# Vegetation: Wraight plots

## Version 1.0

This specification was prepared by Alan Rose in 2012.

## Contents

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Department of Conservation
*Te Papa Atawhai*

# Synopsis

The Wraight permanent plot method was designed primarily to assess and monitor the composition, vegetation cover and ground cover of non-forest ecosystems, e.g. tussock grassland, herbfield, cushionfield, and shrubland. It is most appropriate for vegetation up to about 1 m tall, but has also been used for taller vegetation. There are more than 5000 permanent Wraight plots established in grasslands throughout New Zealand and nearly 3000 of these have been remeasured at least once. Virtually all plot data are archived in the National Vegetation Survey (NVS) databank at Landcare Research. The large number of plots largely reflects the past responsibility of the former New Zealand Forest Service (NZFS) for animal control on public lands and the consequent need to define grassland communities and assess herbivore impacts. Wraight plots evolved from the original 40 m (2-chain) Wraight transects developed for catchment surveys by NZFS in the late 1950s (Wraight 1960, 1962, 1963). By the late 1960s, a more elaborate design consisting of a central transect within a 20 × 20 m permanent plot had become the standard technique.

The use of Wraight plots is well documented in published papers and survey reports held in NVS by Landcare Research. Wraight plots produce statistically testable data and have been used for a wide range of objectives, including to define grassland communities and infer animal impacts (Wraight 1960, 1962, 1963); assess vegetation change after animal control (Rose & Platt 1987; Rose et al. 2004); compare vegetation trends inside and outside animal-proof exclosures (Rogers 1991; Rose & Frampton 2007); and determine the effects of weed invasion on biodiversity and grassland composition (Rose 1983; Rose et al. 1995; Rose & Frampton 2007).

Examples of questions that Wraight plots can address include:

- How do the composition, cover, and ground cover of grasslands compare before and after pest management?
- Are there any changes in species frequency, cover, ground cover, or tussock biomass over time?
- How is the abundance of palatable species changing and are they responding to pest control?
- Are weed species increasing or decreasing in response to animal management?
- What grassland types are present and what are their patterns of distribution in relation to environmental factors?
- How do sites with different pest population histories differ?
- How do site and management history affect grassland composition, ground cover, and plant cover?

The core data for Wraight plots are species frequencies and ground cover obtained from evenly spaced subplots along a permanently marked 20 m or 40 m transect (Wraight 1962; Wiser & Rose 1997). A strength of the Wraight method is that this transect data is relatively rapidly obtained and may be sufficient to meet most study objectives. Species frequencies are obtained by recording all species present in 15 cm diameter subplots (rings) located at 40 cm intervals along the transect (50 or 100 subplots per 20 m or 40 m transect). A single point intercept at the centre of each ring is used to assess the percentage of ground cover of vegetation, litter, bare soil, and other ground cover categories.

In addition to the transect data, other optional data can be collected by establishing a 20 × 20 m plot surrounding each transect. Within the plot, the cover abundance of all species present can be assessed in height tiers using a RECCE plot description. At a more detailed level, cover abundance of individual species and species groups can be assessed using eight randomly located permanent stereophoto points or 1 m$^2$ quadrats (however, the limitations of both methods are discussed in 'Full details of technique and best practice'). Data can also be collected on tussock density and stature at the photopoints or quadrats. The Wraight method is detailed in Wiser & Rose (1997).[1]

Scott height frequency (SHF) transects are an alternative method to monitor non-woody vegetation, and both Wraight plots and SHF are described in Wiser & Rose (1997). Some of the factors that differentiate the two methods are as follows:

- Wraight transect frequencies are more rapidly collected than height-frequencies.
- Wraight plots are suitable for vegetation < 2 m tall. SHF is the more appropriate method for vegetation > 1 m tall.
- Wraight plots use cover and tussock stature measurements as surrogates for biomass while SHF transects use species height-distribution.
- Wraight transects have been used more for broad-scale monitoring where extensive sampling, large numbers of plots, and stratified-random plot location are important. SHF transects are generally more sensitive to within-transect changes at a given site, and historically have been used more for intensive monitoring at a few sites considered 'representative'.
- Neither method is appropriate for plant population studies (e.g. recruitment, mortality).

# Assumptions

- Fifty or 100 sample points are assumed adequate to record most species present on 20 m or 40 m transects, respectively.
- Changes in plant frequency predominantly reflect changes in abundance rather than changes in spatial distribution.
- Cover recorded on stereophotos may be confounded with height, but changes are assumed to reflect changes in abundance.
- Subjective cover estimates on quadrats are assessed consistently between observers and measurement dates.

# Advantages

- A standard and well-proven method that has been used to set up plots in tall- and short-tussock grasslands for the last 50 years. There are more than 5000 Wraight plots established throughout New Zealand and more than 3000 of these have been measured more than once, providing useful data for comparisons.

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[1] Available at http://nvs.landcareresearch.co.nz/

- A repeatable, adaptable, and relatively simple method that is not too time consuming.
- Useful for intensive monitoring of specific sites and monitoring broader-scale changes.

## Disadvantages

- Cover abundance estimates from stereophotos and 1 m$^2$ quadrats are subject to observer variability and bias and it is difficult to positively identify some species in photographs. Cover abundance estimates are difficult when plants are small, indistinct and intermingled (Hill et al. 2005), and photographs distort objects to the side and overestimate the cover of plants that stand above the ground (Wimbush et al. 1967).
- Tussock stature/distance measurements are precluded in dense stands where individual tussocks are not distinguishable.
- Wraight transects may not necessarily detect rare or threatened plants. The associated RECCE plots could record species that may have been otherwise missed.

## Suitability for inventory

Wraight plots are suitable for initial inventory (Wraight 1960, 1963), and because they collect data within a specific, permanently marked area they can then be used for monitoring subsequent changes in the vegetation. Rare and uncommon species may not be picked up from the frequency and cover data but all species present on the plot will be listed on the RECCE plot description.

## Suitability for monitoring

Wraight plots are suitable for monitoring short- and tall-tussock grasslands and other non-forest vegetation up to about 1 m tall. They are intensive and collect a lot of data from one unit area but can also capture a lot of the variation in non-forest habitats. Data from Wraight plots has been used to compare sites with spatial or temporal differences in mammalian herbivore populations and to monitor changes in composition, abundance, species richness, and ground cover (Rose 1983; Rose & Platt 1987; Rogers 1991; Rose et al. 1995; Rose et al. 2004; Rose & Frampton 2007).

## Skills

- A moderate to high level of botanical expertise.
- A good level of navigational and general outdoor skills.
- Data summaries and analyses require a moderate level of skill with computer spreadsheets and statistical analysis packages.
- A background in plant ecology is essential for the interpretation of data.

## Resources

- Two experienced people, confident with grassland species identification, can establish and measure a 20 m transect in 1 hour and a transect plus associated RECCE plot description in 2 hours; 3 or 4 people can measure one full plot including transect, cover and tussock measurements, and RECCE plot in 1–2 hours. Times also depend on species diversity and the structural complexity of the vegetation.
- Standard field equipment includes maps, datasheets, clipboard, compass, pens, pencils, 15 cm diameter steel ring, 20 m tape measures, 5 m tape measure, GPS, binoculars and cruise tape, plant identification books, collection bags and labels, camera, tripod and plaque (see Wiser & Rose 1997, p. 48).
- Take a copy of the most up-to-date plant species codes from Landcare Research with you into the field.[2]
- For previously measured plots, it is good to have photocopies of original datasheets and they are available free of charge. Users must request data using a NVS data request form or by emailing nvs@landcareresearch.co.nz. Complicated data requests may incur fees. Please allow up to 4 weeks for requests to be processed.[3]
- Electronic copies of Wraight plot datasheets are not available from NVS. Observers will need to create their own copies following the example datasheets in Wiser & Rose (1997) and the minimum attributes to record. There are initiatives by Landcare Research to make these datasheets available in the near future as part of the update of the NVS databank.
- There are a number of ways in which the NVS website can be used to identify and locate particular vegetation surveys or search for data: broad-scale maps can be viewed to see listings of survey names within each DOC conservancy; a search can be conducted for a particular survey name, person, or known geographical area; or interactive maps can be viewed that show NVS plot locations and species distributions.[4]
- Adequate budget needs to be set aside to ensure unknown species are collected and identified and correct species names and codes are updated on the plot sheets before data entry.

## Minimum attributes

These attributes are critical for the implementation of the method. Other attributes may be optional depending on your objective. For more information refer to 'Full details of technique and best practice'. Wiser and Rose (1997) list the minimum attributes to record and illustrate examples of standard Wraight plot datasheets.

DOC staff must complete a 'Standard inventory and monitoring project plan' (docdm-146272).

Photograph the transect and record details of the site:

- Survey

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[2] Refer to 'NVS plant names and maps' at http://nvs.landcareresearch.co.nz/

[3] Refer to 'Requesting data' at http://nvs.landcareresearch.co.nz/

[4] Refer to 'Interactive plot location maps' at http://nvs.landcareresearch.co.nz/

- Line
- Plot
- Date
- Observer
- Recorder

At every 40 cm sample point along the transect, record:

- All species (i) rooted within and (ii) overhanging the 15 cm diameter steel ring.
- The type of ground cover intercepted by a first-hit point intercept at the centre of the ring (vascular vegetation, moss, litter, bare ground, erosion pavement, scree, broken rock or rock).

Optionally, at eight random but fixed points within the 20 × 20 m plot, either:

- Take vertical stereophotographs of the vegetation using a camera with a wide angle lens fitted to a purpose-built tripod (Wiser & Rose 1997) and record tripod height and angle, time, and weather.

Or:

- Establish a 1 $m^2$ quadrat and visually estimate the cover of all species as < 1%, 1–5%, 6–25%, 26–50%, 51–75%, or > 75%. Record the distance from the random point to the nearest distinct tussock and from that tussock to its nearest conspecific neighbour. For each tussock record the species, basal diameter, and height (maximum extended leaf length).

Use the non-woody RECCE plot datasheet available online from Landcare Research.[5] Refer to the method description 'Vegetation: RECCE plots' (docdm-359575) for more information on minimum attributes.

Other optional parameters that may enhance data interpretation include:

- Environmental factors (e.g. soil fertility, soil profile descriptions, potential solar radiation)
- Disturbance history (e.g. grazing, burning, roading, skiing)
- The cover of selected species (e.g. weeds like *Hieracium* spp.)
- Specific plant attributes (e.g. tussock flowering intensity, tussock nutrient status)
- Animal use indices (e.g. faecal pellet counts)

## Data storage

- It is standard to deposit all original datasheets in NVS.
- For correct standards and procedures for archiving and retrieval of Wraight plot data, follow the DOC standard operating procedure (SOP) 'National Vegetation Survey (NVS) databank data entry, archiving and retrieval standard operating procedure' (docdm-39000). The SOP describes DOC protocols for submitting and retrieving RECCE, 20 × 20 m permanent plot, SHF transect and Wraight plot data from NVS.
- RECCE plot data can now be entered using NVS Express, an interface where plot data can be entered by staff into fields and electronically submitted to Landcare Research. NVS Express is

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[5] See 'Manuals, sheets and tools' at http://nvs.landcareresearch.co.nz/

available from Landcare Research.[6] DOC staff must request for NVS Express to be loaded onto their computer from DOC's network administrator. Otherwise, you must budget for data entry costs by Landcare Research. There are firm plans by Landcare Research to develop NVS Express to accept Wraight plot data.

- Never take original datasheets into the field. Store copies of datasheets in a safe location.
- Complete a metadata sheet when submitting data to NVS. Refer to 'Depositing data' at http://nvs.landcareresearch.co.nz/ for copies of metadata forms, though submitters are encouraged to use the more complete 'NVS metadata sheet' (docdm-53429).

For more discussion on data collection, common problems and storage protocols, refer to the discussion documents Wiser et al. (1999), Newell & Baldwin (2000), Hurst et al. (2006), or contact the NVS databank administrator direct.

# Analysis, interpretation and reporting

The best approach to Wraight and RECCE plots analysis depends on the objectives of the monitoring programme. Always seek statistical advice from a biometrician or suitably experienced person prior to undertaking any analysis. The time and resources that are needed to undertake analysis of Wraight and RECCE data are substantial and they are routinely underestimated. The skills required to collect the data vary considerably from skills needed to analyse it. Mixed model analysis is relatively specialised and it is recommended that advice be sought from suitability experienced individuals before embarking on analysis. Training courses and guidance on repeated measured analysis using mixed models has been a recent focus of DOC, and it is anticipated they will be advanced through ongoing development work.

Before any analyses are undertaken, it is critical that data errors are identified and corrected. Various data checking and validation programs are run when data are archived into the NVS databank, whether data are submitted using NVS Express or through other avenues (see 'Data storage'). Should any errors be identified, or corrections made to Wraight or RECCE plot data supplied by NVS, it is important to report those corrections back with the NVS databank to ensure that the most up-to-date copy of the data is archived. Contact the NVS databank administrator for advice on lodging data corrections with NVS.

## Summarising species and ground cover data

The core plot data are species presence/absences, species frequencies, species richness, and ground cover obtained from the 20 m or 40 m transect. For each species, calculate presence/absence and frequency (% sample points, i.e. rings, occupied) per transect. Both transect and ring species richness can be calculated for all species combined and for relevant groups of species (e.g. palatable native herbs, exotic weeds, shrubs; Rose & Frampton 2007). Calculate the proportions of different ground cover components per transect from the point intercepts at the ring centres (% vegetation, litter, bare soil, etc.). Categories can be lumped to form relevant groups (e.g.

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[6] Refer to 'Depositing data' at http://nvs.landcareresearch.co.nz/

all types of bare soil and rock). Species and ground cover data can be tabulated or presented in histograms or graphs, e.g. using the graphics function of MS Excel.

The optional data collected from the 8 photocentres or 1 $m^2$ quadrats per plot includes cover estimates for individual species, species groups, and ground cover components. Use the midpoints of the six cover classes to calculate mean values per plot (Rose & Platt 1987; Rogers 1991; Rose & Frampton 2007). Quadrat species richness can be calculated, but photocentres lack sufficient definition. If tussock biomass data has been gathered, calculate mean tussock density, diameter, and height per plot for each species.

## Analysing change on plots

Most studies use transects as replicates to analyse spatial and temporal changes in mean species frequencies, species richness, ground cover, and other parameters. To analyse changes between two measurement dates or between two treatments, use a paired *t*-test, independent *t*-test, or the non-parametric Wilcoxon signed ranks test or Mann-Whitney *U*-test for highly skewed data. When analysing changes over three or more time intervals, or when comparing plots with different treatments over two or more measurements, use repeated measures ANOVA (‘Case study B’; Rose et al. 1995) or mixed model ANOVA (‘Case study C’; Rose & Frampton 2007). When data are highly skewed and measurement dates and time intervals are inconsistent, the mean rate of change per annum can be analysed using the Wilcoxon signed ranks test for two measurements (Rose et al. 2004) or Friedman’s test for more than two measurements. Similar parametric or non-parametric statistics can be used to analyse stereophoto, 1 $m^2$ quadrat, or tussock measurements, with plots as replicates.

Temporal change in frequency, richness, or ground cover within individual Wraight transects can be analysed, but has received little attention. The approach effectively uses individual sample points (rings) as replicates and is commonly used with SHF transects. However, as for SHF transects it assumes that the transect is representative of a wider area and that sample points are independent although they are separated by only 40 cm along the transect. Independence can be increased by pooling groups of sample points (e.g. pooling the first five points starting from one end of the transect). The independence of these pooled values can be tested by correlating each with adjacent pooled groups. If there is no correlation, they are independent. The resulting means, presence/absences, or frequencies of species can then be used as replicates within the transect (C. Frampton, pers. comm.).

## Classification and ordination

Wraight species frequencies and presence/absence data can be used for classification and ordination. Classification groups compositionally similar transects into communities (e.g. Rose & Platt 1987) and also groups species with similar distributions. Ordination extracts the main gradients of compositional change in the data and places the transects and species along these axes. Ordination and classification are frequently used together to interpret vegetation patterns in relation to environment or management (e.g. altitude, soil fertility, grazing history) or to follow changes in composition over time.

A wide range of specialised software is available for implementing the many different classification and ordination techniques, e.g. PC-ORD, CANOCO, DECORANA, TWINSPAN, and specialised packages in R. Analysts should consult the large literature on these topics and relevant websites.[7]

Wraight data can be classified and ordinated using the NVS software package PC-TRANSECT (Hall 1996), but the package is now rather dated. Data are entered in a standard ASCII text file format and run under MS-DOS. Data must be obtained in the appropriate format from the NVS databank. Transects are classified using either agglomerative clustering techniques or two-way indicator species analysis (TWINSPAN). Ordination is performed using detrended correspondence analysis (DECORANA). Data summary programs can be used to analyse changes in species abundance, and comparisons can then be made among species (e.g. in response to changing management). PC-TRANSECT is available for DOC staff on request from the DOC network administrator and manuals can be obtained free-of-charge from Landcare Research. Landcare Research plans to develop an updated set of analysis tools as part of the ongoing upgrade of the NVS databank and NVS Express. It is anticipated that data summaries will graphically display summary results, including the ability to graph relationships between variables calculated by the summaries (e.g. species frequencies).

Regression techniques can be used in common statistical packages to evaluate the relationships between species abundance (e.g. frequency) and covariates such as weed and pest abundance indices (e.g. *Hieracium* cover, faecal pellet counts) and environmental factors (e.g. potential solar radiation, altitude; Rose & Frampton 2007).

# Case study A

**Case study A: recovery of northern Fiordland alpine grasslands after reduction in the deer population**

## Synopsis

This study uses the full Wraight plot technique to quantitatively examine grassland response to deer impacts in relation to hunting pressure, grassland composition, and environment over extensive and remote areas. It also highlights the value of gathering additional interpretive data on landforms, soils, and deer pellet counts. The study monitored the recovery patterns of alpine grasslands in northern Fiordland from 1969 to 1984, resulting from intense commercial deer harvesting. Deer populations had rapidly increased until aerial harvesting began in 1973. By the mid-1980s hunting had further reduced deer to negligible numbers in the grasslands. Concern for the condition of the grasslands was spurred by the threat to takahē from competition for food by deer. These factors resulted in the establishment of a network of permanent grassland plots in 1969 and their remeasurement in 1975 and 1984 as deer numbers declined.

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[7] e.g. http://ordination.okstate.edu/index.html

## Objectives

- Assess the magnitude of recovery of alpine grasslands resulting from markedly reduced deer populations.
- Determine the distribution of food plants preferred by both deer and takahē in relation to different plant communities.
- Determine recovery patterns in relation to plant communities, soil fertility, and deer usage.

## Sampling design and methods

- In 1969 when deer numbers were high, 174 permanent grassland plots were established throughout northern Fiordland along lines chosen on a restricted random basis. Plots were 20 × 20 m in size and located at 60 m intervals along altitudinal gradients. All plots were remeasured in 1975 and 57 of the original plots were selected for remeasurement again in 1984.
- The subset of plots remeasured in 1984 reflected the objectives and resources available. Before the 1984 remeasurement, the original plot data was used to classify all plots into grassland communities using an agglomerative clustering technique. Plots were then selected for remeasurement in all major grassland communities, but priority was given to those that contained snow tussocks palatable to both deer and takahē (*Chionochloa pallens*, *C. flavescens*—now *C. rigida*).
- The standard 20 × 20 m Wraight plot technique was used. A central 20 m transect was used to record the presence of all plant species in 15 cm diameter rings spaced at 40 cm intervals. Ground cover was recorded using a point intercept at the centre of each ring. Paired stereophotos of the vegetation were taken from eight randomly selected and permanently marked photocentres in each plot. Each photograph covered an area of c. 1 $m^2$ and was taken from c. 1 m above the ground. Distance, diameter, and height measurements were recorded for the snow tussock nearest each photocentre and its nearest conspecific neighbour. Site factors (elevation, aspect, slope, drainage, etc.) were recorded for each plot.
- Additional information was collected on deer densities by counting the presence of intact deer pellets in 10 random subplots within each permanent grassland plot.
- Patterns of deer impact and subsequent recovery were examined in relation to community composition and soil fertility. The composition of the four grassland communities was first refined using the 1984 species frequency data from the transects. The distribution of each community was then summarised in relation to site factors including elevation, slope, drainage, landform and inferred soil fertility.
- Changes in the mean transect frequencies of dominant plant species, bare ground, and indicator species palatable to deer and takahē were analysed overall (Table 1) and for each grassland community. Frequencies were compared between the three survey dates using ANOVA.
- Mean tussock height was compared using ANOVA.
- Changes in the percentage cover of indicator species and ground cover were assessed from photocentres, using a rapid analysis technique which allowed stereophotos to be analysed in just a few minutes. Equivalent photos from all three surveys were projected onto a wall and conservatively evaluated by two observers. Cover was assessed in set percentage classes for

predetermined vegetation categories, including tussock species, large-leaved dicotyledonous herbs, *Celmisia* spp., shrubs, mat vegetation, litter, and bare ground. Cover for individual ‘dicot’, *Celmisia*, and shrub species was also recorded, as well as for total vegetation. Repeat scoring by the two observers proved very consistent, with *P* values ranging from 0.1 to 0.5. Changes in cover scores were analysed by Chi square or *G*-tests of independence.

Table 1. Overall changes in mean specific frequency (%) of selected taxa and bare ground on 55 transects measured in 1969, 1975, 1984. 1 = number of transects. 2 = results from analysis of variance after arcsine square root transformation. 3 = significantly different using Duncan’s new multiple range test on transformed data *p* = 0.01.

| **Guilds** | **Regions** | | | | |
|---|---|---|---|---|---|
| | **Chester** | **Takahē Valley** | **Glainsock** | **Year** | **Region—Year Interaction** |
| **Dicot herbs** | | | | | |
| Line Freq (%) | | | | | |
| 1989 | 33.9 | 21.6 | 13.5 | ** | NS |
| 1004 | 34.9 | 21.7 | 14.5 | | |
| 2000 | 41.6 | 24.3 | 17.9 | | |
| Total Height Freq | | | | | |
| 1989 | 163 | 66 | 77 | ** | NS |
| 1994 | 123 | 67 | 59 | | |
| 2000 | 105 | 58 | 45 | | |
| | | | | | |
| **Shrubs** | | | | | |
| Line Freq (%) | | | | | |
| 1989 | 14.7 | 38.5 | 3.4 | *** | * |
| 1004 | 18.1 | 39.5 | 7.8 | | |
| 2000 | 24.0 | 42.2 | 11.7 | | |
| Total Height Freq | | | | | |
| 1989 | 81 | 167 | 31 | NS | ** |
| 1994 | 89 | 163 | 56 | | |
| 2000 | 79 | 140 | 53 | | |
| | | | | | |
| **Monocot herbs** | | | | | |
| Line Freq (%) | | | | | |
| 1989 | 12.3 | 0.6 | 23.4 | NS | ** |
| 1004 | 8.0 | 0.7 | 21.4 | | |
| 2000 | 12.9 | 0.7 | 14.3 | | |
| Total Height Freq | | | | | |
| 1989 | 49 | 2 | 121 | *** | ** |
| 1994 | 23 | 2 | 89 | | |
| 2000 | 26.6 | 2 | 34 | | |
| | | | | | |
| **Grasses** | | | | | |
| Line Freq (%) | | | | | |
| 1989 | 83.6 | 68.6 | 86.4 | NS | NS |
| 1004 | 85.2 | 73.5 | 82.2 | | |

| | | | | | |
|---|---|---|---|---|---|
| 2000 | 81.5 | 73.8 | 85.5 | | |
| Total Height Freq | | | | | |
| 1989 | 657 | 563 | 860 | *** | NS |
| 1994 | 588 | 511 | 641 | | |
| 2000 | 429 | 424 | 487 | | |
| | | | | | |
| **Ferns** | | | | | |
| Line Freq (%) | | | | | |
| 1989 | 0 | 0 | 13.7 | NS | * |
| 1004 | 0.2 | 0.1 | 14.7 | | |
| 2000 | 0.2 | 0.1 | 7.2 | | |
| Total Height Freq | | | | | |
| 1989 | 0 | 0 | 63 | * | * |
| 1994 | 1 | 1 | 59 | | |
| 2000 | 1 | 0 | 18 | | |

- The cluster analysis identified four main grassland communities. These were distinguished by particular plant species and site factors, including soil fertility status. Fifty-five of the 57 selected plots fell within these four communities.
- Trends in alpine grassland condition were assessed from changes in species frequencies, cover, ground cover, tussock height, and deer pellet counts over the three sample periods.

## Results

- Deer pellet data showed that deer preferred the two *Chionochloa pallens* communities characteristic of relatively fertile soils on landforms subjected to frequent soil rejuvenation (communities PC1, PC2). These communities contained the greatest abundance of plant species preferred by deer and takahē. Recovery after reduction in the deer population was also most marked in these communities. There were few preferred plant species, less deer use, and less vegetation change in the two *C. crassiuscula* communities (communities CA1 and CA2) characteristic of infertile soils on stable landforms.
- Deer browsing pressure had decreased on alpine grasslands by 1975 and pellet counts indicated there were negligible populations of deer by 1984. This corresponded with significant increases in the mean frequency of large-leaved herbs and other species preferred by deer. Cover scores from the stereophotos and frequency data from transects showed the most significant recovery occurred in grassland community PC1, a low elevation *C. pallens* community highly preferred by deer.

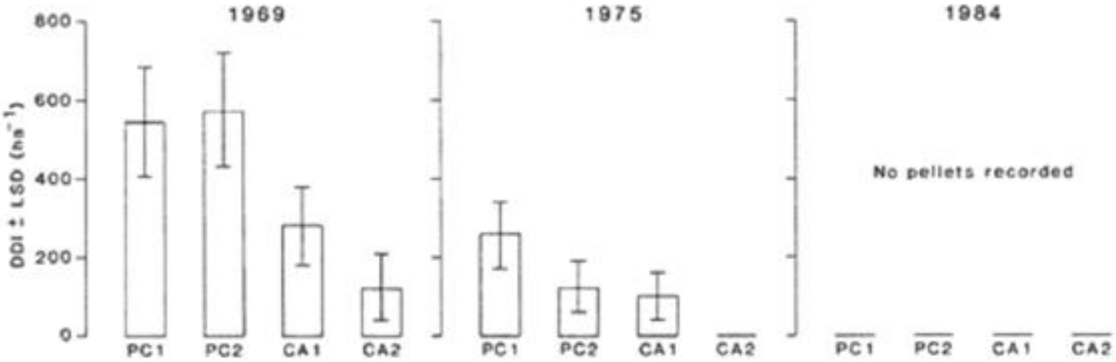


Figure 1. Deer density index by grassland community, calculated from the frequency of intact faecal pellets.

- Differences in biomass and frequency of species between 1969/70, 1975/76 and 1984 corresponded with patterns of deer hunting over the same time period. Grasslands were showing signs of recovery by 1975 as indicated by the regrowth of snow tussocks, just two years after aerial hunting had begun. By 1984, the condition of deer-preferred community PC1 had improved as indicated by the presence of snow tussock seedlings, recovery of large herbs and reduction of bare ground.

## Limitations and points to consider

- Three measurements of 57 Wraight plots distributed on a restricted random basis throughout northern Fiordland yielded quantitative and representative data on alpine grassland composition, vegetation patterns in relation to environment, the abundance of palatable indicator species, and the magnitude of recovery from deer browsing. Additional data collected on deer pellet density and landforms proved invaluable for interpreting patterns of deer usage and vegetation recovery.
- The authors suggested high-fertility sites on unstable landforms are the most sensitive grassland sites for monitoring deer impacts in high rainfall environments. The vegetation pattern and the abundance of palatable species strongly reflected an underlying gradient in soil fertility. This explained why deer preferred specific grassland communities and why recovery was most marked on specific sites when deer were effectively removed by intense hunting.

## References for case study A

Rose, A.B.; Platt, K.H. 1987: Recovery of northern Fiordland alpine grasslands after reduction in the deer population. *New Zealand Journal of Ecology 10*: 23–33.

# Case study B

**Case study B: vegetation change over 25 years in a New Zealand short-tussock grassland: effects of sheep grazing and exotic invasions**

## Synopsis

This study illustrates the use of Wraight plot frequency data to build models of long-term grassland trends in relation to grazing history and weed invasion. The plots originated as part of an extensive survey of the Harper and Avoca catchments, Canterbury, in 1965. They were then used to intensively track changes in composition and ground cover in short-tussock grassland from 1965 to 1990. A particular emphasis was to examine whether grazing promoted invasion by *Hieracium pilosella* and other exotic weeds.

## Objectives

- Determine the main pathways of vegetation change over 25 years and examine how these have been affected by removal of sheep grazing.
- Assess whether sheep grazing is promoting invasion by *Hieracium* species and whether removal of grazing can prevent or arrest this invasion.

## Sample design and methods

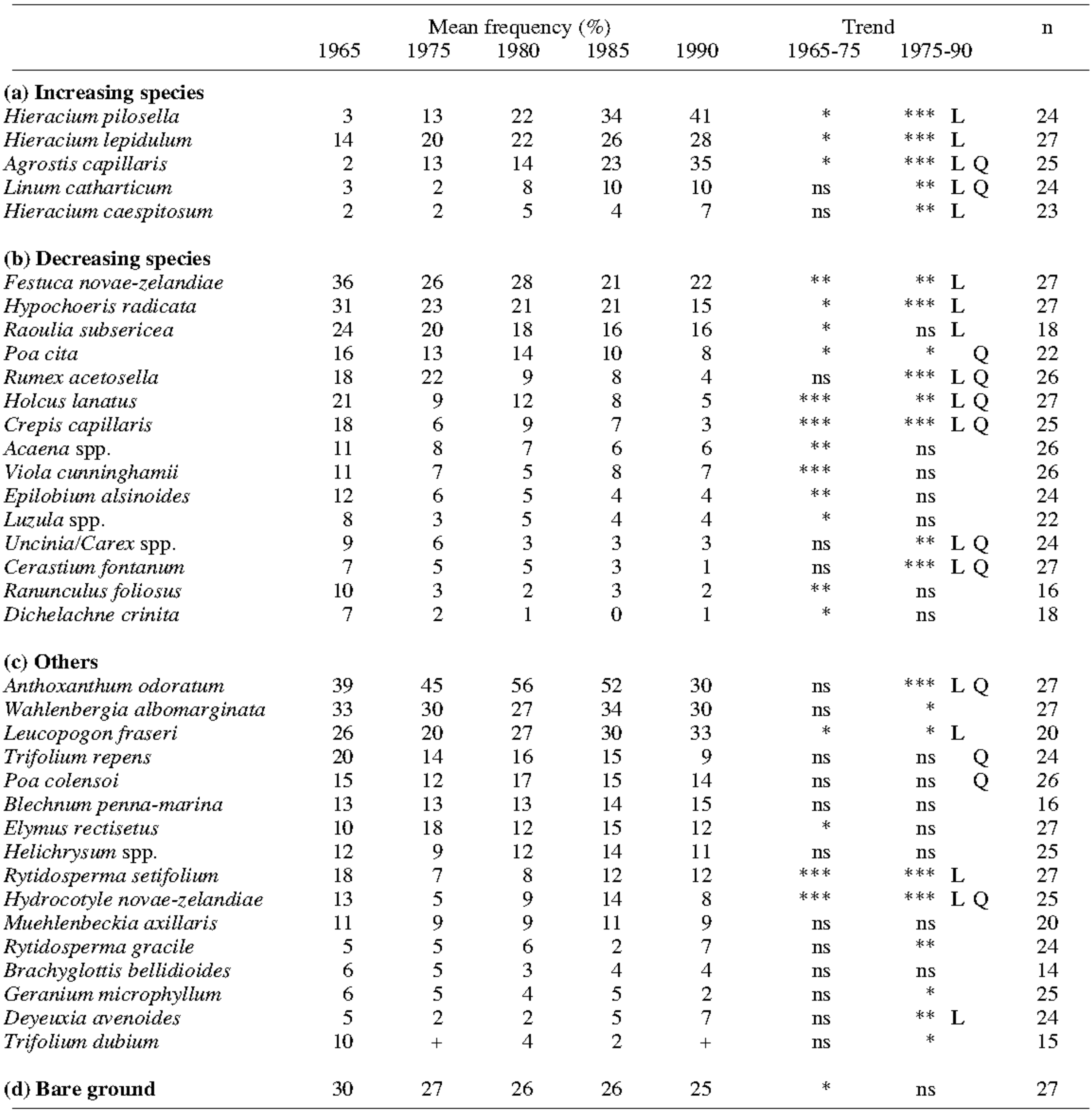
- In 1965, twenty-seven 40 m Wraight transects were established on representative lines throughout the montane grasslands of the Harper-Avoca catchment. The transects were remeasured in 1975, 1980, 1985, and 1990. In 1965, the study area was being grazed by sheep, but parts of the area were subsequently retired from grazing while others remained grazed.
- Overall changes on the 27 transects were examined. In addition, the effects of two different grazing histories could be examined on 16 north-facing transects, 7 of which remained grazed throughout the study and 9 that were retired in 1968.
- Overall changes in mean percent frequency of the 36 most abundant species and bare ground were analysed using ANOVA and multivariate repeated measures ANOVA. Species were then classified as increasing, decreasing, or showing no consistent change over the 25 years (see Table 2; Rose et al. 1995).
- For species on the 16 plots with two different grazing histories, the consistent effects of grazing history were assessed using ANOVA. Interactions between grazing history and time were assessed by ANOVA and multivariate repeated measures ANOVA. Changes in the mean frequencies of representative species were graphed and individual time points were compared using LSD tests.

## Results

- Vegetation change was widespread and characterised by invasions by several exotic species, declines in native species, and a trend towards exotic vegetation dominated by the flatweeds *Hieracium pilosella*, *H. lepidulum* and the grass *Agrostis capillaris* (Table 2).
- The different grazing histories had little impact on the direction of vegetation change (Figure 2; Rose 1992). Although prolonged grazing generally promoted decline in native species and invasion by exotics, these trends also developed on sites retired from grazing.

- There was no evidence that grazing or its removal had a significant effect on the rate or extent of invasion of these grasslands by the main weed, *Hieracium pilosella*.

Table 2. Changes in mean frequency (%) in the most abundant species on bare ground on permanent transects established in 1965 in the Harper-Avoca catchment (source: Rose et al. 1995).



| | Mean frequency (%) | | | | | Trend | | n |
|---|---|---|---|---|---|---|---|---|
| | 1965 | 1975 | 1980 | 1985 | 1990 | 1965-75 | 1975-90 | |
| **(a) Increasing species** | | | | | | | | |
| *Hieracium pilosella* | 3 | 13 | 22 | 34 | 41 | * | *** L | 24 |
| *Hieracium lepidulum* | 14 | 20 | 22 | 26 | 28 | * | *** L | 27 |
| *Agrostis capillaris* | 2 | 13 | 14 | 23 | 35 | * | *** L Q | 25 |
| *Linum catharticum* | 3 | 2 | 8 | 10 | 10 | ns | ** L Q | 24 |
| *Hieracium caespitosum* | 2 | 2 | 5 | 4 | 7 | ns | ** L | 23 |
| **(b) Decreasing species** | | | | | | | | |
| *Festuca novae-zelandiae* | 36 | 26 | 28 | 21 | 22 | ** | ** L | 27 |
| *Hypochoeris radicata* | 31 | 23 | 21 | 21 | 15 | * | *** L | 27 |
| *Raoulia subsericea* | 24 | 20 | 18 | 16 | 16 | * | ns L | 18 |
| *Poa cita* | 16 | 13 | 14 | 10 | 8 | * | * Q | 22 |
| *Rumex acetosella* | 18 | 22 | 9 | 8 | 4 | ns | *** L Q | 26 |
| *Holcus lanatus* | 21 | 9 | 12 | 8 | 5 | *** | ** L Q | 27 |
| *Crepis capillaris* | 18 | 6 | 9 | 7 | 3 | *** | *** L Q | 25 |
| *Acaena* spp. | 11 | 8 | 7 | 6 | 6 | ** | ns | 26 |
| *Viola cunninghamii* | 11 | 7 | 5 | 8 | 7 | *** | ns | 26 |
| *Epilobium alsinoides* | 12 | 6 | 5 | 4 | 4 | ** | ns | 24 |
| *Luzula* spp. | 8 | 3 | 5 | 4 | 4 | * | ns | 22 |
| *Uncinia*/*Carex* spp. | 9 | 6 | 3 | 3 | 3 | ns | ** L Q | 24 |
| *Cerastium fontanum* | 7 | 5 | 5 | 3 | 1 | ns | *** L Q | 27 |
| *Ranunculus foliosus* | 10 | 3 | 2 | 3 | 2 | ** | ns | 16 |
| *Dichelachne crinita* | 7 | 2 | 1 | 0 | 1 | * | ns | 18 |
| **(c) Others** | | | | | | | | |
| *Anthoxanthum odoratum* | 39 | 45 | 56 | 52 | 30 | ns | *** L Q | 27 |
| *Wahlenbergia albomarginata* | 33 | 30 | 27 | 34 | 30 | ns | * | 27 |
| *Leucopogon fraseri* | 26 | 20 | 27 | 30 | 33 | * | * L | 20 |
| *Trifolium repens* | 20 | 14 | 16 | 15 | 9 | ns | ns Q | 24 |
| *Poa colensoi* | 15 | 12 | 17 | 15 | 14 | ns | ns Q | *26* |
| *Blechnum penna-marina* | 13 | 13 | 13 | 14 | 15 | ns | ns | 16 |
| *Elymus rectisetus* | 10 | 18 | 12 | 15 | 12 | * | ns | 27 |
| *Helichrysum* spp. | 12 | 9 | 12 | 14 | 11 | ns | ns | 25 |
| *Rytidosperma setifolium* | 18 | 7 | 8 | 12 | 12 | *** | *** L | 27 |
| *Hydrocotyle novae-zelandiae* | 13 | 5 | 9 | 14 | 8 | *** | *** L Q | 25 |
| *Muehlenbeckia axillaris* | 11 | 9 | 9 | 11 | 9 | ns | ns | 20 |
| *Rytidosperma gracile* | 5 | 5 | 6 | 2 | 7 | ns | ** | 24 |
| *Brachyglottis bellidioides* | 6 | 5 | 3 | 4 | 4 | ns | ns | 14 |
| *Geranium microphyllum* | 6 | 5 | 4 | 5 | 2 | ns | * | 25 |
| *Deyeuxia avenoides* | 5 | 2 | 2 | 5 | 7 | ns | ** L | 24 |
| *Trifolium dubium* | 10 | + | 4 | 2 | + | ns | * | 15 |
| **(d) Bare ground** | 30 | 27 | 26 | 26 | 25 | * | ns | 27 |

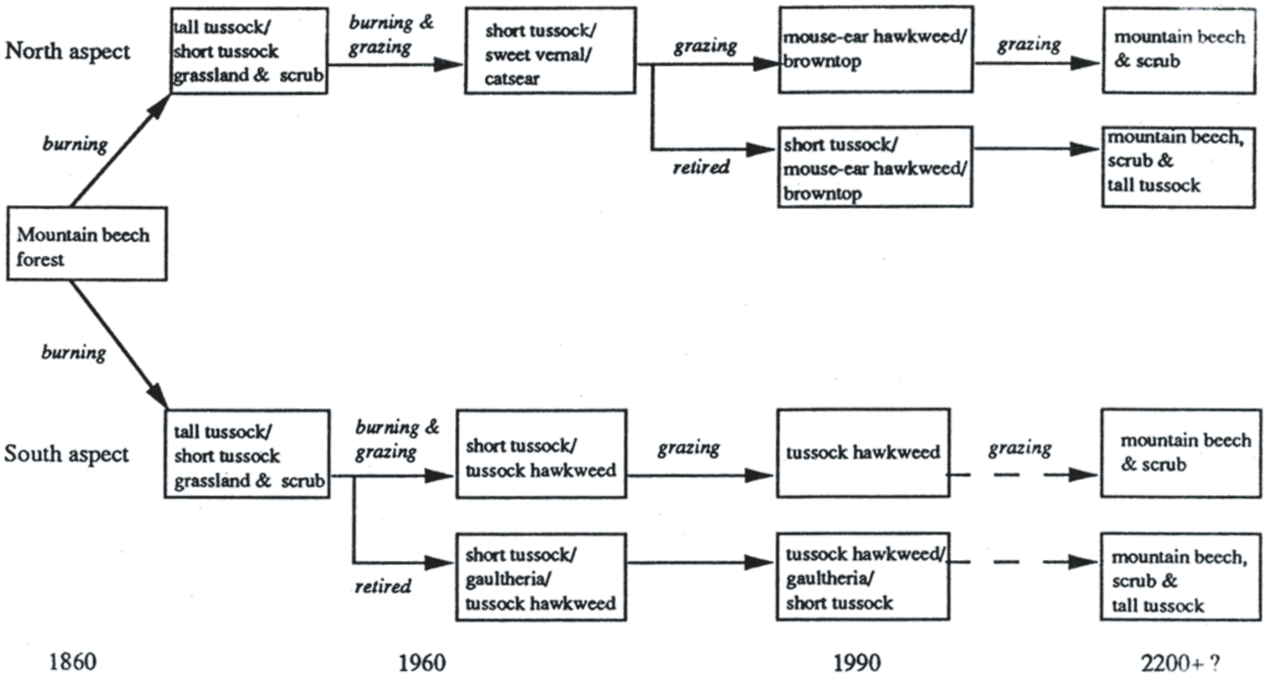


Figure 2. A generalised model of vegetation changes in grazed and retired tussock grasslands of the Harper-Avoca catchment, Canterbury (source: Rose 1992).

## Limitations and points to consider

- Use of Wraight transect frequency data alone successfully identified the dynamic changes occurring in these grasslands. The main pathway of change on both grazed and retired sites involved a dramatic increase in *Hieracium* weeds and exotic grasses, with corresponding declines in tussocks, native herbs, and formerly abundant exotics.
- The study indicated that removal of grazing alone was unlikely to provide much success in preventing or controlling *Hieracium* invasion of similar short-tussock grasslands.
- In a similar study in Marlborough, Rose et al. (2004) used non-parametric analyses because of highly skewed data and inconsistent sample intervals and dates.

## References for case study B

Rose, A.B. 1992: A general model of past and likely future vegetation changes in grazed and retired tussock grasslands of the Harper-Avoca catchment, 700–1400 m altitude, 1200–1500 mm annual rainfall. In Hunter, G.G.; Mason, C.R.; Robertson, D.M. (Eds): Vegetation change in tussock grasslands, with emphasis on hawkweeds. *New Zealand Ecological Society Occasional Publication No. 2*. Christchurch.

Rose, A.B., Platt, K.H., Frampton, C.M. 1995: Vegetation change over 25 years in a New Zealand short-tussock grassland: effects of sheep grazing and exotic invasions. *New Zealand Journal of Ecology 19*: 163–174.

Rose, A.B.; Suisted, P.A.; Frampton, C.M. 2004: Recovery, invasion, and decline over 37 years in a Marlborough short-tussock grassland, New Zealand. *New Zealand Journal of Botany 42*: 77–87.

# Case study C

**Case study C: rapid short-tussock grassland decline with and without grazing, Marlborough, New Zealand**

## Synopsis

This study illustrates the intensive use of standard Wraight 20 m plots to compare 10-year trends in short-tussock grassland composition inside and outside animal-proof exclosures. To meet the objectives, additional vegetation cover data was collected annually. The grasslands studied were in the early stages of invasion by *Hieracium* species (< 5% *Hieracium* cover).

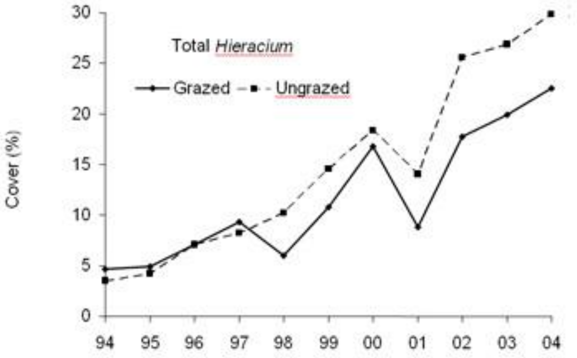
## Objectives

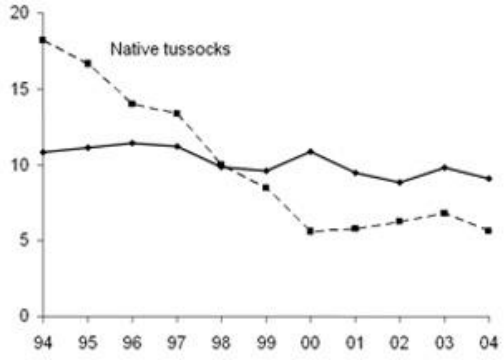
- Does removal of grazing prompt vegetation recovery and inhibit further invasion by *Hieracium* species?
- Is there any evidence that temporal changes in species abundance and species richness reflect changes in *Hieracium* abundance?

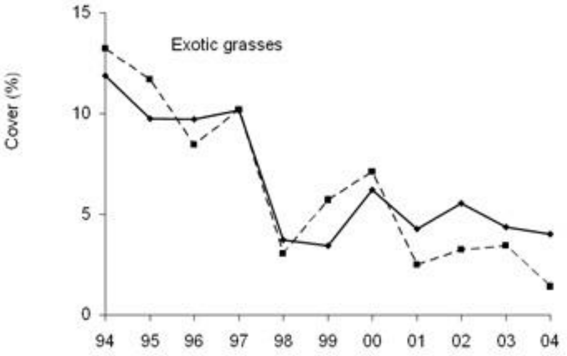
## Sampling design and methods

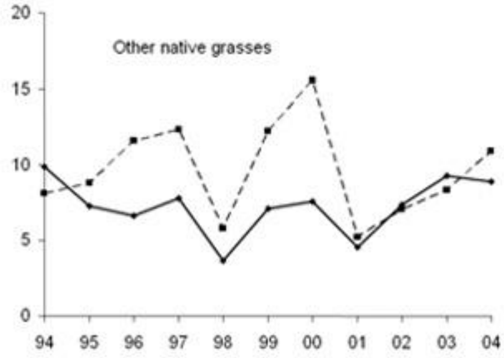
- In 1994, nine study sites were selected along an elevational gradient in the Awatere Valley, Marlborough. The sites sampled the main communities previously identified by ordination of RECCE data (Rose et al. 1998). At each site a 25 × 25 m exclosure was fenced to exclude sheep and feral herbivores. Paired plots were established, with one plot inside each exclosure and one control plot outside in comparable grazed grasslands.
- Species frequencies were measured 5-yearly on standard Wraight 20 m transects. Each exclosure and control plot consisted of three transects, running parallel and 5 m apart (54 transects in total). The presence of all plant species was recorded within 15 cm diameter subplots at 40 cm intervals along the transects (50 subplots per transect; 150 per plot). The presence/absence of different ground cover components was recorded annually as the first point intercept at the centre of each subplot.
- To obtain intensive information on *Hieracium* cover, for each 15 cm subplot the cover of each *Hieracium* species was estimated annually in six standard cover classes (Wiser & Rose 1997).
- To obtain intensive information on cover of all species, a 0.25 $m^2$ gridded quadrat was established at the centre of each transect. This differs from the eight 1 $m^2$ quadrats per plot recommended by Wiser and Rose (1997), but these fewer, smaller quadrats proved adequate for grasslands of relatively low diversity and stature. For each quadrat, the cover of all species, species groups (e.g. tussocks, native forbs, exotic grasses) and ground cover components were estimated annually, using the standard cover classes.

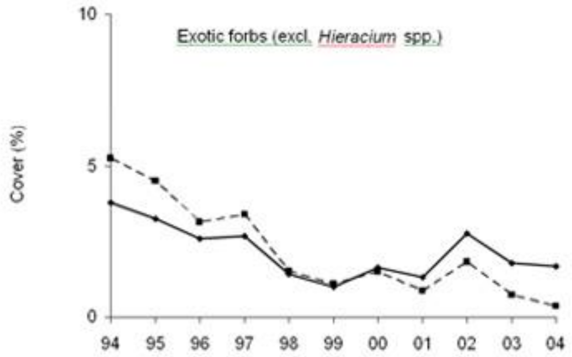
- At establishment, vegetation and site factors were recorded on grassland RECCE sheets and 10 random soil samples were taken per plot.
- Rainfall data was obtained from a nearby recording station.
- Paired *t*-tests were used to compare initial or final means for site and vegetation variables.
- Mixed model ANOVA was used to analyse temporal changes in mean cover, frequency, ground cover, and species richness, and interactions between grazing treatment and time. Site (the paired exclosure and control plots) was a random factor, and time and grazing treatment were fixed effects.
- Net changes in mean cover, frequency, and species richness were also analysed using mixed model ANOVA. These analyses compared only the initial (1994) and final (2004) measurements. The net change resulting from intervention is of direct interest to managers and helps determine whether temporal variation reflects a directional change in composition.
- Mixed model regressions were used to examine whether net increase in *Hieracium* cover predicted net declines in 20 key vegetation variables.

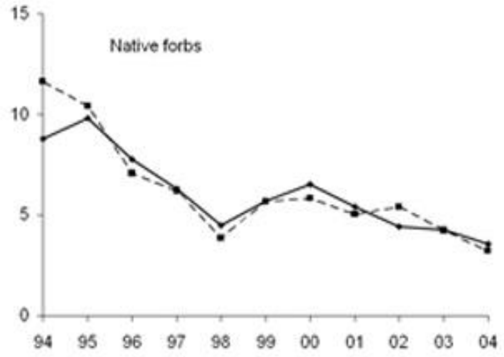


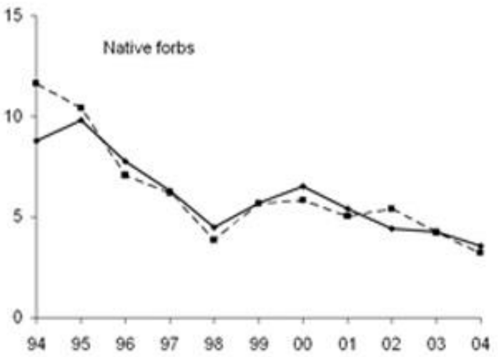


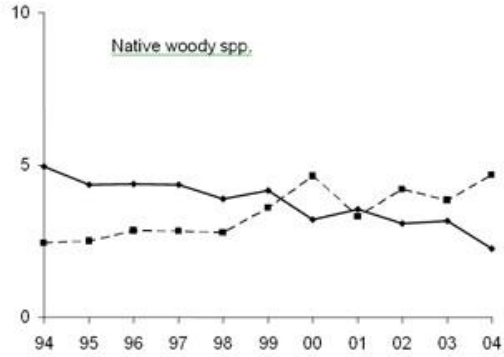


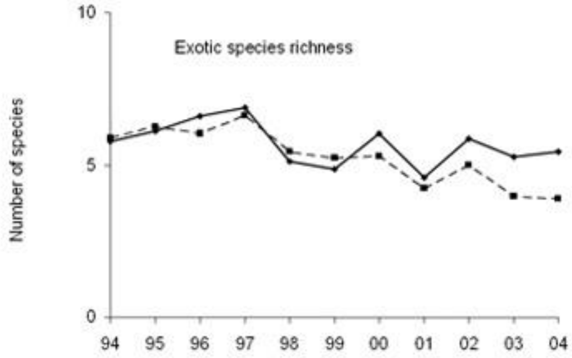


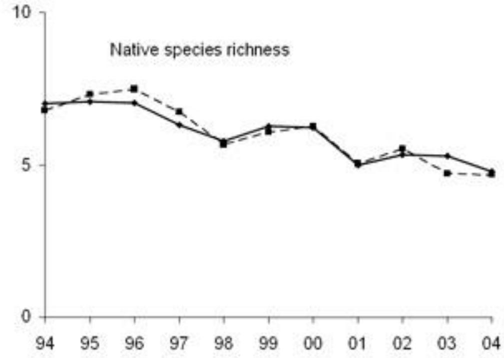

Exotic forbs (excl. Hieracium spp.)
Cover (%)
10
5
0
94 95 96 97 98 99 00 01 02 03 04


Native forbs
15
10
5
0
94 95 96 97 98 99 00 01 02 03 04


Native forbs
15
10
5
0
94 95 96 97 98 99 00 01 02 03 04


Native woody spp.
10
5
0
94 95 96 97 98 99 00 01 02 03 04


Exotic species richness
Number of species
10
5
0
94 95 96 97 98 99 00 01 02 03 04


Native species richness
10
5
0
94 95 96 97 98 99 00 01 02 03 04

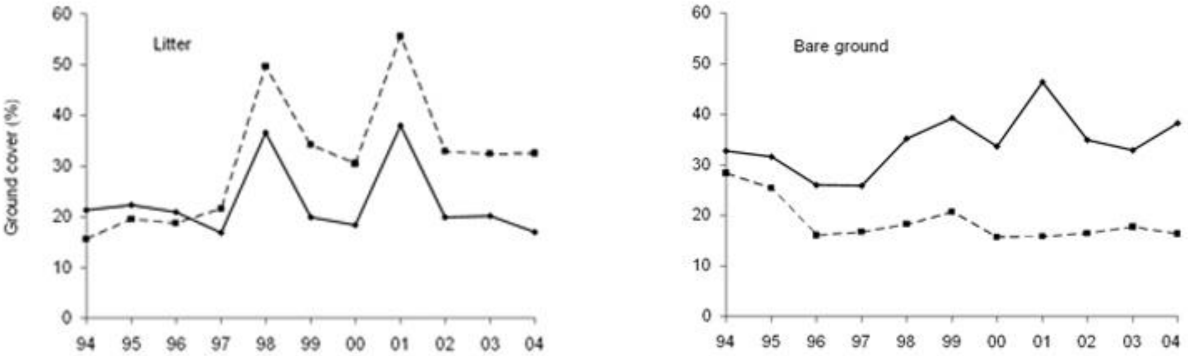


Figure 3. Annual trends in mean quadrat cover, species richness, and ground cover on 9 grazed (solid line) and ungrazed plots (broken line). Note the differing *y*-axis scales (source: Rose & Frampton 2007).

## Results

- The vegetation changed markedly over the 10 years. On the transects, 27 of the 46 most frequent species changed in mean frequency. On the quadrats, 17 of the 21 main species and species groups changed in mean cover (Fig. 3).
- The direction of vegetation change was similar inside and outside the exclosures.
- Species of *Hieracium* increased markedly, e.g. total *Hieracium* cover increased overall from 4% to 26% on the quadrats. On ungrazed plots, rates of increase in *Hieracium* species were either greater than or not significantly different from grazed plots.
- 50% of all native herbs declined. Removal of grazing significantly increased the rate of decline in short tussocks, but had little effect on other native species.
- All measures of species richness declined.
- The amount of bare ground decreased and the amount of litter increased after removing grazing.
- Increase in *Hieracium* was a significant predictor of declines in 13 key vegetation variables, regardless of grazing treatment.

## Limitations and points to consider

- The study design, incorporating paired grazed and ungrazed plots, high sampling intensity, and annual measurements of key parameters was critical in separating out the effects of grazing and fluctuating rainfall on grassland composition, weed invasion, and species richness.
- A similar design could be used for species of special interest in other types of grassland (e.g. highly palatable herbs in tall-tussock grassland).
- The study suggests that competition from *Hieracium* spp. is a direct cause of ongoing declines in short-tussock grassland biodiversity. Other factors are also likely to be involved.
- The study conformed to several others showing there were no significant beneficial effects of removing grazing on short-tussock grassland biodiversity, which is declining with and without grazing.

## References for case study C

Rose, A.B; Basher, L.R; Wiser, S.K.; Platt, K.H.; Lynn, I.H. 1998: Factors predisposing short-tussock grasslands to *Hieracium* invasion in Marlborough, New Zealand. *New Zealand Journal of Ecology 22*: 121–140.

Rose, A.B.; Frampton, C.M. 2007: Rapid short-tussock grassland decline with and without grazing, Marlborough, New Zealand. *New Zealand Journal of Ecology 31*: 232–244.

Wiser, S.K.; Rose, A.B. 1997: Two permanent plot methods for monitoring changes in grasslands: a field manual. Manaaki Whenua – Landcare Research, Lincoln. 51 p.

# Full details of technique and best practice

Full details of the Wraight plot method are described in 'Two permanent plot methods for monitoring changes in grasslands: a field manual' (Wiser & Rose 1997). The complete Wraight plot consists of a 20 m or 40 m frequency transect plus eight optional photocentres or 1 $m^2$ quadrats used to assess cover and tussock biomass within a 20 × 20 m plot. When measuring plots, always measure the frequency transect. It is recommended that you seek advice before collecting the optional data, which requires an approximate doubling of resources. For RECCE plot descriptions, consult the expanded and field versions of the protocol (Hurst & Allen, 2007b,d).[8]

## To establish a Wraight plot:

(a) Frequency transect and RECCE plot:

- Mark the plot origin with a permanent peg, run out a 20 m tape directly downhill and permanently peg it at 20 m. Use four more 20 m tapes and pegs to define a 20 × 20 m quadrat surrounding the first tape, which now forms the central tape in the plot. Ensure the central tape intersects the top and bottom horizontal tapes at their 10 m marks and the quadrat is square (use a compass if necessary).
- The core species frequencies and point intercept ground cover are sampled in 50 subplots defined by a 15 cm diameter steel ring placed at 40 cm intervals along the central tape (e.g. centred on 40 cm, 80 cm, 120 cm, etc.). Lower a pen vertically down at the centre of the ring and record the first ground cover component that it intercepts, as either vegetation, litter, bare ground, broken rock, rock, scree, erosion pavement, or in rare cases water. Then record the presence of all plant species rooted in or overhanging the vertical projection of the ring. Do not record a species as overhanging if it has already been recorded as rooted.
- Transects established before about 1969 are 40 m long with 100 subplots (Wraight 1960, 1962, 1963; Rose et al. 1995, 2004). Always remeasure the full length of the original transect and check the plot sheets to ensure transects are remeasured in the same direction as in the original survey. Usually the 20 m mark was considered the plot origin, and transects were measured downhill (0 to −20 m) and uphill (0 to +20 m) from that mark. If a 20 × 20 m plot has been

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[8] See 'Manuals, sheets and tools' at http://nvs.landcareresearch.co.nz/

superimposed on an original 40 m transect, the plot layout will be described and sketched on the plot sheets.

- It is now standard practice to complete a bounded 20 × 20 m RECCE description for each plot (Hurst & Allen 2007a; Wiser & Rose 1997). The RECCE description lists plot location and observer details, site factors such as slope and elevation, and cover estimates by height tier for all species present in the plot. Electronic copies of the non-woody RECCE datasheets are available on the Landcare Research website. Note that height tiers used for grasslands are different from those specified for forests. Historically, 'Plot Description Sheets' were filled in for all grassland plots and contained some of the information now used in RECCE description sheets (Allen et al. 1983).

(b) Optional cover and tussock biomass measurements:

- Optional photocentres or 1 m$^2$ quadrats are used to assess cover at eight permanently pegged, random points within the 20 × 20 m plot. For the coordinates of these points see Wiser & Rose (1997). Historically, stereophotos have been the main cover technique and can provide important information on changes in cover extending back as far as the late 1960s (Rose & Platt 1987—see 'Case study A'). Both methods have limitations (see below) and are not directly comparable. When remeasuring plots with stereophotos either re-photograph them, or establish new 1 m$^2$ quadrats and also re-photograph the stereophotos to maintain continuity. Stereophoto equipment consists of a camera with a wide angle lens facing the ground on a purpose-built tripod (see Wiser & Rose 1997, p. 21 for details). The vegetation is photographed using pairs of colour transparency or digital photographs taken from approximately 1 m above the ground and parallel to the ground surface. Photographs cover approximately 1–2 m$^2$ but the exact area varies with the height of the tripod and the vegetation. Visually estimate the percentage cover of all species and ground cover components present in the photographs using the standard six cover classes (Wiser & Rose 1997). Observer variability is reduced by using the same observer or team of observers within and between measurements. When analysing temporal change, a conservative approach is taken by simultaneously comparing the same photocentres from each survey. Stereophoto cover has also been analysed by superimposing a point analysis grid on the images (Allen et al. 1983), but this time-consuming technique is generally not warranted. Stereophotos have been widely used in all types of grassland, but can be limited by weather conditions, can confound height and cover, and vegetation beneath the canopy is not visible. They are therefore best suited to short vegetation (< 0.5 m). In taller vegetation (> 0.5 m) it may be better to use 1 m$^2$ quadrats and estimate species and ground cover directly, using the standard six cover classes (Wiser & Rose 1997). Note that total species cover can add up to more than 100% when the vegetation is multilayered. The main advantage of cover quadrats is that all species can be readily identified, but the disadvantage is that biases in subjective cover estimates cannot be evaluated between remeasurements, therefore only gross changes can be relied on.
- The relative biomass of tussocks can be assessed by measuring tussock distance, height, and diameter. The distance from the photocentre peg to the nearest tussock is measured, along with the diameter and height of the tussock. The distance from that tussock to its nearest conspecific neighbour is then measured and the height and diameter measurements are repeated for the

second tussock. These measurements are only applicable when individual tussocks are clearly distinguishable. See Wiser & Rose (1997) p. 24 for method details.

## References and further reading

Allen, R.B.; Rose, A.B.; Evans, G.R. 1983: Grassland survey manual: a permanent plot method. *FRI Bulletin 43*. Forest Research Institute, Christchurch. 71 p.

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# Appendix A

The following Department of Conservation documents are referred to in this method:

| | |
|---|---|
| docdm-39000 | National Vegetation Survey (NVS) databank data entry, archiving and retrieval standard operating procedure |
| docdm-53429 | NVS metadata sheet |
| docdm-359575 | Vegetation: RECCE plots |
| docdm-146272 | Standard inventory and monitoring project plan |