

Impact of cattle on Department of Conservation grazing leases in South Westland: results from monitoring 1989-99, and recommendations

SCIENCE FOR CONSERVATION 179

R.P. Buxton, S.M. Timmins, L.E. Burrows and P. Wardle

Published by
Department of Conservation
P.O. Box 10-420
Wellington, New Zealand

Science for Conservation presents the results of investigations by DOC staff, and by contracted science providers outside the Department of Conservation. Publications in this series are internally and externally peer reviewed.

This report was prepared for publication by Science Publishing, Science & Research Unit; editing by Ian Mackenzie and layout by Lynette Clelland. Publication was approved by the Manager, Science & Research Unit, Science Technology and Information Services, Department of Conservation, Wellington.

© September 2001, Department of Conservation

ISSN 1173-2946

ISBN 0-478-22133-9

CONTENTS

Abstract	5
<hr/>	
1. Introduction	6
<hr/>	
2. Background	6
<hr/>	
3. Objectives	8
<hr/>	
4. Methods	8
<hr/>	
4.1 Plot location and design	8
4.2 Experimental design	9
4.2.1 Recording	9
4.3 Analysis of data	11
4.4 Recording times and intervals	12
4.5 Plot locations and histories	12
4.5.1 Waitangitaona Valley	12
4.5.2 Whataroa Valley	13
4.5.3 Cook Swamp	13
4.5.4 Cook Young Forest	14
4.5.5 Cook Old Forest	14
4.5.6 Jackson River	14
4.5.7 Jubilee Flat, Arawata River	14
5. Results	16
<hr/>	
5.1 Waitangitaona and Whataroa valleys	16
5.1.1 Waitangitaona	16
5.1.2 Whataroa	16
5.2 Cook Valley plots	16
5.2.1 Cook Swamp	16
5.2.2 Cook Young Forest	17
5.2.3 Cook Old Forest	17
5.3 Arawata and Jackson river valleys	18
5.3.1 Jackson River	18
5.3.2 Arawata River	18
5.4 Results attributable to grazing	18
5.4.1 Shrub density	18
5.4.2 Height of the tallest herb	19
5.4.3 Herb species richness	20
5.4.4 Indicator species	21
5.4.5 Change in canopy species	22
6. Discussion and Conclusions	23
<hr/>	
6.1 Natural processes	24
6.1.1 Competition for light	24
6.1.2 Soil properties	24
6.2 Plant attributes affecting grazing susceptibility	24
6.3 Cattle stocking rates and management implications	25

6.4	Comparisons with other browsers	26
6.4.1	Deer impacts	26
6.4.2	Browse patterns	26
6.5	Monitoring options	26
6.6	Conclusions	28
7.	Recommendations	28
7.1	Project monitoring schedule and methodology	28
7.2	Grazing management	29
8.	Acknowledgements	30
9.	References	30
Appendix 1		32
	Glossary of scientific and common names	
Appendix 2		33
	Data analysis methods	
Appendix 3		36
	Detailed results	36
	Ground cover	36
	Herbaceous species	36
	Woody seedlings	38
	Trees	39
	Silver beech	40
	Kahikatea	40
Appendix 4		42
	Summarised transect data	
Appendix 5		58
	Vascular plant species present on each plot	

Impact of cattle on Department of Conservation grazing leases in South Westland: results from monitoring 1989–99, and recommendations

R.P. Buxton¹, S.M. Timmins², L.E. Burrows¹, P. Wardle¹

¹ Landcare Research, P.O. Box 69, Lincoln, New Zealand

² Science and Research Division, Department of Conservation, PO Box 10420, Wellington, New Zealand.

ABSTRACT

To study the impacts of cattle grazing, between 1989 and 1992 seven pairs of matched exclosure and control plots were established across forest-grassland boundaries on river flats in South Westland, South Island, New Zealand. The plots were resurveyed at 4-yearly intervals. After more than a century of stock access, short-term (< 10 years) vegetation responses to exclusion of grazing varied with community type in rapidity and direction. While native woody species in the browse-susceptible tier (0.3–2 m) and herbaceous species of the forest understorey increased in abundance, small native grassland herbs were outcompeted by vigorous adventive herbs and grasses. The herbaceous tier has increased in height, especially at the ecotone, and thereby suppressed the establishment of woody seedlings. Some woody species have emerged as useful indicators of cattle impact, but the species vary between sites. While removal of cattle favoured *Nothofagus menziesii* at all sites where it occurred, *Dacrycarpus dacrydioides* abundance increased at beech sites, but decreased at non-beech sites. At some sites it is difficult to discern whether cattle grazing or natural forest processes are driving vegetation change; it is still too early to judge the impact of grazing on future canopy composition. The project highlights three management principles: (1) each ecological situation should be judged and managed on its individual merits; (2) decisions concerning grazing should be based on the conservation objectives for the site; for example, an emphasis on species diversity may require a management regime different from that needed to retain a forest canopy, and be integrated with wild animal control operations on adjacent land; and (3) monitoring projects will continue to yield new information for decades, and management strategies should be modified in the light of this new information as it comes to hand.

Keywords: Cattle, exclosures, forest margins, grassland, grazing, river flats, South Westland, New Zealand.

© September 2001, Department of Conservation. This paper may be cited as:

Buxton, R.P.; Timmins, S.M.; Burrows, L.E.; Wardle, P. 2001: Impact of cattle on Department of Conservation grazing leases in South Westland: results from monitoring 1989–99, and recommendations. *Science for Conservation* 179. 64 p.

1. Introduction

Cattle grazing on land leased from the Department of Conservation (DOC) in Westland river valleys is a contentious issue, largely because of the perceived impact on forest edges and canopy regeneration. The aim of this project is to determine the current effect of extensive cattle grazing on forest margin plant communities. Objective information obtained on regeneration and changes in frequency of native and introduced plant species with and without cattle grazing will give DOC a basis for assessing management options. The paired enclosure and control plots also have demonstration value, giving a visual account of grazing impact on forest margin vegetation. This long-term monitoring programme began in 1989 and is a joint project between DOC's Science & Research Division and West Coast Conservancy, and Landcare Research.

2. Background

Before the arrival of humans 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 at many others they were very sharp. Sharp transitions reflect discontinuities in soil and drainage patterns, or result from inherent 'switch' effects (Wilson & Agnew 1992), i.e. each vegetation type creates an environment that favours its own species, and deters the species on the other side of the boundary. 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 plants. In some instances the forest advanced into the shorter vegetation, whereas other forest boundaries were essentially static, having reached the tolerance limits of trees in the face of frost, or inadequate or excessive drainage. Rare lightning fires would also have affected vegetation boundaries, at least in drier areas or periods. Until Maori occupation contributed to their disappearance, it is likely that moa and other ground birds reached maximum numbers and exerted maximum browsing pressures on alluvial flats, because the fast-growing seral communities on these fertile sites provided the best food source (McGlone 1989). 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 in the extent of low-altitude valley flats that have never been cleared of their pre-European vegetation. However, for as long as pastoral farming has been carried out in the region—i.e. from the 1870s or even earlier—cattle and, to a lesser extent, sheep have been grazed on these flats (Rosoman 1990). Although the major forest/grassland boundaries do not appear to have changed markedly in response to this grazing, there have been changes in the composition and structure of the vegetation. In particular, the grassland is now almost totally dominated by introduced grasses and clovers, although native plants, mostly low-growing and unpalatable, persist.

Most mountain valleys in central and southern Westland have been retained in state ownership, and the graziers are lessees of the state. Until 1973 the administering authorities were the Department of Lands and Survey and the New Zealand Forest Service, and grazing leases could include both open and forested land. In practice, most of the leases were administered by the Department of Lands and Survey, whether they fell into the Crown Land category, or were 'Provisional State Forests' deemed to be controlled by the Forest Service. Generally unavailable for legal grazing were areas that had, at various times, been gazetted as scenic reserve or national park.

Concern within 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 in respect of which authority administered specific leases, and opportunities were taken to reduce new licences to grazable 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.

From the mid-1970s, nature conservation became an increasingly divisive issue in South Westland. The forest *per se* was the subject of greatest popular concern, but there were also those who considered grazing to be an inappropriate and damaging use of conservation land. 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. DOC inherited the leases, and their associated problems, after the disestablishment of Lands and Survey and the Forest Service in 1987.

In response to the concern over grazing in the proposed Ohinemaka Ecological Area, representatives of DOC, Botany Division of the Department of Scientific and Industrial Research, and the School of Forestry, Canterbury University, visited Ohinemaka and other localities in December 1987 to identify the ecological issues involved. Clearly, these were complex. One of the more apparent was that recent alluvial silts were colonised by vigorous introduced plants, especially *Lotus pedunculatus*¹, which excluded seedlings of native plants. It seemed possible that beneficial effects of excluding cattle might be offset in part through removal of control of such plants by grazing.

The group concluded that, rather than endorse any decision to either continue or cease grazing, it would be better to set up a series of exclosure and control plots, to be monitored over as many years as were needed to arrive at sound recommendations (see Wardle et al. 1988). DOC accepted this advice, and a monitoring programme was set up as a joint project between DSIR (subsequently Landcare Research, after the disestablishment of DSIR in 1992), the Science & Research Directorate (now Division) of DOC, and the West Coast Conservancy of DOC. The first plots were set up in the late summer of 1989.

¹ Scientific names are used throughout, with relevant common names in Appendix 1.

3. Objectives

The objectives of the monitoring were:

- To determine the effect of extensive cattle grazing on forest margin vegetation.
- To demonstrate the potential future states of vegetation in the presence/absence of cattle grazing, to aid decision-making concerning the conservation values of those states when assessing management options.

This report updates previous findings (Wardle et al. 1994) and provides an overview of the study (results from the first 11 years of monitoring, information and recommendations for land managers). Appendices provide detailed analyses and results, that underpin the overview, and form an archive of data summarised for each transect. Original field records are archived in NVS (the National Vegetation Survey databank) held at Landcare Research, Lincoln.

4. Methods

4.1 PLOT LOCATION AND DESIGN

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 (i.e. extensive grazing) being continued.

It was also considered important to capture as many variations of the theme ‘forest boundaries on extensively grazed alluvial flats’ as possible. One important set of variations comprises substrate type and drainage, which grade from coarse gravel to deep silt, and from well-drained to swampy. The composition of both forest and grassy vegetation varies with these differences in substrate. Forest communities also differ according to whether *Nothofagus menziesii* is dominant or absent.

Monitoring is based on six pairs of rectangular plots, mostly in the order of 30 m × 60 m with the long axis at right angles to the forest/grassland boundary. All plots but one extend from grassy vegetation into closed forest; the exception lies wholly within forest.

Enclosure plots are bounded by cattle- and sheep-proof fences 1 m high constructed of posts, battens, and high-tensile wire. They do not exclude deer or small mammals, although they probably provide some discouragement to the former. Each is accompanied by an equal-sized control plot that matches, as closely as possible, the major vegetation pattern within the enclosure, as well as the lesser variations in vegetation and topography.

4.2 EXPERIMENTAL DESIGN

Measurement techniques were designed to be as simple and repeatable as possible, giving results that can be quantitatively analysed, but falling short of the amount of replication that would be needed for tests of statistically significant differences between exclosure and control plots. We have used systematic sampling, which is easier to carry out and more repeatable than random sampling, and acceptable as replication was limited.

Each exclosure and control plot was divided into contiguous (25 m × 5 m) transects with the long axis parallel to the forest-grassland boundary (Fig. 1). Transects per plot range from four to ten. Each transect was treated as a subplot and measured and analysed independently. Overall community changes within transects can therefore be detected, while comparison between transects should reveal significant shifts in vegetation boundaries. Comparison of corresponding transects in control and exclosure plots reveal differences attributable to removal of grazing, although other effects, especially initial differences between the plots, also have to be considered. To allow the effects of cattle grazing to be distinguished with statistical rigour from other effects would require an impracticable level of replication. However, by treating each site as a replicate, site differences can be removed, allowing changes resulting from exclosure to be expressed.

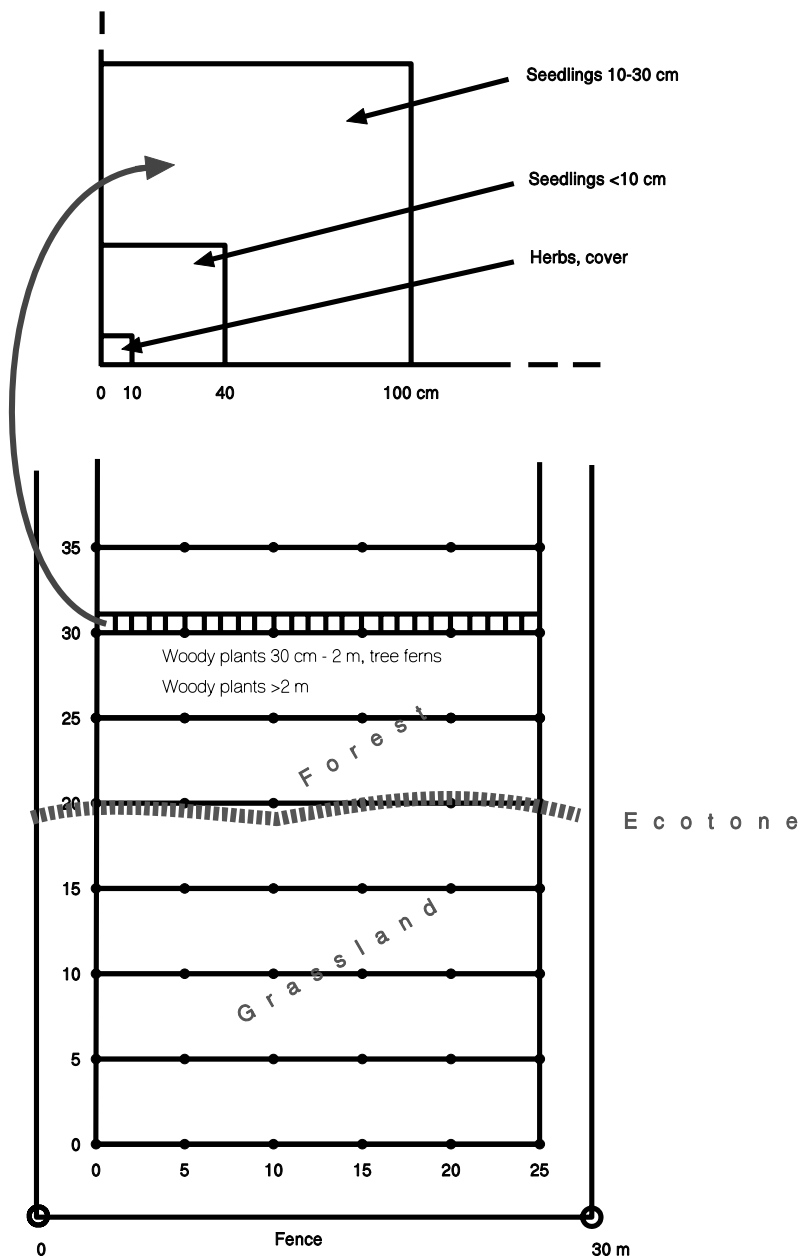
In setting up each plot, two tapes were run out 25 m apart and at right angles to the forest-grassland margin, to define each side. Pegs were driven in at 5 m intervals, and lines joining opposite pegs used to define the transects. Along these lines, which all run approximately east to west, aluminium rods were placed at 5 m intervals (Fig. 1). From time to time rods need to be replaced, as they are lost through disturbance by cattle, sinking into swamp mud or, in one locality, by human interference. Metal detectors have proved valuable for relocating rods.

4.2.1 Recording

Vegetation was divided into successive size classes; herbs and woody plants < 0.3 m tall were measured on nested quadrats distributed along the base line of the transect, i.e. the edge of the transect closest to the zero line of the plot (see points 1-3 below). Larger plants were counted over the whole transect (see points 4-6 below).

1. Percent cover was estimated in quadrats 0.1 m × 0.1 m, placed at 1 m intervals from 0 to 24 m along the base line (i.e. covering 1/500th of the transect); in the following categories: vascular herbs, litter, bryophytes, lichens, bare ground, stones, water, tree roots and tree bases. The cover recorded was that visible from above the herbaceous vegetation; i.e. surfaces obscured by the latter were not considered. Herbs were listed by species. We also noted the maximum leaf height in the quadrat (excluding leaves borne on flower stems or culms).
2. Numbers of woody seedlings up to 0.1 m tall were counted by species in quadrats 0.4 m × 0.4 m, placed at the same intervals (i.e. covering slightly over 1/30th of the transect).

Figure 1. Layout of an enclosure (axes are in metres).



3. Species and numbers of woody seedlings 0.1–0.3 m tall were recorded in 25 contiguous quadrats 1.0 m × 1.0 m (covering 1/5th of the transect).
4. Species, numbers and heights of saplings and shrubs 0.3–2.0 m tall were recorded over the whole transect. Clustered stems of the same species sharing a common base were bracketed. (Height measurements in this detail have proved superfluous, and from 1994 plants were assigned to only two categories, i.e. 0.3–1.0 m and 1.0–2.0 m).
5. Species, numbers, and diameters (at breast height—dbh) of saplings and trees > 2.0 m tall were recorded over the whole transect. Again, stems of the same species sharing a common base were bracketed. ('Breast height' had to be applied with some flexibility, especially for stems that fork about this level, where it seemed more appropriate to measure a single stem below the fork than multiple stems above it).

6. All tree ferns with stems < 0.3 m tall were recorded in the appropriate seedling quadrats. All taller tree ferns were recorded, with their heights, in the 0.3–2.0 m category, even when taller than this. *Phormium tenax* was also recorded in the 0.3–2.0 m category, with both isolated fans and clumps of fans counted as individuals.
7. Frequency of liane species was recorded for the nested quadrats, and only presence in transects for the 0.3–2.0 m and > 2.0 m tiers. For *Metrosideros* species, which exist as ground cover as well as tall stems, there was some inconsistency in the recording of isolated stems < 0.1 m tall. Some were recorded as small seedlings (quadrats 0.4 m × 0.4 m), and others as cover (quadrats 0.1 m × 0.1 m); the latter is recommended for future measurements.

With the experimental design described above, we have been able to set up or fully resurvey one to three exclosure plots and their matching control plots each year. New plots were set up from 1989 to 1992, and a subsequent plot in 1996. Full resurvey of plots commenced in 1992. Partial resurveys helped to determine the interval between full resurveys which, so far, has been 3–4 years. Excepting eroded plots and their replacements, all plots have now had two full resurveys.

4.3 ANALYSIS OF DATA

Data were analysed transect by transect, to yield the following sums and means:

- Frequencies of all vascular herb species in quadrats 0.1 m × 0.1 m (i.e. numbers of quadrats out of 25 that each species occurred on); mean leaf height; mean percentage cover contributed by each cover category.
- Woody seedlings in quadrats 0.4 m × 0.4 m and 0.1 m × 0.1 m (including small tree ferns) under and > 0.1 m tall, respectively; total numbers in each quadrat according to species.
- Shrubs and saplings 0.3–2.0 m tall, and all tree ferns > 0.3 m tall; total numbers in each transect according to species. Bracketed stems were counted as one plant, at least for the primary analysis.
- Saplings and trees > 2.0 m tall are total numbers in each transect according to species, with bracketed stems 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.

The transect summary data for herbaceous height and cover for each exclosure plot and its control are presented as graphs in Appendix 3.

The five sites that have had two full remeasurements (i.e. three measurements per transect) were treated as replicates in the analyses to remove differences between sites. For each parameter measured, the changes in the exclosure and control data were compared separately in each community type (grassland, ecotone, and forest) using paired *t*-tests. The transects were separated by community type (Table 1) as different trends were observed in each of these communities, and reducing major vegetation differences would allow impacts of cattle to be more easily determined.

TABLE 1. ALLOCATION OF 5-m-DEEP TRANSECTS AMONG COMMUNITY TYPES AT EACH SITE. THREE TRANSECTS WERE ALLOCATED TO THE COOK SWAMP ECOTONE DUE TO ITS LESS DISTINCT NATURE.

SITE	GRASSLAND	ECOTONE	FOREST
Cook Old Forest			0-15
Cook Swamp	0-10	15-25	30-45
Cook Young Forest	0-10	15-20	25-35
Arawata	0-15	20-25	30-45
Jackson	0-5	10-15	20-35

4.4 RECORDING TIMES AND INTERVALS

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

All transects were measured when plots were first set up. In following years, partial resurveys were conducted biennially to provide information to help determine when full resurvey was due. For partial resurveys only selected transects (usually two in each enclosure and the matching pair in the control) were remeasured. To avoid too-frequent disturbance, different transects were chosen in successive years. So far, full resurveying has been at intervals of 3-4 years. However, plots were visited annually to check their condition, particularly with respect to the fences, and it is advisable that this continues. Only data from full resurveys were used in the analyses.

4.5 PLOT LOCATIONS AND HISTORIES

Five general locations of plots are shown in Figure 2.

4.5.1 Waitangitaona Valley

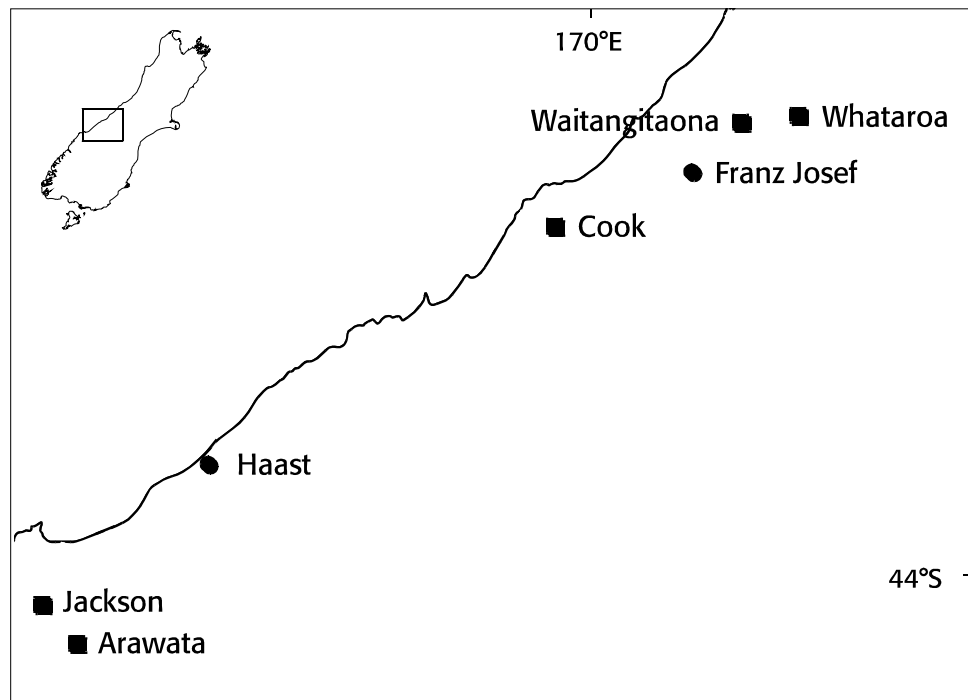
The *Upper Terrace* plot pair (NZMS 260 I35/914646; established in 1989², and fully resurveyed in 1992) were on deep alluvial silt on a terrace 1 m high. Five pairs of enclosure and control transects were in grassland and forest margin, and five pairs were inside forest dominated by *Pennantia corymbosa* and *Plagianthus regius*.

The *Lower Terrace* plot pair (established in 1989, and resurveyed as far as possible in 1992) were west of and adjacent to the Upper Terrace. The plots crossed two terrace levels, the lower being the flood plain. In 1989 this supported grassland on stony ground, and five pairs of transects were laid out on it. The upper level was the same silty terrace that contained the Waitangitaona Upper Terrace plots, and supported the same kind of forest.

Although there is no definite stocking rate, the old permits note an estimated '20 head', presumably breeding stock, on 140 ha of land, which equates to 0.9 SU/ha. The adjacent freehold is also grazed so this may not accurately reflect the number of stock that actually used the area adjacent to the enclosure.

² Years cited refer to late summer, i.e. 1989 in this context means February or March 1989.

Figure 2. Location of plots. Cook includes swamp, young forest, and old forest plots.



Erosion of these plots by floods has led to their ultimate loss. In spring 1990 a massive flood swept away the transects on the lower, stony level, as well as that part of the enclosure fence. In summer 1991 the enclosure plot was re-enclosed by fencing along the edge of the upper terrace, before any detectable damage by stock had occurred. However, the river continued to erode these plots, and by April 1995 only 15 m of the lower terrace enclosure plot, and six forest transects in the upper terrace enclosure (i.e. from 20 m to 50 m) remained intact. By February 1996 when these plots were due for their second full resurvey, the third of a series of major floods had removed the remainder of the plots.

4.5.2 Whataroa Valley

The plots (NZMS 260 I35/999636; established in 1996, but not fenced until 1999 when fully resurveyed) are on stony alluvium/alluvial silt on a high terrace on the true left bank of the Whataroa River near Tommy Creek. Each plot is 25 m wide by 40 m deep. Vegetation grades from swampy pasture to forest dominated by *Pennantia corymbosa*. The grassland portion has a high number of native herbs and the seedling layers contain several palatable species. The stocking rate was approximately 5 SU/ha, grazed all year by both sheep and cattle, but spelled for periods during normal rotation of stock. However, the rate was changed on the most recently issued licence to 6 breeding cows and calves on 35 ha (1.0 SU/ha).

These plots replace those lost in the Waitangitaona Valley.

4.5.3 Cook Swamp

The enclosure and its control (NZMS 260 H35/559433; established in 1989, resurveyed in 1993 and 1997) are on wet alluvial silt. Vegetation grades from dense sedge and grass with an open shrub overstorey on the northern three transects, to dense scrub of small-leaved divaricating shrubs with an open overstorey of trees, including *Dacrycarpus dacrydioides*. The southern ends of the plots have pockets of *Phormium tenax*.

4.5.4 Cook Young Forest

These plots (NZMS 260 H35/564436; established in 1990, resurveyed in 1994 and 1998) are on stony alluvium. The first four pairs of transects are predominantly in grass, which is separated by a small terrace riser from young closed forest that covers the remaining four pairs.

4.5.5 Cook Old Forest

The enclosure and control (near and east of Young Forest; established in 1990, resurveyed in 1994 and 1998) contain only four transects each, all in forest. They are situated a few metres east of Cook Young Forest, beyond a clear vegetation boundary that separates young forest from a much older stand with some large podocarp trees.

The stocking rate on the Cook River flats was equivalent to 2 SU/ha, and the area received most of its grazing over 6 months of the year. The recently issued licence calculates the grazable area as 1660 ha, with the equivalent of 220 breeding cows and calves, and 440 sheep (1.1 SU/ha).

4.5.6 Jackson River

The enclosure and control (NZMS260 E38/587690; established in 1991, resurveyed in 1994 and 1998) lie on a mainly silty river flat, and run from grassland to mature *Nothofagus menziesii* forest that has a dense understorey of shrubs and ferns. 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 plots were given a herringbone layout (Fig. 3). Since the sides of these transects are not perpendicular to the baseline, their depth is slightly less than 5 m. Two transects are in grassland, one is on the forest margin, and five are within *Nothofagus menziesii* forest. The 360 ha grazable area is stocked with 40 breeding cows and calves (0.7 SU/ha).

4.5.7 Jubilee Flat, Arawata River

These plots (NZMS260 E38/657616; established in 1992, resurveyed in 1995 and 1999) cover river-flat grassland that includes a swampy strip, and adjoining *Nothofagus menziesii* forest on a terrace about 1 m higher. Four transects are in grassland, one is on the forest margin, and five are in *Nothofagus menziesii* forest with an open understorey. The valley carries 400 breeding cows.

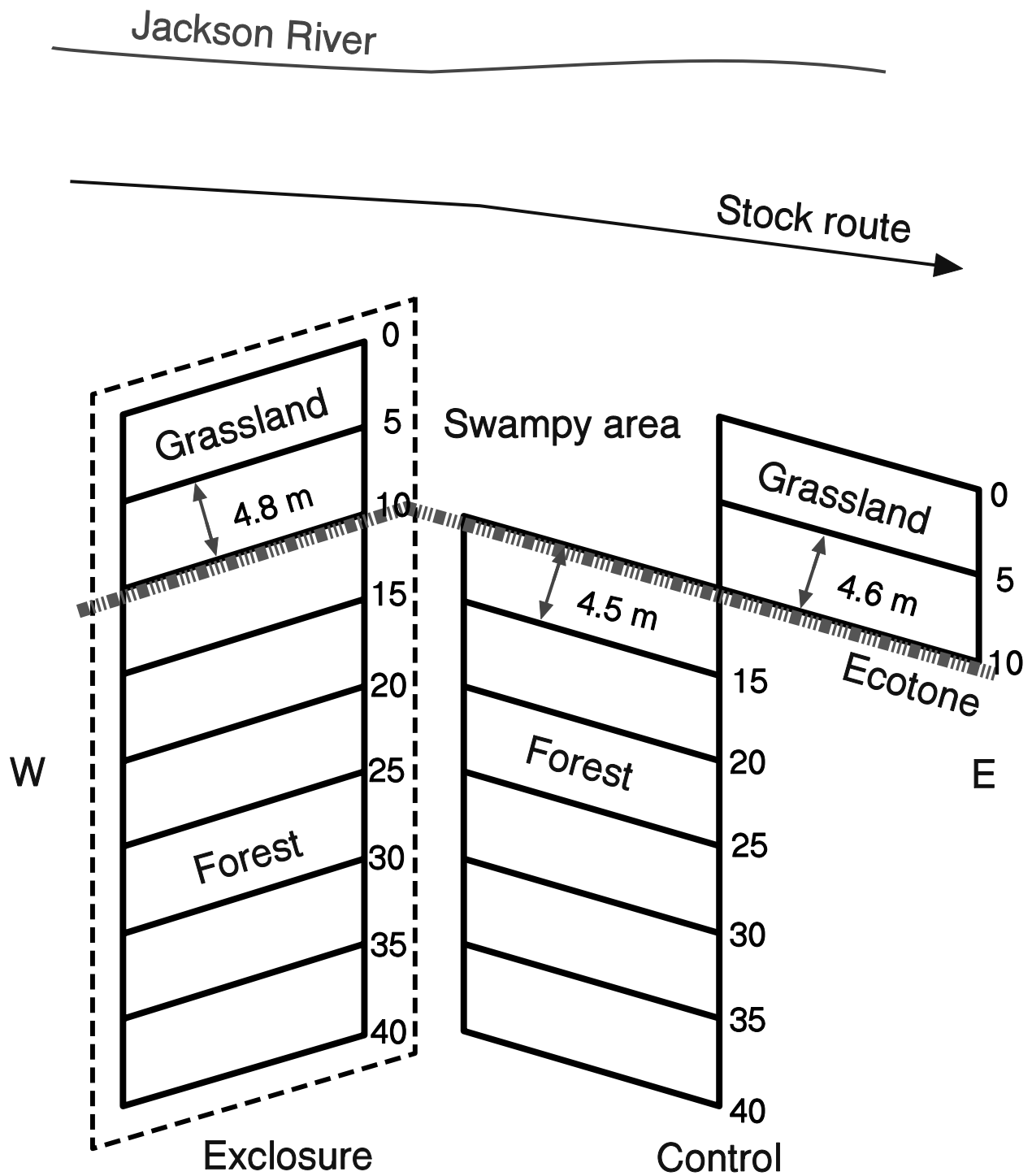


Figure 3. Herringbone plot layout at Jackson River, adopted to enable comparable vegetation to be represented in the two plots without impinging on a stock route to the north. The depth of these transects varies due to minor variations in the side/baseline angle.

5. Results

Monitoring of plots over the past 11 years has shown that while some early trends have continued, others have changed direction, and some species have exhibited cyclic patterns of abundance.

5.1 WAITANGITAONA AND WHATAROA VALLEYS

5.1.1 Waitangitaona

(Established 1989, resurveyed 1992, destroyed by 1996.)

Initial responses to the exclusion of grazing from these plots are recorded in our previous report (Wardle et al. 1994). Subsequent erosion of these plots by flooding has led to their ultimate loss. However, in April 1995 the remaining forested portions of the exclosures continued to show an increase in frequency of ferns, particularly *Polystichum vestitum*, *Dicksonia squarrosa*, *Cyathea smithii*, and *Pneumatopteris pennigera*, and *Coprosma rotundifolia* seedlings. Podocarps, especially *Dacrycarpus dacrydioides*, appeared to show more vigorous top growth.

5.1.2 Whataroa

(Established 1996 and fully resurveyed in 1999.)

Although these plots have now been fully surveyed twice, the fence was not erected until just prior to the second remeasurement. This provides us with good baseline information but, as yet, no measure of cattle impact in this valley.

5.2 COOK VALLEY PLOTS

5.2.1 Cook Swamp

(Established in 1989 and fully resurveyed in 1993 and 1997.)

A cycle of vascular/litter dominance appears to exist, i.e. although vascular ground cover dominated, increases or decreases in vascular cover occurred between measurements that were mostly offset by changes in litter cover. Excluding cattle has increased the amplitude and slowed the rate of this cycle, and also increased the mean height that non-woody vascular species attain. As shrubs become taller and more dominant, the degree of fluctuation appears to decrease.

Many herbs are ephemeral in all transects. *Lotus pedunculatus* is the most frequent herbaceous species overall and, with other exotics, is excluding many small herbs, particularly in the exclosure where plant diversity has decreased. Seedling numbers of woody species fluctuated widely between measurements in both plots, but generally more so in the exclosure. No seedlings of woody plants have yet been found in grassland transects at 0 m (i.e. 0–5 m, Fig. 1), and in 5 m transects the small number of seedlings initially present have disappeared, presumably due to the consistently high cover of vascular herbs.

In the ecotone from grassland to forest there has been considerable recruitment in both plots, especially of coprosmas and *Myrsine divaricata*. Species diversity and composition has altered little in forested portions.

In the control plot, plants 0.3–2.0 m tall have consistently increased in number in the forest beyond 30 m. However, in the grassland and ecotone (i.e. 0–25 m) of the control plot and in the exclosure plot, where numbers increased more dramatically in intermediate years, there has been a decline due, in some cases, to plants entering the > 2.0 m tier.

Species diversity and composition of trees > 2.0 m has altered little in ecotone and forested transects beyond 20 m, but there has been considerable recruitment in the ecotone (15 m and 20 m) transects. Overall, total basal area of individual tree species in the control has fluctuated more compared with the exclosure, where increases have generally been more consistent and the total net gain in basal area has been greater. Only in some grassland and ecotone transects (10 m, 20 m and 25 m) does the net gain in basal area of the control exceed that of the exclosure.

5.2.2 Cook Young Forest

(Established 1990 and fully resurveyed in 1994 and 1998.)

Litter cover increased in the grassland portion of the Cook Young Forest exclosure at the expense of vascular cover. In the ecotone between grassland and forest, bryophytes also increased, as did the height of herbaceous cover. The frequency of herbs changed little overall. An area of *Pteridium esculentum* in the grassland, which initially increased in the exclosure between 1990 and 1994, had collapsed in 1998. Woody seedlings have established in the grassland portion of the exclosure since the last survey in 1994, with much more success than equivalent portions of the control. However, where there was existing shrub cover there has been seedling recruitment in both plots, particularly in the ecotone of the control. Coprosmas, *Dacrycarpus dacrydioides* and, to a lesser extent, *Myrsine divaricata*, have been the most frequently recruited species. The increase in shrub and sapling numbers in the exclosure was far greater and more consistent than in the control. The main species involved were *Myrsine divaricata*, *Pennantia corymbosa*, *Carpodetus serratus*, and coprosmas.

5.2.3 Cook Old Forest

(Established 1990 and fully resurveyed in 1994 and 1998.)

The frequency and height of herbs fluctuated in both Cook Old Forest plots, but increased most consistently in the exclosure, which gained more palatable ferns (especially *Asplenium bulbiferum*), although total herb frequency remained lower than in the control. In both plots, numbers of woody seedlings, mostly *Dacrycarpus dacrydioides* and coprosmas, increased up to 1994 then subsequently decreased. In the exclosure, some palatable shrubs, such as *Hedycarya arborea* and *Melicytus ramiflorus*, have increased relative to the control.

5.3 ARAWATA AND JACKSON RIVER VALLEYS

5.3.1 Jackson River

(Established 1991 and fully resurveyed in 1994 and 1998.)

In the Jackson River enclosure, vascular cover and height has increased in the grassland portion at the expense of bryophytes, while in the forested portions vascular ground cover decreased, and litter increased. Frequency and diversity of herbaceous species have decreased in the enclosure, while remaining relatively stable in the control. Woody seedling numbers in the grassland portion of the enclosure have decreased considerably, and those in the forested portions of both plots have decreased after initial increases. Shrub numbers initially increased considerably in the enclosure ecotone and, despite later decreases, remain higher than 1991 values, whereas overall values for the control ecotone and forest portions of both plots have decreased. There has also been recruitment in the tree tier (> 2.0 m) in the enclosure ecotone.

5.3.2 Arawata River

(Established 1992 and fully resurveyed in 1995 and 1999.)

Between 1992 and 1995 the frequency of herbaceous cover and the extent to which this changed was much greater in grassland than in forested transects. Overall, there was a greater decline in species diversity and frequency in the grassland portion of the enclosure relative to the control. This was associated with increases of *Holcus lanatus*, *Lotus pedunculatus* and *Ranunculus repens*, which tended to overwhelm other grasses, small herbs (especially *Isolepis reticularis*) and *Carex* species. From 1995 to 1999 there was little change in species diversity, but in both plots diversity remained high in grassland transects that are periodically flooded. The frequency of exotic grasses such as *Holcus lanatus* increased in grassland portions of the control. In the enclosure grassland *Hydrocotyle novae-zelandiae* increased and *Ranunculus repens* decreased.

5.4 RESULTS ATTRIBUTABLE TO GRAZING

5.4.1 Shrub density

The most significant response to removal of grazing was exhibited by woody species in the browse-susceptible shrub tier (0.3–2.0 m). Figure 4 shows the shrub density in grassland, ecotone and forest portions of control and enclosure plots at Cook Young Forest. Each group of three bars on the x-axis represents the shrub density at the time of each remeasurement (1990, 1994, 1998). Shrub density increased significantly in the ecotone and grassland portions of the enclosure relative to the control. The decline in the forested portion of the control may have been due to cattle physically reducing the plant height.

When all sites were considered, the most significant increase in shrub density was in the forested portion of the enclosures, with substantial but non-significant increase in the ecotone (Fig. 5).

Figure 4. Shrub density at each remeasurement (1990, 1994, 1998) in each community type for control and exclosure plots at Cook Young Forest.

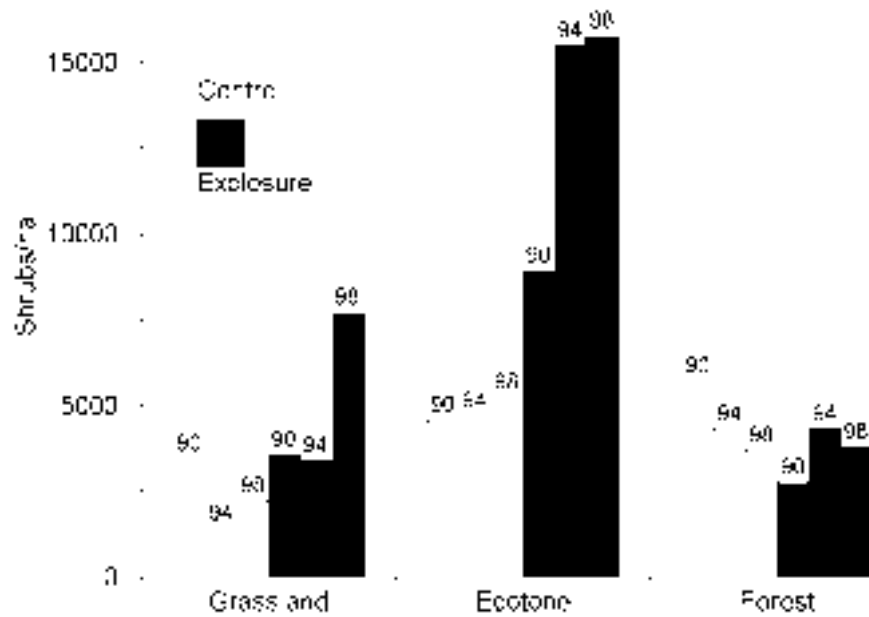
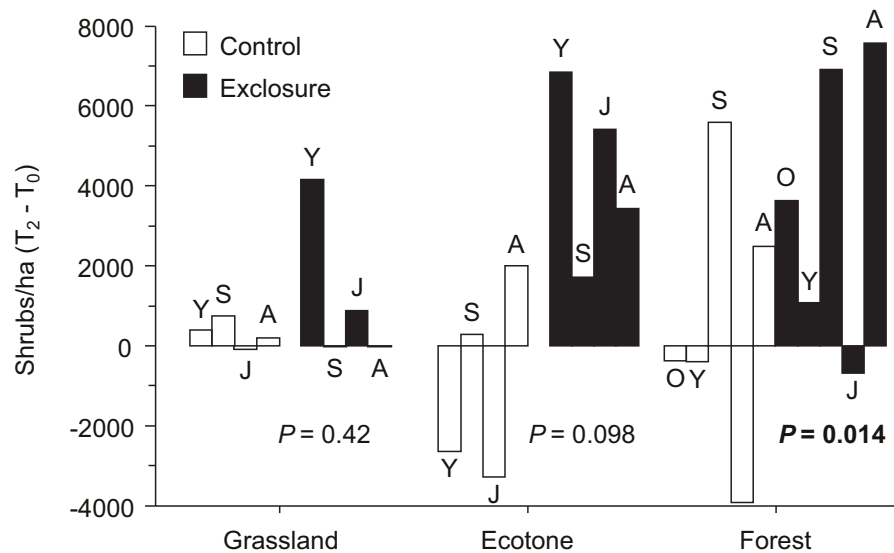


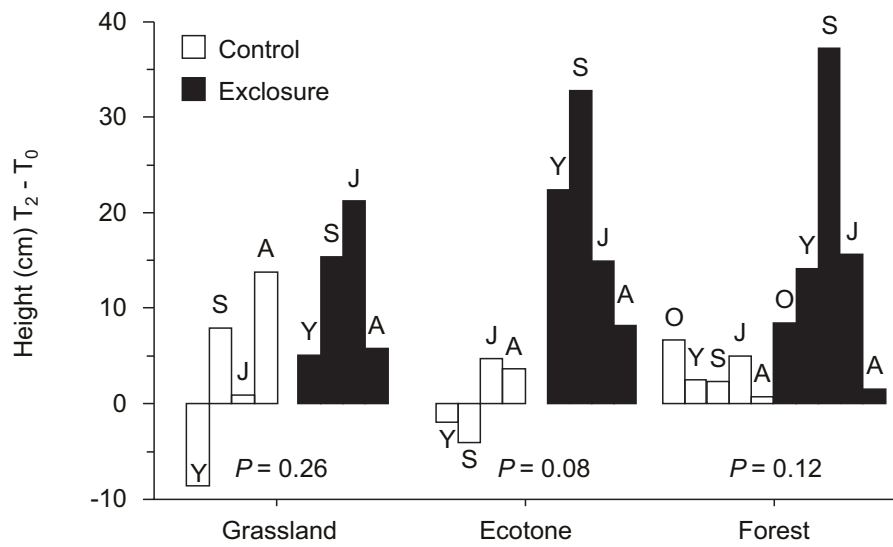
Figure 5. Change in shrub density from the time of exclosure (t_0) to the time of the second remeasurement (t_2) at each site. The bars represent sites: O = Cook Old Forest (only forest); Y = Cook Young Forest; S = Cook Swamp; J = Jackson; and A = Arawata, and are in the same order for each community type. *P* values in bold indicate that differences between the control and exclosure are significant.



5.4.2 Height of the tallest herb

The height of the tallest herb (Fig. 6) increased in all exclosure plots, and notably so in the ecotone and forest portions relative to the controls. This, in combination with increased shrub density in exclosures, has reduced the amount of light reaching the seedling layer, and in transects where both measures have increased, the establishment of woody seedlings has been suppressed. Although seedling numbers were generally inversely proportional to herb height and shrub density, there was no overall relationship with grazing, i.e. seedling numbers in the exclosures have not changed significantly relative to controls.

Figure 6. Change in height of the tallest herb from the time of exclosure (t_0) to the time of the second remeasurement (t_2) at each site. The bars represent sites: O = Cook Old Forest (only forest); Y = Cook Young Forest; S = Cook Swamp; J = Jackson; and A = Arawata, and are in the same order for each community type. *P* values indicate differences between the control and exclosure in each community type.



5.4.3 Herb species richness

The number of *native* herbaceous species per plot (Fig. 7) decreased significantly in the grassland portion of the exclosures relative to the controls. This was due to the dominance of a few rank exotic herbs and grasses, but involved different species at each site. An initial decrease in species richness of native herbs is a common effect of removal of grazing in grassland systems.

Species richness of *exotic* herbs (Fig. 8) decreased significantly in all exclosure plots, especially in grassland and ecotone portions where there were more exotic species initially. Forested portions initially had very few, if any, exotic herbs. These results are supported by other studies that have found very few weeds in undisturbed forest, and the abundance of weeds in shrubland to increase with disturbance and proximity to source.

Figure 7. Change in species richness of native herbs from the time of exclosure (t_0) to the time of the second remeasurement (t_2) at each site. The bars represent sites: O = Cook Old Forest (only forest); Y = Cook Young Forest; S = Cook Swamp; J = Jackson; and A = Arawata, and are in the same order for each community type. *P* values in bold indicate that differences between the control and exclosure are significant.

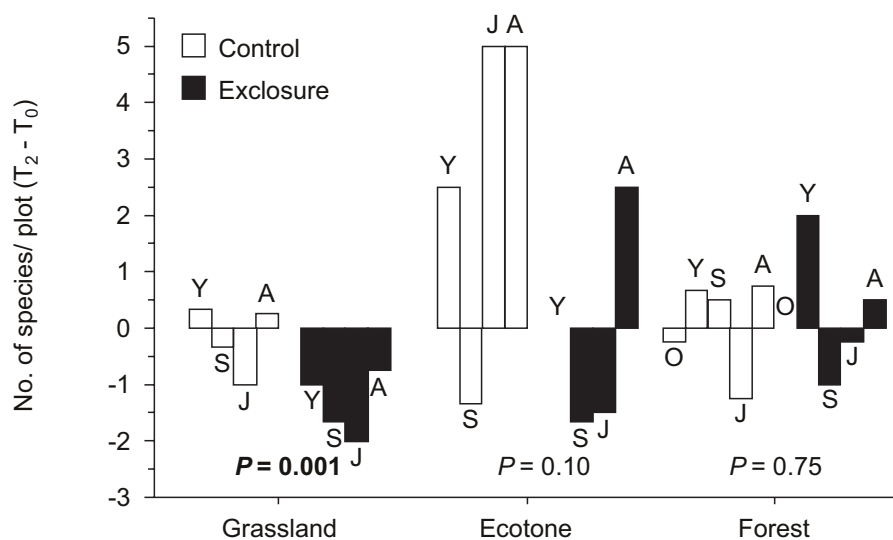
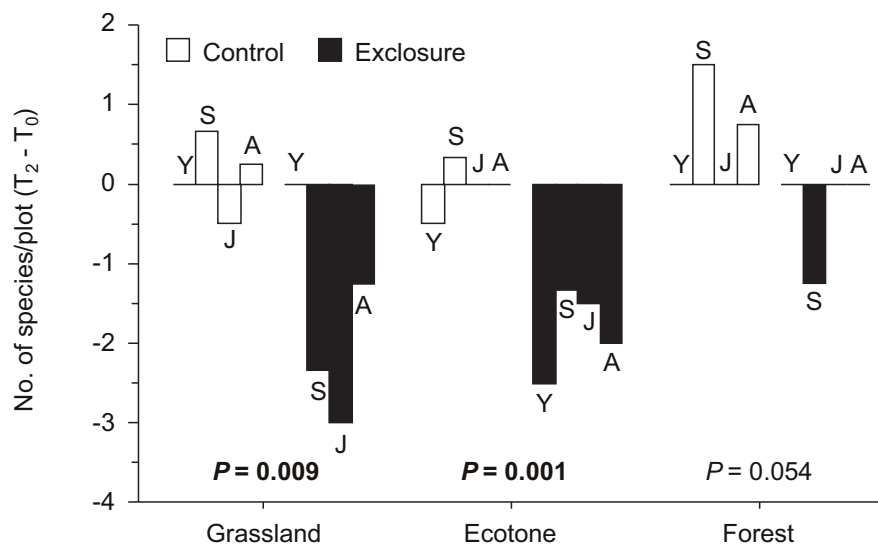


Figure 8. Change in species richness of exotic herbs from the time of enclosure (t_0) to the time of the second remeasurement (t_2) at each site. The bars represent sites: O = Cook Old Forest (only forest); Y = Cook Young Forest; S = Cook Swamp; J = Jackson; and A = Arawata, and are in the same order for each community type. *P* values in bold indicate that differences between the control and enclosure are significant.



5.4.4 Indicator species

Some species emerged as being particularly sensitive to grazing pressure. This was revealed by relatively rapid positive or negative responses to enclosure, and changes in these species could be useful indicators for future monitoring. In the tables below the species are listed separately for beech and non-beech sites.

Table 2 lists those exotic herbs that were found to increase in abundance more commonly with grazing than without, and did so at more than one site. *Prunella vulgaris* became more abundant in the two beech-dominated controls, but not at the non-beech sites, whereas *Anthoxanthum odoratum* appears to be a good indicator of grazing pressure at all sites.

The shrub species listed in Table 3 most commonly became more abundant in enclosures, and are therefore indicators of *reduced* grazing pressure. *Myrsine divaricata* increased in enclosures at one of the beech sites, and all three non-beech sites, whereas *Weinmannia racemosa* abundance is a useful indicator of reduced grazing only at beech-dominated sites.

TABLE 2. EXOTIC HERB SPECIES INDICATING GRAZING PRESSURE.

SPECIES MOST COMMONLY MORE ABUNDANT IN CONTROLS	SITE FREQUENCY (%)	
	NON-BEECH SITES (N = 3)	BEECH SITES (N = 2)
<i>Anthoxanthum odoratum</i>	66	100
<i>Agrostis capillaris</i>	66	50
<i>Holcus lanatus</i>	66	50
<i>Lotus pedunculatus</i>	66	0
<i>Prunella vulgaris</i>	33	100

The site frequency values refer to the percentage of sites in which species abundance, in the time between enclosure and second remeasurement, has increased more in the control than in the enclosure. Non-beech sites are Cook Swamp, Cook Young Forest, and Cook Old Forest, and beech sites are Jackson and Arawata.

TABLE 3. SHRUB SPECIES INDICATING REDUCED GRAZING PRESSURE.

SPECIES MOST COMMONLY MORE ABUNDANT IN ENCLOSURES	SITE FREQUENCY (%)	
	NON-BEECH SITES (N = 3)	BEECH SITES (N = 2)
<i>Myrsine divaricata</i>	100	50
<i>Carpodetus serratus</i>	67	50
<i>Hedycarya arborea</i>	67	0
<i>Pennantia corymbosa</i>	67	0
<i>Meliccytus ramiflorus</i>	67	0
<i>Schefflera digitata</i>	67	0
<i>Coprosma lucida</i>	67	0
<i>Pseudopanax crassifolius</i>	67	0
<i>Coprosma rotundifolia</i>	33	100
<i>Coprosma</i> sp. 't'	33	100
<i>Griselinia littoralis</i>	33	100
<i>Coprosma propinqua</i>	33	100
<i>Weinmannia racemosa</i>	0	100
<i>Nothofagus menziesii</i>	0	100
<i>Cyathea smithii</i>	0	100

The site frequency values refer to the percentage of sites in which species abundance, in the time between enclosure and second remeasurement, has increased more in the enclosure than in the control. Non-beech sites are Cook Swamp, Cook Young Forest, and Cook Old Forest, and beech sites are Jackson and Arawata.

5.4.5 Change in canopy species

The enclosures show no definitive results in the tree layer (> 2.0 m). This at least suggests stability, which validates our other comparisons, but it means that more time is required to measure a response in the canopy to removal of grazing. However, some indications can be gained from potential canopy species (*Nothofagus menziesii* and podocarps) emerging in the shrub layer.

Table 4 shows the change in abundance of emergent and canopy-forming species in the shrub tier at each site. In beech sites, *Nothofagus menziesii* and, to a lesser extent, *Dacrycarpus dacrydioides* recruitment has been better in enclosures than controls. There has been no *Nothofagus menziesii* increase in grazed plots, whereas in non-beech sites *Podocarpus totara* var. *waitoensis* and *Dacrycarpus dacrydioides* recruitment appears to be higher in grazed plots, although significant numbers of plants were also established in enclosures.

At non-beech sites, cattle may be removing the more palatable herbaceous and woody species (Table 3), reducing the competition for the less palatable canopy-formers and, to some extent, facilitating their recruitment. In beech-dominated sites, grazing may be limiting replacement of canopy trees, especially *Nothofagus menziesii*. However, there is still some recruitment of canopy species occurring in beech control sites, especially *Dacrycarpus dacrydioides*. So grazing may not lead to the demise of the canopy in beech sites, but could alter its composition. (Detailed demographics of *Nothofagus menziesii* and *Dacrycarpus dacrydioides* are presented in Figures A3.8 and A3.9, Appendix 3). Due to the complex interaction of factors affecting plant competition and variability between sites, it is still too early to judge the importance of grazing in determining future canopy composition compared with these other factors.

TABLE 4. CHANGE IN ABUNDANCE OF SAPLINGS (0.3–2.0 m) OF EMERGENT AND CANOPY-FORMING SPECIES OVER 8 YEARS IN EXCLOSURES (EXCL.) AND CONTROLS (CONT.) AT EACH SITE.

SPECIES	NON-BEECH SITES						BEECH SITES			
	OLD FOREST		YOUNG FOREST		SWAMP		JACKSON		ARAWATA	
	CONT.	EXCL.	CONT.	EXCL.	CONT.	EXCL.	CONT.	EXCL.	CONT.	EXCL.
<i>Dacrydium cupressinum</i>	1	1					1	2	0	1
<i>Dacrycarpus dacrydioides</i>	33	6	-10	-13	2	5			20	43
<i>Nothofagus menziesii</i>							0	19	0	71
<i>Podocarpus totara</i> var. <i>waihoensis</i>	-5	0	-1	-5	32	14				
<i>Prumnopitys ferruginea</i>	-2	1								
<i>Prumnopitys taxifolia</i>			2	4	1	2				

6. Discussion and Conclusions

The debate over the impact of cattle in New Zealand's native forests is not new (Harrison-Smith 1944), and although some effects of cattle grazing and its removal are well documented, 'knowledge of the responses of whole communities to different grazing regimes is still in its infancy' (Hearn 1995). Our results show that vegetation responses to the exclusion of grazing vary greatly in rapidity and direction with vegetation type, particularly between beech and non-beech sites, and forest and grassland sites. Other enclosure studies from Stewart Island (Stewart & Burrows 1988) and Fiordland (Burrows et al. 1999) have found plant responses to the removal of browsing pressure can be immense in places (e.g. 'partial-coastal-dieback forest') and non-existent in others (e.g. high-altitude mountain beech); that is, it is highly site dependent.

Cattle remove biomass, affect regeneration, and may damage whole plant populations. This has direct and indirect effects: a direct effect on the persistence of some species and on vegetation structure; and indirectly through excrement, which locally increases the nutrient supply rate, and modification of nutrient composition in understorey foliage. This, in turn, affects plant competition and succession, as an increase in nutrients promotes taller plants which, without further grazing, reduces the light available to the herb layer.

Grazing can operate in two ways:

1. To suppress dominants and natural succession, and increase species richness (as in grassland transects) of sward-forming natives and exotics.
2. To remove palatable species, enhancing dominance of non-palatable species, reducing species richness, and promoting succession by reducing competition (forest transects; Timmins, unpubl. data).

Grazing also has an impact on other biotic groups. For instance, several workers have found that invertebrate diversity is greater in ungrazed woodland, most likely due to greater diversity of food and habitat resources, than in more disturbed vegetation (Bromham et al. 1999).

6.1 NATURAL PROCESSES

All sites in this study are in areas prone to high natural disturbance, as exemplified by the Waitangitona floods. At some sites less extreme natural forest processes appear to obscure the impact of extensive cattle grazing on vegetation change. The *successional stage* of a stand affects light levels which, in turn, influence which species will respond.

6.1.1 Competition for light

McDonald & Norton (1992) emphasise that spatial and temporal heterogeneity in light is both a product of, and a contributing factor in, spatial species diversity in forest ecosystems. Canopy structure influences the spatial distribution of light environments within a forest, and floristic composition is also affected by the size and frequency of canopy disturbances. For instance, understorey species such as tree ferns respond quickly to the removal of grazing by growing new fronds and thereby reduce light levels and competition from other plants beneath their crowns.

6.1.2 Soil properties

In some sites, e.g. Cook Swamp, the ecotone is advancing into grassland, but elsewhere this advancement appears to be either slow or totally impeded. Old river channels are obvious natural boundaries, but often these ecotones are associated with changes in soil texture or fertility, which are not apparent above ground, yet these factors greatly influence the direction of plant successions and spread.

The rate of change of some soil properties following cessation of grazing can be very slow. After 45 years of enclosure from sheep, Basher & Lynn (1996) found vegetation recovery in the Canterbury high country was not consistently reflected in soil differences. Recent studies by Wardle et al. (in press) comparing ecosystem functioning inside and outside deer enclosures have shown that significant differences in plant biomass and composition above ground are not consistently reflected in biotic groups below ground and vice versa.

6.2 PLANT ATTRIBUTES AFFECTING GRAZING SUSCEPTIBILITY

Hearn (1995) identifies several attributes of plant species that influence the degree of damage that they will sustain from grazing:

- Growth form—the position and degree of protection of the growing points.
- Palatability—may alter with season/age.
- Growth phase of the plant in relation to timing of grazing.
- Regenerative strategy—grazing increases tillering in some grasses (*Lolium perenne* and *Agrostis stolonifera*), but can damage/kill others (*Alopecurus pratensis* and *Anthoxanthum odoratum*).
- Competitive ability—competitive species such as *Holcus lanatus*, and *Dactylis glomerata* can dominate semi-natural vegetation on fertile soils but

are suppressed or eliminated by heavy grazing. Stress-tolerant plants (small, prostrate, unpalatable) have a competitive advantage in grazed situations. Many rare or local species depend on grazed habitats, but can only tolerate light grazing, and are often characteristic of scrub margins where they gain some protection.

The complex array of variables that these attributes express demonstrates that making generalised statements about the susceptibility of plants to cattle grazing is difficult. As few plant species show consistent, directional responses to grazing or cessation of grazing, care must be taken when extrapolating results to other sites.

6.3 CATTLE STOCKING RATES AND MANAGEMENT IMPLICATIONS

For sites where stocking rates are available (see Section 4.5), these vary from 0.7 to 1.1 SU/ha. Total cattle numbers range from 20 to 400, and the valleys differ in their extent of river flats. Anecdotal evidence suggests cattle are very territorial, and their impacts can be quite localised. At lower stocking densities cattle spend most of their time in the grassland, probably entering the forest mainly for shelter, while at high 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. In nutrient-poor systems species richness is reduced under high grazing intensity (Proulx & Mazumder 1998).

Cattle impacts on vegetation structure and composition are complex. Depending upon the plant species or communities that one wishes to maintain or protect, it may be more appropriate to manage the season and/or duration of grazing than limit cattle numbers or cease grazing completely. To manage grazing on a finer scale requires input and cooperation from farmers, which may be necessary to attain specific conservation goals. Ideally, grazing management should include one or more of the following:

- design for a particular site, community or species,
- appropriate stocking rate (usually low),
- seasonal control,
- flexibility for adjustment (to compensate for weather/growing season, fire etc.).

Cattle impacts are not always negative for all elements of the biota (Timmins, unpubl. data), and in Europe emphasis is now placed on cattle management rather than cessation of pastoralism (van Wieren 1995). In South Westland, on moist, fertile soils, natural turf communities containing *Leptinella squalida* and *Hydrocotyle novae-zeelandiae* are maintained by close grazing on recently disturbed ground where succession to taller vegetation is prevented (Wardle 1991). Results from the South Westland exclosures, particularly the increased abundance in the shrub tier, show that these plant communities have retained some regenerative capacity even after 130 years of grazing.

6.4 COMPARISONS WITH OTHER BROWSERS

Caughley (1989) points out that New Zealand is often, mistakenly, thought of as a land without native herbivores, and that what we now see inside an enclosure is considered 'normal'. However, the impact that moas had on our vegetation is unknown (Wardle 1989), but it was probably very different from that of introduced mammalian grazers such as cattle. Of the other mammalian herbivores present in the study areas, deer and brushtail possums have the greatest potential to impact on conservation values in South Westland forests.

6.4.1 Deer impacts

In areas where *Nothofagus menziesii* dominates, it has been found to be the most frequent food in the stomachs of red deer and wapiti next to *Griselinia littoralis* (Wardle 1967). Browsing by deer often results in the death of *Nothofagus menziesii* seedlings within forest, but more vigorous plants in the open are more likely to withstand browsing. Our results show the combined impact of cattle and other mammalian herbivores (deer, possums) is limiting *Nothofagus menziesii* regeneration in the browse-susceptible tier (0.3–2.0 m), and excluding cattle can alleviate this. However, we do not know the degree to which the enclosures deter deer or the impact of deer alone at these sites. Other enclosure studies (Allen et al. 1984) suggest that, in forest, deer impacts are consistent with those of cattle.

6.4.2 Browse patterns

Other browsers may have compensatory or additive effects to that of cattle. Deer and possums are selective browsers, whereas Hearn (1995) suggests cattle graze unselectively, taking dead and tall shrubby vegetation, and species, which might otherwise dominate. However, large-hooved animals also create bare ground, which can aid seedling establishment. To assess the relative importance of all browsers on plant recruitment would require a system of nested enclosures to progressively exclude each species.

This study separates cattle and sheep effects from those of all other browsers, but does not attempt to estimate effects due to others such as deer and possums. These additive effects will vary from site to site and may explain some of the variations in results. This suggests that wild animal control on adjacent land should also be included when grazing management options are being considered.

6.5 MONITORING OPTIONS

Plant species that indicate reduced stock grazing at any site vary according to the vegetation type and the distributional range of the individual species. The structure and composition of the vegetation, and the presence of other browsers, also influences the competitive ability of any particular species, and therefore the degree to which that species is able to respond to changes in grazing pressure.

Despite this, the results show that some species may be good indicators for a particular vegetation type and, to some extent, across types. Many of the shrub species in Table 3 were also identified as good indicators of grazing by Timmins (unpubl. data). However, these species also tend to be palatable to deer. The scarcity or absence of a species at any site cannot, therefore, be automatically attributed to stock grazing alone.

Subtle differences in plant species abundance may be difficult to detect without direct comparisons with ungrazed sites, or over time. Species from different geographical areas and different vegetation types may respond differently to grazing management (Stohlgren et al. 1999), and only experimental assessments can provide comprehensive information to managers (Bullock & Pakeman 1997). Although indicator species can be useful in evaluating grazing impact, they are merely indicators, and interpretations based solely on these should be treated with caution.

Without a long-term approach many of the initial responses to the exclusion of cattle could easily have been misinterpreted, and inappropriate management 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.

Is there a standard monitoring technique to assess stock impacts?

Exclosures are expensive and impractical to establish at every site. However, maintaining exclosures and controls in a range of vegetation types and stocking rates provides bench marks for comparisons over time, and with sites of 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 at each site. 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. If, however, the objective was to maintain plant diversity in the forest understorey, then it would be necessary to monitor the presence/absence of all 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, though, that without direct comparisons with ungrazed sites, and with limited replication, it may be difficult to separate impacts attributable to cattle from those of other factors.

How much effort should DOC put into monitoring grazing impacts?

If grazing licences are granted on the basis that conservation values are maintained, then some form of monitoring, as outlined above, is necessary. Results have confirmed that the impact of grazing on vegetation structure and composition is not simplistic, or isolated from other biotic or environmental factors. While it is impractical to measure all variables at every site, the possibility that some impacts of grazing could be overlooked increases as the range of measurements and degree of replication decreases. However, there is a need to balance the conservation benefits of monitoring with the effort involved.

6.6 CONCLUSIONS

- Even after 10 years of monitoring at several sites we can make few conclusive statements about the impact of extensive cattle grazing in South Westland. There are no consistent effects on ecological processes; however, there are consistent effects on biodiversity, with palatable species typically increasing inside exclosures.
- In grassland, the removal of cattle grazing results in the initial dominance of a few, mostly exotic, herbaceous species. This reduces the frequency and diversity of both native and exotic grazing-tolerant or low-growing herbs, but can promote the expansion of the forest margin.
- Continued grazing in grassland maintains native and exotic herbaceous species richness, but slows the recruitment of woody species.
- In forest, the removal of cattle grazing facilitates increased density of palatable woody species, and the height and diversity of herbaceous species. This favours recruitment of canopy-forming species in silver beech forest, but in podocarp-hardwood forest some canopy formers may be disadvantaged through increased competition for light.
- Continued grazing in forest suppresses palatable species. This limits species richness and canopy recruitment in silver beech forest, but can enhance recruitment of less palatable canopy formers in podocarp-hardwood forest.
- Forest species retain their regenerative capacity after 130 years of grazing where a propagule source exists in close proximity.
- Our research demonstrates some potential future states; grazing decisions need to be based on the conservation values of those states.
- Cattle are only one of the introduced herbivores likely to be determining the rate and direction of ecological processes at the forest-grassland boundary.

7. Recommendations

7.1 PROJECT MONITORING SCHEDULE AND METHODOLOGY

- We believe that the monitoring project is continuing to yield results of management and theoretical value. Our original estimate that ten years would be required to provide definitive results seems well founded, and our suggestion that useful data should emerge over a much longer period also appears valid. The exclosures are and will continue to provide permanent demonstration value. For these reasons we recommend that the project should continue as a co-operative study involving Landcare Research, DOC Science & Research and West Coast Conservancy.
- Partial resurveys have been conducted during intervening years to determine the rate of change and, consequently, the suitable interval between full resurveys. The rate of change so far indicates that a 5-year interval will be

adequate to capture important changes in the vegetation between full resurveys. Having achieved their purpose, it is recommended that partial resurveys be discontinued, but annual checking of all plots with a view to maintaining fences should continue.

- Based on the rate of change so far, and to increase cost efficiency, we recommend that future monitoring be more synchronised, and on a 5-yearly basis, at least until the Whataroa plots have had two full resurveys. We propose to resurvey all three Cook Valley plots in 2001/02, and resurvey the Jackson, Arawata and Whataroa plots in 2003/04. Initially, this would have been very difficult, but with refined methodology and familiarity it is not such an onerous prospect to resurvey three sites in one year. It may be possible to increase the monitoring interval once the Whataroa plots have had two full remeasurements, and we recommend that it be reviewed at that time.
- Earlier we recommended that the resurvey effort be spread as evenly as possible to enable forward planning for commitment of people and funds. However, as travel time to and from Westland forms a considerable part of the cost each year, synchronising remeasurements on a 5-yearly basis will reduce costs of any future monitoring, as remeasurements would be limited to two years in five. The responsibility of checking fences will, however, rest more heavily on West Coast Conservancy.
- For future resurveys or any additional plots that are established, it would be useful to tag individual trees greater than 2 m tall (or 0.03 m dbh). This would reduce time spent on identification, and prevent trees from 'wandering' between transects from year to year. Tagging also allows mortality/new recruits to the tree layer to be readily identified, and provides a reference point at which to measure dbh, thus reducing error. The fact that changes in the tree layer are only beginning to occur, and the long-term monitoring value of these plots, means that tree tagging would be a useful addition.

7.2 GRAZING MANAGEMENT

This project highlights three main management principles:

- Each ecological situation should be judged and managed on its individual merits.
- Grazing decisions should be based on conservation objectives specific to each site, and integrated with wild animal control operations on adjacent land.
- Management strategies need to be flexible and modified as more information from long-term monitoring comes to hand.

8. Acknowledgements

This report originated from work carried out under Department of Conservation investigation 453.

Many people have helped in the field and expedited what would have been time-consuming and tedious work. They include staff of the Department of Conservation on the West Coast (John Reid, Steven O’Dea, Glen Macdonald, Martin Abel, Calvin Jose, Fred Overmaars, Phil Knightbridge, Paul van Klink, and Megan Heatt); Carol West (DOC) who stood in for Susan Timmins in 1993; temporary employees of DOC who were seconded to the project (Debbie Zanders, Steve Moss); Bill Lee and Bryony Macmillan of Landcare Research; Ros Lister, a student from Otago University 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); 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, Wolfgang G.E., Keir Daborn, Mark Muller, Grit Walther, Angelika Triebke). Trevor Partridge and David Coomes (Landcare Research) gave advice on statistical methods, and Ian Payton 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.

9. References

- Allen, R.B.; Payton, I.J.; Knowlton, J.E. 1984: Effects of ungulates on structure and species composition in the Urewera forests as shown by exclosures. *New Zealand Journal of Ecology* 7: 119-130.
- Basher, L.R.; Lynn, I.H. 1996: Soil changes associated with cessation of sheep grazing in the Canterbury high country, New Zealand. *New Zealand Journal of Ecology* 20: 179-189.
- Bromham, L.; Cardillo, M.; Bennett, A.F.; Elgar, M.A. 1999: Effects of stock grazing on the ground invertebrate fauna of woodland remnants. *Australian Journal of Ecology* 24: 199-207.
- 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.
- Burrows, L.; Coomes, D.; Newell, C.; Allan, C. 1999: Forest vegetation changes in the Murchison Mountains, Fiordland National Park, with special emphasis on takahe management. Landcare Research Contract Report LC9899/112 (unpublished), 30 p.
- Caughley, G. 1989: New Zealand plant-herbivore systems: past and present. *New Zealand Journal of Ecology* 12 (supplement): 3-10.
- Harrison-Smith, J.L. 1944: Cattle in the indigenous forest. *New Zealand Journal of Forestry* 5: 69-70.

- 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).
- McDonald, D.; Norton, D.A.; 1992: Light environments in temperate New Zealand podocarp rainforests. *New Zealand Journal of Ecology* 16: 15-22.
- 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.
- 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. Unpubl. M.Appl.Sci. thesis, Lincoln University, Canterbury, New Zealand.
- Stewart, G.H.; Burrows, L.E. 1988: Assessment of animal effects on forest regeneration in Stewart Island. Forest Research Institute Contract Report FGE 4.2.1 (unpublished).
- Stohlgren, T.J.; Schell, L.D.; Vanden Heuvel, B. 1999: How grazing and soil quality affect native and exotic plant diversity in Rocky Mountain grasslands. *Ecological Applications* 9: 45-64.
- van Wieren, S.E. 1995. The potential role of large herbivores in nature conservation and extensive land use in Europe. Pp. 11-23 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).
- Wardle, D.A.; Barker, G.M.; Yeates, G.W.; Bonner, K.I.; Ghani, A. (in press): Impacts of introduced browsing mammals in New Zealand Forests on decomposer communities, soil biodiversity and ecosystem properties. *Ecological Monographs*.
- 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. 1989: Grazing and management of natural areas; re-introducing an indigenous factor? Pp. 86-88 in Horton, D.A. (Ed.): Management of New Zealand's Natural Estate. Occasional Publication 1, New Zealand Ecological Society, Christchurch.
- Wardle, P. 1991: Vegetation of New Zealand. Cambridge University Press, Cambridge, U.K.
- 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.
- Wardle, P.; Lee, W.G.; Norton, D.A. 1988: Monitoring the impact of grazing animals on Department of Conservation grazing leases in South Westland. Unpublished Botany Division DSIR report held at Landcare Research, Lincoln.
- Wilson, J.B.; Agnew, A.D.Q. 1992: Positive-feedback switches in plant communities. *Advances in Ecological Research* 23: 263-336.

Continue to next file: Sfc179a.pdf