *Coprosma rotundifolia*, *C. rhamnoides*, soft tree fern (*Cyathea smithii*), wheki, bush rice grass and, rather surprisingly, kamahi.

Using just presence/absence data, four groups of transects were formed at the second division in the classification: (A) non-cattle (1 exception); (B) non-cattle (1/6 exception); (C) mixture of cattle and non-cattle; (D) cattle (2/10 exceptions). These groups match differences in cattle pressure, but equally, they could be related to light levels or the presence of tree ferns.

Ground cover

Whataroa: Ordination of the Whataroa ground data separated the transects into three groups on the second axis on the basis of cattle sign observed in the field: (A) light use by cattle; (B) cattle excluded; (C) moderate use by cattle, however the eigenvalue for axis 2 was only 0.16. By the third division in the classification of samples there was a clear separation into groups of cattle or non-cattle transects but minimal separation of intensity of cattle use. Although moss, litter, tree fern litter and dead wood were the dominant ground cover throughout, the first three of these cover types, along with *Nertera villosa* and prickly shield fern, showed the most variation between cattle and non-cattle transects. These last two species, and *Nertera depressa*, were found exclusively on cattle sites and, in contrast, kahikatea seedlings were found exclusively on non-cattle transects. Several other species had only single records, all from non-cattle transects e.g. pate, hen and chickens fern, mahoe, pigeonwood, *Earina mucronata*. Similarly, the classification of species separated out those associated with the presence of cattle such as prickly shield fern, and those associated with absence of cattle such as mahoe, pate, and hen and chickens fern.

Arawhata: Ordination of the Arawhata ground data showed some partitioning of cattle plots on the first and second axes (eigenvalue 0.35), but the clustering seemed to be more heavily influenced by light gaps, microtopography and presence of treeferns than presence/absence of cattle. The classification, both on percentage cover data and presence/absence data, showed an equally equivocal result in relation to cattle influence. Some species, such as hen and chickens fern and broadleaf, were confined to transects where cattle were excluded, while mountain horopito was confined to transects where cattle were present, but number of occurrences and eigenvalues were low (0.25).

Recruitment

The Whataroa species demographic profiles showed both similarities and differences between cattle and non-cattle data. Totara short saplings were rare at both cattle and non-cattle sites (Table 2). Kahikatea showed a strong reverse-J curve, i.e. plenty of short sapling recruitment in both types of site. Although the two profiles scored as significantly different this was due to the higher numbers of short and tall saplings in the presence of cattle (Table 2). Recruitment of putaputaweta (*Carpodetus serratus*), *Coprosma rotundifolia*, kaikomako and *Coprosma rhamnoides* also appeared to be favoured by presence of cattle, with the difference testing as significant ($P < 0.001$) for the first three species (data not presented). Likewise, there were significantly more, and taller, wheki in the cattle transects than in the non-cattle ones.

In contrast, the profiles for pate were dramatically different with abundant short and tall saplings in the absence of cattle and minimal recruitment in their presence (Fig. 6) and the chi-square test confirmed that there was a significant difference ($P < 0.001$). There also appeared to be more recruitment of lancewood in the absence of cattle. Broadleaf and rimu were only recorded in the absence of cattle, and then only as short saplings (class I). Pigeonwood and mahoe too were scarce in the cattle transects, but pigeonwood showed good recruitment and mahoe some recruitment in the non-cattle transects. Data were insufficient to test for significance with any power for these species.

Comparison of the demographic profiles generated for the Arawhata species showed that recruitment of kamahi and kahikatea was depressed under cattle (Fig. 7, Table 2). A typical reverse-J curve was found for kahikatea (non-cattle) and for miro (both cattle and non-cattle data; Fig. 7). The curves for miro appeared to differ in magnitude but this was not significant (Table 2). Recruitment of pigeonwood, broadleaf,

Table 2. Demographic spread of canopy species at Whataroa and Arawhata under cattle and non-cattle conditions (percent abundance) in six height/dbh categories: short saplings I (≥ 0.3 m, < 1 m tall), short saplings II (≥ 1 m, < 2 m tall), tall saplings I (≥ 2 m tall, < 5 cm dbh), tall saplings II (≥ 2 m tall, ≥ 5 cm but < 10 cm dbh), small trees (≥ 2m tall, ≥ 10 but <50 cm dbh), large trees (≥ 2 m tall, ≥ 50 cm dbh).

Species	Total count		Short sapling I		Short sapling II		Tall sapling I		Tall sapling II		Small Tree		Large Tree		Chi-sq.	Signif.
	Cattle	Non-cattle	Cattle	Non-cattle	Cattle	Non-cattle	Cattle	Non-cattle	Cattle	Non-cattle	Cattle	Non-cattle	Cattle	Non-cattle		
Whataroa canopy species																
Dacridium cupressinum	0	15	0	100	0	0	0	0	0	0	0	0	0	0	-	ns
Hedycarya arborea	2	71	100	68	0	20	0	13	0	0	0	0	0	0	1.0	ns
Podocarpus totara	176	115	3	1	1	0	1	0	4	0	82	90	9	10	9.6	ns
Prumnopitys ferruginea	1	0	100	0	0	0	0	0	0	0	0	0	0	0	-	ns
Dacrycarpus dacrydioides	473	288	79	78	17	16	4	3	0.2	0	0.2	1	0	2	13.4	*
Pennantia corymbosa	320	129	74	68	15	12	7	7	1	1	3	12	0	0	13.0	*
Arawhata canopy species																
Weinmannia racemosa	228	232	15	45	0.4	10	4	6	10	4	53	28	18	7	87.0	***
Griselinia littoralis	4	106	0	92	0	6	0	1	50	0	25	1	25	0	95.7	***
Dacridium cupressinum	36	60	14	12	11	15	36	57	17	8	17	8	6	0	8.3	ns
Dacrycarpus dacrydioides	406	467	57	40	12	22	22	30	6	6	3	3	0	0	30.6	***
Hedycarya arborea	3	171	100	95	0	5	0	0	0	0	0	0	0	0	-	
Melicytus ramiflorus	3	8	33	25	0	63	0	13	0	0	67	0	0	0	-	
Nothofagus menziesii	60	100	3	0	0	0	0	11	8	5	77	57	12	27	12.6	*
Pennantia corymbosa	24	10	75	50	4	20	21	30	0	0	0	0	0	0	2.9	ns
Prumnopitys ferruginea	237	186	83	79	8	12	4	4	4	1	1	4	0.4	1	9.6	ns

Significant differences(signif.) between the profiles, determined by chi-square test, are indicated: * = $P < 0.05$, ** = $P < 0.01$, *** = $P < 0.001$, ns = not significant.

pate and mountain horopito was minimal in the presence of cattle but moderate to abundant in their absence. In contrast, *Coprosma rotundifolia* and kaikomako short saplings (class I) were more abundant under cattle than where cattle were excluded. With the exception of miro and kaikomako, these demographic profile differences were significant ($P < 0.001$).

Understorey species abundance

Only 19 of the 45 understorey species present in at least one transect at Whataroa could be tested for significant difference between cattle and non-cattle transects (Table 3); the other species had too many zero values for valid comparison. There was a significant difference between cattle and non-cattle transects in the abundance of nine species. Supplejack was present in all non-cattle transects but in only one cattle transect. Pate was abundant in all non-cattle transects but present in only one quarter of cattle transects. There was no association between this paucity of pate in the cattle transects and abundance of prickly shield fern. Wineberry (*Aristotelia serrata*) saplings were also more prevalent in the non-cattle transects. The other six species were more abundant in the cattle transects: *Blechnum fluviatile, Coprosma rhamnoides*, kahikatea, kaikomako, wheki and prickly shield fern. Totara saplings were absent also from the non-cattle transects and present in five of the cattle transects. It is worth noting that this result for kahikatea is inconsistent with the ground cover data where seedlings were found in non-cattle transects only.

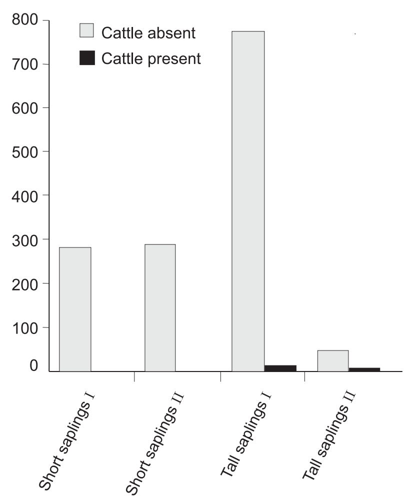

Fig. 6. Demographic profile for pate (*Schefflera digitata*) at Whataroa, under presence and absence of cattle, using four of the height/dbh categories: short saplings I (≥ 0.3 m, < 1 m tall), short saplings II (≥ 1 m, < 2 m tall), tall saplings I (≥ 2 m tall, < 5 cm dbh), tall saplings II (≥ 2 m tall, ≥ 5 cm but < 10 cm dbh).

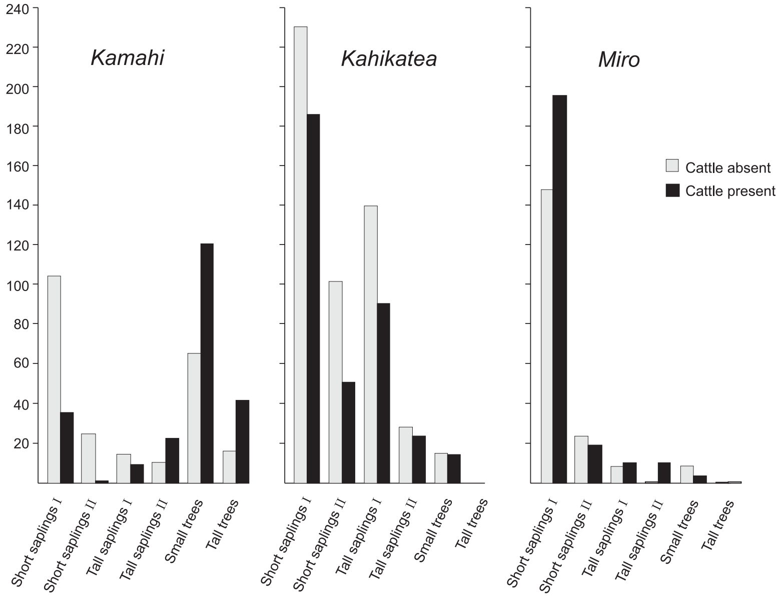

Fig. 7. Demographic profile of kamahi (*Weinmannia racemosa*), kahikatea (*Dacrycarpus dacrydioides*) and miro (*Prumnopitys ferruginea*) at Arawhata, under presence and absence of cattle, using six height/dbh categories: short saplings I (≥ 0.3 m, < 1 m tall), short saplings II (≥ 1 m, < 2 m tall), tall saplings I (≥ 2 m tall, < 5 cm dbh), tall saplings II (≥ 2 m tall, ≥ 5 cm but < 10 cm dbh), small trees (≥ 2 m tall, ≥ 10 but <50 cm dbh), large trees (≥ 2 m tall, ≥ 50 cm dbh).

Table 3. Abundance of understorey species (mean cover estimate, with standard error SE) at Whataroa and Arawhata sites under cattle and non-cattle conditions.

	Whataroa					Arawhata				
	Cattle		Non-cattle			Cattle		Non- cattle		
Species	mean	(SE)	mean	(SE)	Signif.	mean	(SE)	mean	(SE)	Signif.
Schefflera digitata	7.4	(4.3)	1205.0	(698.2)	***	1.4	(1.4)	704.0	(651.7)	***
Ripogonum scandens	0.5	(0.5)	6.0	(1.3)	***	6.8	(4.2)	9.4	(2.0)	*
Griselinia littoralis	n/a					0.0	(0.0)	12.5	(4.0)	***
Hedycarya arborea	n/a					2.3	(1.9)	15.5	(2.8)	***
Asplenium bulbiferum	1.	(1.1)	0.9	(0.5)	*	4.1	(2.8)	4.8	(1.6)	ns
Aristotelia serrata	171.6	(102.5)	1119.1	(706.1)	*	1323.5	(1321.2)	17.2	(17.2)	ns
Coprosma foetidissima	n/a					0.0	(0.0)	8.0	(3.3)	*
Carpodetus serratus	31.6	(15.4)	301.5	(216.8)	ns	n/a				
Coprosma colensoi	7.5	(3.5)	213.0	(210.8)	ns	n/a				
Pseudopanax crassifolius	138.9	(86.6)	743.8	(715.5)	ns	62.3	(42.1)	1007.7	(962.4)	ns
Weinmannia racemosa	n/a					681.6	(421.1)	1103.4	(953.7)	ns
Coprosma rotundifolia	695.9	(300.4)	1193.1	(693.6)	ns					
Leptopteris superba	n/a					8.9	(4.1)	10.3	(3.2)	ns
Coprosma ciliata	n/a					3.9	(2.6)	9.1	(4.2)	ns
Melicytus ramiflorus	n/a					0.5	(0.5)	4.3	(2.5)	ns
Streblus heterophyllus	5.3	(2.1)	4.5	(1.4)	ns	2.1	(1.5)	4.5	(2.8)	ns
Fuchsia excorticata	462.1	(306.6)	342.2	(218.8)	ns	n/a				
Clematis paniculata	3.9	(2.2)	1.3	(0.6)	ns	n/a				
Pseudowintera colorata	72.9	(34.4)	31.6	(24.2)	ns	194.2	(151.9)	63.7	(31.9)	ns
Coprosma rhamnoides	58.3	(8.0)	11.7	(3.1)	*	435.7	(414.2)	118.9	(101.7)	ns
Neomyrtus pedunculatus	131.2	(116.6)	26.6	(24.2)	ns	n/a				
Dacrycarpus dacrydioides	475.7	(321.6)	19.5	(11.3)	*	1954.0	(1330.3)	1821.5	(1092.5)	ns
Myrsine divaricata	15.1	(3.4)	5.0	(1.8)	*	n/a				
Blechnum fluviatile	19.4	(4.3)	5.0	(2.2)	*	3.1	(2.1)	10.8	(3.5)	*
Pennantia corymbosa	151.6	(83.9)	115.5	(87.9)	**	n/a				
Polystichum vestitum	37.3	(5.7)	10.3	(4.2)	***	14.1	(4.5)	11.7	(3.6)	ns
Dicksonia squarrosa	39.0	(4.5)	4.9	(2.1)	***	23.5	(4.4)	15.1	(2.6)	ns

Significant differences (signif.) determined by student t-test: * = $P < 0.05$, ** = $P < 0.01$, *** = $P < 0.001$, ns = not significant.

With the Arawhata understorey data there was a significant difference in abundance between cattle and non-cattle transects for six of the 19 species tested (Table 3). Again pate was abundant and broadleaf, supplejack, pigeonwood, *Blechnum fluviatile* and *Coprosma foetidissima* were present in the non-cattle transects but absent, or nearly so, in the cattle transects. Hen and chickens fern was present in 66.6% of the non-cattle transects and only 16% of the cattle transects, but the t-test found no significant difference. The same was true for Prince of Wales' feathers (*Leptopteris superba*), where the percentages were 92% and 42% respectively. Kahikatea and other species such as *Coprosma rhamnoides* and wheki showed no significant difference.

Discussion

This study provides some evidence that cattle browse can alter the understorey and ground vegetation. The ordination and classification of Whataroa and Arawhata data showed relatively little difference in the canopy vegetation, but major differences in the understorey vegetation, between sites where cattle had access and those where cattle were excluded. This suggests that the separation for understorey species was not due to overhead canopy, proximity to edge or some other environmental factor. The ground cover results were more equivocal, with a clear separation for Whataroa but not for Arawhata (or Waitangiroto). The recruitment and understorey species abundance testing showed that some species appear to be significantly affected by cattle and thus only grow in their absence. These predominantly subcanopy species include pate, broadleaf, pigeonwood and supplejack, as well as mahoe, milk tree, lancewood and hen and chickens fern. Cattle had less impact on most other species including those of the main canopy. A third group of species appears to be regenerating better in the presence of cattle than in their absence, particularly mountain horopito and prickly shield fern. These trends were consistent at all three study sites except for a few species — kahikatea, wheki, *Coprosma rhamnoides* and *Blechnum fluviatile* — which were apparently enhanced by presence of cattle at one site but suppressed by them at another.

At a general level, the results of this study are consistent with those from studies on the effects on forest of other ungulates, such as red deer. Continued deer browsing impairs the ability of some plant species to regenerate, although they tend to re-establish when protected from deer browsing. For a few plant species regeneration is enhanced, either during or after deer browsing. In their Urewera study, Allen *et al*. (1984) found that hen and chickens fern, lancewood, mahoe, and supplejack increased inside the deer exclosure and pate particularly so. Walton (1972) found that fivefinger (*Pseudopanax arboreus*), mahoe and wineberry were very palatable to cattle. The present study found that cattle are similar to deer in their plant preferences.

Cattle tend to be less selective browsers than deer. Thus, in sites lightly used by cattle like those of this study, it would be expected that the bulk of species would be just lightly browsed. Sometimes it was difficult to detect these small effects due to cattle from the myriad other environmental influences.

A few species appear not to be eaten by cattle. Mountain horopito was much more abundant at cattle sites in this study. Similarly, Allen *et al*. (1984) found at some sites that mountain horopito was more abundant outside the deer exclosures. Jane and Pracy (1974) described the replacement of normal canopy species in the Haurangi Ranges by species unpalatable to deer, especially silver tree fern (*Cyathea dealbata*) and soft tree fern. However, Allen *et al*. (1984) did not find the same pattern of replacement. At Whataroa there was more wheki in the canopy and at Arawhata proportionally more recruitment of soft tree fern and wheki in the cattle than the non-cattle transects. This may have been a function of presence of cattle, or some other site feature.

The regeneration of kahikatea appeared to be enhanced by the presence of cattle at Whataroa but inhibited at Arawhata. At Waitangiroto the results were equivocal. Previous workers have suggested that kahikatea is not highly palatable to cattle (e.g. Rosoman, 1990). In this study only the occasional seedling and sapling had been browsed. Cattle do damage plants by trampling and breaking (Adams, 1975), and thus suppress their growth. However, regeneration of kahikatea may be enhanced through the opening up of the undergrowth and consequent increased light. Both these effects seemed to be occurring at Waitangiroto. Beveridge (1973) showed regenerating kahikatea seedlings in good light at Pureora Forest had an annual height increment of 8 to 10 cm, compared with less than 3 cm for seedlings suppressed by overshadowing broadleaved trees. Kahikatea seedlings and saplings aged from Whataroa had an average annual height increment of only 2 cm (Buxton 1994). It appears that since the exclusion of stock there, the growth of broadleaved species has reduced light levels sufficiently to suppress the growth of kahikatea seedlings.

Browsing, by increasing light levels, may enhance kahikatea regeneration. However, Duncan (1993) showed that while kahikatea seedlings and saplings may be common in light gaps in intact podocarp forest, there will be no trees beyond the sapling stage without a major disturbance providing fresh surfaces and abundant light. The presence of totara saplings in cattle transects and their absence from non-cattle transects in this study may suggest that very light use by cattle could also facilitate regeneration of totara. Veblen and Stewart (1980) found a similar result on Bench Island off Stewart Island where seedlings and low herbs actually increased in the presence of deer due to the destruction of the understorey and increased light at the forest floor.

When cattle densities are low it is likely that stock stay mostly on the river flat grasslands, entering the forest mainly for shelter and perhaps lightly browsing the more palatable species. The variation in kahikatea seedling regeneration between the three study sites may reflect a different balance in the regeneration enhancing/inhibiting activities of the cattle. This variation lends support to Wardle's (1989) hypothesis that low browsing pressure may actually encourage podocarp regeneration by preventing broadleaved species, ferns, and tree ferns from dominating light gaps.

The dearth of silver beech short saplings (class I) found in both cattle and non-cattle sites at Arawhata is typical of closed canopy beech (*Nothofagus*) forest (James, 1974). In contrast, the lack of recruitment of kamahi, even in the transects not used by cattle, probably reflects the palatability of kamahi to deer.

Despite the provisos mentioned in the introduction, the results of this study are consistent with those of other ungulate studies. However, two other study site difficulties must be noted. First, at Whataroa it is likely that prior to the exclusion of stock, the part of the forest from which cattle are now excluded was actually used more intensively than the side to which the cattle now have access (P. Nolan, landowner, Whataroa, NZ, *pers. comm.*). This differential cattle pressure prior to fencing complicates interpretation of differences in species composition resulting from the subsequent removal of cattle. As Bellingham *et al.* (1999) have shown, the effects of past disturbances last a long time.

Second, at Arawhata, the fence that excludes stock from part of the forest runs parallel to the river. The differences detected between the cattle and non-cattle transects could be, in part, a function of distance from the river, e.g. differences in depth of silt, frequency of flooding, fertility and previous accessibility to stock. However, the similarity in canopy vegetation suggests this is not a major confounding factor.

The study sites represent snapshots in time and but a few of the myriad variables relevant to investigating the relationship between cattle and vegetation, each of which varies throughout South Westland (Wardle 1980; Duncan and Norton, 1990). They include vegetation type, soil type, fertility, rainfall, flooding history, wind history, site type and stock use. Unfortunately, while there are abundant areas used by cattle and available for sampling, comparable areas where cattle are absent are few.

Because the areas studied have been used by cattle for a long time, the succession patterns upon removal of stock were probably different from those that would have occurred without any stock influence, but they are likely to reflect the situation on most land licensed for grazing. Further, the time period since stock removal may have been insufficient for the long-term changes which may occur to be obvious. After browsing mammals are removed it takes from 5 to 10 years for the litter/soil cycle to redevelop and perhaps up to 25 years for full recovery (Jane and Pracy, 1974). Vegetation takes even longer to return to something close to its pre-stock state. It may take decades or even centuries for forests to recover after the selective removal of palatable species from the regenerating understorey. Species unaffected by browsing or benefiting from increased light will have increased their numbers and may dominate for decades (Jane, 1983; Nugent and Fraser, 1993).

It is likely that different stocking regimes in terms of grazing licences issued will have dramatically different effects on vegetation structure and indeed on individual species. A small amount of cattle browse pressure may promote some species, while more pressure from cattle may inhibit the same species. Rosoman (1990) found that, in general, an increase in the level of cattle browse and trampling in South Westland forest margins meant less or even no regeneration in the cattle browsed tier. At lower densities, stock spent most of their time on the grassland; at higher densities they were more likely to enter the forest, browsing vegetation, and trampling and pugging the ground, thus influencing forest regeneration. It is likely that the difference in vegetation response is greater between degrees of stock pressure than between the presence/absence of stock that was investigated in this study. Cattle also influence the vegetation by addition of dung and urine, and by creating microsites for the introduction and dispersal of weed seeds (Tanner, 1992).

Conclusions

This study indicates that the presence of cattle has an impact on vegetation species composition, structure and regeneration in forests, that the effects of a particular grazing regime may take many decades to dissipate, and that the impacts of cattle change with intensity of use. Possible management options for the land licensed for grazing include: (1) continued use as in existing grazing licences, (2) continued use but at relatively low stocking rates, (3) revoke some grazing licences and permit only very light use in others, (4) revoke all grazing licences.

Several factors must be considered in deciding between these options. First, grazing is a long-established traditional land use in South Westland going back over 100 years and the Department of Conservation wishes to work co-operatively with local communities in deciding on the future management of land licensed for grazing. Conversely, cattle use has perceived and proven impacts on natural plant communities. When the management of land licensed for grazing came under the auspices of the Conservation Act 1987, the mandate changed from a multiple use regime (Forests Act 1949, Lands Act 1948) to the protection of conservation values. The public expects this conservation mandate to be implemented. The decision should also be guided by the West Coast Conservancy Management Strategy (NZ Department of Conservation, 1999). The stated vision includes protecting, enhancing and restoring the West Coast's unique biodiversity.

A final element in the decision making process is the conservation aim which is determined for any site. This may be to protect: (1) the mixed grassland, (2) the forest canopy, (3) the forest understorey, or (4) the forest margin and its expansion. The aim must be precise, as the impact of cattle varies between different vegetation types and plant species and thus prompts different actions.

To determine more accurately the relative impacts of differing intensities of cattle use would require a longer, more robust and comprehensive study. It would need to include experiments designed to test what management actions are required to achieve specific desired conservation outcomes. In the meantime, this study suggests that to give full effect to the Conservation Act's mandate, future stock use of land managed by the Department of Conservation in South Westland should be restricted. Stock should be confined to modified sites, such as grassy river flats and clearings, where off-site impacts can be limited by control of stocking levels or by fencing. If any stock use is continued, it could be under a sustainable arrangement in which the density, frequency and seasonality of use specified in the licence ensures minimal damage to conservation values at each site. This may be difficult because once the understorey of a forest has been depleted it probably takes relatively few animals to keep it in that state. For the stock use to be 'sustainable', stocking levels must be reduced to below the threshold level. Any of the selectively browsed plant species will still be heavily impacted, even at low stocking levels. It is the less preferred species that will show the best response to reduction, as opposed to elimination, of stock. Ultimately, the Department's position must be about protecting conservation values, not just about revoking grazing licences.

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