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

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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

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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.

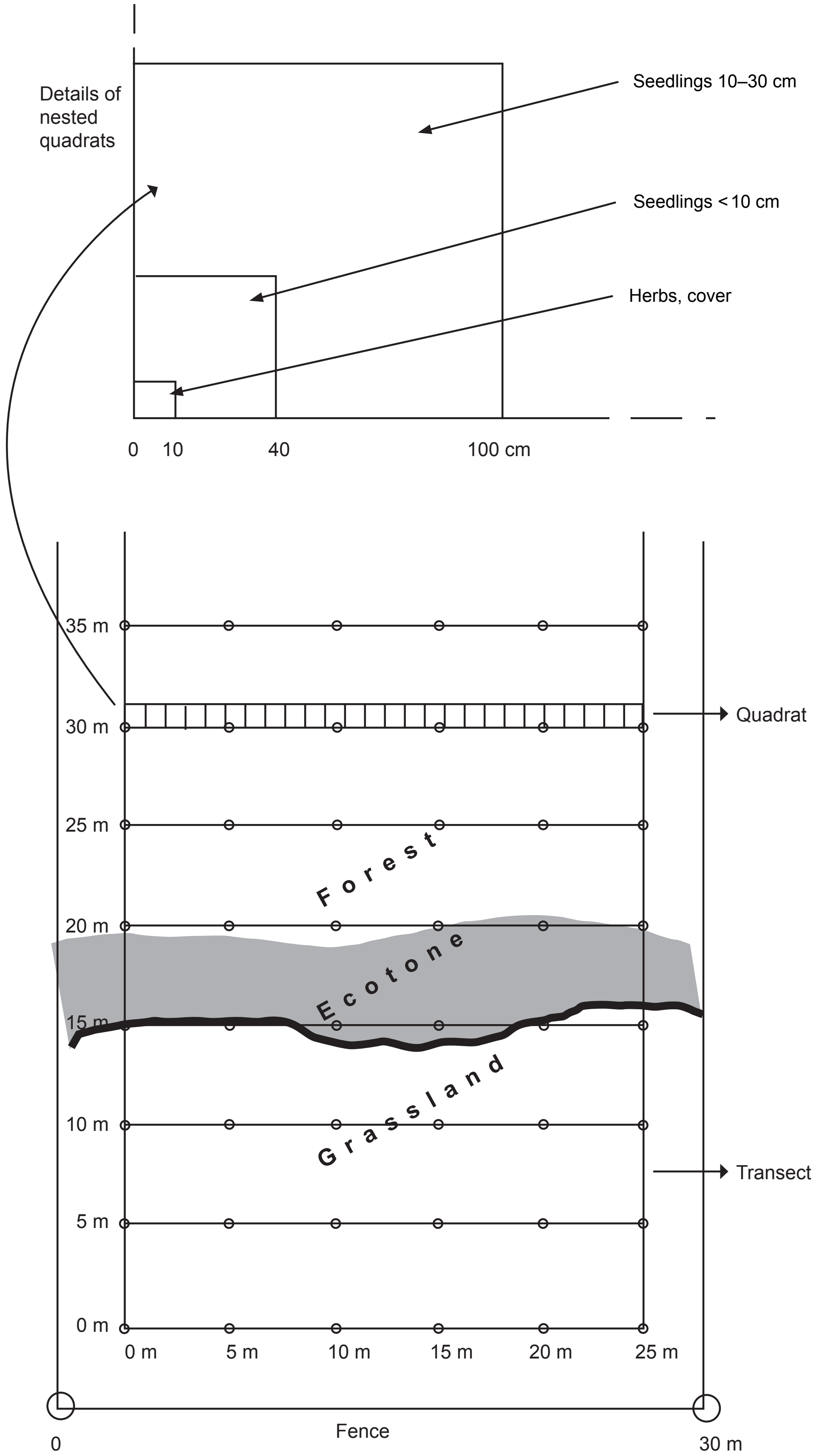
We also considered it important to capture as many variations of the theme 'forest boundaries on extensively grazed alluvial flats' as possible. One important set of variations comprised substrate type and drainage, which graded from coarse gravel to deep silt, and from well drained to swampy. The composition 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.

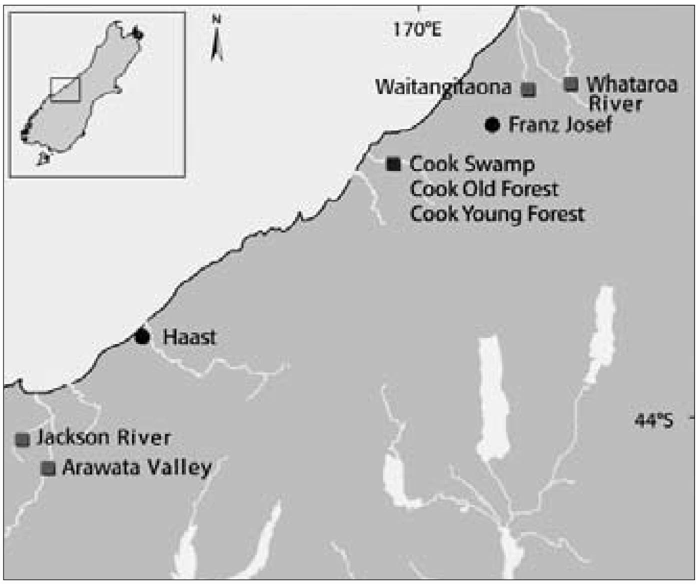


Figure 2. Location of paired exclosure and control plots (squares) and nearby settlements (circles) established to monitor the impacts of stock grazing in South Westland.

The 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).

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*

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