Vegetation: RECCE plots

Version 1.0

This specification was prepared by Kate McNutt in 2012.

Contents

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Synopsis

Reconnaissance plot descriptions (RECCEs) are a versatile technique used for inventory and monitoring in a wide range of vegetation types. The RECCE method is derived from relevé (or 'sample stand') methods, which are simple approaches for describing floristic composition. Relevés were developed in Europe to quickly sample and classify large tracts of vegetation and have been widely adopted throughout the world, including in New Zealand (e.g. Connor 1964; Wardle et al. 1971). Relevé plots do not have a prescriptive size or shape, but a recommended rule of thumb is: their size should reflect the height of the canopy (Hutcheson et al. 1999) and the life form(s) of the dominant species, e.g. smaller plots would be used for a short herbfield than a tall forest. Plot size is largely determined by the concepts of species area curves and minimal area. These suggest an eventual levelling-off in the number of species encountered as plot size increases (although both concepts have been shown to be somewhat arbitrary; Kershaw 1973; Mueller-Dombois & Ellenberg 1974). The ideal plot size is the smallest required to sample all species present; thus sufficient numbers of plots will adequately sample the composition of the community. For each relevé, the composition and structure of the vegetation is assessed using subjective quantitative techniques. Subjectively estimated Braun-Blanquet cover-abundance scores are assigned to each species present, with separate values for each layer or 'height tier' it occupies. Estimates of cover abundance more closely reflect the biomass of a species than the number of plants present (Elzinga et al. 1998). Environmental and site factors are usually assessed concurrently, because of their important influences on community composition and structure.

For RECCE plots in New Zealand (Hurst & Allen 2007c,d) the cover-abundance of all species present is assessed in six standard height tiers (the height tiers differ for woody and non-woody vegetation). Six standard, simplified Braun-Blanquet cover-abundance classes are used (< 1%, 1–5%, 6–25%, 26–50%, 51–75%, 76–100%). Because communities are often multilayered, total cover can exceed 100%. Depending on study objectives, RECCEs can be bounded or unbounded and permanently or temporarily located. The specific application of the RECCE method that is chosen has important implications for the types of analysis that can be performed on the data.

Variable area (or 'unbounded') RECCE plots are more rapid but also less accurate. They are best suited to initial inventory, where there is no intention to remeasure. The size and shape of variable area RECCE plots is determined in the field and is judged to be large enough to contain most species present in the plant community, but must be also small enough to sample uniform vegetation and landform in the plot.

RECCE plot surveys need to be well designed in order to interpret the main causes for compositional change; the results from a well-designed study are also less likely to be challenged. RECCE plot surveys with carefully formulated objectives can address questions such as:

- What vegetation associations are present in a study area?
- Do the vegetation associations differ between and within study sites, and how does composition differ?
- What are the main site factors affecting the distribution of plant species and communities?

- What are the representative vegetation types?
- How have herbivore pests affected vegetation composition and structure?

RECCE plots are commonly used to inventory indigenous vegetation. Typical aims include vegetation typing, mapping, or stratification of the vegetation before initiating more quantitative monitoring with permanent plots (Hurst & Allen 2007a,b). To analyse and describe the vegetation pattern, two main types of approach can be used together or independently. Classification groups plots with similar species composition into distinct associations or communities, while ordination/gradient analysis extracts the main axes of compositional change and places the plots along them so that compositionally similar plots are close to each other. Results of these analyses reflect the presence or absence of species as well as the cover abundance scores. The distribution of plant communities or the ordination coordinates of plots are compared with the site factors in order to infer the causes for spatial changes in species composition, such as elevation, aspect, slope, landform, physiography, soil moisture and soil fertility (Wardle et al. 1971; Wardle et al. 1973; Burns & Leathwick 1996; Stewart et al. 1987; Stewart et al. 1993; Rose et al. 1998; Bellingham 2001).

RECCE plots have also been widely used in Protected Natural Area Programme (PNAP) surveys (Myers et al. 1987) to help identify Recommended Areas for Protection based on representative vegetation types (Mark et al. 1989). RECCE surveys are often used to help interpret patterns of herbivore-induced modification on vegetation associations, in combination with estimates of animal pest impacts (e.g. browse indices) and animal pest population density (e.g. pellet counts) (Wardle et al. 1971; Wardle et al. 1973; Nugent et al. 1997; Bellingham & Allan 2003).

It is important to recognise that natural processes are also important influences on patterns of vegetation structure and composition, and not to assume that all observed patterns are directly caused by animal browse. As well as one-off assessments, RECCE plots have been used to examine temporal patterns of vegetation change in New Zealand. Bounded, fixed area and permanently marked RECCE plots are more accurate and are recommended when absolute comparisons of species richness per unit area are required for assessing changes between sites or within sites over time. Temporal patterns can be interpreted with more confidence if bounded RECCE plots are combined with additional quantitative data on plant populations, such as total counts, density and frequency.

Thus, bounded RECCEs are a mandatory component of the following methods in New Zealand:

- permanent 20 × 20 m forest plots (Hurst & Allen 2007b)
- permanent Wraight grassland plots (Wiser & Rose 1997)
- permanent Scott height frequency transects (Wiser & Rose 1997)

Two versions of the New Zealand RECCE protocol are available: a compact field version, and an expanded version that has additional information about survey design and sampling (Hurst & Allen 2007c,d).[1] RECCE data are stored and curated by the National Vegetation Survey (NVS) databank managed by Landcare Research at Lincoln, Canterbury.

[1] Refer to 'Manuals, sheets and tools' at http://nvs.landcareresearch.co.nz/

Assumptions

- All species present are recorded.
- All species are equally observable, i.e. rare or cryptic species are able to be recorded.
- For inventory, plot size is large enough to sample most or all species present.
- Observer accuracy is similar between areas and over time.
- At least some of the recorded site factors have a dominant influence on vegetation composition or are correlated with the main environmental and disturbance gradients influencing vegetation composition.

Advantages

- RECCEs are versatile and adaptable to many study questions and most vegetation communities.
- Plots are relatively cheap and quickly measured (but effort increases with increasing plot size and species diversity).
- Able to rapidly survey complex vegetation and can evaluate species within a tiered structure.
- Useful method even when individuals cannot be consistently identified and counted.
- Cover abundance is correlated with biomass (see Nordmeyer & Evans 1985).
- Increased likelihood of recording rare species compared with other methods, because every species present must be assigned a cover-abundance score regardless of how frequently it occurs in the plot.
- Species of all life forms are recorded, some of which (e.g. lianas) may be under-represented using other methods (e.g. stem diameters in permanent plots).
- The existing large national network of RECCE plots enhances comparability between sites at different spatial and temporal scales, depending on the objectives of the study.

Disadvantages

- Subjective cover abundance estimates are imprecise with an unknown level of observer bias and are only capable of detecting large spatial or temporal trends, e.g. observers may overestimate conspicuous species, or cover values may change with natural seasonal fluctuations in growth.
- Variable area, unbounded RECCE plots are imprecise and provide a limited range of valid comparisons between and within sites.
- Can not be used to assess temporal or spatial changes in plant density or in the size of individual plants.
- An inconsistent level of 'taxonomic resolution' for repeated measurements on bounded RECCE plots will render studies incomparable for absolute measures of species richness per unit area.

Suitability for inventory

RECCE plots are an excellent tool for inventory and they were principally developed to rapidly survey habitats and identify the plant communities present at one point in time. They can be relatively quick to carry out and collect comprehensive and detailed information on species composition, species abundance, vegetation structure, and site factors. Because all species are listed, they help to identify the distribution of uncommon and rare species.

Suitability for monitoring

RECCE descriptions can be used to identify broad temporal trends, but are not advocated as a stand-alone method for monitoring. Subjective cover scores are semi-quantitative estimates with unknown observer bias and are only capable of detecting large trends. Estimated cover must change by two classes before the result can be relied on (Elzinga et al. 1998; Payton et al. 1998).

Temporal trends in RECCE data are best identified if bounded, fixed-area plots are used and if data are interpreted in combination with other quantitative vegetation monitoring data (e.g. permanent 20 × 20 m forest plots), covariate data on pest animal abundance (e.g. faecal pellet counts) and other habitat and site condition assessments.

Skills

- Training is now compulsory for all DOC staff that apply RECCE plots in the field—even if you have been doing this work for many years you still need to undertake training. Please refer to DOC's field based courses [2]for more information.
- High level of botanical expertise. Many RECCE plots have been carried out by observers who assume that it is either unimportant, or too difficult, to conduct exhaustive species descriptions. For example, many observers have been content to record 'grass spp.', '*Uncinia* spp.' or '*Hymenophyllum* spp.'. Some have even thought it unimportant to record alien species. This can preclude the utility of RECCE plots in meta-analyses or to address questions that were not foreseen at the time.
- A good level of navigational and general bush skills.
- Specialist skills in data analysis are required.
- A background in plant ecology is essential for the interpretation of data.
- Practice is needed to estimate cover abundance scores and height tiers.

Resources

- A single observer can carry out a RECCE description, although two people make it easier and faster and minimises observer bias in cover abundance scores and height tier estimates.

[2] http://www.doc.govt.nz/getting-involved/get-trained/field-based-courses/20-x-20-plots-and-reconnaissance-descriptions/

- The amount of time to measure a RECCE plot varies greatly because it depends on the diversity of the vegetation, experience of field teams and plot size. A simple RECCE can be completed in less than 1 hour, more complicated RECCEs may take longer than 2 hours.
- Standard field equipment includes maps, datasheets, clipboard, compass, pens, pencils, GPS, compass, binoculars, cruise tape, plant identification books, clinometer or abney level, altimeter, Foliar Browse Index foliar cover sheets (docdm-115014), collection bags and labels. Hurst & Allen (2007c,d) have a full list of equipment for field teams.
- Take a copy of the most up-to-date plant species codes from Landcare Research with you into the field.[3]
- For correct standards and procedures for archiving and retrieval of permanent plot datasheets and electronic data, consult the DOC standard operating procedure (SOP) 'National Vegetation Survey (NVS) databank data entry, archiving and retrieval standard operating procedure' (docdm-39000).
- For previously measured plots, it is essential to have copies of the original datasheets. Datasheets from previous measurements 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.[4]
- 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.[5]
- RECCE plot data can now be entered using NVS Lite, an interface where plot data can be entered by staff into fields and electronically submitted to Landcare Research. Otherwise Landcare Research can enter data promptly for a fee. Refer to 'Data storage' for more details on entering and submitting RECCE plot data.
- 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'.

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

All datasheets can be accessed from Landcare Research for RECCE in permanent plot forest, non-permanent plot forest and non-forest.[6]

[3] Refer to 'NVS plant names and maps' at http://nvs.landcareresearch.co.nz/
[4] Refer to 'Requesting data' at http://nvs.landcareresearch.co.nz/
[5] Refer to 'Interactive plot location maps' at http://nvs.landcareresearch.co.nz/
[6] Refer to 'Manuals, sheets and tools' at http://nvs.landcareresearch.co.nz/

Plot details:

- RECCE identifier
- Survey
- Region
- Catchment
- Sub-catchment
- Measurer
- Recorder
- Date
- Aerial photo name
- Topographic map
- GPS make
- GPS model
- GPS reference
- GS 2D or 3D fix
- Datum

Site factors

- Plot layout (tape lengths, direction) or size of RECCE
- Altitude (m)
- Physiography (ridge, face, gully, terrace)
- Aspect (degrees)
- Slope (percent, convex, concave, linear)
- Parent material (from map or observed)
- Drainage (good, medium, poor)
- Cultural (none, burnt, logged, cleared, mined, grazed, tracked)
- Approach
- Notes
- Surface characteristics (percentage bedrock, percentage broken rock, size of rock (< 30 cm, > 30 cm))
- Soil (alluvial, colluvial, moraine or volcanic)
- Mesoscale topographic index (N, NE, E, SE, S, SW, W, NW)
- Percentage groundcover (vegetation, non-vascular, litter and bare ground)
- Average top height (m)
- Canopy cover (percentage)
- Browse (herbivore species and severity—high, medium, low)

Cover abundance assessments:

- RECCE plot identifier
- Date
- Measurer
- Recorder

- For woody vegetation, assess the cover abundance of vascular species in the following height tiers: 1 (> 25 m), 2 (12–25 m), 3 (5–12 m), 4 (2–5 m), 5 (0.3–2 m), 6 (< 0.1 m), 7 (epiphytes). Use the standard six letter species code.
- For non-woody vegetation, assess the cover abundance of vascular species in the following height tiers: 3 (5–12 m), 4 (2–5 m), 5a (1–2 m), 5b (0.3–1 m), 6a (0.1–0.3 m), 6b (< 0.1 m), 7 (epiphytes). Use the standard six letter species code.
- Use the following cover abundance categories: 1 (< 1%), 2 (1–5%), 3 (6–25%), 4 (26–50%), 5 (51–75%), 6 (76–100%).
- Record the following common and widespread non-vascular species as a minimum:
  - *Atrichum androgynum*
  - *Cyathophorum bulbosum*
  - *Dawsonia superba*
  - *Dendroligotrichum dendroides*
  - *Dicranoloma*
  - *Leucobryum candidum*
  - *Ptychomnion aciculare*
  - *Sphagnum*
  - *Weymouthia cochlearifolia*
  - *Weymouthia mollis*

Optional site factors that may enhance data interpretation include:

- Soil (e.g. fertility, soil profile descriptions)
- Disturbance history (e.g. grazing, burning, roading, skiing)
- Specific plant attributes (e.g. tussock flowering intensity, tussock nutrient status)
- Animal 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 permanent plot data, consult the 'NVS databank data entry, archiving and retrieval standard operating procedure' (docdm-39000). The SOP describes the protocols for submitting and retrieving RECCE plot data from NVS.
- RECCE plot data can now be entered using NVS Lite, an interface where plot data can be entered by staff into fields and electronically submitted to Landcare Research. NVS Lite is available from Landcare Research.[7] DOC staff must request for NVS Lite to be loaded onto their computer from DOC's network administrator. Otherwise, you must budget for data entry costs by Landcare Research.
- 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).

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

- 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

Overall analytical approaches

The approach to data analysis depends on the objectives of the monitoring programme. It is imperative that monitoring objectives are clearly stated before undertaking any analysis. The time and resources that are needed to undertake analysis of RECCE data are substantial, but they are routinely underestimated. Advanced data handling and analytical skills are necessary to process and interpret this data. Inadequate training in the analysis packages is thought to be an impediment to routine analysis of plot data (Richardson et al. 2005).

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 Lite or through other avenues (see 'Data storage'). Should any errors be identified, or corrections made to RECCE data supplied by NVS, it is important to lodge any 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.

For RECCE plot data, the analysis program PC-RECCE has been specifically tailored for RECCE data. Like any analysis package, it requires training and expertise to use proficiently. The program uses data entered in a standard ASCII text file format and runs under MS-DOS. If PC-RECCE is to be used, then data must be obtained in the appropriate file format from the NVS databank. PC-RECCE is available for DOC staff on request from the network administrator. Manuals for the PC-RECCE (Hall 1992) can be obtained free-of-charge from Landcare Research. These manuals outline the file formats needed and the various summary statistics and analyses available. The programs are rather clunky and lack flexibility, but there are plans by Landcare Research to develop an updated set of analysis tools as part of the ongoing upgrade of the NVS databank and NVS Lite. It is anticipated that summaries will be capable of visualising the data summary results. This will include, as a minimum, the ability to graph relationships between any variables calculated by the summaries.

Data from NVS can be made available to users in several other formats including MS-Excel, and analyses of data can be run in statistics programs such as R, S-Plus, SPSS, etc.

RECCE data analyses are often used to stratify habitats into similar vegetation associations to target more intensive monitoring. Analysis of vegetation compositional patterns and how composition changes with environment falls into two main groups of analysis: classification and ordination. Both approaches are complementary because stands can be classified and then ordination applied (Mueller-Dombois & Ellenberg 1974).

Classification (or clustering)

Classification (or clustering) groups individual plots by their compositional similarities and dissimilarities, and is useful when describing compositional patterns. PC-RECCE groups plots using the cover abundance estimates and site factors. Analyses can take place on data at the species level (species lists, species distributions and correlations with site factors) and community level (forest types and their correlation with site variables).

Ordination

Ordination techniques attempt to explain compositional patterns as a function of other variables, usually environmental (e.g. altitude, soil fertility). It assesses the degree of association within and between plant communities (and species) and their environment.

A large range of software is available for implementing a myriad of classification and ordination techniques. Many analyses of this type are best undertaken using specialised software packages (e.g. PC-ORD, Canoco, R (specialised packages exist), Decorana, TWINSPAN). Analysts interested in such approaches should consult the large literature on these topics, including the reference material listed below and relevant websites.[8] Only one such function, TWINSPAN, is available through PC-RECCE. Detrended Correspondence Analysis (DCA) groups similar plots together and TWINSPAN analysis can explore the factors that drive differences between the groups (e.g. Husheer 2005).

Useful reference material on classification and ordination to consult includes:

Lepš, J., Šmilauer, P. 2003: Multivariate Analysis of Ecological Data using Canoco. Cambridge University Press, Cambridge.

Gauch, Jr., H.G. 1982: Multivariate Analysis in Community Structure. Cambridge University Press, Cambridge.

Økland, R.H. 1990: Vegetation ecology: theory, methods and applications with reference to Fennoscandia. *Sommerfeltia Supplement 1*: 1–233.

Jongman, R.H.G.; ter Braak, C.J.F.; van Tongeren, O.F.R. 1987 (Eds.): Data analysis in community and landscape ecology. Pudoc, Wageningen. (Now available in a 1995 edition by Cambridge University Press.)

Legendre, P.; Legendre, L. 1998: Numerical ecology (second English edition). Elsevier, Amsterdam. 853 p.

ter Braak, C.J.F.; Šmilauer, P. 1998: CANOCO Reference manual and user's guide to Canoco for Windows: software for canonical community ordination (version 4). Microcomputer Power, Ithaca, New York. 352 p.

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

Case study A

Case study A is pending.

Case study B

Case study B: community structure and forest invasion by an exotic herb over 23 years

Synopsis

This study examines community and site factors affecting the invasion of a mountain beech forest by the exotic perennial herb *Hieracium lepidulum* over 23 years. The 9000 ha study area is in the Harper and Avoca catchments, inland Canterbury. The study uses data from 250 20 × 20 m permanent forest plots (Hurst & Allen 2007a) with associated 20 × 20 m RECCE plot descriptions (Hurst & Allen 2007b), measured in 1970, 1985, and 1993. The study highlights the interpretive value of repeated measurements of composition, tree diameter and understorey subplots, combined with detailed data on environmental factors, plot location, and disturbance history. For each year of measurement, invasion patterns were examined in relation to forest community structure, disturbance history, environmental factors, and distance from potential seed sources. Data was analysed using Wilcoxon rank-sum tests, Wilcoxon signed-ranks tests, and multiple logistic regressions. The main aim was to test the widely held view that species-poor habitats are more prone to invasion by exotic species. Mountain beech forest provides an ideal opportunity to determine whether low species richness promotes invasion as 17% of the 250 plots contained < 5 vascular plant species.

Objectives

The objectives of the study were to determine how invasibility is related to:

- Community structure, including species richness and the occurrence of species in the same morphological guild as *H. lepidulum*
- Disturbance history, as indicated by changes in tree biomass
- Characteristics of the physical environment
- Distance from potential seed sources

Sampling design and methods

- In 1970, permanent 20 × 20 m forest plots and associated RECCE plots were established at 250 sites located at 200 m intervals along 98 random compass lines that ran uphill from stream channels to treeline.
- In 1970, 1985 and 1993 all tree diameters were measured and understorey composition was sampled on twenty-four 0.75 m^2 circular subplots per plot.

- 20 × 20 m RECCE plot descriptions listed all species present on 217 randomly selected plots in 1970, and all 250 plots in 1985 and 1993. For each plot, cover abundance estimates were assigned to all species present (including *Hieracium*) in seven height tiers.
- Grid references and standard site factors were recorded for each plot. Potential solar radiation was calculated from aspect and slope. The *x*-coordinates of grid references were used as surrogates for the west–east decline in rainfall in the study area. Elevation was assumed to predominantly reflect temperature.
- Additional site factors were also recorded, including soil fertility, site protection/shelter, and distance from the forest margin. In 1992 eight soil samples (10 cm deep) were systematically collected from each plot, bulked, and analysed for pH, exchangeable cations (Ca, Mg, K), P, N, and C. N availability was estimated from C:N ratios. An index of site protection/shelter was calculated, using eight systematic measurements of the angle from the centre of the plot to the horizon. For example, gullies were the most sheltered and ridge crest the most exposed. The closest distance from the plot to non-forested areas below treeline (the most likely initial source of *H. lepidulum* propagules) was measured using NZMS 260 topographic maps (compiled in 1988).
- For each plot and subplot, two community structure attributes were determined: species richness (number of species) and the proportion of the total species in the same morphological guild as *H. lepidulum* (i.e. herbaceous species > 100 mm in height).
- Initial tree biomass in 1970 was used as an indicator of site occupancy, while change in biomass between measurements was an indicator of the disturbance history (Wardle 1984; Harcombe et al. 1998).
- Factors related to *H. lepidulum* invasion were determined by comparing community structure, disturbance history, environmental factors, and distance to initial seed source for invaded v uninvaded plots (Wilcoxon rank-sum tests) and subplots (Wilcoxon signed-ranks tests for paired comparisons).
- Multiple logistic regression was used to determine which combinations of recorded site variables best predicted *H. lepidulum* presence, whether the relationship changed over time, and whether *H. lepidulum* presence reflected community structure regardless of site conditions.

Results

- *H. lepidulum* occurred on 11%, 43%, and 57% of 20 × 20 m RECCE plots measured in 1970, 1985, and 1993 respectively, and once established it usually persisted and increased, e.g. in 1993 it remained on 85% of those plots where it occurred in 1970 (Fig. 1).
- In 1970, invaded plots had more species, a higher percentage of species in the tall herb guild, lower potential solar radiation, and were closer to forest margins than plots without *H. lepidulum* ($P < 0.05$; Table 1). After 1970, *H. lepidulum* continued to invade plots and subplots with high species richness and a high percentage of species in the same guild, but invaded plots were now significantly further from the forest margin than those initially invaded, and there was no relationship with potential solar radiation (Table 1).
- In 1985, invaded plots were further distinguished as occurring at lower elevations, on more sheltered topography, and having lost more tree biomass between 1970 and 1985 compared

with uninvaded plots. Elevation and topographic differences persisted until 1993; by then invasion was more common on the western, wetter side of the study area (Table 1).

- In 1993 when soils data were collected, invaded plots had significantly higher soil fertility as indicated by higher N, Ca, Mg, P and lower C:N ratios than uninvaded plots (Table 1).
- *H. lepidulum* occurrence was best predicted by community structure attributes (species richness and percentage of tall herb species; Table 2). Less important variables included distance to forest margin and potential solar radiation (in 1970), elevation (1985, 1993), and soil fertility (1993). The two community attributes explained variation in *H. lepidulum* occurrence above and beyond that explained by other site factors.
- The predictability of the invasion increased over the study period (Table 2).

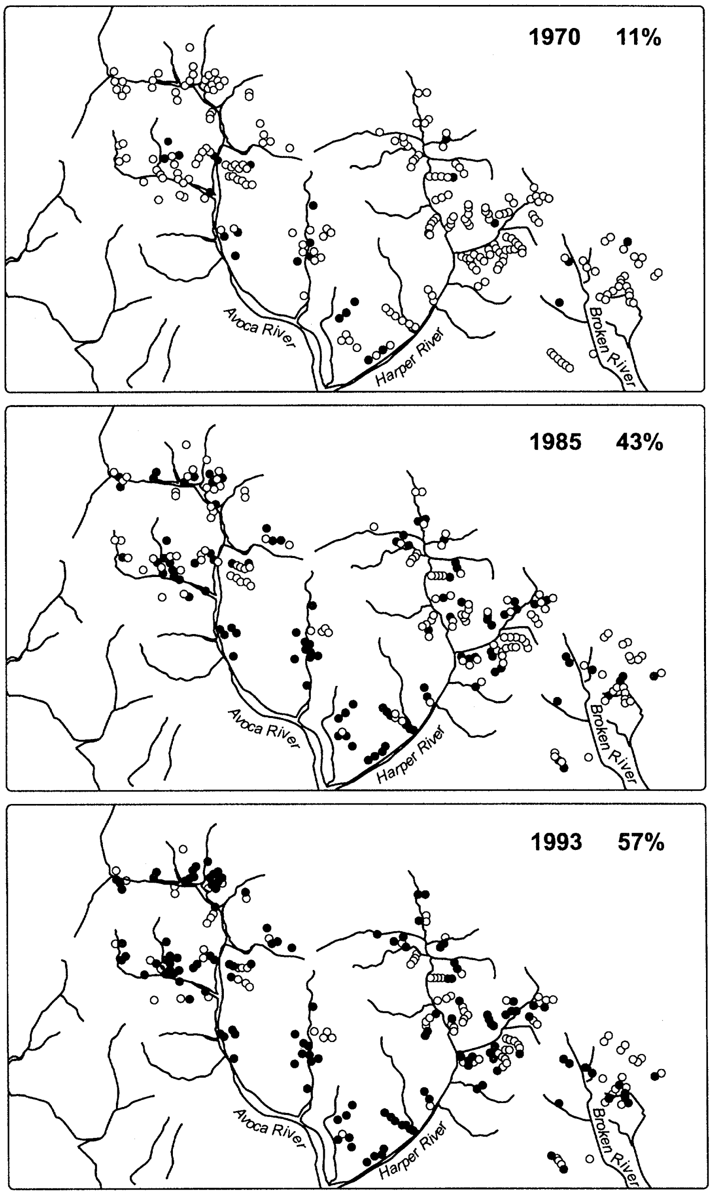

Figure 1. Progress of *Hieracium lepidium* invasion into the area. Plots invaded 1970, 1985, 1993 are indicated by black dots, those not invaded are clear dots. The percentage of plots invaded is also given for each year (source: Wiser et al. 1998).

Table 1. Mean of site variables invaded by *Hieracium lepidium* and not invaded in 1970, 1985 and 1993, the number of plots (*N*) and significance (*P* values from the Wilcoxon sum rank test, Bonferroni adjusted) (source: Wiser et al. 1998).

	1970			1985			1993		
Site variable†	Invaded (N = 24)	Uninvaded (N = 193)	P	Invaded (N = 107)	Uninvaded (N = 142)	P	Invaded (N = 143)	Uninvaded (N = 107‡)	P
Community structure									
Richness	13.2	8.1	<0.0009	15.3	6.1	<0.001	21.2	7.3	<0.0018
Guild (%)	23	12	<0.0009	29	12	<0.001	25	8	<0.0018
Site characteristics									
Elevation (m)	1003	1059	NS	999	1086	<0.001	1018	1090	0.0216
Solar ($MJ \cdot m^{-2} \cdot yr^{-1}$)	7770	9560	0.024	8960	9660	NS	8980	9860	NS
Slope (°)	31	30	NS	29	30	NS	30	28	NS
West–East	5043	5074	NS	5056	5075	NS	5052	5086	0.009
Protection index	21.8	20.5	NS	21.9	19.9	0.009	21.9	19.1	<0.0018
Ca (μg/g)							921	403	<0.0018
K (μg/g)							99	100	NS
Mg (μg/g)							107	70	<0.0018
P (μg/g)							26.7	18.4	0.0162
pH							4.19	4.04	NS
N (%)							0.37	0.30	0.0271
C:N							23.9	28.6	<0.0018
Disturbance history									
Biomass 70 (Mg/ha)	180	180	NS	180	180	NS	170	180	NS
Biomass Δ 70–85 ($Mg \cdot ha^{-1} \cdot yr^{-1}$)				−2.24	−1.02	0.033	−1.95	−1.05	NS
Biomass Δ 85–93 ($Mg \cdot ha^{-1} \cdot yr^{-1}$)							0.70	0.64	NS
Spatial influences									
Distance (m)	90	155	0.038	130	150	NS	130	150	NS

† Site variable abbreviations are as follows: Richness, species richness; Guild, percentage of the total species (excluding *H. lepidulum*) in the tall herb guild in 1970, 1985, and 1993, respectively; Solar, annual potential solar radiation; West–East, grid reference x coordinate, with value increasing from west to east; Biomass 70, total plot stem biomass in 1970; Biomass Δ 70–85 and Biomass Δ 85–93 are changes in total plot stem biomass from 1970 to 1985 and from 1985 to 1993, respectively; Distance, distance to the nearest mappable, non-alpine open land.

‡ One plot had aberrantly high values for Ca and another for K. These two plots were deleted from the analysis, so that N = 249 in those two comparisons.

Table 2. Significance (*P*) response curve shape, and initial and final deviance for step-wise regression modules predicting occurrence probability of *Hieracium lepidium* on plots from site variables (source: Wiser et al. 1998).

Site variables†	*P*	Response curve shape	Percentage of deviance explained
1970 (*N* = 217)			
Guild (%)	0.0017	linear (+)	
Distance (m)	0.0110	linear (−)	
Solar ($MJ \cdot m^{-2} \cdot yr^{-1}$)	0.0047	linear (−)	
Initial deviance = 155.0			
Final deviance = 123.8			20.1
1985 (*N* = 249)			
Richness	<0.0001	linear (+)	
Guild (%)	0.0004	linear (+)	
Elevation (m)	0.0077	linear (−)	
Initial deviance = 339.7			
Final deviance = 225.1			33.7
1993 (*N* = 248)‡			
Guild (%)	0.0072	linear (+)	
Richness	<0.0001		
$(Richness)^2$	0.0020	sigmoidal	
Ca (μg/g)	0.0153	linear (+)	
Slope (°)	0.0037	linear (+)	
Elevation (m)	0.0076	linear (−)	
Initial deviance = 339.1			
Final deviance = 170.1 (with Ca excluded)			49.8
Final deviance = 163.5 (with Ca included)			51.8

† Site variables are abbreviated as in Table 1. The percentage of species in the *H. lepidulum* guild was arcsine square-root transformed, and Ca was log-transformed.
‡ Two plots, one with an aberrantly high value for Ca and another with an aberrantly high value for K, were excluded from the analysis.

Limitations and points to consider

- Bounded 20 × 20 m RECCE plots successfully detected the increasing presence and abundance of *Hieracium lepidulum* over 23 years. Additional site factors, including changes in tree biomass recorded on associated permanent plots, were important in interpreting the main factors influencing the invasion.
- The study contradicts the views that species-poor habitats are more susceptible to invasion and that communities tend to be more readily invaded if the invader represents an under-represented growth form.
- Species-rich sites in forests may be more prone to invasion because of a surplus of available soil nutrients.
- Disturbance may promote invasion, but is not a pre-requisite for invasion.
- The predictability of invaded sites increases over time, from an early, unpredictable dispersal-limited stage to a later, more predictable non-dispersal limited stage.

- The exact mechanisms that promote invasion of species-rich sites are as yet unclear and may not apply to all ecosystems.

References for case study B

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Full details of technique and best practice

The RECCE method is fully described in the expanded and field versions (Hurst & Allen 2007c,d).[9]

- Site factors are usually completed first and are recorded on the front page of the RECCE datasheet. Some additional information on the plot layout and tape measurements are required if the RECCE is being carried out on a permanent plot. Document the severity of animal browse on the plot. Record any cultural interference and fauna seen or heard in the general vicinity. On the front page, make a sketch of the route to the plot emphasising prominent landscape and vegetation features, and include a north arrow. The sketches are usually one of the final things completed on a RECCE plot and if time is short, they can be completed and tidied up at base camp.
- Over on the flip side of the datasheet, record the species cover abundance scores. RECCE cover abundance scores are assessed for all vascular species in fixed height tiers. Make a thorough attempt to record all vascular species present. There are height tiers that are applicable for woody habitats (> 25 m, 12–25 m, 5–12 m, 2–5 m, 0.3–2 m, < 0.3 m) and another set of height tiers for non-woody habitats (< 0.1 m, 0.1–0.3 m, 0.3–1 m, 1–2 m, 2–5 m, 5–12 m). Observers visually estimate the cover abundance of all vascular species using a modified Braun-Blanquet cover abundance scale (< 1%, 1–5%, 6–25%, 26–50%, 51–75%, 76–100%).

[9] Refer to ‘Manuals, sheets and tools’ in http://nvs.landcareresearch.co.nz/

When a species is not present in a tier, it is represented by a dash on the datasheet. The protocol has practical tips to assist observers to estimate cover abundances.

- The following common and widespread non-vascular species must also be recorded as a minimum:
  - *Atrichum androgynum*
  - *Cyathophorum bulbosum*
  - *Dawsonia superba*
  - *Dendroligotrichum dendroides*
  - *Dicranoloma*
  - *Leucobryum candidum*
  - *Ptychomnion aciculare*
  - *Sphagnum*
  - *Weymouthia cochlearifolia*
  - *Weymouthia mollis*
- Observers need to routinely calibrate their cover abundance score estimates and height tier estimates to minimise observer bias.
- Cover scores are attributed to species whose living foliage occurs within the plot boundaries including foliage that overhangs it. Cover scores for variable area RECCE plots are generally harder to estimate because the boundaries are not so clearly defined, but observers should estimate cover abundance scores of species in the immediate area of homogenous vegetation and landform.
- Cover abundance scores may exceed 100% because the vegetation is likely to be multi-layered.
- Lianas are assigned cover scores in the height tiers where their foliage is present.
- Epiphytic species are noted on the left hand side of the datasheet and attributed a single cover abundance for entire plot (not in a height tier).
- A total cover abundance score is assessed for each height tier which represents the total cover of all species collectively.
- When absolute comparisons of species richness per unit area are desired to measure change over time a consistently-sized plot is required to allow assessment of change between sites and between measurements.
- Observers often forget to accord cover abundance to epiphytic species which affects measures of change in species richness.

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Appendix A

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

docdm-115014	Foliar Browse Index foliar cover sheets
docdm-39000	National Vegetation Survey (NVS) databank data entry, archiving and retrieval standard operating procedure
docdm-53429	NVS metadata sheet
docdm-146272	Standard inventory and monitoring project plan