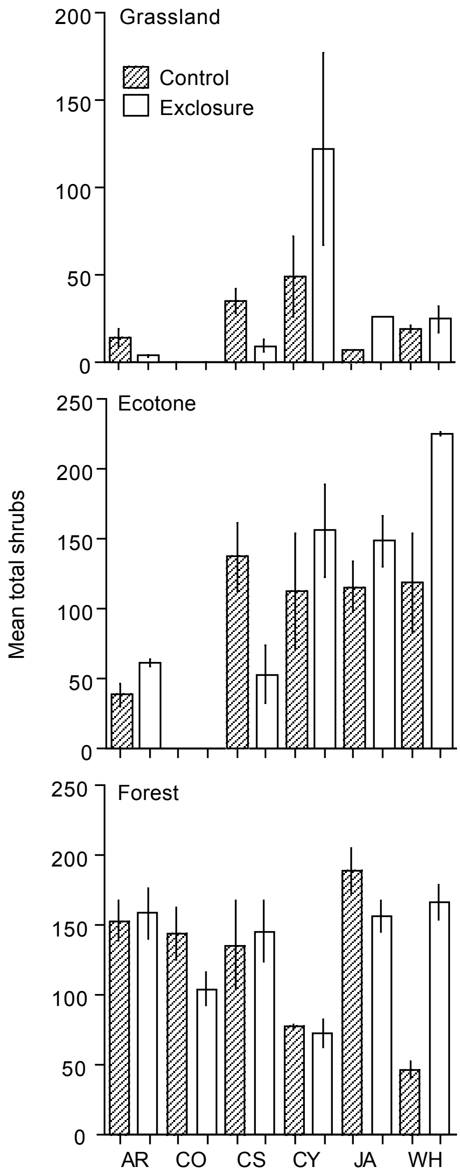

Figure 16. Mean total shrub numbers (± 1 SEM) in grassland (top panel), ecotone (middle panel) and forest (bottom panel) habitats at each of six study sites (AR = Arawhata, CO = Cook Old Forest, CS = Cook Swamp, CY = Cook Young Forest, JA = Jackson, and WH = Whataroa). Control (hatched bars) and exclosure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

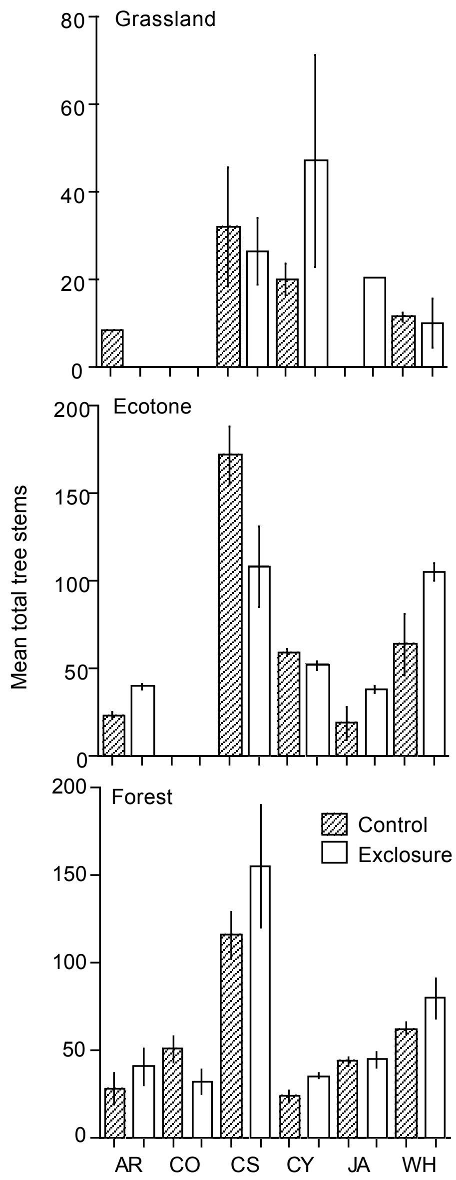

Figure 17. Mean total tree stems (± 1 SEM) in grassland (top panel), ecotone (middle panel) and forest (bottom panel) habitats at each of six study sites (AR = Arawhata, CO = Cook Old Forest, CS = Cook Swamp, CY = Cook Young Forest, JA = Jackson, and WH = Whataroa). Control (hatched bars) and exclosure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

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

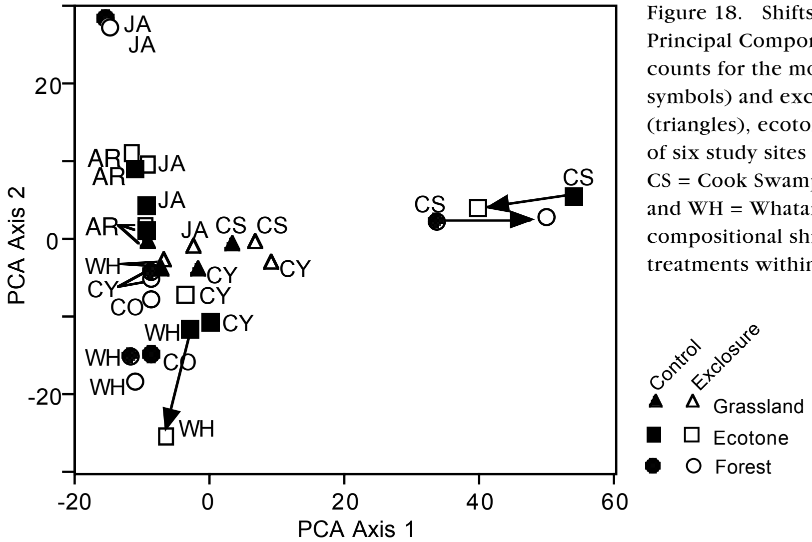

Figure 18. Shifts in tree species composition. Data shown are Principal Components Analysis (PCA) centroid scores using stem counts for the most recent remeasurement of control (filled symbols) and exclosure plots (open symbols) located in grassland (triangles), ecotone (squares) and forest (circles)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

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

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

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

5.1 STOCK RATES AND MANAGEMENT IMPLICATIONS

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

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

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

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

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

5.2 IMPACTS OF CATTLE VERSUS OTHER BROWSERS

5.2.1 Cattle v. deer impacts

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

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

5.2.2 Browse patterns

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

5.2.3 Related studies

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

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

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

5.2.4 Why herbivore impacts may not be reversible

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

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

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

5.3 CONTINUATION OF THE SOUTH WESTLAND GRAZING TRIAL

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

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

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

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

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

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

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

5.3.1 Maintenance of exclosures

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

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

5.3.2 Monitoring and evaluating grazing effects

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

Is there a standard monitoring technique to assess stock impacts?

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

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

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

How much effort should DOC put into monitoring grazing impacts?

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

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

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

Monitoring frequency

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

6. Conclusions

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

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

7. Recommendations

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

7.1 GRAZING MANAGEMENT AND BIODIVERSITY

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

7.2 PROJECT MONITORING SCHEDULE AND METHODOLOGY

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

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Appendix 1

GLOSSARY OF SCIENTIFIC AND COMMON NAMES OF PLANTS

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

Appendix 2

SUMMARY OF PCA AXES FOR SHRUB COMPOSITIONAL DATA

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

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

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

Appendix 3

MEAN TOTAL SHRUB NUMBERS BY PALATABILITY

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

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

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

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

Appendix 4

MEAN HERB NUMBERS FOR NATIVE AND EXOTIC SPECIES

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

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

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

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