Impact of domestic stock on vegetation in South Westland, 1989–2004

Rowan P. Buxton, Duane Peltzer, Larry E. Burrows, Susan M. Timmins and Peter Wardle

DOC RESEARCH & DEVELOPMENT SERIES 294

Published by
Science & Technical Publishing
Department of Conservation
PO Box 10420, The Terrace
Wellington 6143, New Zealand

DOC Research & Development Series is a published record of scientific research carried out, or advice given, by Department of Conservation staff or external contractors funded by DOC. It comprises reports and short communications that are peer-reviewed.
Individual contributions to the series are first released on the departmental website in pdf form. Hardcopy is printed, bound, and distributed at regular intervals. Titles are also listed in our catalogue on the website, refer www.doc.govt.nz under *Publications*, then *Science & technical*.

ISSN 1176-8886 (hardcopy)
ISSN 1177-9306 (web PDF)
ISBN 978-0-478-14451-2 (hardcopy)
ISBN 978-0-478-14452-9 (web PDF)

This report was prepared for publication by Science & Technical Publishing; editing by Amanda Todd and layout by Lynette Clelland. Publication was approved by the General Manager, Research and Development Group, Department of Conservation, Wellington, New Zealand.

In the interest of forest conservation, we support paperless electronic publishing. When printing, recycled paper is used wherever possible.

CONTENTS

Impact of domestic stock on vegetation in South Westland, 1989–2004

Rowan P. Buxton[1], Duane Peltzer[1], Larry E. Burrows[1], Susan M Timmins[2] and Peter Wardle[1]

[1] Landcare Research, PO Box 40, Lincoln 7640, New Zealand
Email: buxtonr@landcareresearch.co.nz

[2] Department of Conservation, PO Box 10420, Wellington 6143, New Zealand

ABSTRACT

This long-term study aimed to determine the effect of domestic stock (particularly cattle) grazing on forest margin plant communities in South Westland, New Zealand. Between 1989 and 1992, six pairs of matched exclosure and control plots were established across forest–grassland boundaries on river flats grazed by cattle. These were resurveyed at intervals of 3–5 years. Short-term (8–13 years) vegetation responses to stock exclusion varied with community type in both rapidity and direction. Fencing reduced the number of all herbs, particularly in floodplain grassland habitats, and increased the cover of exotic herbs. Fencing appeared to promote establishment of *Nothofagus menziesii* seedlings and saplings in forest habitats, but may have suppressed woody seedling establishment in ecotone habitats. The number of shrubs preferred by stock only increased with fencing or between measurements in some locations, suggesting that previous or ongoing grazing by mammals other than domestic stock was continuing to have an impact. Fencing increased tree fern numbers in forest habitats. The results clearly showed that the effect of excluding stock was variable. In part, this was due to indirect competition effects of weeds and the impacts of other browsing animals. Manipulative experiments are required to disentangle the direct effects of cattle grazing from those of other animals. A survey of local grazing concessions in the vicinity of each exclosure is needed to determine how representative these sites are of grazed forest margin vegetation in South Westland, and thus how widely predictions about the effects of grazing exclusion based on them might be applied. Maintenance of native herb species diversity in grasslands can be compatible with low-intensity grazing; however, maintenance of woody regeneration in many ecotone forest types is not compatible with grazing. Therefore, no one approach can be applied in all situations and site-specific information is required for conservation management.

Keywords: cattle, exclosures, fencing, forest margins, grassland, grazing, river flats, South Westland, New Zealand

Buxton, R.P.; Peltzer, D.; Burrows, L.E.; Timmins, S.M.; Wardle, P. 2008: Impact of domestic stock on vegetation in South Westland, 1989–2004. *DOC Research & Development Series 294*. Department of Conservation, Wellington. 45 p.

1. Introduction

Prior to human arrival in New Zealand, transitions between forest on valley slopes and the shrubby, grassy, or swampy vegetation occupying recent wet or frosty flats were a conspicuous feature of most alluvial valleys. In some places, these transitions (or ecotones) were gradual, but in many others they were very sharp, reflecting discontinuities in soil and drainage patterns, or they were the result of inherent ‘switch’ effects (where each vegetation type creates an environment that favours its own species, and deters the species on the other side of the boundary) (Wilson & Agnew 1992). Sharp boundaries also arose when a river cut a new channel into the forest edge and then retreated, leaving a new river terrace to be colonised by young vegetation. During this pre-human period, it is likely that moa and other herbivores reached maximum numbers and exerted maximum browsing pressures on alluvial flats, because the fast-growing seral communities on these fertile sites would have provided the best food source (McGlone 1989). However, Maori occupation contributed to the disappearance of moa, and following the arrival of Europeans, natural forest boundaries on valley floors disappeared from most of lowland New Zealand, because the alluvial soils were those most in demand for agriculture, intensive grazing and settlement.

South Westland is unique in New Zealand for the amount of low-altitude valley flats remaining that have never been cleared of their pre-European vegetation. Cattle have grazed these river flats for as long as pastoral farming has been carried out in the region—i.e. since the 1870s or even earlier. The major forest–grassland ecotones coincide with natural boundaries such as floodplains (pers. obs.), which suggests that they have not changed markedly in response to grazing. However, changes in the composition and structure of the vegetation are apparent. In particular, the grassland is now almost totally dominated by introduced grasses and clovers; although native plants persist among these, they are mostly low-growing species.

Since the mid-1970s, nature conservation has became an increasingly divisive issue in South Westland, with some people considering stock grazing to be an inappropriate and damaging use of conservation land. Concern from the New Zealand Forest Service about the amount of Provisional State Forest that was being cleared for grazing led to an amendment of the Forest Act in 1973 that declared this category to be permanent State Forest. The Forest Service thereby acquired responsibility for administering the affected leases. However, around 1977 there was some rationalisation with respect to which authority administered specific leases, and opportunities were taken to reduce new licences to grazeable areas only. During its final years, the Forest Service was developing a network of areas (ecological reserves) subject to special protection, and this affected some of the South Westland leases. Further, the importance of the lowland forest boundaries was well recognised within the scientific community. The Ohinemaka Ecological Reserve was proposed by the New Zealand Forest Service largely to protect vegetation on lowland alluvial soils, including forest boundaries. This area also contained a grazing lease, and the conflict of interest became a matter of public concern. The Department of Conservation (DOC) inherited the grazing leases after the dissolution of Lands and Survey and the

Forest Service in 1987. Rather than endorse any decision to either continue or cease grazing, it was decided that a series of exclosure and control plots should be set up and monitored over as many years as was necessary to arrive at sound recommendations.

This long-term monitoring programme began in 1989 as a joint project between the former Science & Research Division (DOC), West Coast Conservancy (DOC) and Landcare Research. Its aim was to determine the effect of domestic stock grazing, particularly cattle, on forest margin plant communities in South Westland. It was envisaged that stock impacts would differ between habitat types (grassland, ecotone, forest) and that protection of conservation values, whether grassland biodiversity or maintenance of the forest canopy, forest understorey, or forest margin vegetation, would be determined by DOC's conservation goals at any site. Further background information about this project can be found in Buxton et al. (2001).

This report updates findings up to 1999 (Wardle et al. 1994; Buxton et al. 2001) and reviews the main results from this study after 15 years of monitoring. The report expands on previous results in three ways, and makes use of a further remeasurement to determine:

- Shifts in plant species composition by vegetation layer
- Changes in numbers of plants
- Differences amongst forest, ecotone and grassland habitats resulting from fencing

It also provides information and recommendations for land managers, and discusses issues that arose from a grazing impacts workshop held with West Coast Conservancy staff in Hokitika on 12 September 2006. Original field records are archived in the National Vegetation Survey databank (NVS) held at Landcare Research, Lincoln. Plants are referred to by their specific names throughout; common names are listed in Appendix 1.

2. Objectives

This monitoring programme had two objectives:

1. To determine the effect of extensive cattle grazing on forest margin vegetation. Forest margin ecotones (the transitional vegetation between forest and grassland) were expected to respond quickly to grazing removal (i.e. both herbaceous and woody plant species were expected to respond to herbivory). These are a major area of concern for DOC staff.
2. To demonstrate the changing state of vegetation in the presence/absence of stock grazing, in order to assess the conservation values (e.g. the abundance and diversity of native plant species) of those states when considering management options.

3. Methods

3.1 EXPERIMENTAL DESIGN AND RECORDING

From the outset, it was realised that the study would need to be long term—at least 10 years was envisaged. Therefore, it was necessary to select sites where there was reasonable certainty of present management being continued, i.e. extensive grazing.

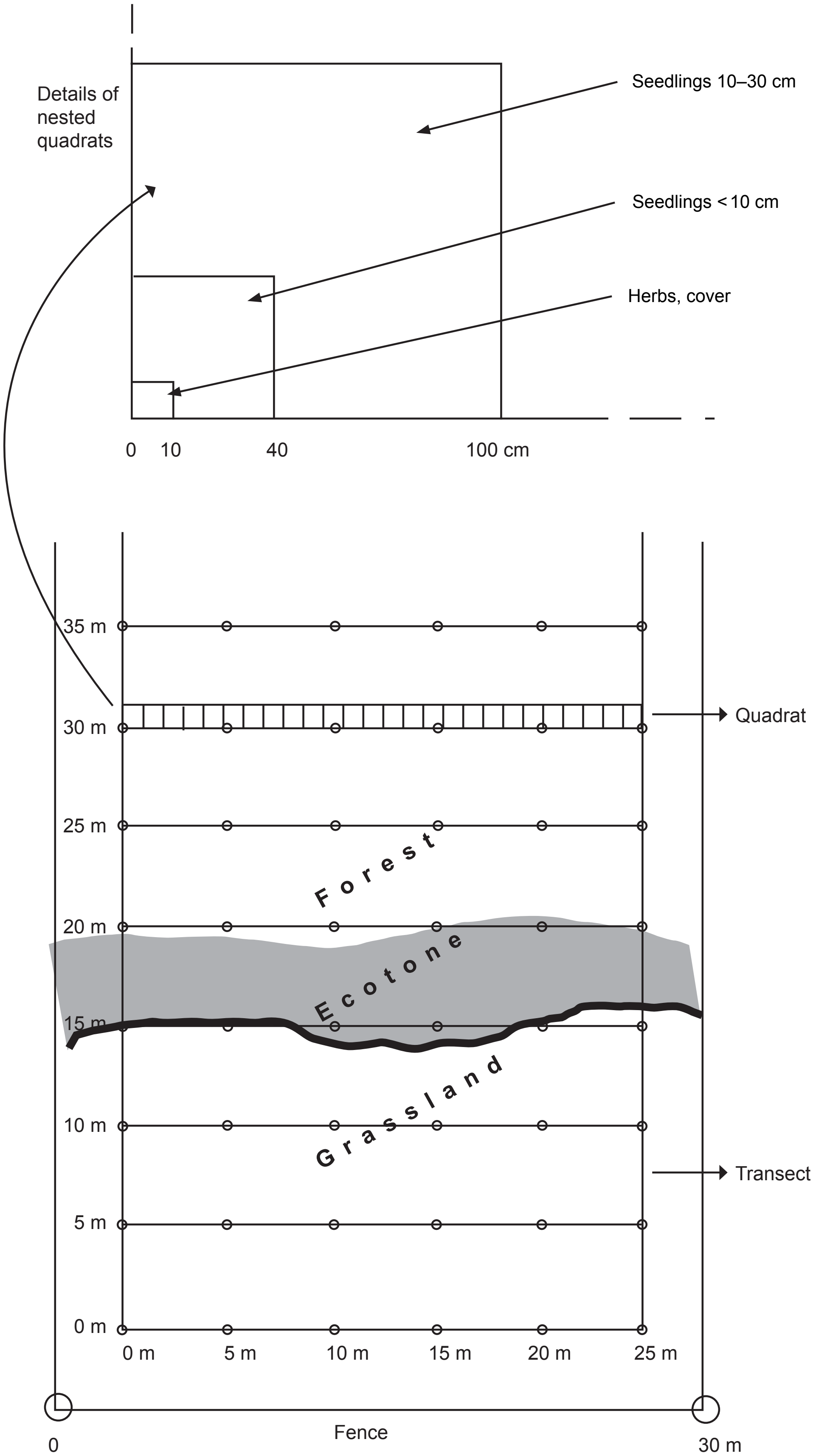
We also considered it important to capture as many variations of the theme 'forest boundaries on extensively grazed alluvial flats' as possible. One important set of variations comprised substrate type and drainage, which graded from coarse gravel to deep silt, and from well drained to swampy. The composition of both forest and grassy vegetation varied with these differences. Forest communities also differed according to whether *Nothofagus menziesii* was dominant or absent.

Six pairs (fenced or unfenced) of rectangular plots were monitored, each of which was c. 30 m × 60 m, with the long axis at right angles to the forest–grassland boundary. All plots extended from grassy vegetation into closed-canopy forest; the sole exception to this lay wholly within forest.

Exclosure plots were bounded by 1.2-m-high cattle- and sheep-proof fences, which were constructed of posts, battens and high-tensile wire. These fences did not exclude deer or small mammals such as rabbits (*Oryctolagus cuniculus*), possums (*Trichosurus vulpecula*) and rodents, although they may have provided some discouragement to the former. There was a control plot adjacent to each exclosure plot, which matched as closely as possible both the major vegetation pattern and the lesser variations in vegetation and topography within the exclosure. Each exclosure and control plot was divided into contiguous transects (25 m × 5 m), with the long axis parallel to the forest–grassland boundary (Fig. 1). There were 4–10 transects per plot. To distinguish the effects of cattle grazing from other effects such as the initial differences between plots with statistical rigour would have required an impracticable level of replication. However, by treating each site as a replicate, the site differences could be removed, allowing changes resulting from exclosure to be expressed.

Vegetation was divided into four successive size classes. Herbs and woody plants < 0.1 m tall and 0.1–0.3 m tall were measured in nested quadrats distributed at 1-m intervals along the transect baseline, i.e. the edge of the transect closest to the zero line of the plot (Fig. 1). Plants ≥ 0.3–2 m tall and > 2 m tall were counted over the whole transect. For full details of the experimental design see Buxton et al. (2001).

Figure 1. Layout of a stock exclosure used to monitor impacts on forest boundaries in South Westland. Data for woody plants > 30 cm was recorded in 25 × 5 m transects. A series of 25 nested quadrats runs across the baseline of each transect at 1-m intervals, as illustrated at the 30-m line. Details of data recorded in nested quadrats are shown. The heavy dark line represents the forest edge, and the shading represents the ecotone. Small circles = metal pegs placed at 5-m intervals to aid relocation; large circles = fence posts.



3.2 PLOT LOCATIONS AND HISTORIES

The location of the six study sites is shown in Fig. 2. Podocarp/hardwood forest dominated the margins of the Whataroa Valley and Cook River/Weheka sites, whereas the Jackson River and Arawhata River forests were dominated by *Nothofagus menziesii*. More detailed descriptions of these sites are summarised in Table 1 or given below. All plots were 25 m wide, but the depth that they extended into forest varied between sites (see Table 1). The number of transects at each site was the same for both exclosure and control plots. The Whataroa plots replaced those lost to floods in the Waitangitaona Valley (details are provided in Buxton et al. 2001). The number of transects in grassland, ecotone and forest portions of each plot are shown in Table 2.

The Whataroa Valley exclosure and its control were on a high terrace on the true left bank of the Whataroa River near Tommy Creek. Prior to 2001, the plots were grazed year-round by both sheep and cattle, but spelled for periods during normal rotation of stock. In 2002, stock were set-stocked all year round. These plots replaced those lost to a series of floods between 1990 and 1996 in the Waitangitaona Valley (see Buxton et al. 2001).

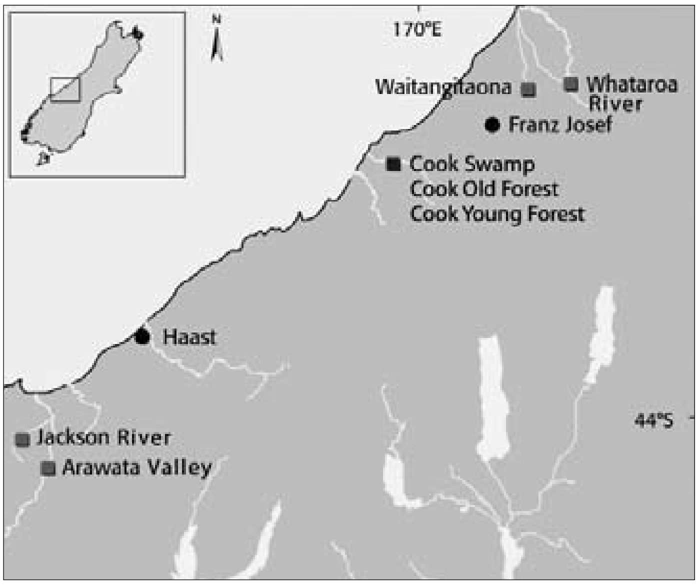


Figure 2. Location of paired exclosure and control plots (squares) and nearby settlements (circles) established to monitor the impacts of stock grazing in South Westland.

The Cook Old Forest exclosure and control were situated a few metres east of Cook Young Forest, beyond a clear vegetation boundary that separated young forest from a much older stand with some large podocarp trees.

Because of a marked curve in the forest margin, as well as a need to allow space for movement of stock between the plots and the river, the two Jackson River plots were given a herringbone layout (Buxton et al. 2001). Since the sides of these transects were not perpendicular to the baseline, their depth was slightly less than 5 m.

3.3 RECORDING TIMES AND INTERVALS

Plots were measured between late January and the end of March, when herbs and grasses (especially) were flowering, and were therefore more readily identifiable.

All transects were measured when plots were first established. A full resurvey of the plots commenced in 1992; this was initially repeated at intervals of 3–4 years, but the interval has been increased to 5 years since 1999. We have fully resurveyed the exclosure plots and their matching control plots three times (i.e. four measurements per transect), following the experimental design described in Buxton et al. (2001). The sole exception to this was the Whataroa Valley plots, which replaced the eroded Waitangitaona plots in 1996; these have been resurveyed twice.

TABLE 1. SITE DETAILS FOR PAIRED EXCLOSURE AND CONTROL PLOTS. STOCKING RATES (WHERE AVAILABLE) ARE APPROXIMATE. THE THREE COOK RIVER/ WEHEKA SITES LAY WITHIN 1660 ha GRAZED BY THE EQUIVALENT OF 220 BREEDING COWS AND CALVES, AND 440 SHEEP. NOTE: SU = STOCK UNITS.

SITE	GRID REF	ESTABLISHED	FENCED	REMEASURED	SOIL	DEPTH (m)	VEGETATION	STOCKING RATE	NUMBER OF TRANSECTS
Whataroa Valley	E2299900, N5763600	1996	1999	1999, 2004	Stony alluvium/ alluvial silt	40	Swampy pasture to forest dominated by *Pennantia corymbosa*. The grassland portion had high numbers of native herbs. Seedlings of several palatable species were present.	5 SU/ha prior to 2001; 2.1 SU/ha (six breeding cows and calves on 27.3 ha) since 2002	8
Cook Swamp	E2255900, N5743300	1989	1989	1993, 1997, 2002	Wet alluvial silt	50	Dense sedge and grass with an open shrub overstorey, to dense scrub of small-leaved divaricating shrubs with an open overstorey of trees, including *Dacrycarpus dacrydioides*. The southern end of the plots had pockets of *Phormium tenax*.	2.5 SU/ha	10
Cook Young Forest	E2256400, N5743600	1990	1990	1994, 1998, 2002	Stony alluvium	40	Grassland adjoined closed forest of young podocarps on a low terrace.	2.5 SU/h	8
Cook Old Forest	E2256500, N5743600	1990	1990	1994, 1998, 2002	Stony alluvium	20	Mature podocarp forest.	2.5 SU/ha	4
Jackson River	E2158700, N5669000	1991	1991	1994, 1998, 2004	Alluvial silt	40	Grassland to mature *Nothofagus menziesii* forest that had a dense understorey of shrubs and ferns.	1.05 SU/ha 40 breeding cows and calves on 360 ha	8
Arawhata River	E2165700, N5661600	1992	1992	1995, 1999, 2004	Stony alluvium/ alluvial silt	50	Grassland that included a swampy strip and adjoining *Nothofagus menziesii* forest with an open understorey on a 1-m-high terrace.	The valley carried 400 breeding cows	10

TABLE 2. ALLOCATION OF 5-m-DEEP CONTIGUOUS TRANSECTS ACROSS HABITATS AT EACH SITE (e.g. 0 = 0–5 m, SEE FIG. 1).

Note: Three transects were allocated to the Cook Swamp ecotone due to its less distinct nature. The numbers of transects in each habitat are shown in parentheses.

SITE	GRASSLAND	ECOTONE	FOREST
Whataroa	0–5 (2)	10–15 (2)	20–35 (4)
Cook Swamp	0–10 (3)	15–25 (3)	30–45 (4)
Cook Young Forest	0–10 (3)	15–20 (2)	25–35 (3)
Cook Old Forest			0–15 (4)
Jackson	0–5 (2)	10–15 (2)	20–35 (4)
Arawhata	0–15 (4)	20–25 (2)	30–45 (4)

From 2002, all stems > 2 m tall were tagged with metal tree tags at breast height (1.35 m) to aid future monitoring. Although many tree ferns changed categories from the shrub to the tree layer in 2002 and 2004, all tree ferns have been treated as shrubs in the analyses to allow comparisons with previous data.

3.4 ANALYSIS OF DATA

The following data were summarised for individual transects:

- Herbs: The frequencies of all vascular herb species (i.e. numbers of 0.1 m × 0.1 m quadrats (out of 25) in which each species occurred); mean leaf height; and mean % cover contributed by each cover category: vascular herbs, bryophytes, lichens, litter, bare ground, rock, tree roots and bases.
- Woody seedlings: Counts of individual species under and over 0.1 m tall (including small tree ferns) in 0.4 m × 0.4 m and 0.1 m × 0.1 m quadrats, respectively.
- Shrubs and saplings: Counts of each species of woody plant 0.3–2.0 m tall, and all tree ferns > 0.3 m tall.
- Saplings and trees: Counts of each species of woody plant > 2.0 m tall. Multi-stemmed individuals were counted as one plant. Also, diameters at breast height of all stems > 2.0 m tall were converted to basal areas and summed for each species.

Nested analysis of variance (ANOVA) was used to compare the effects of exclosures at each site and in three habitats (forest, ecotone and grassland) at each site. Cook Old site was excluded from some analyses because no shrubland or grassland habitats existed at this site. These analyses focussed on differences in the abundance and cover of vegetation in the herb, seedling, shrub and tree layers recorded during the most recent remeasurement at individual sites. Principal Components Analysis (PCA) was used to examine compositional shifts in vegetation.

4. Results

Qualitative changes in the vegetation within each of the three habitat types for each layer in the exclosure and control plots at each site are described below. Quantitative assessments follow.

When interpreting the following results, it should be noted that many species preferred by cattle (Timmins 2002) are also palatable to deer or possums (Forsyth et al. 2002), which had access to the exclosures and may have been responsible for decreased abundance in some cases.

4.1 WHATAROA VALLEY

Although these plots have now been fully surveyed twice, the fence was not erected until just prior to the second remeasurement. Therefore, the effects of stock removal in this valley were 6–7 years behind other sites.

Litter cover increased in the ecotone of both exclosure and control plots at the expense of vascular cover and bryophytes. Herb height increased in all portions of the exclosure relative to the control, but especially in the grassland. The percent frequency and diversity of native and exotic herbs decreased in all portions of the exclosure, while the abundance of native herbs also decreased in the grazed control. The palatable fern *Histiopteris incisa* showed a 4-fold increase in percent frequency in the exclosure compared with the control. The number of seedlings (< 10 cm tall) decreased in the forested portion of the control and the ecotone portion of the exclosure. The number of shrubs decreased in the forest and ecotone portions of both plots; this decrease was substantial in the exclosure, mostly due to self-thinning of *Dacrycarpus dacrydioides*, numbers of which were initially almost an order of magnitude greater than in the control. In the exclosure, the palatable shrubs *Schefflera digitata* and *Melicytus ramiflorus* increased markedly (by 134 plants); there was also recruitment of *Dacrycarpus dacrydioides* and, to a lesser extent, *Schefflera digitata* and *Pennantia corymbosa* into the tree layer, mostly in the ecotone.

4.2 COOK SWAMP

The mean height of non-woody vascular species increased by 34 cm in the exclosure compared with 2 cm in the control. There was also a greater increase in litter (11%) and a corresponding decrease in vascular cover in the grassland and forest portions of the exclosure than in the control. The abundance and diversity of both native and exotic herbs showed a greater decrease in the exclosure than in the control.

Numbers of seedlings of woody species fluctuated widely between measurements in both plots, especially in the forested portion of the exclosure. Numbers of shrubs 0.3–2.0 m tall increased in all but the grassland portion of the exclosure, while numbers of trees > 2 m tall increased in all parts of both plots (Fig. 3).

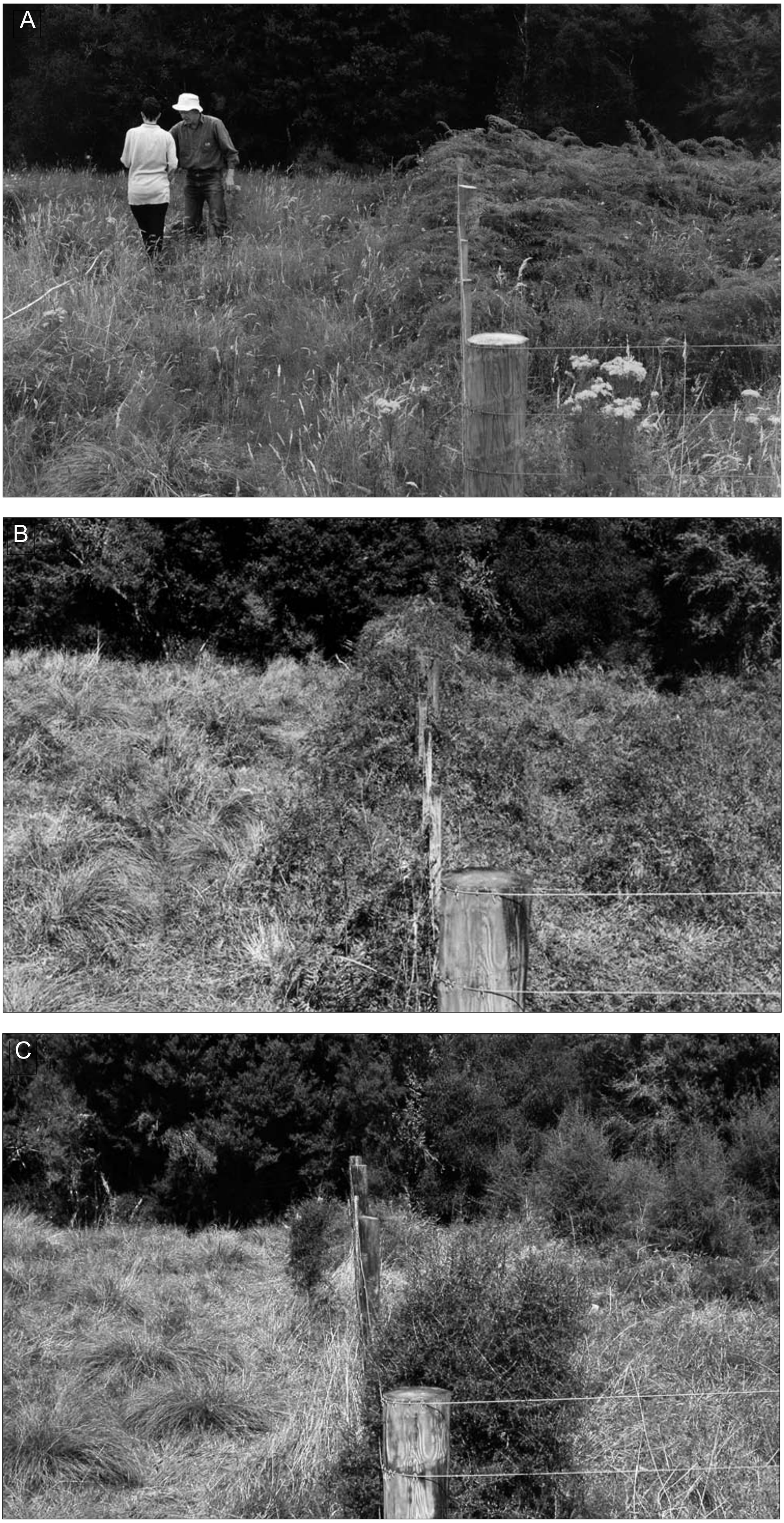
Figure 3. A pair of photographs looking across the northeast corner of the Cook Swamp exclosure into the control plot, showing A. the open grassland and ecotone in 1990; and B. the recruitment of shrubs and trees by 2002.

4.3 COOK YOUNG FOREST

Litter cover increased in the grassland portion of the Cook Young Forest exclosure and control plots, while vascular cover declined. Herb height increased by 10 cm in the ecotone of the exclosure and decreased by 3 cm in the control. Native herbs increased and exotics decreased in percent frequency in both exclosure and control plots.

In the grassland portion of the exclosure, an area of *Pteridium esculentum* that increased between 1990 and 1994 had collapsed in 1998 and 2002 (Fig. 4). Woody seedlings established with much more success in the grassland portion of the exclosure (95 additional plants) than in equivalent portions of the control (15 plants). However, where there was existing shrub cover there was seedling recruitment in both plots, particularly in the ecotone of the control (81 plants). *Coprosma* spp., *Dacrycarpus dacrydioides* and, to a lesser extent, *Myrsine*

Figure 4. A sequence of photographs in the grassland portion of the exclosure in Cook Young Forest, showing A. *Pteridium esculentum* in 1994; B. its collapse in 1998; and C. shrub recruitment in 2002.



divaricata were the most frequently recruited species. Although the number of saplings increased in both plots, additional numbers were far greater in the control (492) than in the exclosure (124). Numbers of shrubs and trees increased in both plots, but more so in the exclosure (508 v. 162), particularly in the grassland (310 v. 76). The main species involved were *Coprosma* spp., *Myrsine divaricata*, *Melicytus ramiflorus* and *Pennantia corymbosa*.

4.4 COOK OLD FOREST

Litter cover increased from 80% to 90% in the exclosure, while bryophyte cover decreased from 9.6 to 1.5%. The percent frequency and height of herbs increased most consistently in the exclosure, which also gained more ferns (especially *Asplenium bulbiferum*); however, total herb abundance remained lower than in the control (means of 14.3 cf. 20.8 respectively). No exotic herbs were present in either plot.

There was little change in numbers of woody seedlings and saplings in either plot. Numbers of preferred shrubs, such as *Hedycarya arborea, Melicytus ramiflorus* and *Dicksonia squarrosa*, showed small decreases (c. 10%) in both control and exclosure plots.

At the time of the 2002 remeasurement, a very large *Prumnopitys taxifolia* tree (160 cm diameter at breast height (dbh)) that had been recorded in the southwest corner of the control plot (20-m line at 25 m) in 1990 had fallen into the exclosure, flattening the fence and many plants. The fence was repaired by 21 June 2002. This highlights the critical need for regular inspection and ongoing maintenance of exclosure fencing.

4.5 JACKSON RIVER

Overall vascular cover increased by about 10% at the expense of bryophyte cover, which decreased by 20.2% in the grassland portion of the exclosure. Similarly, herb height more than doubled with exclosure from 17.8 to 41.3 cm. However, vascular cover decreased in the exclosure ecotone, where litter cover increased by 19.5%, and bryophyte cover increased in the forested control, where litter cover decreased by 17.3%.

The percent frequency and diversity of herbaceous species decreased in the exclosure, while that of native herbs increased in the control. Total herb richness was 30 in controls but only 15 in exclosures for grassland. Similarly, numbers of woody seedlings (0–30 cm tall) decreased from 197 in controls to 133 in exclosures in the grassland.

Numbers of shrubs decreased in both plots, but more so in the exclosure. Most of this decrease resulted from three-fold fewer *Pseudowintera colorata* shrubs in the forested portion. In the tree layer of the exclosure, there was recruitment of preferred species such as *Schefflera digitata*, *Fuchsia excorticata* and *Aristotelia serrata*, all of which remained absent in the control.

4.6 ARAWHATA RIVER

Vascular cover became exclusively dominant in the grassland of both plots (99% in the controls and 92% in the exclosure). In the ecotone, vascular cover increased slightly more in the exclosure than in the control. Herb height increased accordingly. In the grassland, total and native richness of herbaceous species increased in the exclosure by 4–5 species on average.

Numbers of seedlings (0–30 cm tall) roughly doubled in both plots, but by greater numbers in the exclosure, particularly for *Nothofagus menziesii* and *Cyathea smithii*, both of which had also recruited into the shrub layer of the exclosure.

In both plots, the number of *Griselinia littoralis* seedlings increased up to13 per transect in 1999 but then decreased to 5 by 2004, presumably due to red deer (*Cervus elaphus*) browsing. Despite this, there had been recruitment of *Griselinia littoralis* into the shrub layer in the exclosure. However, other species preferred by deer, possums, or cattle such as *Schefflera digitata*, *Fuchsia excorticata*, *Melicytus ramiflorus* and *Hedycarya arborea,* had not increased in either plot.

Dacrycarpus dacrydioides numbers increased two-fold in the shrub layer of both plots, whereas *Pseudowintera colorata* numbers declined slightly in the shrub layer of both plots, as plants had recruited into the tree layer.

4.7 EFFECTS OF GRAZING ON VEGETATION LAYERS

The exclusion of stock has led to increased densities of preferred species in the shrub and tree layers at some sites. However, not only has this effect sometimes been masked by other processes, but the species involved may also vary between sites. For example, in the Jackson River exclosure, many preferred species were recruited into the tree layer, possibly reducing numbers in the shrub layer below through competition for light. In the Arawhata plots, numbers of avoided species, such as *Dacrycarpus dacrydioides* and *Nothofagus menziesii*, increased following protection from cattle, suggesting that other browsers (e.g. deer and/ or possums) may have prevented the recruitment of preferred species. Below, we quantitatively assess the changes in numbers of plants seen in each of the different vegetation layers.

4.7.1 Herbs

The height of the tallest herb showed a greater increase in all exclosure plots (23.4 cm to 36.5 cm) than in the controls (25.0 cm to 27.1 cm). The percent frequency of herbs generally showed a greater decrease in the exclosures than in the controls (Table 3, Fig. 5). Some palatable herbs showed greater increases in percent frequency in exclosures than in controls, e.g. *Histiopteris incisa* in Whataroa Valley, *Astelia grandis* in Cook Swamp, and *Asplenium bulbiferum* at all sites where it occurs. Herb percent frequency varied greatly between habitats and sites (Table 3). Fencing reduced the number of herbs and species richness, particularly in grassland habitats (Fig. 6A, B). Similarly, herb species composition shifted from native to exotic dominance most dramatically in fenced grassland habitats (Fig. 7).

TABLE 3. ANOVA TABLE FOR HERB ABUNDANCE (NUMBER OF INDIVIDUALS PER TRANSECT).

The five Sites were Cook Young forest, Cook Swamp, Whataroa, Arawhata and Jackson. Cook Old Forest was excluded because it contained only forest habitat.
Factors include Site, Treatment (fenced, no fencing), Habitat (forest, ecotone, grassland), Year (initial, most recent) and Biostatus (Exotic, Native). Higher order interactions are not included here because of sample size limitations. Model overall error df = 64, SS = 1011.8.

SOURCE	df	SUM OF SQUARES	*F* RATIO	PROB > *F*
Site	4	25845.22	22.84	< 0.0001
Treatment	1	4721.09	16.7	< 0.0001
Year	1	1510.78	5.33	0.022
Habitat	2	224964.63	397.6	< 0.0001
Biostatus	1	11869.80	42.0	< 0.0001
Site × Treatment	4	1247.54	1.10	0.356
Site × Year	4	3788.89	3.35	0.012
Site × Habitat	8	30460.74	13.5	< 0.0001
Site × Biostatus	4	5741.48	5.07	0.001
Treatment × Year	1	3796.41	13.4	0.0003
Treatment × Habitat	2	4182.13	7.40	0.0007
Treatment × Biostatus	1	113.64	0.40	0.527
Year × Habitat	2	701.99	1.24	0.291
Year × Biostatus	1	90.01	0.32	0.573
Habitat × Biostatus	2	9433.96	16.7	< 0.0001

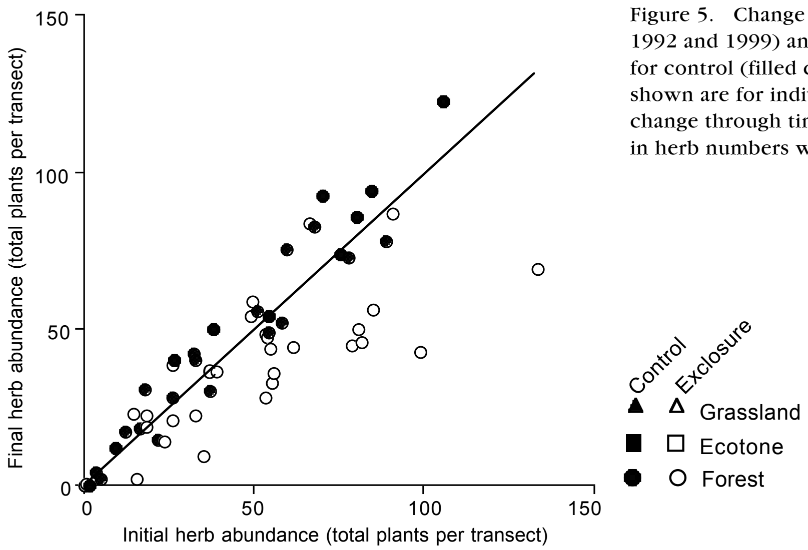


Figure 5. Change in the abundance of herbs between initial (1989–1992 and 1999) and most recent (2002 and 2004) remeasurements for control (filled circles) and exclosure (open circles) plots. Data shown are for individual transects. The 1:1 line represents no change through time: points below this line generally had declines in herb numbers while points above had increases.

4.7.2 Seedlings (< 10 cm)

Seedlings showed no consistent response to fencing, with numbers either declining or increasing depending upon site and habitat (Fig. 8). Although seedling species composition shifted at two sites in response to stock exclusion, fencing caused convergence in seedling species composition at Cook Young site but divergence at Whataroa Valley (Fig. 9).

4.7.3 Saplings (10–30 cm)

Fencing had no effect on sapling numbers, which varied greatly between sites and habitats (Fig. 10). Although sapling numbers increased two- to four-fold at the Cook Young Forest site, this change was not driven by stock exclusion,

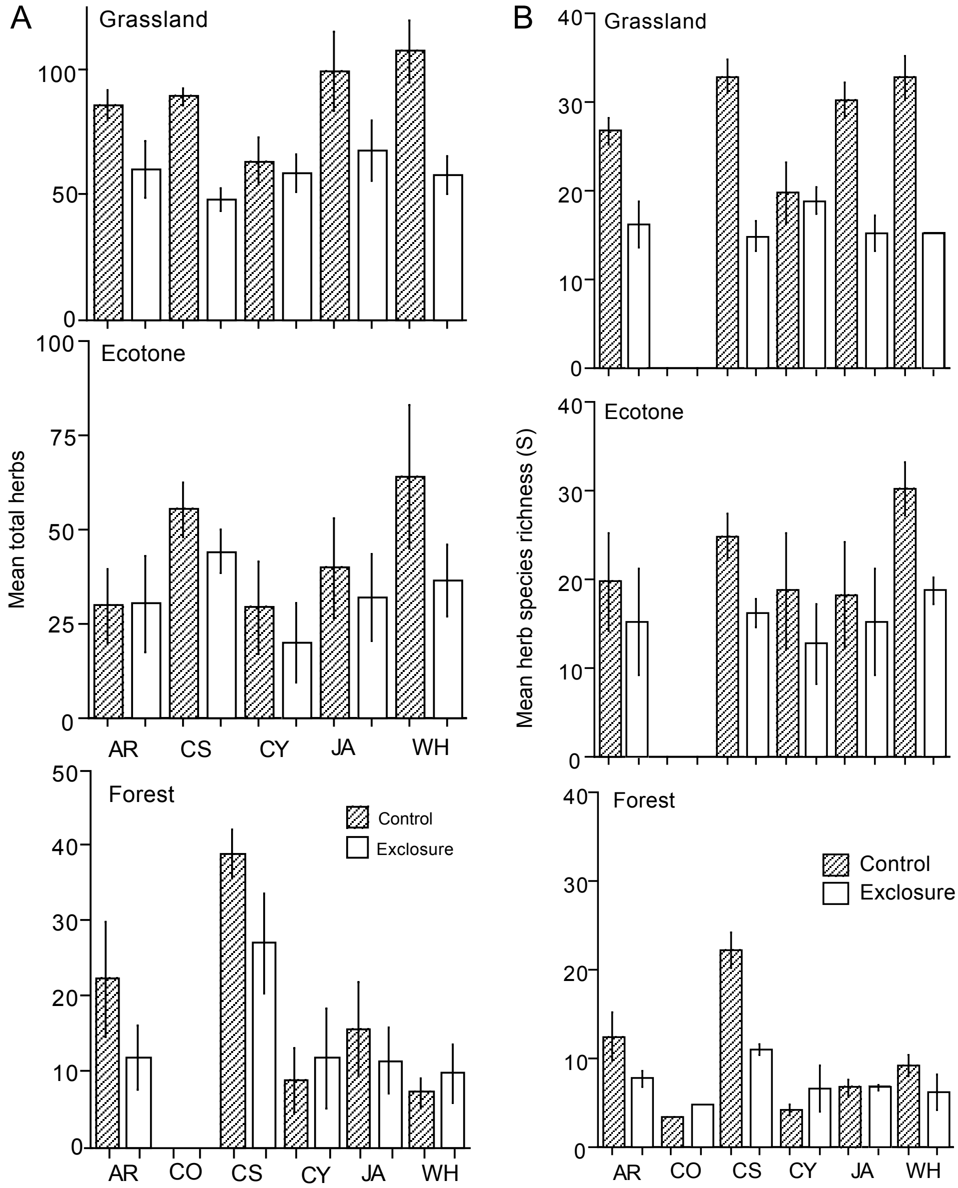


Figure 6. A. Mean total herb numbers (± 1 SEM), and B. Mean herb species richness (± 1 SEM) in grassland (top panel), ecotone (middle panel) and forest (bottom panel) habitats at each of six study sites (AR = Arawhata, CO = Cook Old Forest, CS = Cook Swamp, CY = Cook Young Forest, JA = Jackson, and WH = Whataroa). Control (hatched bars) and exclosure (open bars) treatments are nested within sites.

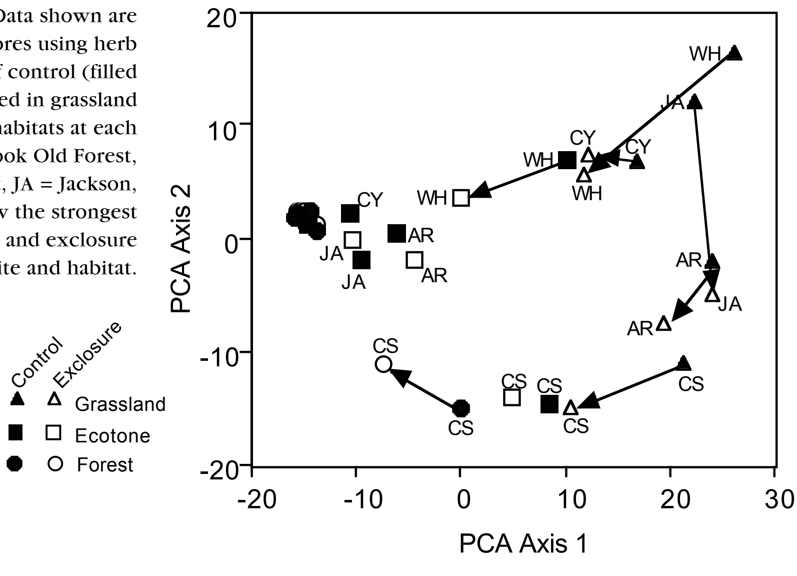


Figure 7. Shifts in herb species composition. Data shown are Principal Components Analysis (PCA) centroid scores using herb counts for the most recent remeasurement of control (filled symbols) and exclosure (open symbols) plots located in grassland (triangles), ecotone (squares) and forest (circles) habitats at each of six study sites (AR = Arawhata, CO = Cook Old Forest, CS = Cook Swamp, CY = Cook Young Forest, JA = Jackson, and WH = Whataroa). Lines with arrows show the strongest compositional shifts between pairs of control and exclosure treatments within study site and habitat.

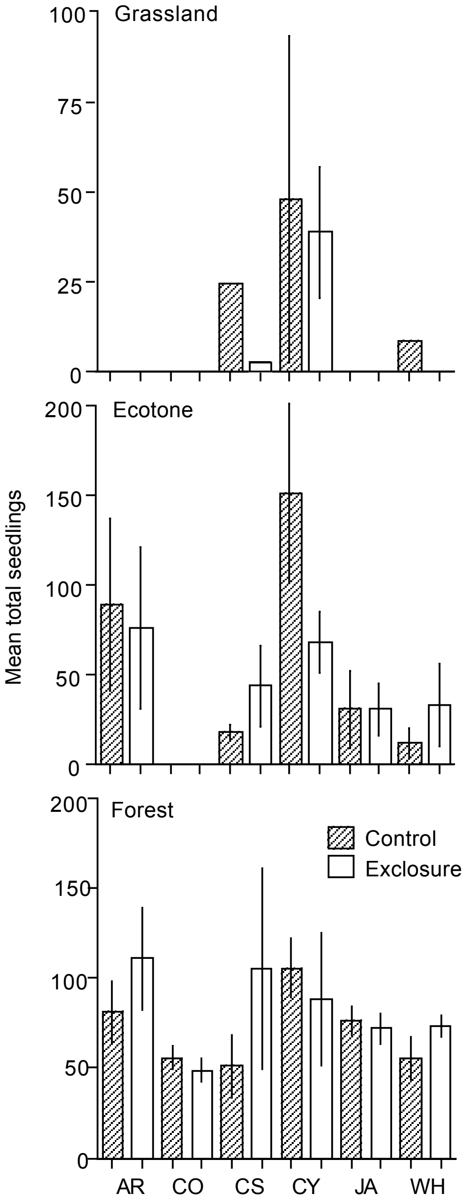


Figure 8. Mean total seedling abundance (± 1 SEM) in grassland (top panel), ecotone (middle panel) and forest (bottom panel) habitats at each of six study sites (AR = Arawhata, CO = Cook Old Forest, CS = Cook Swamp, CY = Cook Young Forest, JA = Jackson, and WH = Whataroa). Control (hatched bars) and exclosure (open bars) treatments are nested within sites.

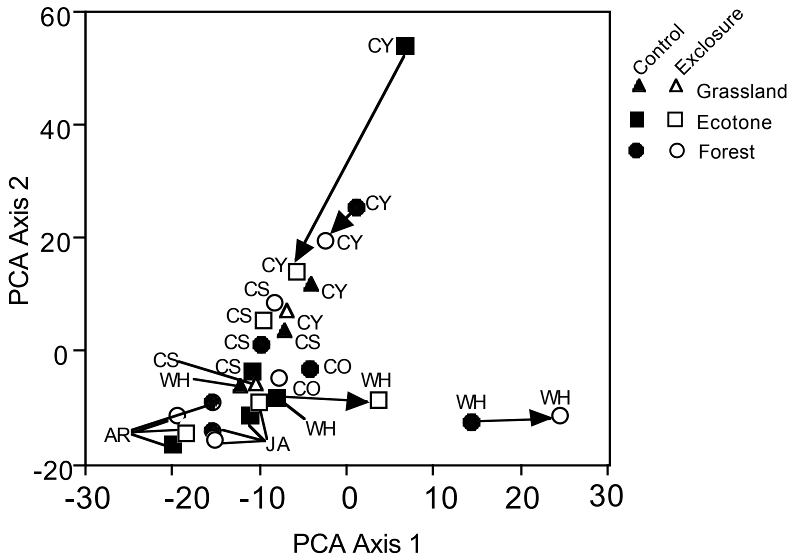


Figure 9. Shifts in seedling species composition. Data shown are Principal Components Analysis (PCA) centroid scores using seedling counts for the most recent remeasurement of control (filled symbols) and exclosure (open symbols) plots located in grassland (triangles), ecotone (squares) and forest (circles) habitats at each of six study sites (AR = Arawhata, CO = Cook Old Forest, CS = Cook Swamp, CY = Cook Young Forest, JA = Jackson, and WH = Whataroa). Lines with arrows show the strongest compositional shifts between pairs of control and exclosure treatments within study site and habitat.

as the increase in the control (492 plants) was greater than that in the exclosure (124). There was some convergence in species composition, particularly in forest habitats at the Jackson River and Cook Young Forest sites (Fig. 11).

4.7.4 Shrubs (0.3–2 m)

At most sites, there were larger increases or decreases in shrub numbers in exclosures than in unfenced controls (Fig. 12). A notable exception was the Cook Swamp grassland, where shrub numbers increased substantially in the control plot. Other exceptions were the Jackson River grassland, Whataroa Valley grassland and Whataroa Valley ecotone.

Tree ferns showed greater increases in numbers in all exclosures than in their corresponding controls, with the exception of *Dicksonia squarrosa* in the Jackson River ecotone (Fig. 13), where only seedlings were initially present in the control plot, *Cyathea smithii* numbers in the Jackson River forest, and the forested portion of the Whataroa Valley, where the increase of *Cyathea smithii* numbers in the control (Fig. 14) marginally exceeded the increase of *Dicksonia squarrosa* in the exclosure (Fig. 13). Otherwise, most changes in tree fern numbers resulted from changes in *Dicksonia squarrosa*, which increased in virtually all exclosures and decreased in many controls, especially in the Cook Valley sites and forest of the Jackson River. The large percentage change in the forested portion of the Arawhata exclosure was due to the recruitment of *Dicksonia squarrosa*, which only occurred as seedlings when the initial measurements were made.

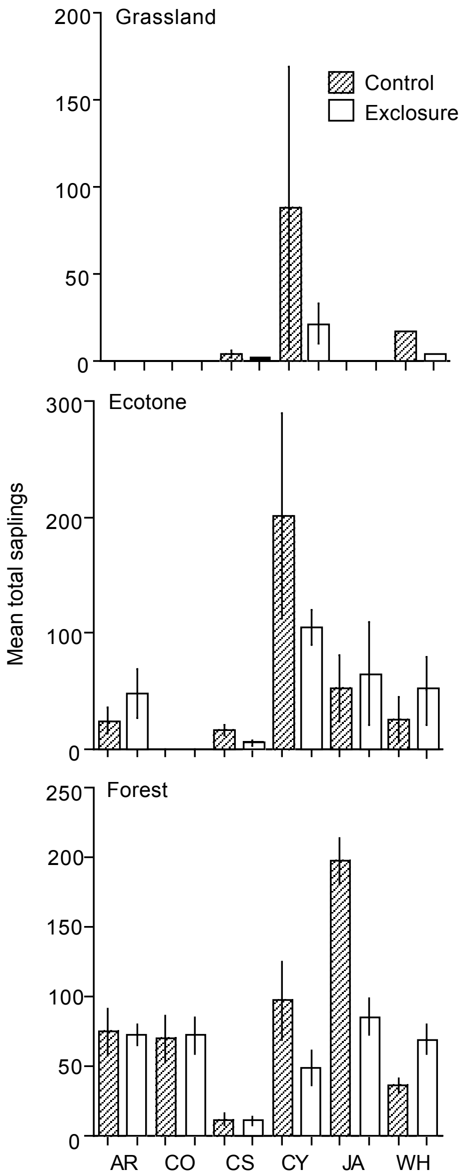


Figure 10. Mean total sapling numbers (± 1 SEM) in grassland (top panel), ecotone (middle panel) and forest (bottom panel) habitats at each of six study sites (AR = Arawhata, CO = Cook Old Forest, CS = Cook Swamp, CY = Cook Young Forest, JA = Jackson, and WH = Whataroa). Control (hatched bars) and exclosure (open bars) treatments are nested within sites.

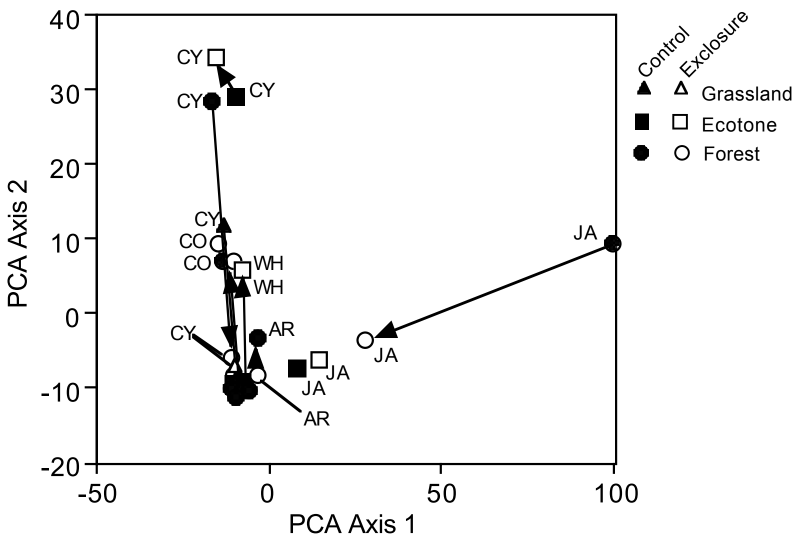


Figure 11. Shifts in sapling species composition. Data shown are Principal Components Analysis (PCA) centroid scores using sapling counts for the most recent remeasurement of control (filled symbols) and exclosure (open symbols) plots located in grassland (triangles), ecotone (squares) and forest (circles) habitats at each of six study sites (AR = Arawhata, CO = Cook Old Forest, CS = Cook Swamp, CY = Cook Young Forest, JA = Jackson, and WH = Whataroa). Lines with arrows show the strongest compositional shifts between pairs of control and exclosure treatments within study site and habitat.

Tree ferns did not have a strong influence on compositional shifts, having very small loadings on Principal Components (PCA) axes. A summary of PCA axes for shrub compositional data, using first and latest measurement data, is given in Appendix 2. The first three axes explained 82% of the variation in shrub species composition. Species that did influence compositional changes were *Pseudowintera colorata* and *Dacrycarpus dacrydioides*, *Coprosma rotundifolia* and *Raukaua anomalus*. However, compositional changes varied between sites and there was no consistent effect of fencing (Fig. 15).

Several species consistently reponded positively to the removal of stock (Appendix 2), including *Melicytus ramiflorus*, *Schefflera digitata*, *Carpodetus serratus*, *Coprosma lucida*, *C. rhamnoides*, *Griselinia littoralis*, *Nothofagus menziesii*, *Pseudopanax crassifolius*, *Weinmannia racemosa*, and, at Cook Swamp, *Phormium tenax*. Some shrub species responded positively to the removal of grazing at one or two sites and negatively at other sites, e.g. *Myrsine divaricata*, *Coprosma tayloriae*, *C. rotundifolia*, *Hedycarya arborea*, and *Pennantia corymbosa*. *Podocarpus totara* var. *waihoensis* had a negative response to the removal of grazing.

4.7.5 Numbers of palatable species in the shrub layer

Forsyth et al. (2002) classified the palatability of common native forest species into three groups (preferred, not selected, and avoided) based on ungulate preferences. 'Preferred' is defined as those plant species eaten more than expected from their availability; 'not selected' is those plant species that are eaten in proportion to

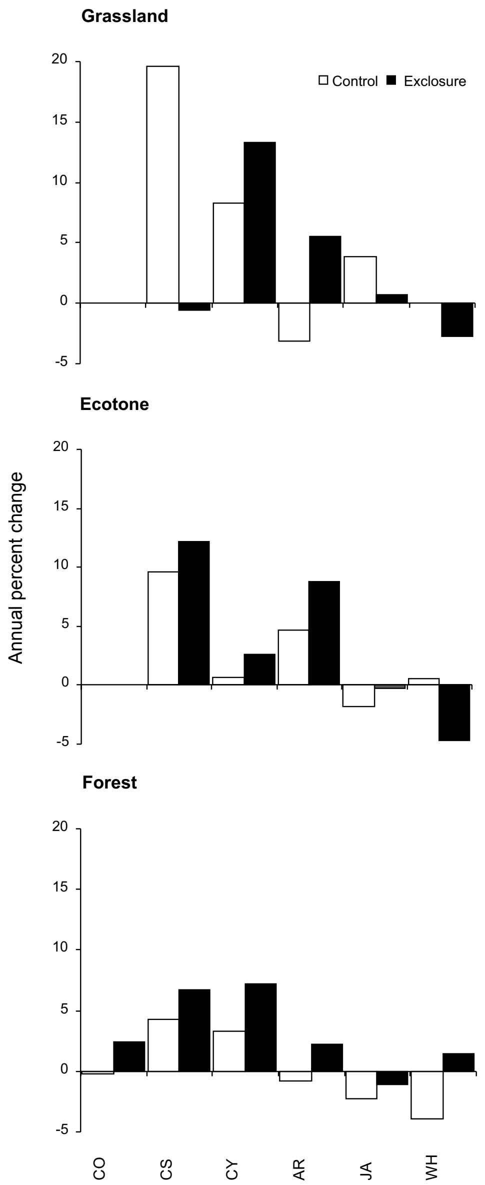


Figure 12. Annual percent change in shrub numbers between initial and most recent remeasurements in grassland (top panel), ecotone (middle panel) and forest (bottom panel) habitats within the control (open bars) and exclosure (filled bars) plots at each of six study sites (CO = Cook Old Forest, CS = Cook Swamp, CY = Cook Young Forest, AR = Arawhata, JA = Jackson, and WH = Whataroa).

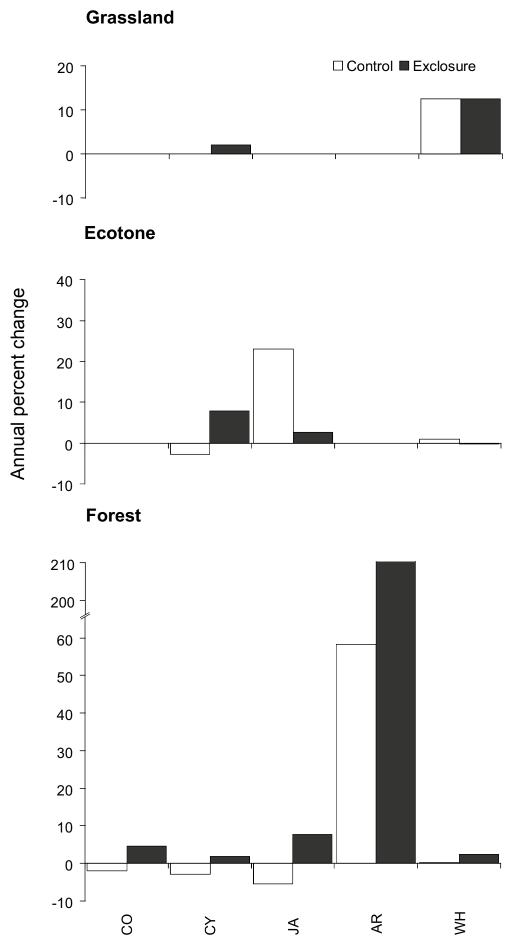


Figure 13. Annual percent change in *Dicksonia squarrosa* numbers between initial and most recent remeasurements for grassland (top panel), ecotone (middle panel), and forest (bottom panel) habitats within the control (open bars) and exclosure (filled bars) plots at each study site in which they occur. CO = Cook Old Forest, CY = Cook Young Forest, JA = Jackson, AR = Arawhata, and WH = Whataroa.

their availability; and 'avoided' is those plant species that are eaten less than expected based on their availability. There were fewer palatable species in ecotone and grassland than in forest habitat (Table 4, Appendix 3). The number of shrubs preferred by stock only increased with fencing or between measurements in some locations, suggesting that previous or ongoing browsing by mammals other than domestic stock was continuing to have an effect on palatable species in places (Fig. 16).

4.7.6 Trees (> 2 m)

There was some recruitment of new stems of tree species at some sites (Cook Swamp and Cook Young), with the biggest changes occurring in the Cook Swamp ecotone and forest areas (Fig. 17). However, stock exclusion did not have a consistent, strong effect. Not surprisingly, tree species composition did not change much between control and exclosure plots, with the exception of Cook Swamp, where ecotone and forest habitat composition were converging more quickly with stock exclusion (Fig. 18).

TABLE 4. SUMMARY OF ANOVA RESULTS FOR THE ABUNDANCE OF INDIVIDUALS IN THE SHRUB LAYER.

The five sites were Cook Young Forest, Cook Swamp, Whataroa, Arawhata and Jackson. Cook Old Forest was excluded because it contained only forest habitat.

Factors include Site, Treatment (fenced, no fencing), Habitat (forest, ecotone, grassland), Year (initial, most recent) and Palatability (palatable, not palatable). Higher order interactions are not included here because of sample size limitations. Model overall error df = 34, SS = 59916.9.

SOURCE	df	SUM OF SQUARES	*F* RATIO	PROB > *F*
Site	4	30196	5.31	0.000
Treatment	1	4546	3.20	0.075
Habitat	2	136067	47.9	< 0.0001
Year	1	1038	0.73	0.393
Palatability	1	503827	354.5	< 0.0001
Site × Treatment	4	43170	7.59	< 0.0001
Site × Habitat	8	114163	10.0	< 0.0001[a]
Site × Year	4	14871	2.62	0.036
Site × Palatability	4	41350	7.27	< 0.0001[b]
Treatment × Habitat	2	2174	0.77	0.466
Treatment × Year	1	461.9	0.33	0.569
Treatment × Palatability	1	90.7	0.064	0.801
Habitat × Year	2	152.8	0.054	0.948
Habitat × Palatability	2	94159	33.1	< 0.0001
Year × Palatability	1	37.65	0.027	0.871

[a] The significant Site × Treatment interaction is driven by fencing, resulting in increased shrub numbers at Whataroa Valley compared with other sites.

[b] The significant Site × Palatability effect is driven by palatable species having greater declines in numbers at Jackson River than at other sites.

4.7.7 Exotic species

Woody exotics were not present in the shrub layer at any of the sites. Fencing suppressed both herbaceous exotics and native herbs (Appendix 4). The percent frequency and species richness of exotics declined more than native herbs in forest (–4.6%/y) and ecotone (–4.1%/y) habitats.

4.7.8 Summary of effects

Results from the South Westland exclosures showed that the removal of stock grazing had distinct effects on the vegetation. However, these effects:

- Were site-specific and varied with habitat (Table 5)
- May take several decades to eventuate
- Did not promote unpalatable canopy species
- Resulted in a lower abundance of herbaceous species
- Resulted in an increased abundance of seedlings and saplings at some sites

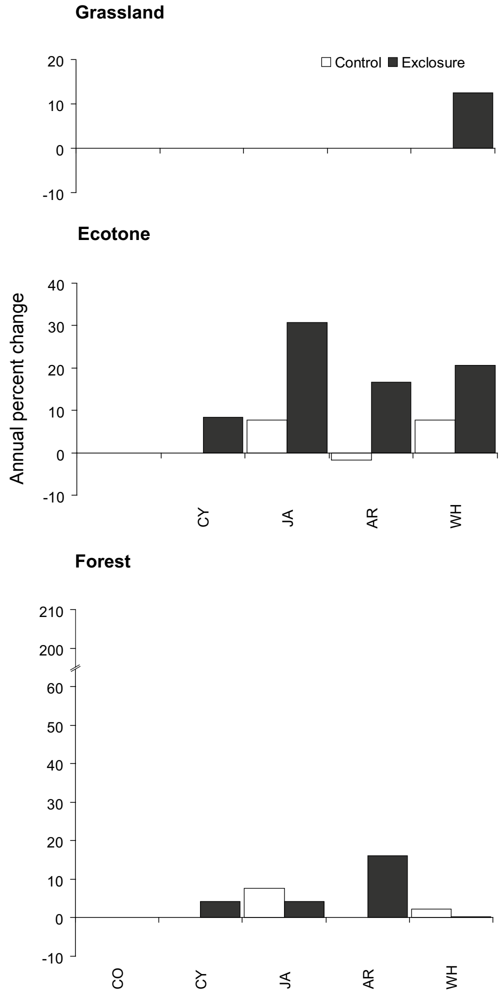


Figure 14. Annual percent change in *Cyathea smithii* numbers between initial and most recent remeasurements for grassland (top panel), ecotone (middle panel), and forest (bottom panel) habitats within the control (open bars) and exclosure (filled bars) plots at each study site in which they occur. CO = Cook Old Forest, CY = Cook Young Forest, JA = Jackson, AR = Arawhata, and WH = Whataroa.

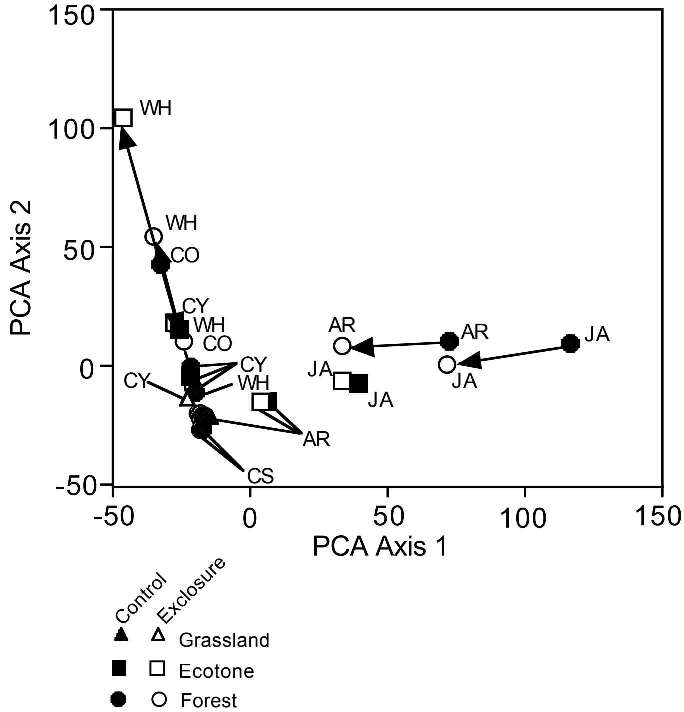


Figure 15. Shifts in shrub species composition. Data shown are Principle Components Analysis (PCA) centroid scores using shrub abundance for the most recent remeasurement of control (filled symbols) and exclosure (open symbols) plots located in grassland (triangles), ecotone (squares) and forest (circles) habitats at each of six study sites (AR = Arawhata, CO = Cook Old Forest, CS = Cook Swamp, CY = Cook Young Forest, JA = Jackson, and WH = Whataroa). Lines with arrows show the strongest compositional shifts between pairs of control and exclosure treatments within study site and habitat.

5. Discussion

Several attributes of plant species influence the degree of damage that they will sustain from grazing, including growth form, palatability, associations with other plant species and competitive ability (e.g. Hearn 1995). This makes it difficult to make generalised statements about the susceptibility of plants to stock grazing. Furthermore, natural processes can alter, interact with or obscure the impact of extensive stock grazing on vegetation change (see Buxton et al. 2001). Consequently, few plant species show consistent, directional responses to grazing or the cessation of grazing, so care must be taken when extrapolating results to other sites or species. Our results showed that vegetation responses to grazing exclusion varied greatly both in rapidity and direction according to vegetation and habitat type.

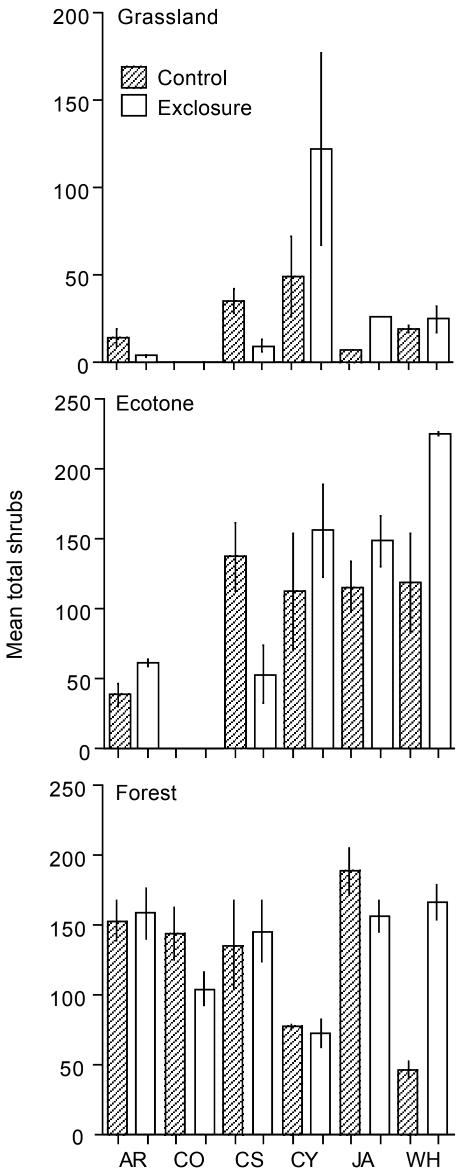


Figure 16. Mean total shrub numbers (± 1 SEM) in grassland (top panel), ecotone (middle panel) and forest (bottom panel) habitats at each of six study sites (AR = Arawhata, CO = Cook Old Forest, CS = Cook Swamp, CY = Cook Young Forest, JA = Jackson, and WH = Whataroa). Control (hatched bars) and exclosure (open bars) treatments are nested within sites.

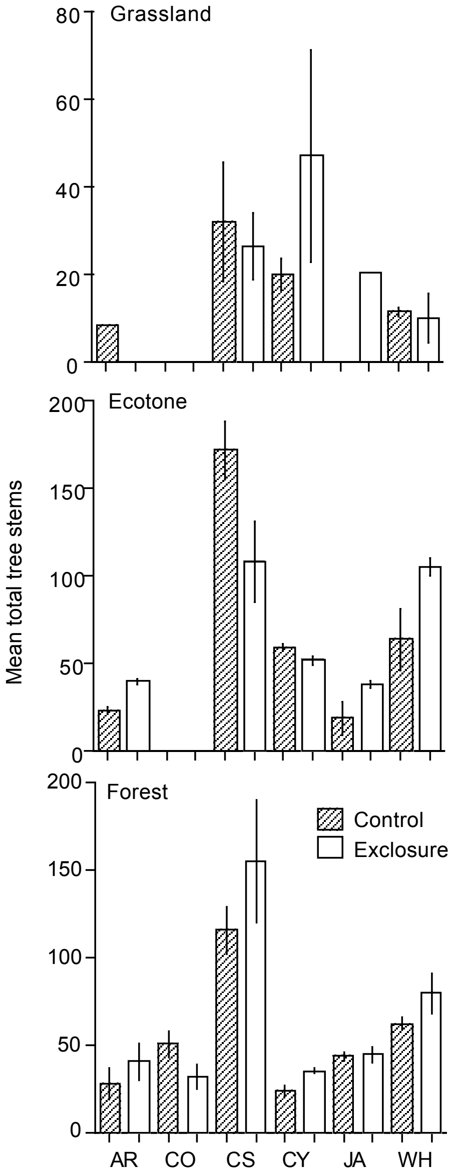


Figure 17. Mean total tree stems (± 1 SEM) in grassland (top panel), ecotone (middle panel) and forest (bottom panel) habitats at each of six study sites (AR = Arawhata, CO = Cook Old Forest, CS = Cook Swamp, CY = Cook Young Forest, JA = Jackson, and WH = Whataroa). Control (hatched bars) and exclosure (open bars) treatments are nested within sites.

Grazing can affect vegetation in at least two ways: by suppressing dominant species and natural succession, thus increasing species evenness of sward-forming natives and exotics (e.g. grassland transects); and by removing palatable species and enhancing the dominance of non-palatable species, and promoting succession by reducing competition (forest transects; Timmins 2002). Both processes can operate simultaneously. For example, while fencing to exclude stock had a direct positive effect on some native species, it also encouraged exotics (Fig. 6A), particularly in the grassland and ecotone, which will indirectly have a detrimental effect on native species recruitment. In general, preferred

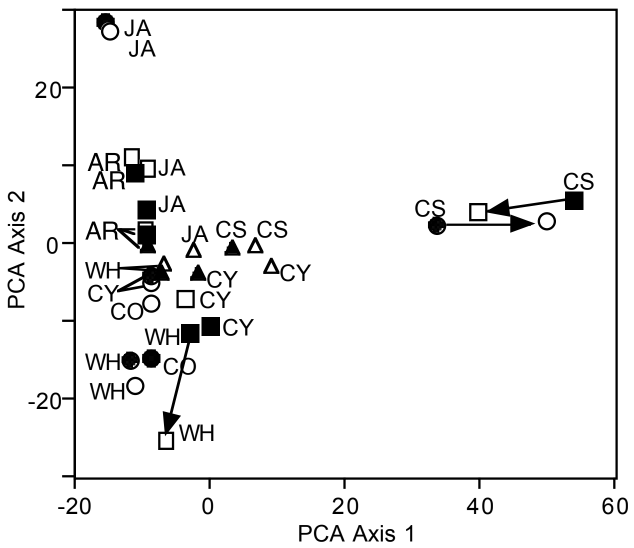


Figure 18. Shifts in tree species composition. Data shown are Principal Components Analysis (PCA) centroid scores using stem counts for the most recent remeasurement of control (filled symbols) and exclosure plots (open symbols) located in grassland (triangles), ecotone (squares) and forest (circles) habitats at each of six study sites (AR = Arawhata, CO = Cook Old Forest, CS = Cook Swamp, CY = Cook Young Forest, JA = Jackson, and WH = Whataroa). Lines with arrows show the strongest compositional shifts between pairs of control and exclosure treatments within study site and habitat.

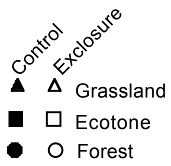


TABLE 5. SUMMARY OF KEY EFFECTS IN EACH HABITAT. VALUES FOR PERCENT CHANGE IN HERB SPECIES RICHNESS PER YEAR (%/y) ARE BASED ON RESULTS TO DATE.

TREATMENT	GRASSLAND	ECOTONE	FOREST
Exclosure	• Increase in exotic herbaceous cover • Decrease in native grassland herb species richness (–2.6%/y) • Decrease in species richness of exotic herbs (–1.9%/y)	• Increase in exotic herbaceous cover • Decrease in species richness of exotic herbs (–4%/y) • Suppressed establishment of woody seedlings?	• *Nothofagus menziesii* seedlings and saplings increased • *Dacrycarpus dacrydioides* increased/decreased • Tree ferns increase • Few exotics in forest • Increased shrubs of *Melicytus ramiflorus*, *Schefflera digitata*, *Carpodetus serratus*, *Coprosma lucida*, *C. rhamnoides*, *Griselinia littoralis*, *Nothofagus menziesii*, *Pseudopanax crassifolius*, *Weinmannia racemosa* and (at Cook Swamp) *Phormium tenax*
Control	• Decrease in exotic herbaceous cover • Increase in native grassland herb species richness (0.3%/y)	• Decrease in exotic herbaceous cover	• Tree ferns decrease • Few exotics in forest

species are favoured by fencing, whereas unpalatable species gain no direct advantage, but face increased competition. With release from grazing, species that are more competitive will dominate in grasslands, shrublands and forests, and many invasive exotics fall into this class. The composition of future resulting communities and conservation values is yet unknown.

5.1 STOCK RATES AND MANAGEMENT IMPLICATIONS

To disseminate the results of this study to relevant DOC staff and obtain their feedback, West Coast Conservancy, DOC, hosted a 1-day grazing impacts workshop in Hokitika on 12 September 2006. During this workshop, DOC staff involved with stock grazing concessions raised several management issues. One such issue was how grazing intensity influences vegetation. The level of grazing pressure was not controlled during this research project, but stock grazing was generally of low intensity (i.e. typically < 2 SU/ha). Stocking rates on sites for which information was available varied from 1.05 to 2.5 SU/ha (Table 1), and total cattle numbers ranged from 6 to 440. Anecdotal evidence suggests that cattle are very territorial and their impacts can be quite localised. At lower stocking densities cattle spend most of their time in grassland, probably entering the forest mainly for shelter, while at higher densities or when grassland forage is limited they are more likely to enter forest, where they affect forest regeneration (Rosoman 1990). Light grazing can create patchiness, especially in complex vegetation, and promote species diversity.

DOC staff also asked questions relating to stock impacts on forest margins, which this project aimed to answer, and discussed the variable nature of grazing impacts. Stock have complex impacts on vegetation structure and composition, and grazing management will vary depending upon the plant species or communities to be maintained or protected (i.e. canopy dominant trees v. herbaceous species). To manage grazing on a finer scale, which may be necessary to attain specific conservation goals relating to the composition and abundance of native trees, shrubs, grasses and herbs at forest margins requires input and cooperation from farmers. Ideally, grazing management should include one or more of the following:

- A specific plan for a particular site, describing the target or desirable community or species
- Appropriate stocking rate (usually low)
- Seasonal control of grazing animal numbers
- An adaptive approach and flexibility to adjust for changing conditions

It is also important for managers to know what the long-term strategy is for land subject to grazing concessions. The Conservation Management Strategy gives general criteria regarding the approval of grazing concessions, but does not go into specifics for particular sites. There was general consensus at the grazing impacts workshop that a strategic piece of work that identified priorities for restoration would assist with decisions on whether to retire, continue to graze, or dispose of land under grazing concessions. The exclosure plot research outlined in this report provides valuable information on the potential for restoration in a range of typical grazing lease sites, and by pointing out that not all locations can be expected to respond in a similar manner.

Stock impacts are not always negative for all elements of the biota (Timmins 2002), and results from this study show that these South Westland plant communities have retained some native regenerative capacity, even after more than 130 years of grazing. This is particularly shown by the increased abundance of preferred species in the shrub layer in some locations. Stock may suppress herbaceous exotics, thus reducing weed impacts on other species, or may not graze canopy species, which are often avoided (Forsyth et al. 2002).

5.2 IMPACTS OF CATTLE VERSUS OTHER BROWSERS

5.2.1 Cattle v. deer impacts

We do not know the degree to which the exclosures deterred deer or the impact of deer at these sites. In areas where *Nothofagus menziesii* dominates, it is frequently found in the stomachs of red deer and wapiti (*Cervus elaphus* var. *canadensis*), along with *Griselinia littoralis* (Wardle 1967). Browsing by deer may result in the death of *Nothofagus menziesii* seedlings within forest, but more vigorous plants in the open are more likely to withstand browsing. What is not known is whether the combined impact of cattle and other mammalian herbivores such as deer and possums limits *Nothofagus menziesii* regeneration in the browse-susceptible layer (0.3–2.0 m).

Dicksonia squarrosa is more palatable to deer than *Cyathea smithii* (pers. obs.; Forsyth et al. 2002). Although it appears that this is also true for cattle, Timmins (2002) found proportionally more recruitment of *Cyathea smithii* and *Dicksonia squarrosa* in cattle-grazed transects than in fenced transects, which contrasts with our findings (Figs 13 & 14).

5.2.2 Browse patterns

The effects of other browsers may be additive to those of cattle or they may promote compensatory growth of unbrowsed species. (Compensatory growth (extra growth) occurs when competition is reduced.) Deer and possums are selective browsers, whereas cattle graze unselectively (Hearn 1995), taking dead and tall shrubby vegetation, and species that might otherwise dominate. To assess the relative importance of each species of browser on plant recruitment, a system of nested exclosures to progressively exclude each species would be required.

5.2.3 Related studies

Since the publication of our previous report (Buxton et al. 2001), there have been a number of publications relevant to grazing in South Westland forests (e.g. Wardle et al. 2001; Timmins 2002; Coomes et al. 2003; Miller & Wells 2003; Miller et al. 2004).

Wardle et al. (2001) compared soil biota and ecosystem functioning inside and outside deer exclosures, and demonstrated that significant differences in plant biomass and composition above ground are not consistently reflected in biotic groups below ground, and vice versa; furthermore, the patterns were not consistent across sites. Duncan et al. (2006) showed that following deer control there is a delay of decades before mountain beech (*Nothofagus solandri*) forest recovers and reaches sufficient density above deer browse height to ensure canopy replacement. In addition, the length of this delay and the final forest canopy cover depends on the effectiveness of the control regime. The removal of stock grazing in South Westland is most analogous to fencing treatments in Duncan et al.'s (2006) model, which showed that removal of animal effects in forests that have been disturbed by natural events allows seedlings of canopy species to grow and achieve sufficient density to ensure canopy replacement within about 20 years. Under less strict control regimes (aerial or recreational hunting) sufficient stems could be expected to occur within c. 40 and > 80 years respectively. In the case of the South Westland exclosures it is likely, therefore, that woody regeneration will take a very long time (possibly decades) to respond to grazing removal.

Côté et al. (2004) showed that large herbivores can act as 'biological switches' that move forest communities toward alternative successional pathways and distinct stable states. In classical succession models, the relationship between browsing pressure and plant abundance, whether gradual or sudden, is reversible. However, alternative stable states are not readily reversible when the browsing pressure is reduced. Although the system may not appear to change much as herbivore densities gradually increase, a sudden transition may occur that sharply reduces plant population levels (or overall system diversity or productivity). Once this point is reached, even dramatic reductions in herbivore density will have little effect; recovery will only occur if their densities are kept low for an extended period of time and interventions favouring vegetation recovery are applied.

5.2.4 Why herbivore impacts may not be reversible

Coomes et al. (2003) outlined several reasons why herbivore impacts may not be reversible:

- Palatable species remain highly browsed even at low animal densities (this is unlikely at most of the South Westland sites)
- Less-palatable species occupy vacated niches (possible)
- Local extinction of seed sources (not the case in South Westland sites)
- Fundamental alterations to successional pathways (possible)
- Shifts in ecosystem processes (probably?)
- Other species impact following single-species control (yes—multiple pests at South Westland sites)
- Exotic plants weaken the effectiveness of single-species control (only in grassland habitats?)

For the South Westland sites, the last two factors may have the greatest impacts on the vegetation, although further work is needed to determine whether grazing impacts are reversible and whether or not conservation goals are attainable. At current stocking rates, it seems unlikely that stock grazing alone would push plant communities beyond a reversible threshold in most valleys. However, impacts of other browsers in combination with domestic stock may be having irreversible impacts on the vegetation. In addition, herbaceous exotics have greatly altered the grassland communities of these valleys, irrespective of present stock impacts. This affects native establishment and hence vegetation communities or subsequent succession trajectories that may result. It is important that any management also allows for these other pressures that will influence achievement of conservation goals, by controlling the browsers or the exotic weeds. Manipulative experiments such as nested fencing for deer and/or possum control could be used to disentangle the direct and indirect effects of herbivores in these systems.

5.3 CONTINUATION OF THE SOUTH WESTLAND GRAZING TRIAL

Continuation of the South Westland grazing trial in some form is recommended, while taking into account conservation needs in relation to management of grazing leases and past experience fitted within financial resources. This type of low-input long-term study provides results and understanding that can otherwise be misinterpreted by any other approach. In this case, the clear finding is that the effects of excluding domestic stock on DOC grazing leases are complex.

Complex issues such as management of grazing leases while maintaining conservation values and biodiversity goals require a broad mix of appropriate approaches to enhancing ecological understanding to support management outcomes. These might include long-term studies, large-scale comparative studies, space-for-time substitution, modelling, experimentation and observational approaches. The best solutions will normally include more than one approach. The long-term benefits from permanent trial sites can be substantial for foreseeing management outcomes, particularly where, without a long-term approach, many of the initial responses to the exclusion of stock could have been misinterpreted, and inappropriate management been applied. Therefore, it is important that the current results are not seen as the final outcome, but merely as a management guide to be reviewed as the plots yield further information.

There are many good reasons to maintain the fenced exclosures and permanently marked controls for future re-evaluation:

- Results have clearly shown that responses to grazing removal have been different from any initial expectations, and are still happening.
- The exclusion of stock has long-term outcomes that remain idiosyncratic (i.e. vary widely among sites and habitats). The period of time that the exclosures have been in place (c. 16 years) offers an invaluable baseline to measure very long-term effects.
- The original purpose of the trial, to aid development of a long-term strategy for management of grazing leases, has not changed.
- The exclosures are readily accessible and thus have a clear demonstrative value for both conservation and farmer groups.
- Although the trial is focused on the forest ecotone, it also allows monitoring of both the marginal forest and the grasslands.
- The set of paired exclosures and controls on alluvial terraces and covering both forest and grassland systems are unique in the country for grazing lease lands and so can be used to inform managers of outcomes of their decisions.
- The mixtures of indigenous and exotic species present in the plots present an opportunity to aid our understanding of weed and pest impacts on native biodiversity and their interaction with grazing domestic stock. The trials to date are an indication of likely outcomes in these communities and provide useful results for answering the original questions about stock impacts. How long to monitor is an open question, but changes are still happening, DOC is still managing grazing leases and future questions are unknown, e.g. the impacts on carbon sequestration.

These are the only long-term stock exclosures on grazing lease land in Westland, or in New Zealand as far as we know, and the consistent methodologies and well-constructed exclosures offer an opportunity to inform future decisions and biodiversity outcomes.

Should the trial be continued? Decisions need to be made about two aspects:

1. Maintenance of the exclosure fences and associated markers and pegs
2. Vegetation remeasurement intervals to track further change

5.3.1 Maintenance of exclosures

If the trial is to be continued, the fences will need to be maintained. Ideally, fences should be checked on an approximately 6-month rotation in conjunction with other visits to the localities where the plots are found; at a minimum, annual visits to each site will be needed to maintain exclusion fences. Some repairs have been necessary during the course of the research to date, e.g. a treefall across the Arawhata River site fence.

DOC's Fencing Asset Management System (FAMS), a nationwide inventory of fencelines on or near Conservation land, was undertaken in Franz Josef and South Westland areas in 2007 and included exclosures. However, a source of funding for repairs needs to be identified until FAMS is in place. During the grazing impacts workshop held by West Coast Conservancy, DOC, on 12 September 2006, the priority for expenditure to maintain the exclosures rather than for other research priorities was questioned. It was generally agreed that maintenance of the exclosures in the long term should be a priority, as they provide an opportunity to demonstrate the benefits (or otherwise) of excluding stock, even if the plots within them are measured much less frequently. The most efficient way to do this would be to inspect the fencelines during grazing concession inspections.

5.3.2 Monitoring and evaluating grazing effects

Optimal remeasurement intervals and grazing effects depend on rates of vegetation change, how quickly management questions need to be addressed and the costs involved. Subtle differences in plant species abundance may be difficult to detect without direct comparisons with ungrazed sites, or the analysis of changes through time. Species from different geographical areas and different vegetation types may respond differently to grazing management (Stohlgren et al. 1999). Therefore, only appropriate approaches including multiple techniques, e.g. experimental assessments, can provide comprehensive information to managers (Bullock & Pakeman 1997). Our results confirm this, and show that although some species may be useful in evaluating grazing impact, responses are not consistent among sites and habitats (Appendix 2). This suggests that stock grazing is certainly not the only driver of vegetation change and interpretations based solely on indicators should be treated with caution.

Is there a standard monitoring technique to assess stock impacts?

Exclosures are always expensive and therefore impractical to establish at every site. However, the maintenance of exclosures and controls in a range of vegetation types and stocking rates provides benchmarks for comparisons over time and with other sites that have a similar vegetation type. The conservation value of an area could be used to determine which sites warrant monitoring, the suitable location of transects, and the level of monitoring required.

An appropriate subset of our monitoring techniques could be applied, depending on which community types the conservation objectives identified for protection. For example, if the conservation objective was regeneration of the forest canopy, it may be sufficient to monitor only the abundance of canopy-forming species in the shrub and tree layers, whereas if the objective were to maintain plant diversity in the forest understorey, it would be necessary to monitor the abundance of shrub and herbaceous species. In this way, any monitoring would be appropriate to the conservation objectives for a site, and would allow comparisons over time.

It must be accepted that without direct comparisons with ungrazed sites and with limited replication, it may be difficult to separate impacts attributable to stock from those of other factors. Therefore, to statistically disentangle the direct versus indirect effects of various herbivores, and their influence in grassland or forest habitats, a subset of the established plots could be used in combination with additional smaller, newly established replicate plots.

How much effort should DOC put into monitoring grazing impacts?

If grazing licences are granted on the proviso that conservation values are maintained, some form of monitoring will be necessary. Results have confirmed that the impact of grazing on vegetation structure and composition is not simple, or isolated from other biotic or environmental factors. While it is impractical to measure all variables at every site, the likelihood of overlooking some of the impacts of grazing increases as the range of measurements increases and replication decreases (i.e. statistical power to detect changes in vegetation or other effects becomes low). However, there is a need to balance the conservation benefits of monitoring with the effort involved.

The low number of sites and their idiosyncratic nature limits our ability to extrapolate from these results to other sites. However, the results could be applied more widely if we knew how representative these sites are of grazed forest margin vegetation in South Westland. For example, it may be possible to predict outcomes of stock exclusion for sites that closely match pre-fenced conditions or controls at our study sites.

To make results of this study more widely applicable requires an understanding of the extent of each forest margin type and its distribution throughout the grazing leased land of South Westland.

Monitoring frequency

Previously, we recommended that remeasurements be synchronised on a 5-yearly basis (Wardle et al. 1994). Although it may be possible to increase the monitoring interval beyond 5 years, there is a risk that institutional knowledge of the exclosures and their value will be lost if visits are too infrequent.

6. Conclusions

The following conclusions can be drawn from this long-term monitoring project:

- Stock impacts are not always negative for all elements of the biota.
- Maintenance of native herb species diversity in grasslands can be compatible with low-intensity grazing.
- In grassland habitats, the removal of stock grazing results in the initial dominance of a few, mostly exotic, herbaceous species. This reduces the abundance of both native and exotic herbs, but may promote the expansion of the forest margin.
- Continued grazing in grassland maintains native herbaceous species richness, but can slow the recruitment of native woody species.
- Maintenance of woody regeneration in ecotone forests is not compatible with grazing in many ecotone vegetation types.
- In forest, the removal of stock grazing facilitates an increase in the density of palatable woody species, and the height and diversity of herbaceous species. This favours recruitment of canopy-forming species in *Nothofagus menziesii* forest, but may disadvantage some canopy-formers in podocarp–hardwood forest due to increased competition for light.
- Continued grazing in forest suppresses preferred species. This limits species richness and canopy recruitment in *Nothofagus menziesii* forest, but can enhance recruitment of less-palatable canopy-formers in podocarp–hardwood forest.
- Forest species retain their regenerative capacity after more than 130 years of grazing.
- Although the focus of this long-term study has been directly on grazing impacts, it is difficult to separate those effects from the effects of other herbivores. Cattle are only one of the introduced herbivores at these sites; other species and other factors are likely to be determining the rate and direction of ecological processes. It may be valuable to consider all browsers in an integrated manner when making management decisions about grazing leases.

7. Recommendations

Based on the findings of this long-term monitoring project, several recommendations can be made for future work and management of native herb communities and succession of forest margins in South Westland.

7.1 GRAZING MANAGEMENT AND BIODIVERSITY

- Grazing decisions should be based on local conservation objectives that are specific to each site, e.g. an emphasis on plant species diversity in grassland may require a management regime that differs from that needed to retain a forest canopy.
- Management strategies need to be flexible and modified as more information from long-term monitoring comes to hand.

7.2 PROJECT MONITORING SCHEDULE AND METHODOLOGY

- We believe that the monitoring project is continuing to yield results that have implications for management and theoretical value. Our original statement that a substantial period of time would be required to provide definitive results appears to have been well founded, and our suggestion that useful data should emerge beyond the period of the present study also appears valid. The exclosures have provided permanent demonstrative value.
- Knowledge from ongoing remeasurements of the plots will be greatly enhanced if manipulative experiments are established simultaneously to disentangle the direct effects of cattle grazing from those of other animals.
- In conjunction with manipulative experiments, a survey of South Westland grazing concession areas and of forest ecotone types would determine how well these sites represent grazed forest margin vegetation in South Westland, and thus the degree to which predictions of grazing exclusion based on these sites might be more widely applied.
- Remeasurements have been synchronised on a 5-yearly basis and monitoring limited to 2 years out of every 5. It may be possible to increase the monitoring interval beyond 5 years; however, to ensure institutional knowledge of the exclosures and their value is maintained, annual contact by monitoring staff is recommended.
- Annual inspection of the exclosures should be added to the inspection schedule for the grazing concessions on which these exclosures are located, i.e. Whataroa, Cook Flats, Arawhata and Jacksons, with a view to maintaining the fences.

8. Acknowledgements

Many people have helped in the field and expedited what would have been time-consuming and tedious work. They include DOC staff on the West Coast (John Reid, Steven O'Dea, Glen Macdonald, Martin Abel, Calvin Jose, Fred Overmars, Phil Knightbridge, Paul van Klink, Megan Hieatt, Mike Elliott, Ian Wightwick, Paula Penno, Ingrid Grüner and Jo Macpherson); Carol West (DOC), who stood in for Susan Timmins in 1993; temporary employees of DOC who were seconded to the project (Debbie Zanders and Steve Moss); Bill Lee, Bryony Macmillan, Caroline Thomson and Laura Fagan of Landcare Research; Ros Lister, a student from University of Otago, who also did much of the data inputting in 1993; temporary employees of Landcare Research (Beatrice Lee, Moira Pryde, Max Dewdney, Tony Moore, Malcolm Douglas, Deb Zanders, Robert Arnold, Sandra Sinatsch and Zemin (Ted) Zhang); Claire Washington, who donated her time; and foreign students who donated their time in exchange for the 'New Zealand experience' (Monica Wimmer, Monica Gödde, René Mielson, Werner Müller, Claudia Niemeyer, Ute Rommeswinkel, Karin Jehn, Gunther Stauss, Astrid Baumbach, Steve Côté, Monique Poulin, Wolfgang G.E., Keir Daborn, Mark Muller, Grit Walther and Angelika Triebke). Trevor Partridge and David Coomes (Landcare Research) gave advice on statistical methods, and Ian Payton, Sarah Richardson and Rob Allen provided valuable comments. Alex Miller (DOC, Franz Josef) helped with accommodation and other arrangements. Finally, we wish to acknowledge the invaluable participation of Chris Woolmore, also of DOC at Franz Josef, from the inception of the project until he was transferred from the district in 1992. Financial support from the New Zealand Department of Conservation is acknowledged (Science Investigation No. 453).

9. References

Bullock, J.M.; Pakeman, R.J. 1997: Grazing of lowland heath in England: management methods and their effects on heathland vegetation. *Biological Conservation 79*: 1–13.

Buxton, R.P.; Timmins, S.M.; Burrows, L.B.; Wardle, P. 2001; Impact of cattle on Department of Conservation grazing leases in South Westland: results from monitoring 1989–1999, and recommendations. *Science for Conservation 179*. Department of Conservation, Wellington, New Zealand. 64 p.

Coomes, D.A.; Allen, R.B.; Forsyth, D.M.; Lee, W.G. 2003: Factors preventing the recovery of New Zealand forests following control of invasive deer. *Conservation Biology 17*: 450–459.

Côté, S.D.; Rooney, T.P.; Tremblay, J.-P.; Dussault, C.; Waller, D.M. 2004: Ecological impacts of deer overabundance. *Annual Review of Ecology, Evolution and Systematics 35*: 113–147.

Duncan, R.; Ruscoe, W.; Richardson, S.; Allen, R. 2006: Consequences of deer control for Kaweka mountain beech forest dynamics. Unpublished Landcare Research Contract Report LC0607/021. 25 p.

Forsyth, D.M.; Coomes, D.A.; Nugent, G.; Hall, G.M.J. 2002: Diet and diet preferences of introduced ungulates (Order: Artiodactyla) in New Zealand. *New Zealand Journal of Zoology 29*: 323–343.

Hearn, K.A. 1995: Stock grazing of semi-natural habitats on National Trust land. Pp. 25–37 in Bullock, D.J.; Harvey, H.J. (Eds): The National Trust and nature conservation: 100 years on. *Biological Journal of the Linnean Society 56 (supplement)*.

McGlone, M.S. 1989: The Polynesian settlement of New Zealand in relation to environmental and biotic changes. *New Zealand Journal of Ecology 12 (supplement)*: 115–129.

Miller, C.J.; Wells, A. 2003: Cattle grazing and the regeneration of totara on river terraces, south Westland, New Zealand. *New Zealand Journal of Ecology 27(1)*: 37–44.

Miller, C.J.; Norton, D.A.; Miller, T.K. 2004: Kahikatea and totara-matai forest patches in the agricultural landscape, Westland, New Zealand: representatives of a past and future condition. *Pacific Conservation Biology 9*: 278–293.

Proulx, M.; Mazumder, A. 1998: Reversal of grazing impact on plant species richness in nutrient-poor vs. nutrient-rich ecosystems. *Ecology 79*: 2581–2592.

Rosoman, G.B. 1990: People and grazing in South Westland. Unpublished MApplSci thesis, Lincoln University, Canterbury, New Zealand. 205 p.

Stohlgren, T.J.; Schell, L.D.; Van den Heuvel, B. 1999: How grazing and soil quality affect native and exotic plant diversity in Rocky Mountain grasslands. *Ecological Applications 9*: 45–64.

Timmins, S. 2002: Impact of cattle on conservation land licensed for grazing in South Westland, New Zealand. *New Zealand Journal of Ecology 26*: 107–120.

Wardle, D.A.; Barker, G.M.; Yeates, G.W.; Bonner, K.I.; Ghani, A. 2001: Introduced browsing mammals in natural New Zealand forests: aboveground and belowground consequences. *Ecological Monographs 71*: 587–614.

Wardle, P. 1967: Biological flora of New Zealand 2. *Nothofagus menziesii* (Hook. F.) Oerst. (Fagaceae) silver beech. *New Zealand Journal of Botany 5*: 276–302.

Wardle, P.; Buxton, R.P.; Partridge, T.R.; Timmins, S.M. 1994: Monitoring the impact of grazing animals on Department of Conservation leases in South Westland: 1989–1993. Unpublished Landcare Research Contract Report LC9394/124. 192 p.

Wilson, J.B.; Agnew, A.D.Q. 1992: Positive-feedback switches in plant communities. *Advances in Ecological Research 23:* 263–336.

Appendix 1

GLOSSARY OF SCIENTIFIC AND COMMON NAMES OF PLANTS

Scientific name	**Common name**
Aristotelia serrata	Wineberry
Asplenium bulbiferum	Hen and chickens fern
Astelia grandis	Swamp astelia
Carpodetus serratus	Marble leaf, putaputaweta
Coprosma lucida	Shining karamu
Coprosma rotundifolia	Round-leaved coprosma
Cyathea smithii	Soft tree fern, kātote
Dacrycarpus dacrydioides	Kahikatea
Dicksonia squarrosa	Wheki
Fuchsia excorticata	Tree fuchsia
Griselinia littoralis	Broadleaf
Hedycarya arborea	Pigeonwood
Histiopteris incisa	Water-fern
Melicytus ramiflorus	Mahoe
Myrsine divaricata	Weeping mapou
Nothofagus menziesii	Silver beech
Pennantia corymbosa	Kaikomako
Phormium tenax	Flax
Podocarpus totara var. *waihoensis*	Westland totara
Prumnopitys taxifolia	Matai
Pseudopanax crassifolius	Lancewood
Pseudowintera colorata	Pepper tree, horopito
Pteridium esculentum	Bracken
Schefflera digitata	Pate
Weinmannia racemosa	Kamahi

Appendix 2

SUMMARY OF PCA AXES FOR SHRUB COMPOSITIONAL DATA

Data included in this analysis are from the latest measurement at each site. The first three axes explain 82% of the variation in shrub species composition. Data shown for individual species are loadings for Principal Components Analysis (PCA) axes; larger numbers (either positive or negative) show the importance of species to explaining variation of each PCA axis.

	AXIS 1	AXIS 2	AXIS3
Eigenvalue	2408.549	1087.019	533.4965
Percent	48.9377	22.0864	10.8397
Cum Percent	48.9377	71.0241	81.8638
Eigenvectors			
Alseuosmia pusilla	−0.00002	0.00003	0.00065
Aristotelia fruticosa	0.00093	−0.01138	0.01345
Aristotelia fruticosa × serrata	0.00016	−0.00000	0.00024
Aristotelia serrata	0.00037	−0.00019	0.00633
Ascarina lucida	−0.00022	0.00069	−0.00044
Astelia grandis	−0.00048	−0.00114	0.00079
Calystegia tuguriorum	0.00008	0.00001	−0.00004
Carmichaelia arborea	0.00017	−0.00008	0.00538
Carmichaelia australis	−0.01440	−0.04333	−0.00021
Carpodetus serratus	−0.01318	0.02589	0.18498
Clematis species	−0.00003	0.00009	0.00008
Clematis paniculata	0.00004	0.00223	−0.00061
Coprosma antipoda	0.00005	−0.00010	0.00009
Coprosma ciliata	0.03321	0.03596	0.01238
Coprosma colensoi	0.00204	0.00116	0.00026
Coprosma cuneata	0.00010	0.00002	0.00018
Coprosma foetidissima	0.00492	0.00111	0.00118
Coprosma lucida	−0.00120	0.00184	0.00019
Coprosma propinqua	−0.02567	−0.05741	0.00502
Coprosma rhamnoides	0.03258	0.01686	0.00149
Coprosma rigida	−0.00283	−0.00774	−0.00223
Coprosma rotundifolia	−0.01386	0.09060	0.90520
Coprosma rugosa	−0.00027	−0.00067	−0.00078
Coprosma tayloriae	−0.03059	−0.07077	−0.00452
Cyathea cunninghamii	−0.00009	0.00006	−0.00002
Cyathea smithii	−0.00593	0.04670	−0.02364
Cytisus scoparius	−0.00002	−0.00004	−0.00005
Dacrydium cupressinum	0.00252	0.00465	0.00436
Dacrycarpus dacrydioides	−0.22099	0.94602	−0.07514
Dicksonia squarrosa	−0.03948	0.13251	0.01559
Elaeocarpus hookerianus	−0.00010	−0.00025	−0.00000
Fuchsia excorticata	−0.00023	−0.00081	0.01681
Fuchsia species	−0.00003	0.00010	0.00007
Griselinia littoralis	0.00656	0.00285	0.00217
Griselinia lucida	−0.00010	0.00014	−0.00017

Appendix 2 continued on next page

Appendix 2 continued from previous page

	AXIS 1	AXIS 2	AXIS3
Hebe salicifolia	−0.00002	−0.00003	0.00010
Hedycarya arborea	−0.00122	0.00636	0.00689
Hoberia glabrata	0.00017	0.00003	0.00003
Hypericum androsaemum	−0.00060	−0.00039	0.00489
Ileostylus micranthus	−0.00002	−0.00002	−0.00000
Manoao colensoi	−0.00008	−0.00025	−0.00005
Melicytus ramiflorus	−0.01023	0.02795	−0.00079
Metrosideros diffusa	−0.01883	0.07208	−0.02085
Metrosideros fulgens	−0.00002	−0.00002	−0.00002
Metrosideros perforata	−0.00015	0.00084	−0.00007
Metrosideros umbellata	0.00006	0.00001	0.00000
Muehlenbeckia australis	−0.00130	0.00096	0.02382
Muehlenbeckia axillaris	0.00050	−0.00021	−0.00095
Muehlenbeckia complexa	−0.00008	−0.00019	−0.00021
Myrsine australis	−0.00054	0.00150	0.00023
Myrsine divaricata	0.00245	0.03963	0.10101
Neomyrtus pedunculata	0.03329	0.01285	0.01651
Nothofagus menziesii	0.01151	0.00057	0.00326
Olearia virgata	−0.00067	−0.00185	−0.00143
Parsonsia heterophylla	−0.00181	0.00246	−0.00070
Pennantia corymbosa	−0.01161	0.02346	0.09624
Phormium tenax	−0.01400	−0.04260	−0.02715
Phyllocladus alpinus	−0.00010	−0.00024	0.00008
Pittosporum colensoi	−0.00001	−0.00002	0.00014
Plagianthus regius	−0.00104	−0.00054	0.01221
Podocarpus totara var. *waihoensis*	−0.01833	−0.01669	0.05813
Prumnopitys ferruginea	−0.00001	0.00570	−0.00138
Prumnopitys taxifolia	−0.00336	0.00157	0.01698
Pseudopanax colensoi	0.00684	0.00148	0.00312
Pseudopanax crassifolius	0.00074	−0.00653	0.00534
Pseudowintera colorata	0.96862	0.22140	−0.02377
Raukaua anomalus	0.06553	−0.05036	0.33586
Raukaua edgerleyi	−0.00055	0.00038	−0.00106
Raukaua simplex	−0.00000	0.00023	−0.00018
Raukaua simplex × anomalus	0.00005	−0.00001	0.00001
Ripogonum scandens	−0.00981	0.02051	−0.00266
Rubus australis	−0.00028	0.00050	−0.00024
Rubus cissoides	−0.00051	0.00083	−0.00053
Rubus fruticosus	−0.00003	−0.00007	−0.00004
Rubus parvus	−0.00002	−0.00003	−0.00003
Rubus schmidelioides	−0.00534	0.00061	0.00786
Rubus species	0.00007	0.00002	0.00001
Schefflera digitata	−0.00202	0.01340	0.01684
Ulex europaeus	−0.00100	−0.00256	−0.00330
Weinmannia racemosa	−0.00761	0.04227	−0.00596

Appendix 3

MEAN TOTAL SHRUB NUMBERS BY PALATABILITY

Site: AR = Arawhata River, CO = Cook Old Forest, CS = Cook Swamp, CY = Cook Young Forest, JA = Jackson River, and WH = Whataroa Valley.
Year: 1 = initial, 2 = latest remeasurement.
Unpalatable species refer to those not selected or avoided by ungulates.

SITE	HABITAT	PLOT	YEAR	PALATABLE	MEAN TOTAL SHRUBS	SE
AR	Grassland	Control	1	Yes	0	0
				No	21	18
			2	Yes	0	0
				No	13	5
		Exclosure	1	Yes	0	0
				No	3	0
			2	Yes	0	0
				No	2.5	0.5
	Ecotone	Control	1	Yes	0	0
				No	22.5	3.5
			2	Yes	0.5	0.5
				No	36.5	7.5
		Exclosure	1	Yes	0	0
				No	29.5	14.5
			2	Yes	1.5	1.5
				No	59	4
	Forest	Control	1	Yes	0.8	0.5
				No	165.5	36.1
			2	Yes	1.8	0.8
				No	151	13.4
		Exclosure	1	Yes	5.5	2.5
				No	117.3	20.2
			2	Yes	10.3	4.3
				No	148.3	16.8
CO	Forest	Control	1	Yes	9.5	2.3
				No	138.3	44.8
			2	Yes	27	19.4
				No	116.8	12.1
		Exclosure	1	Yes	8.3	3.3
				No	99	17.3
			2	Yes	22.8	3.3
				No	81.3	9.6
CS	Grassland	Control	1	Yes	0	0
				No	14.5	7.5
			2	Yes	0	0
				No	34.3	6.9
		Exclosure	1	Yes	0	0
				No	9	4.5
			2	Yes	0	0
				No	8.3	3.5

Appendix 3 continued on next page

Appendix 3 continued from previous page

SITE	HABITAT	PLOT	YEAR	PALATABLE	MEAN TOTAL SHRUBS	SE
	Ecotone	Control	1	Yes	0.3	0.3
				No	60	8.9
			2	Yes	4.7	3.3
				No	131	22.5
		Exclosure	1	Yes	0	0
				No	20	8.1
			2	Yes	0.7	0.7
				No	51	20.2
	Forest	Control	1	Yes	1.8	1.8
				No	85.5	10.7
			2	Yes	6.3	2.6
				No	129.3	29.6
		Exclosure	1	Yes	1.5	1
				No	76.3	6.5
			2	Yes	2	0.9
				No	143.5	22.7
CY	Grassland	Control	1	Yes	1	0.6
				No	23	13.7
			2	Yes	0.3	0.3
				No	47.7	23.1
		Exclosure	1	Yes	1	1
				No	69	58
			2	Yes	18.7	12
				No	102.3	43.4
	Ecotone	Control	1	Yes	8.5	4.5
				No	94.5	4.5
			2	Yes	3	1
				No	108	42
		Exclosure	1	Yes	4	3
				No	113.5	3.5
			2	Yes	31.5	11.5
				No	123	22
	Forest	Control	1	Yes	3.7	3.2
				No	51.7	15.9
			2	Yes	1.7	1.7
				No	75.3	1.9
		Exclosure	1	Yes	3	1.5
				No	35.7	9.1
			2	Yes	17	5.7
				No	55	4.5
JA	Grassland	Control	1	Yes	0	0
				No	2	0
			2	Yes	0	0
				No	6	0
		Exclosure	1	Yes	3	0
				No	20	0
			2	Yes	0	0
				No	25	0
	Ecotone	Control	1	Yes	0.5	0.5
				No	147.5	10.5

Appendix 3 continued on next page

Appendix 3 continued from previous page

SITE	HABITAT	PLOT	YEAR	PALATABLE	MEAN TOTAL SHRUBS	SE
			2	Yes	0.5	0.5
				No	113.5	17.5
		Exclosure	1	Yes	3	0
				No	149.5	7.5
			2	Yes	8.5	4.5
				No	138.5	13.5
	Forest	Control	1	Yes	5	0.9
				No	263	24.4
			2	Yes	3.8	0.9
				No	185.3	15.3
		Exclosure	1	Yes	2.8	0.9
				No	178.3	25.6
			2	Yes	15.8	2.4
				No	140.8	10.7
WH	Grassland	Control	1	Yes	0	0
				No	17.5	1.5
			2	Yes	0.5	0.5
				No	17.5	1.5
		Exclosure	1	Yes	0	0
				No	30	8
			2	Yes	0	0
				No	23.5	7.5
	Ecotone	Control	1	Yes	3	3
				No	102	52
			2	Yes	1.5	0.5
				No	116.5	35.5
		Exclosure	1	Yes	6	3
				No	341	97
			2	Yes	12	2
				No	212	1
	Forest	Control	1	Yes	1.8	0.8
				No	50.3	7.4
			2	Yes	1.3	0.5
				No	44.5	6.6
		Exclosure	1	Yes	3.3	0.8
				No	138.3	45.7
			2	Yes	44.3	11
				No	122.5	23

Appendix 4

MEAN HERB NUMBERS FOR NATIVE AND EXOTIC SPECIES

Site: AR = Arawhata River, CO = Cook Old Forest, CS = Cook Swamp, CY = Cook Young Forest, JA = Jackson River, and WH = Whataroa Valley.
Year: 1 = initial, 2 = latest remeasurement. Exotic: Y = yes, N = no.

SITE	HABITAT	PLOT	YEAR	EXOTIC	MEAN NUMBER OF HERBS	SE
AR	Grassland	Control	1	N	59.5	3.6
				Y	84.5	6.8
			2	N	75.8	7.6
				Y	94	8.2
		Exclosure	1	N	55.5	8.5
				Y	67.8	9.2
			2	N	36	11.3
				Y	82.8	10.6
	Ecotone	Control	1	N	32.5	16.5
				Y	16.5	16.5
			2	N	40	6
				Y	18.5	17.5
		Exclosure	1	N	26	7
				Y	26	26
			2	N	38.5	19.5
				Y	21	21
	Forest	Control	1	N	26.3	3.1
				Y	3.3	1.8
			2	N	40	7.6
				Y	4.3	2.8
		Exclosure	1	N	18.3	1.1
				Y	0.8	0.3
			2	N	22.8	2.5
				Y	0.8	0.5
CO	Forest	Control	1	N	28.8	3.5
				Y	0.3	0.3
			2	N	20.8	2.3
				Y	0	0
		Exclosure	1	N	10	0.4
				Y	0.5	0.3
			2	N	14.3	2.2
				Y	0	0
CS	Grassland	Control	1	N	66.3	5.5
				Y	70	3.2
			2	N	83.7	1.9
				Y	92.7	5.2
		Exclosure	1	N	61.7	1.2
				Y	80.7	1.8
			2	N	44.3	4.4

Appendix 4 continued on next page

Appendix 4 continued from previous page

SITE	HABITAT	PLOT	YEAR	EXOTIC	MEAN NUMBER OF HERBS	SE
				Y	50	7.9
	Ecotone	Control	1	N	54.3	4.3
				Y	51	10.5
			2	N	54	3.1
				Y	55.7	15.7
		Exclosure	1	N	49	5.1
				Y	55	2
			2	N	54.3	6.3
				Y	33	4.2
	Forest	Control	1	N	53.8	3.6
				Y	37	9.2
			2	N	47.3	0.9
				Y	30.3	1.9
		Exclosure	1	N	54.8	6.5
				Y	35	7.8
			2	N	44	3.5
				Y	9.8	1.3
CY	Grassland	Control	1	N	58.3	9.6
				Y	77.7	13
			2	N	52.3	13.9
				Y	72.7	11.9
		Exclosure	1	N	49.3	2
				Y	85	4.9
			2	N	59	8.7
				Y	56.3	14.3
	Ecotone	Control	1	N	32	13
				Y	21.5	15.5
			2	N	42.5	19.5
				Y	15	11
		Exclosure	1	N	39	2
				Y	15.5	13.5
			2	N	36.5	7.5
				Y	2.5	2.5
	Forest	Control	1	N	12	2.5
				Y	0	0
			2	N	17.3	3.8
				Y	0	0
		Exclosure	1	N	14.7	4.7
				Y	0	0
			2	N	23.3	9
				Y	0	0
JA	Grassland	Control	1	N	105.5	9.5
				Y	75.5	0.5
			2	N	123	14
				Y	74	9
		Exclosure	1	N	81.5	6.5
				Y	90.5	9.5
			2	N	46	6
				Y	87	0
	Ecotone	Control	1	N	38	6
				Y	26	26

Appendix 4 continued on next page

Appendix 4 continued from previous page

SITE	HABITAT	PLOT	YEAR	EXOTIC	MEAN NUMBER OF HERBS	SE
			2	N	50	2
				Y	28.5	28.5
		Exclosure	1	N	53.5	7.5
				Y	23.5	23.5
			2	N	48.5	2.5
				Y	14.5	14.5
	Forest	Control	1	N	18	1.5
				Y	0	0
			2	N	31	4
				Y	0	0
		Exclosure	1	N	32.5	4.9
				Y	0	0
			2	N	22.5	2.3
				Y	0	0
WH	Grassland	Control	1	N	166.5	15.5
				Y	80	5
			2	N	126.5	7.5
				Y	86	4
		Exclosure	1	N	133.5	4.5
				Y	78.5	2.5
			2	N	69.5	6.5
				Y	45	1
	Ecotone	Control	1	N	89	42
				Y	54.5	24.5
			2	N	78	34
				Y	49	25
		Exclosure	1	N	99	51
				Y	53.5	23.5
			2	N	43	15
				Y	28.5	14.5
	Forest	Control	1	N	9	3.2
				Y	4.8	2.8
			2	N	12	0.9
				Y	2.3	0.8
		Exclosure	1	N	18.3	4
				Y	1.5	0.9
			2	N	18.8	3.8
				Y	0.5	0.3