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Table 12. Fertiliser effect on grass cover (mean % cover, Std. Dev.)

Fert	*A. odoratum*	*A. capillaris*	Sown native spp.
0	1.8 3.4	2.8 4.7	0.8 3.2
20	1.9 3.3	2.0 4.1	2.5 6.3
50	3.4 6.0	4.1 5.6	2.9 7.9
100	7.1 7.7	6.1 6.1	3.8 8.2
Sig.	***	***	*

The mean cover of the individual native species is shown in Table 13, their fertility response was similar to that shown in Fig.3a.

Table 13. Mean cover of sown native grasses (%)

Species	Mean	Std. Dev
Elymus rectisetus	7.0	11.4
Blue tussock	3.2	6.6
Silver tussock	1.8	5.3
Fescue tussock	1.0	3.8
Snow tussock	0.6	2.1
Red tussock	0.3	1.4

5.5 TRANSPLANT ESTABLISHMENT OF NATIVE GRASSES

Despite the rabbit poison, within a week of introduction rabbits had killed or browsed between 44 to 78% of the transplants, averaging 65% damaged on the outwash sites and 52% on the moraine sites (Table 14). This is consistent with rabbit numbers, as pellet cover was 2.4x and 2.6x higher on the outwash vegetation plots in 1993 and 1995 respectively (Tables 5-7).

Table 14. Transplant assessment one week after planting (No. Plants).

Plant Status	Moraine Site 1	Moraine Site 2	Outwash Site 1	Outwash Site 2
Killed	3	1	6	27
Browsed	58	43	46	51
Intact	40	46	48	22

After 10 months *Elymus* and plume grass had been almost entirely removed and fescue tussock survival ranged from 0 to 29% with all plants being severely browsed (Table 15).

Table 15. Transplant assessment 10 months after planting

Plant Status	Moraine Site 1	Moraine Site 2	Outwash Site 1	Outwash Site 2
Survival (%)				
Dichelachne	1.3	0	-	-
Elymus	0.5	0	-	-
Festuca	28.7	0.7	0	6.0
Plant Total (No.)				
Dichelachne	2	0	-	-
Elymus	1	0	-	-
Festuca	85	3	0	22
Mean Height (cm)				
Dichelachne	0.40	0.0	-	-
Elymus	0.5	0.0	-	-
Festuca	9.94	0.18	0	2.74
Mean Diameter (cm)				
Dichelachne	1.2	0.0	-	-
Elymus	0.5	0.0	-	-
Festuca	1.7	1.8	0	2.7

- Not transplanted at this site.

The enormous impact of rabbits is shown by comparing the survival of 1227 similar transplants in a rabbit free exclosure at the nearby Mt. John research station (Table 16). These were transplanted at approximately the same time as those in the reserve, though propagated directly from local field material. They were also assessed at the same time (Feb. 1995). The high survival rates show this can be a very successful way of establishing plants, particularly for those such as snow tussock which are not easy to establish from seed.

Table 16. Transplant survival of native grasses (%), Mt. John exclosure.

Species	Live	Dead
Silver tussock	91.9	8.1
Blue tussock	81.2	18.8
Elymus rectisetus	63.6	36.4
Snow tussock	64.3	35.7

6. Discussion

Protecting viable samples of the full range of ecological diversity existing in a country is a central objective of the World Conservation Strategy (IUCN 1980) and, as specified in the Reserves Act 1977, forms the basis of New Zealand's nature conservation policy. The short tussock and associated communities found in the reserve are grossly under-represented in protected areas elsewhere (O'Connor *et al.* 1990), though they are both regionally and nationally extensive. The biogeographical combinations of landforms and vegetation present are representative of the ecological diversity occurring elsewhere in the Mackenzie Ecological Region (Espie *et al.* 1984). Thus the reserve provides an excellent area for conservation research.

The close relationship between landform, soils and vegetation in the reserve is shown both by the cluster analysis of natural communities and the significant site effects on vegetation change, seedling establishment and cover. Soil water holding capacity is almost certainly the principal underlying abiotic environmental factor responsible, both through moisture stress and by the derivative differences in soil chemistry. Thus the sequence from the well drained moraine soils to the progressively more excessively drained outwash, scarp and river terrace soils is almost exactly mirrored by the magnitude of the recent increases in *Hieracium pilosella,* browntop and sweet vernal cover.

In the immediate pre-Polynesian era, tall tussock (*Chionochloa rigida* and C. *rubra*) probably occurred on the morainic landforms with short tussock grassland on the deeper phases of the outwash soils and a mixed sparse grassland with bare ground on the shallower phases (Espie *et al.* 1984). Polynesian influence plus 150 years of pastoral grazing and colonisation by adventive European weed species has significantly altered the floristic composition of the grassland, particularly those on the deeper soils. The vegetation on the shallower, stony soils is less modified. Active ecological restoration is necessary if it is desired to return the dominant *Hieracium* herbfields to pre-Polynesian grassland. Such management will be necessary to re-introduce species eliminated or reduced to very low abundance e.g. *Chionochloa, Sophora* and *Corallospartium.*

The success of the direct drilling in establishing native grasses on all four of the most extensive landforms in the reserve is important because it has demonstrated a practical technique is available for large scale restoration for certain native species, even in the presence of low numbers of rabbits. Either single species or multi-species mixtures could be sown, depending on the desired conservation objective.

Due consideration must be given to the fact that because of funding constraints, the effect of climatic variation on establishment has not been tested and that 1993-4 was a favourable growing season. Nevertheless it is reasonable to speculate from similar pastoral research that in most seasons it will probably be possible to establish both large seeded, vigorously growing native grasses such as *Elymus* and smaller seeded, slower growing species such as fescue, blue and silver tussocks. The failure of tall tussocks to establish was clearly due to their very low seed viability rather than drilling technique. As much higher germination of *Chionochloa* seed can occur than in the particular seed lines we used (Espie unpub. data), it may yet be possible to introduce tall tussocks by drilling, and this requires further investigation, together with examining seed pelleting to improve drill flow rates.

As the Mt John and Canterbury *Chionochloa* transplant results (Holgate 1976) show, transplanting can result in high field survival rates of mature plants. The main disadvantage is the intensive labour required, which limits its application to sites justifying the establishment costs. The location of the reserve on one of New Zealand's premier overseas tourist routes, may justify such resource investment for targeted areas, for example along the highway or walkway margins. As a minimum comparison, only considering field application, direct drilling in the reserve involved 4 people for 2 days and resulted in initial establishment of 8,800 seedlings, falling to 2,500 plants after one and a half years: transplanting involved 6 people for 3.5 days and resulted in introduction of 1800 plants. Agronomic drilling would require half, or less, our research labour requirements.

Agronomic research has shown superior establishment resulted from using a single-pass strip seeder drill compared with a conventional triple-disk drill and herbicide (Lowther *et al.* 1993). However landscape disturbance may be an issue with such conservation tillage drilling. The initial disturbance, caused by mechanically removing a turf strip to reduce resident competition, has an small but immediate visual impact, but within 18 months this is considerably reduced. Strip seeding is both more cost effective and environmentally less damaging than alternative techniques using chemical applications to reduce competition. It is possible to minimise the slot swathe, but there is a direct trade off between quantity of turf removal, reduction of competition and speed of resident re-invasion. Reducing resident competition is well established as a key requirement for enhancing seedling establishment in the high country (Woodman 1993).

Different successional processes will be initiated with the cessation of grazing and the possible biological control of *Hieracitim*. Species present in the reserve such as *Elymus rectisetus,* blue and fescue tussocks can be expected to slowly increase with the removal of rabbits and sheep. The current recovery of, tussock, and smaller native grasses such as *Poa lindsayi* and *Pyrranthera exigua* is a direct result of reduction in grazing pressure, though this has also resulted in the increase of the adventive grasses browntop and sweet vernal. There has been a corresponding, but minor, decrease in small statured native herbs such as *Wahlenbergia, Polytrichum* and *Stellaria.* This highlights the conflict between the grazing management requirements for different native species. Protection from mammalian herbivory will benefit native species with an upright growth habit and disadvantage small or prostrate species. Most native species, having persisted to date, are predicted to remain in the reserve, though population dynamics may change through competition with adventive species. Continued assessment is required.

Maintaining rabbit control in the reserve is essential.The importance of rabbits as a destructive agent in degrading conservation grasslands cannot be overemphasised. The significant decrease in bare ground and litter cover is due to effective rabbit control limiting soil disturbance and not simply to an increase in vegetation. How much effect the rabbits have had on reducing drilled seedling survival is not known, but the frequency of browsed plants and pellets suggests that they have had a greater effect than self-thinning through competition. Other factors, such as local ponding in drill rows following rain, are probably relatively minor. The vulnerability of the transplant sites to browsing, was in part, a function of their small size relative to surrounding untreated areas. If they were protected during the critical period immediately after introduction and if soil disturbance was minimised, far better survival could be expected.

We recommend maintaining the current grazing and rabbit management policy and annual monitoring of the drilling and transplant experiments and biennial monitoring of the vegetation changes. Further research is required to determine transplant and drilling survival after rabbit exclosure, and to extend the range of species tested. Establishment of seed orchids for native plants is warranted.

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Appendix 1: Observer Seedling Count Accuracy

Observer counting accuracy was checked by recounting 80 strip quadrats, with four observers each assessing quadrats previously counted by a different observer. Regression analysis showed 12% variation in counts due to observers:

Regression Analysis - Linear model:Y = a+bX

Dependent variable: .COUNT—2 Independent variable: .COUNT—1

Parameter	Standard Estimate	Error	T Value	Prob. Level
Intercept	0.868085	0.482783	1.7981	.07603
Slope	0.911809	0.038420	23.7325	.00000

Four percent of this was due to a single error, the failure of one observer to score an single row in one quadrat, as seen when this value was excluded from the dataset:-

Regression Analysis - Linear model: Y = a+bX, excluding one anomalous datapoint.

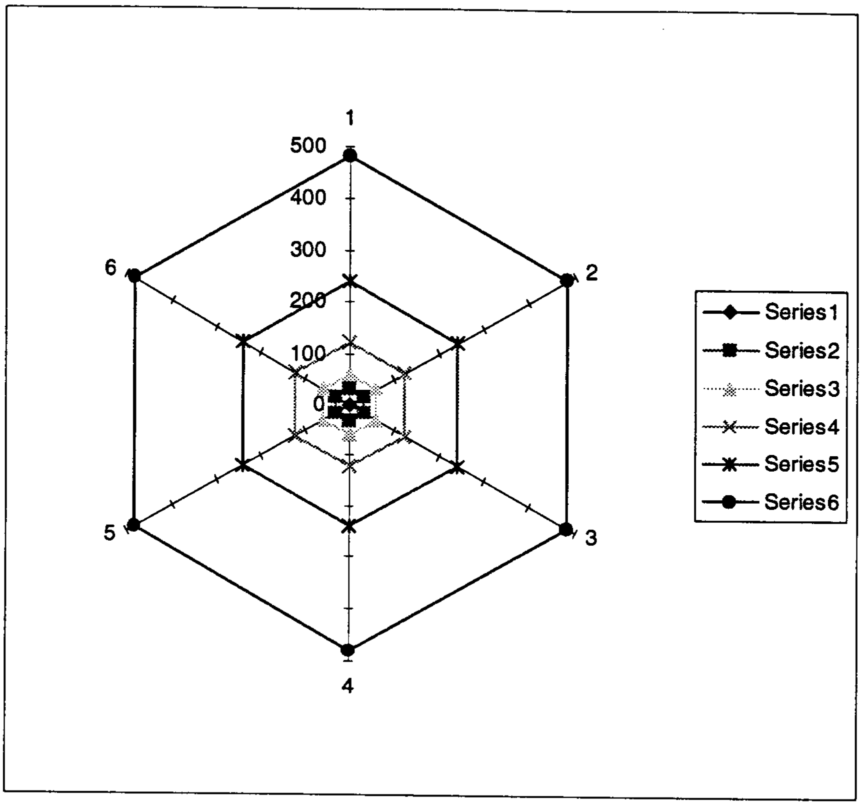
Dependent variable: COUNT—2 Independent variable: COUNT—1

Parameter	Standard Estimate	Error	T Value	Prob. Level
Intercept	0.52697	0.392491	1.34263	.18334
Slope	0.92634	0.031039	29.8443	.00000

Correlation Coefficient = 0.95939 R-squared = 92.04 percent
Stnd. Error of Est. = 2.9394

The mean difference between counts, averaged across all the treatments in the recount, was only 0.6 of a seedling (P non significant). In short, observer variation exists, but is within reasonable limits.

Appendix 2: Transplant Plot Plant Positions (cm)



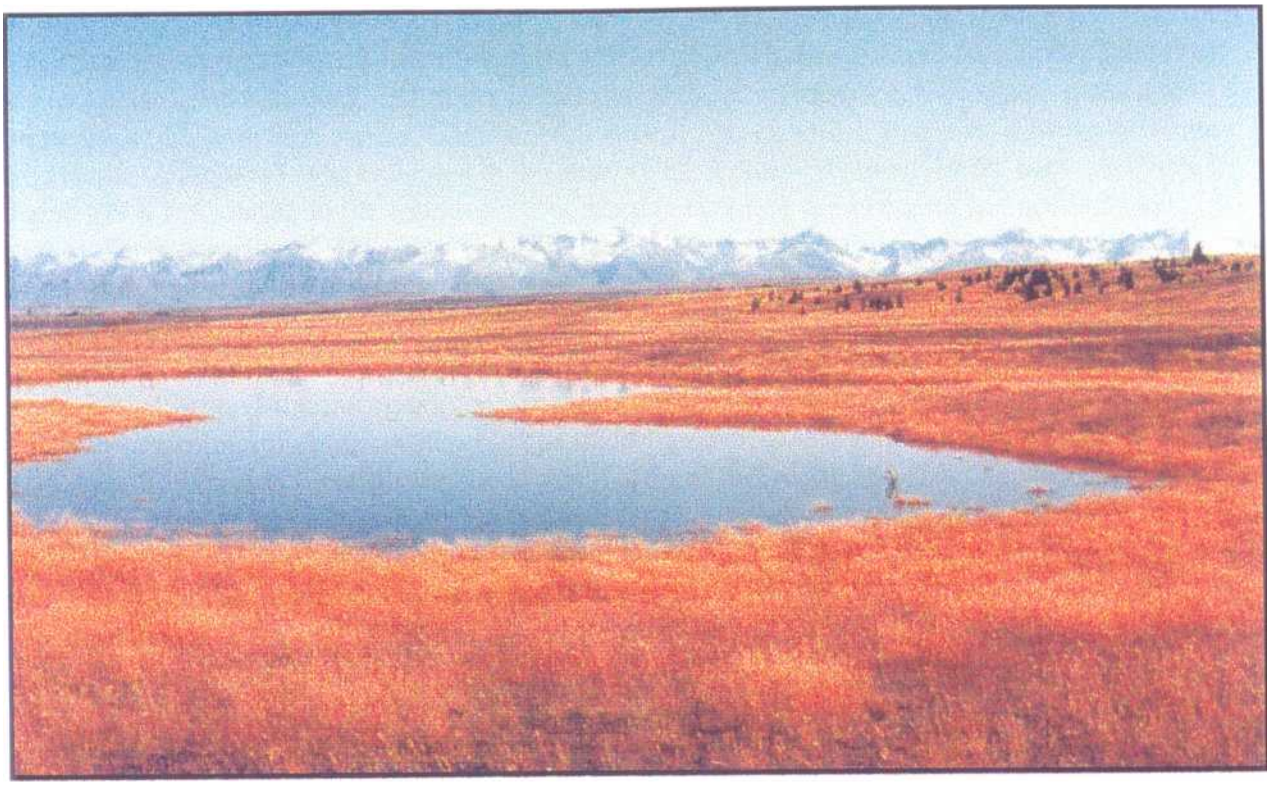


Plate 1: Kettle Tarn at moraine margin, view West.

Plate 2: Drilling Site 2, moraine scarp view East.

Plate 3: Transplant Site 4, outwash hollow and dune, view S.E.

Plate 4: Transplanted fescue tussocks.