Vegetation: seedling ratio index to measure ungulate impacts

Version 1.0

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Contents

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Te Papa Atawhai

Synopsis

This section is a brief overview of the purpose of the method.

This is a best practice guide for DOC staff and other conservation managers to follow when using the seedling ratio index (SRI) method to measure the impact of deer, goats, and other ungulates on seedling regeneration in woody vegetation.

The method provides a tool to rapidly assess regeneration patterns within tall (> 2.0 m) woody vegetation. It is not suitable for monitoring short vegetation dominated by non-woody species or where vegetation stature is suppressed by harsh environmental conditions such as in alpine areas, on frost flats, or in wetlands. Its primary purpose is to assess the extent to which ungulates are suppressing seedling growth. It is mostly used to assess the need for, or the short-term outcomes of, ungulate population control in forests.

Seedling ratios provide a lower cost alternative to vegetation assessments on permanent plots (e.g. 20 × 20 m permanent plot method; Hurst & Allen 2007) that measure seedling, sapling, and taller tier density (stem counts and stem diameters). Instead, seedling-ratio surveys only record the presence of target (mainly woody) species in two height tiers (< 30 cm, 30–200 cm) on small (141 cm radius), unmarked plots. The method assumes that all species can establish short seedlings in the presence of ungulates (they need to establish before they can be eaten) but that most individuals of some species will be prevented from growing taller than 30 cm where ungulates are common. Consequently, the ratio of tall to short seedling frequencies will decline with increasing ungulate abundance for many species eaten by ungulates. The method is further focused on the impact of ungulates by calculating SRIs for groups of species belonging to three preference classes, labelled ‘preferred’, ‘non-selected’, and ‘avoided’, for species known to be eaten more frequently than, as frequently as, and less frequently than their proportional availability, respectively. This pared-down seedling-focused method provides cost-effective information on the regeneration of key species groups. SRIs can also be calculated from permanent plot data where it exists (Sweetapple & Burns 2002; Sweetapple & Nugent 2004; Gruner & Hawcroft 2024).

For each preference class, the numbers of species recorded on each plot are totalled across a 20-plot, 400 m long transect for tall and short seedlings, separately. These totals are, essentially, measures of plot species richness (total number of species present) in the two height classes. Ratio indices are then calculated from these totals for each transect and preference class. The resulting SRIs range from −1 (short seedlings present but no tall seedlings present) to +1 (tall seedlings present but no short seedlings present). Values between −0.5 and −0.9 are typical for preference classes heavily impacted by ungulates, while values of 0.0 to 0.5 are indicative of little or no ungulate impact (Sweetapple & Nugent 2004). Approximately 10–20 transects provide SRI estimates of adequate precision (Sweetapple & Nugent 2004; Sweetapple 2022) with diverse forests (e.g. podocarp-hardwood forests) requiring fewer transects than low-diversity forests (e.g. high-altitude beech forests).

The SRI method also records ungulate browse observed on foliage 15–200 cm above each plot. These browse scores are recorded for each species. A browse index (BI) is calculated for each transect from combined preferred and non-selected species browse scores to provide an index of ungulate activity (abundance). It is important to appreciate that unlike SRIs, BIs are not a measure of impact on regeneration. Some species are much more tolerant of being browsed than others and can survive and continue achieving positive height growth despite being frequently browsed. They do provide supporting information on species preference that may be used to help assign preference classes to species with little published preference data or where local preferences to ungulates may differ from elsewhere due to complexities of local abundance and species mix. They also can provide further insight to ungulate-regeneration dynamics where SRIs may have had insufficient time to fully respond to recent changes in ungulate abundance.

It is recommended to consider whether to use SRIs in conjunction with collecting data on the occurrence of faecal pellets using the Faecal Pellet Index method (see 'Animal pests: faecal pellet counts'—docdm-323171)[1] as both can be measured along SRI transects. The Faecal Pellet Index has a known quantitative relationship with deer density. However, also consider that additional methods could compromise the goal of SRI being a quick method.

Calculating ratios of the presence of seedlings in different height tiers to index impacts of ungulates was first used by Rose & Burrows (1985) when they assessed the condition of the forests in what is now Kahurangi National Park. They divided the number of plots with tall seedlings (30–200 cm tall) and/or canopy trees by the number of plots with short seedlings (< 30 cm tall) on a species-by-species basis and called them 'susceptibility ratios'. No further work on seedling height ratios was undertaken until Sweetapple & Burns (2002) further developed the idea by excluding canopy trees from the tall stratum and combined species into the above three ungulate preference classes before calculating a simple ratio of tall to short seedling occurrences and called them 'seedling ratios'. These were further developed and formally published by Sweetapple & Nugent (2004), where these seedling/species richness ratios were converted into an index that varied between −1 and +1, thus eliminating the skewed nature of ratio data. They found very strong but contrasting correlations between SRIs and an index of ungulate abundance based on browse records for each of the three species preference classes across a wide range of forest types in both New Zealand and Hawai'i.

Assumptions

This method makes the following assumptions:

- Species richness of short seedlings (< 30 cm) is unrelated to ungulate abundance.
- Species richness of tall seedlings (30–200 cm) is negatively correlated to ungulate abundance for preferred and not-selected species.

[1] https://www.doc.govt.nz/globalassets/documents/science-and-technical/inventory-monitoring/im-toolbox-animal-pests-faecal-pellet-counts.pdf

- Short seedling richness is positively correlated with that of tall seedlings when ungulate abundance is low. All three assumptions regarding species richness held when tested by Sweetapple & Nugent (2004).
- SRIs for preferred and not-selected plant species decline with increasing browsing ungulate density.
- SRIs for all plant preference classes will be near or above zero after the prolonged absence of ungulates.
- SRIs are unrelated to site factors other than ungulate abundance and will, therefore, trend towards similar values across all sites with similar ungulate abundance.
- Plant species included in SRI measurements will attain heights exceeding 30 cm in the absence of ungulates across all sites in which the method is used.
- All ungulates have similar dietary preferences within and across different sites and forest types. This may be violated in some situations (see 'Disadvantages' below).
- If preferred seedlings have a high SRI (0+), plant groups not surveyed (ground ferns, prostrate vegetation, climbers, monocotyledons) will also be free of significant ungulate impact.

Advantages

This method has the following advantages:

- The use of small, unmarked plots, and a restricted set of species, height tiers, and parameters measured means fewer resources are required, particularly labour, compared with established permanent plot methods of vegetation measurement.
- Grouping of plant species into three ungulate-preference classes for data analysis increases data richness within each analysed subset and, therefore, reduces sample size requirements compared with analysis on a species-by-species basis. It also reduces stochasticity (variability) due to inherent and annual variability within and between species regeneration patterns, and local differences in preference rankings (see 'Disadvantages' below).
- Seeding ratios are an absolute rather than a relative attribute. They can be interpreted without comparison to an experimental control (untreated area) or data from inside fenced exclosure plots. Ungulate impacts can therefore be directly compared between sites with widely differing biological and physical characteristics.
- A restricted set of plant species measured (most non-woody species are excluded) means field staff require less botanical knowledge than is required for permanent plot measurements.
- An index of ungulate abundance (from browse scores) is simultaneously measured during SRI-plot measurement. The index used is a relative browse pressure index—the amount of browse observed divided by the number of shoots available. This is essentially a

preference index. It can, therefore, be used to classify the preference classes of species without sufficient existing published dietary preference data.

Disadvantages

This method has the following disadvantages:

- Published dietary preference data are limited, contradictory, or unavailable for some plant species.
- The SRI method and published preference data assume that plant preferences are similar between different browsing ungulate species, but some differences are likely. For example, different rumen morphology between red and sika deer mean that sika deer are better equipped to digest poorer quality forage and so may have higher preferences for some lower red deer preference foods (Fraser 1996).
- Some local differences in preference ranking of plants do occur due to differences in the species mix and relative abundance of those species.
- Possums feed on the ground as well as in tree canopies, but their impact on forest regeneration is poorly understood. The SRI cannot distinguish between the impacts of ungulate and non-ungulate browsers or separate the impacts of different ungulate species (deer, goats, pigs) on forest understories.
- Field staff require the ability to identify most woody and a small number of fern species present in the surveyed area.
- SRIs provide no data on vegetation tiers above 2.0 m, so if the objective of monitoring includes tracking trends in taller tiers, then periodic measurement of permanent vegetation plots will also be required.
- It is unknown what minimum SRI values are consistent with sufficient recruitment of all preference classes to maintain natural forest development processes.
- There is limited data on time frames required for SRIs to respond to ungulate removal.
- The index may vary seasonally, at least at low ungulate densities, as plants undergo seasonal flushes of growth and browsers respond to these. This effect has not been quantified.
- Very low diversity forests (e.g. high-altitude beech forests) may provide few records of target species on many transects, especially for the important preferred-species class. This can result in high variance between transects and low statistical power, thus reducing the sensitivity of SRIs in detecting changes in understorey condition. This can only be corrected for by increasing sampling effort (measuring more plots per transect and/or more transects).

Suitability for inventory

- The SRI method is unsuited for the quantitative inventory of vegetation abundance. It provides no information on vegetation taller than 2.0 m and the resultant indices are unrelated to seedling density (number per unit area, basal area, or biomass).
- The indices generated by the SRI method do have some characteristics of an inventory; a one-off survey can quantify the extent to which forest ungulates are suppressing seedling regeneration and can be directly compared with those from other areas allowing the severity of ungulate impacts to be ranked across sites.

Suitability for monitoring

- The SRI method is a tool specifically designed to monitor the impact of ungulates on forest understories and the efficacy of ungulate population control in reducing those impacts. It is not suitable for monitoring short vegetation dominated by non-woody species or where vegetation stature is suppressed by harsh environmental conditions such as in alpine areas, on frost flats, or in wetlands.
- The minimum natural vegetation height for applying the method is nominally 2.0 m, being the top of the tall seedling tier. This includes small patches of shorter vegetation resulting from recent disturbance (e.g. windfall gaps) within tall vegetation. It may also be suitable for monitoring extensive areas of woody vegetation with a mean top height < 2.0 m, either naturally short or due to recent disturbance, but further study would be required to confirm this.
- The method is designed to focus on groups of species of similar preference, not individual species. Recommended sample sizes are relevant to SRIs for the three preference classes described above. Consequently, recommended sample sizes may be inadequate to robustly assess seedling ratios of individual species, especially less common species.
- Physically travelling to and measuring transects in heavily vegetated and often difficult terrain is labour intensive. Some extensively difficult sites may not be practical to be surveyed by field crew on foot. Travel times in large but navigable blocks can be reduced by the use of appropriate semi-random (clustered) transect selection techniques.

Skills

This method requires the following skills and training:

- A thorough understanding of the methodology (see 'Full details of technique and best practice' section).
- A basic understanding of the aims and rationale of the method (see 'Synopsis', 'Assumptions' and 'Advantages' above).

- The ability to identify most woody plants to species level and tree ferns to genus level, and hen and chickens fern (*Asplenium bulbiferum/A. gracillimum*). Small-leaved coprosmas, small-leaved pittosporums, hebes, *Carmichaelia,* and *Dracophyllum* need only be identified to genus level.
- The ability to identify ungulate browsing damage to plants and distinguish it from damage from other animals or causes (disease, windfall, or trampling). See figures 14–18.
- Be field competent with a good level of physical fitness and experienced at travelling off track in forested habitats and along natural water courses in rough and steep terrain in a range of weather conditions.
- Basic competency in map and compass navigation. A thorough knowledge of GPS operation for general cross-country navigation, locating waypoints, waypoint management, and data transfer.
- Receive SRI training in the field from an experienced SRI practitioner before collecting data without direct supervision, and obtain all required health and safety training and qualifications before starting fieldwork.

Resources

This method requires the following resources:

- This method can be undertaken by individuals, but if institutional protocols prevent staff working alone in remote locations, then teams of two will be required. Individuals or teams can complete 1–3 transects a day depending on travel distances and the nature of the terrain and vegetation, and individual staff attributes.
- A copy of the SRI Field Protocol (see 'Full details of technique and best practice' section).
- A copy of the metadata from the most recent measurement (if any) for the transects to be measured during the current survey.
- A copy of the latest National Vegetation Survey Databank (NVS) species list and codes for target species.
- A GPS receiver pre-programmed with the most recent coordinates for transect starts.
- Spare batteries for the GPS.
- A paper map with transect start locations as backup for the GPS.
- A quality hand-held field compass.
- Permolat (painted aluminium strips at least 10 cm long) or plastic track markers (not orange) for marking/remarking transect start points.
- Four spare seedling pegs and flagging tape (when working in pairs, these can be used to mark out plots ahead of the measurer).
- Hammer and nails (50–75 mm galvanised flathead in a sturdy bag/bumbag) for marking/remarking transect start points.

- One 10 m or 20 m running line/hipchain or 20 m tape measure. A running line consists of a 10 or 20 m length of 3 mm nylon paracord with a bicycle-wheel spoke attached to both ends. The cord is threaded through a small pulley before the spokes are attached by screwing the threaded end of the spoke through the cord fibres then bending it in a tight loop around the attachment point to prevent the cord sliding off the spoke. An aluminium plot peg or similar is inserted through the hole/loop at the top of the pulley and bent into a loop to serve as a handle.
- One search-radius string. This consists of a peg with an attached 1.6 m string marked at 0.49 cm and 1.41 m. Marks can be made using a permanent marker pen, attaching small pieces of twisted wire, or tying knots. String lengths to these marks need periodic checking as some string materials can shrink or stretch over time.
- A 3 m builders tape measure (to check seedling heights and plot radius for plants near parameter limits).
- A clipboard, blank waterproof data sheets, pencils, and erasers.
- If collecting plant specimens, bring waterproof labels, a fine-tipped permanent marker, and a combination of sample bags, envelopes, and newspapers. Bring a small plant press and use absorbent paper to preserve collected plant specimens secured with rubber bands around the book for later identification if immediate identification is not possible.
- Camera with macro function to photograph unidentified plants to complement or replace collected specimens.
- Personal protective equipment (PPE). Take all clothing and equipment necessary to adhere to all health and safety standards and procedures.
- Backpacks and bumbags for transport of field equipment and personal gear.
- Stapler, staples, highlighter pen, and folders for organising and the temporary storage of completed and checked data sheets during a field survey.
- Reference books for plant identification and a list of target species likely to be or previously encountered on transects in the survey area.
- Develop an ungulate preference classification (preferred, not-selected, avoided) for all target species and species groups for the survey area. These can be derived from browse score data if published data are unavailable or contradictory. They may include variations from published data for common species that appear to have local ungulate preferences that vary from other regions.
- Laptop, software for mapping and processing data, and data backup devices and or systems.

Minimum attributes

Consistent measurement and recording of the following attributes is critical for the implementation of the method. Other attributes may be optional depending on your objective.

It is recommended to complete a 'Standard inventory and monitoring project plan' (docdm-146272) for each study/operation. The project plan should define the survey boundaries, and the number and location (start point and bearing) of transects to be measured. The plan will also define the dates between which all transects need to be measured.

The minimum data to record once for each transect (metadata) are:

- Transect number
- Location identifier (reserve/catchment/range name)
- Start GPS waypoint (Easting and Northing) from the GPS unit, using either the pre-stored start coordinates or a new set of coordinates if the original start proves to be impractical
- Whether this is the old or a new transect start (start shifted 50–150 m or a new/contingency transect), using a check in the appropriate data-sheet cell
- Stratum (if sampling is stratified)
- Observers
- Date
- Distance between plots (plot interval: 10 m or 20 m; mark/tick (✓) the appropriate box)
- Plot number, GPS waypoint, and new bearing for all turn points if the original transect bearing can no longer be followed
- Transect start and finish times

The minimum data to record for each plot are:

- Plot number.
- Species name (six-letter code, e.g. DACcup (for *Dacrydium cupressinum* (rimu)) for seedlings (≤ 200 cm) of all target species or species groups rooted within the plot.
- Height class(es) (short (< 30 cm) and/or tall (30–200 cm) for all species and species groups (see 'Full details of technique and best practice' section for naming conventions) recorded as seedlings rooted within the plot (tick (✓) in the appropriate column. Heights are measured to the nearest centimetre.

Optional data to record:

- Browse score for each target species/groups with foliage present 15–200 cm above the plot (optional but recommended). Scores are for all shoots/foliage present regardless of plant size class (seedlings to canopy trees) or whether the plants are rooted within the plot. Therefore, browse scores can be given for target species not rooted on the plot but with shoots/foliage overhanging the plot. Scoring ungulate browse is recommended and is required if preferences classes are to be adjusted to accommodate local ungulate preference ratings.
- Transect notes; unusual conditions or marked changes in vegetation type/structure.

A sample SRI field data sheet is shown in Appendix A.

Data storage

The following instructions should be followed when storing data obtained from this method:

- All data sheets are cleaned and dried at the end of each day in the field and checked (and corrected) for any missing or incorrect data, plant name spelling mistakes, and illegible entries. All pages from the same transect will be stapled together and stored in a folder containing all completed data sheets.
- Any new transect starts, transect turns, skipped sections, or notes are marked with a highlighter pen to flag them for updating the master metadata and GPS start-point files. Metadata and GPS data updates are organised/undertaken by the data coordinator when they receive the original data sheets.
- Field staff will attempt to identify any collected plant samples using reference books and species lists as soon as possible after collection (within 48 hrs) and update the data sheets. Specimens that remain unidentified are placed in a plant press and labelled with a temporary name (that is used on the data sheet, e.g. 'PaleThinLf') transect, plot, tier, and date, for future identification. See Appendix D for more details on plant collection protocols.
- Collected plant specimens (see 'Plant collection and photographing protocol' in Appendix D) are presented to and identified by an expert as soon as is practical after the survey completion. The corrected names are written on the original plant tag/label while leaving the temporary name intact so the appropriate entry on the data sheet can easily be recognised and amended. These corrected names are then transcribed to the photocopied and/or original data sheets (depending on the steps taken below). If sending the corrected names to the data administrator is required, the labels are scanned and emailed, with the original labels retained by the sender until advised that they are no longer needed.
- Best practice is to send the data sheets to the data administrator as soon as practical after the completion of a survey, preferably after all collected plants are identified and data sheets updated. If that requires the use of a postal/courier service, then all sheets are photocopied or scanned prior to sending. The sender will retain the copies until the project coordinator notifies them that they can be discarded (data has been entered, checked, backed up, and the originals archived).
- Data should be entered into an electronic database as soon as is practical after collection. The preferred option for data entry and storage is the NVS http://nvs.landcareresearch.co.nz/). NVS has developed an SRI template that can be used to enter vegetation data, metadata, GPS coordinates, and information about time taken to measure each transect. A template needs to be used for each project to ensure specific transect details are correct. Template projects for use in NVS Express can be obtained by contacting the NVS administrator (nvs@landcareresearch.co.nz). Data can then be downloaded in various formats for analysis, including Excel.
- Alternatively, data can be entered into a Microsoft Excel or similar spreadsheet program. Metadata (the top panel of the first data sheet of each transect) is entered into a separate file from the plot data. This most easily can be done by scanning the top panel of the first

data sheet for each transect and compiling the scans into one file. This file is named as below and replaces the previous version. Additionally, metadata can be entered into a spreadsheet that contains data from all previous measurements so that statistics such as number of transects per day and transect measurement times can be easily compiled and tracked over time. For repeat surveys, copy the previously measured data into a new row for the current survey, identified by year, and update the fields where highlighted cells on the data sheets indicate changes to previous measurements were made. Name metadata files **'SRI_Metadata_*survey identifier_Year*'** for scanned metadata files and **'SRI_Metadata_*survey_identifier_*All Years'** for multi-survey spreadsheets. If a spreadsheet version is not created, all earlier versions of the scanned files are kept as a record of changes made.

- During planning, a GPS file of transect line start waypoints, for uploading to GPS units, will have been created. At the completion of each measurement this file is edited to update shifted (50–150 m from original start) or new transect starts and named **'SRI_GPSpoints_*survey identifier_Year*'**. If no changes are required, the previous GPS file is copied and named as for amended files.
- Plot data are entered into a separate file from metadata. A new file is created for each survey and named **'SRI_PlotData_*survey identifier_Year*'**. Each line in the second panel on the data sheet is entered as a separate row. The 'SRI PlotData' spreadsheet has six compulsory columns ordered and namedas follows: Transect No., Plot No., Species, Short tier, Tall tier, and Browse score. Transect and plot numbers are copied down for each species listed on the plot. Optional data collected are added as new fields to the right of the compulsory fields.
- Completed electronic files are backed up (e.g. external drive, company server, the cloud). The SRI data file can then be analysed.

Data analysis

Standard analysis and interpretation allows comparisons to be made at different sites and at different times. Follow these instructions when analysing and interpreting data.

Assigning preferences classes

Before analysis commences, preference classes (preferred, non-selected, or avoided) for each plant species need to be added to the survey database ('SRI PlotData' file). For repeat surveys this will be a previously compiled list of species encountered and their assigned preference classes (i.e. use the same preference classifications for each survey). A new database will need to be compiled if this is the first SRI survey of the area. This will be largely based on the data in Forsythe et al. (2002), which provides a comprehensive compilation of New Zealand ungulate dietary preference data. Some additional data are provided in Table 2 in Sweetapple & Nugent (2004). Data from these studies are summarised in Appendix C.

Where preference data are lacking or ambiguous for locally common species, or there is a desire to accommodate local ungulate preferences, preference classes can be estimated from browse data (if collected) as follows:

- Calculate the mean of all browse scores (MBS) by species for all non-divaricate species with at least 10 browse scores (including zeros) recorded across the whole survey.
- Create a database list of all target species and add the MBS for each where available. Leave the MBS field blank for small-leaved, tightly branched species (divaricate species) and uncommon species (< 10 browse records).
- Add a 'published preference class' (PPC) field and fill using the classes listed in Appendix C. For uncommon species (< 10 browse records) not listed, assign as 'none'. For unlisted divaricates use 'non-selected'.
- Sort the database by MBS in descending order.
- Fill in blank preference class cells using the modal preference class among the six species with the most similar MBS.
- If the goal is to adjust PPCs to reflect local ungulate preferences, add a field for 'local preference class' (LPC) and copy across the 'none' and 'non-selected' PPC entries for species without MBSs.
- Assign remaining LPCs by dividing the sorted species list into three groups of contiguous species and classify each group as preferred (top group), non-selected (middle group), and avoided (bottom group) with divisions located so that the number of differences between PPCs and LPCs are similar immediately above and below the division boundaries.

Once the ungulate species preference table has been finalised, the SRI data file can be manually updated with preference classes by adding a preference class field and using the species-field filter to select species in one preference class, then pasting in the appropriate class name (preferred, non-selected, or avoided) down all filtered rows. This will be from either the PPC or the LPC field, depending on the goal of the above species classification (fill in blanks only, or adjust for local preference patterns). Alternatively, use the 'VLOOKUP' function in Microsoft Excel (or equivalent in the spreadsheet software being used) to select the correct class from the above list of species codes copied to another sheet in the database.

Calculating SRIs and BIs

The transect, not the plot, is the unit of measure for analysis; therefore, analysis is performed on transect totals. This avoids most issues of data interdependence within transects (auto correlation). The SRI for each of the three preference classes for each transect is calculated as:

$$SRI_a^{PC} = \frac{\sum Tall_a^{PC} - \sum Short_a^{PC}}{\sum Tall_a^{PC} + \sum Short_a^{PC}}$$

where:

- ^{PC} = preference class
- $_a$ = transect number
- $\sum Tall$ = number of tall seedling records (= total number of ticks in the 'Tall tier' column for the given preference class)
- $\sum Short$ = number of short seedling records (ticks in the 'Short tier' column for the given preference class)

Tall and *Short* are essentially species richness for tall and short seedlings, respectively. When divided by the number of plots, they give the mean species richness on plots.

Summing seedling records in this manner results in SRI estimates that are weighted towards the most common species, which makes biological sense. It also avoids uncommon species having a disproportionate influence on the estimate, particularly when the number of their records is so low that stochastic effects dominate. It does, however, make the index vulnerable to distortion if the preference class assigned to a very common species is inappropriate to the local site due to local variations in ungulate preference or that species has an unusual mode of regeneration (e.g. see kāmahi in case study B). Therefore, it can be prudent to calculate separate SRIs for common individual species that contribute more than 30% of total records to their preference class, then calculate the SRI for the remaining species within the class.

A single BI to index ungulate abundance is calculated for each transect as:

$$BI = \frac{(mean(BSN) + mean(BSP))}{2}$$

where:

- *BSN* = non-selected species browse scores
- *BSP* = preferred species browse scores

Data analysis, other than simple summary statistics, should only be undertaken after discussing the aims of analysis with a statistician. In many circumstances, this analysis will need to be undertaken by the statistician.

Simple summary statistics (mean, standard deviation, variance) can then be calculated for common species and the three preference classes SRIs and BI using the transect results (i.e. N = the number of transects measured), using the '=AVERAGE', '=STDEV.S', and '=VAR.S' functions in Excel, or equivalent. These are the standard deviation (STD) and variance (VAR) options for *samples* (not *populations*). These can be used to calculate standard error (SE) of the mean as follows.

$$SE = \sqrt{\frac{VAR.S}{N}}$$

$$\text{or } SE = \frac{STDEV.S}{\sqrt{N}}$$

where:

- *VAR.s* = the sample variance of the mean
- *STDEV.s* = the sample standard deviation of the mean
- *N* = the sample size (number of transects)

A 95% confidence interval (95% CI) can then be calculated from the SE as follows.

$$95\%\ CI = mean\ \pm t(SE)$$

Where *t* is the Student's *t*-test statistic at the 0.05 level for the appropriate degrees of freedom ($N - 1$).

The simplest way to test for statistically significant differences between BIs, or SRIs for different species, or preference classes from previous measurements or other surveys is to determine if their 95% CIs overlap. Those that do not overlap are significantly different. A more sensitive way to compare these statistics is to perform a two-sample *t*-test to compare data from different surveys. Data from one measurement is entered as sample 1 and data from the other survey as sample 2. Excel will perform this test (under Data > Data Analysis menu). Where appropriate, an even more sensitive test is the paired two-sample *t*-test (available in Excel), for comparing the means for repeated measurements of SRIs from within the same survey area (i.e. where data from the same transects are compared over time). Data must be entered so that data from the same transects are in the same rows.

To compare SRI results between the three preference classes, the data can be analysed using a one-way analysis of variance (ANOVA) table (again available in Excel). The resultant *F*- and *P*-values will indicate if there is a significant difference between the three SRI values ($P < 0.05$) or not. To determine which of the individual SRI values are different from each other when $P < 0.05$ requires calculation of the least significant difference (LSD), using values from the ANOVA table results ('within groups Mean Sums of Squares' (MS), 'degrees of freedom') and Student's *t* as follows:

$$LSDa,b = t \times \sqrt{(MS \times \left(\frac{1}{N_a} + \frac{1}{N_b}\right))}$$

where:

- *LSDa,b = least significant difference for comparing groups a and b*
- *t* = Student's $t_{(0.05)}$

- N_a = number of transects in group *a* being compared
- N_b = number of transects in group *b* being compared
- *MS = within groups Mean Sums of Squares* (from the ANOVA table)

Degrees of freedom for *t* are calculated as $3 \times N - 2$.

Means are significantly different if they differ by more than the LSD.

Interpretation

The SRI varies between −1.0 and 1.0. The method assumes that values of or above zero represent little or no depression of seedling regeneration due to browsing animals. The index is independent of seedling density (number per unit area) so that different sites are directly comparable. For example, a lower SRI for non-selected or preferred species at one site compared with a second site indicates that ungulate impacts are greater at the first site. Except for sites with zero or near-zero ungulate abundance, SRIs for avoided species will be higher than for non-selected species, which will be higher than for preferred species. At moderate to high ungulate abundance, SRIs for preferred species are consistently around −0.7 to −0.9, while those for non-selected species generally lie between −0.25 and −0.5. Those for avoided species are almost universally between 0.0 and +0.5 (Sweetapple & Nugent 2004).

The response of SRIs for preferred seedlings to changes in ungulate abundance is strongly non-linear. They initially decline steeply as ungulate abundance increases from zero, but level out to show virtually no response to further increases in ungulates beyond low–moderate abundance (Sweetapple & Nugent 2004). This means that there will be little response of preferred seedlings to animal control unless ungulates are reduced to low densities. Non-selected species respond positively to reductions in ungulate abundance in a near-linear fashion. Avoided species are largely unresponsive to changes in ungulate abundance, except for a small increase in SRIs with a shift from zero to low ungulate abundance, probably reflecting a reduction in competition from non-selected and preferred seedlings.

Some uncertainty exists as to expected SRI values in the absence of ungulates, and the time required for SRIs to respond to ungulate abundance reduction. All preference-class SRIs cluster around +0.25 at lowest measured ungulate abundances, and all vary between 0.0 and +0.5 (Sweetapple & Nugent 2004). It is unclear whether this variation is due to small sample sizes, different preference rankings at some sites, a lack of time for seedlings to fully respond to reductions in ungulate abundance, or natural variation between zero-impact values between sites or plant species. The time that seedlings take to respond to a change in ungulate abundance will vary widely and will depend on factors such as habitat type and altitude and residual animal density. However, it is recommended to remeasure SRI transects two years after new ungulate control is initiated to determine if seedling ratios are increasing and BIs meet management goals. Three- to five-yearly remeasurements might be appropriate for longer term monitoring. Consider factors such as the intensity and duration of the ungulate control to determine an appropriate time to remeasure transects.

It is unknown what minimum SRI values are compatible with sufficient recruitment into taller tiers to maintain forest overstorey composition. Without knowing these thresholds, the management of ungulates needs to take a conservative approach and aim to attain SRIs of zero or above.

BIs are intended to help interpret the SRI results. If seedlings have not responded to ungulate control, the BI will help determine if that was due to insufficient time since control for seedlings to recover or if the control was not intensive enough. Preferred seedlings will undergo little or no recovery if BIs remain over about 1.0, while non-selected species are capable of near full recovery at most sites when BIs are below 1.0 (see case study A). Recovery under an intact canopy can be slow; SRIs for preferred seedlings at 400–500 m near Nydia Saddle in the Marlborough Sounds rose from −0.8 to only −0.5 while those in canopy gaps at the same site fully recovered (+0.05) during three years of goat control, which reduced BIs from 2.7 to 0.4 (see case study A).

Reporting

The type of reporting of study results will be outlined in the project plan. The structure and detail of reports will vary depending on the intended audience. All reporting needs to focus on the objectives of the survey, as stated in the project plan and, usually, in the report introduction. In short, most reporting will state:

- What was done and why (Introduction)
- How, where, and when the survey was undertaken and how the data was analysed (Methods)
- What the analysis of the survey data shows (Results)
- What these results mean for vegetation health, ungulate abundance, or other management issues (Discussion/Conclusions)

Case study A: SRIs: testing assumptions and interpreting results

Synopsis

The SRI method assumes that richness of ungulate-palatable species will be related to ungulate abundance for tall but not short seedlings, and that both tall and short seedling richness will be related in the absence of browsing ungulates. Sweetapple & Nugent (2004) measured SRIs at 43 sites spanning a wide range of forest types (31 in New Zealand and 12 in Hawai‘i) and ungulate species (red and axis deer, goats, pigs, sheep, cattle) and densities (absent to abundant) to test these assumptions. The study also investigated the applicability of the method across a wide range of sites and forest types to determine the relationship between SRIs and ungulate abundance, and to measure the temporal response to ungulate control of seedling populations as measured by the SRI method.

Objectives

- To test the assumptions that for preferred species short seedling richness is unrelated to ungulate abundance, tall seedling richness is negatively correlated to ungulate abundance, and short and tall seedling richness are positively correlated where ungulate abundance is low.
- To determine the relationship between SRIs and ungulate abundance across a wide range of sites and ungulate species.
- To determine if SRIs at two widely different sites respond to 2–3 years of ungulate control.

Sample design and methods

New Zealand data were collected from either permanent plots using 0.75 m^2 and 6.25 m^2 subplots for short and tall seedling richness, respectively, or on circular plots. Hawaiian data were collected on 2.0 m radius plots for both short and tall seedlings. Plant growth forms measured included ground ferns and some monocotyledons but otherwise were similar to those described in this method specification. Hawaiian ungulate preference classes were estimated using browse scores recorded on plots with preference classes for New Zealand species largely derived from Forsyth et al. (2002) and Nugent et al. (1997). SRIs were calculated as above (see 'Data analysis') and browse was recorded on all non-selected and preferred individual non-woody and woody species using the categories in Table 3 (see 'Full details of technique and best practice'), with individual fern fronds and strap-shaped leaves on monocotyledons treated as individual shoots.

Ungulate control was initiated at one New Zealand site (Nydia Saddle) and one Hawaiian site (Puʻu Waʻawaʻa Wildlife Sanctuary) after an initial SRI was undertaken. Transects were stratified between open woodland and closed canopy forest at Puʻu Waʻawaʻa and between canopy gaps and closed canopy at Nydia Saddle. The surveys were repeated after 2 and 3 years of ungulate control at Puʻu Waʻawaʻa (sheep and pigs) and Nydia Saddle (goats and deer), respectively.

Results

Preferred short seedling richness on plots across all 43 sites was unrelated ($P = 0.52$) to ungulate abundance, which ranged from zero to high (mean BI = 2.6). Across the same sites, preferred tall species richness was strongly and negatively correlated ($P < 0.001$) with ungulate abundance. For a subset of 14 New Zealand sites where there were low abundances of ungulates, short and tall seedling richness for all species was positively correlated ($P = 0.005$). Therefore, all three main assumptions of the SRI method were found to hold across the wide range of sites measured.

SRIs for all three preference classes were strongly correlated to ungulate abundance ($P < 0.001$), but none of these were linear and all differed markedly from each other (Figure 1). Avoided species SRIs initially increased, from 0.0 to about +0.2, with increasing ungulate abundance (mean BIs increasing from 0.0 to 0.5). Further increases in ungulate abundance above mean BIs of 0.5 had no impact on avoided seedling SRIs (Figure 1). Preferred species SRIs responded strongly and negatively to small increases in ungulate abundance when abundance was low but were largely unresponsive to changes in abundance in the moderate to high ungulate abundance range, where SRIs levelled out at −0.75 to −0.8. (Figure 1). Non-selected species SRIs declined gradually over a wide range of ungulate abundance and appeared (visually) to be more variable across the range of ungulate abundance.

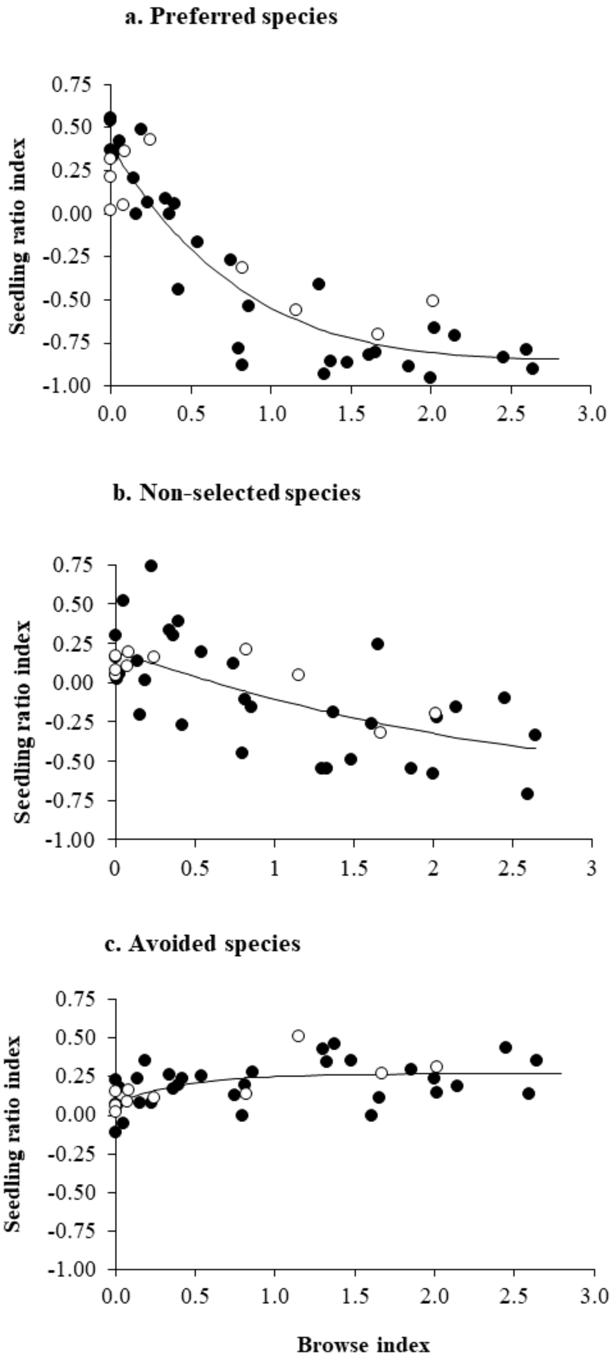

Figure 1. SRIs from 43 sites plotted against an index of ungulate abundance (BI) for (a) preferred species, (b) non-selected species, and (c) avoided species. Solid circles are from New Zealand and open circles are from Hawai'i. BIs are site means and are back-transformed from those in Sweetapple & Nugent (2004) to produce values equivalent to the BI described in this SRI method. Trend lines are exponential regression functions. Adapted from Sweetapple & Nugent (2004).

Preferred seedlings under broken canopies responded strongly over 2–3 years of ungulate control (PW and NG data points in Figure 2 for Hawai'i and Nydia Saddle, respectively). SRIs increased from strongly negative (about −0.7) to positive values at both sites during this period. Seedling responses under closed canopies were much more muted. They increased from −0.65 to only −0.4 (averaged over both study sites) during a period of ungulate control. That difference at Pu'u Wa'awa'a (Hawai'i) may have been largely due to less effective pest control in heavy forest than in the more open woodland. BIs under intact canopies and in canopy gaps was reduced to similarly low levels at Nydia Saddle (Figure 2), suggesting seedlings under intact canopies are inherently slower to respond to ungulate removal than on disturbed sites.

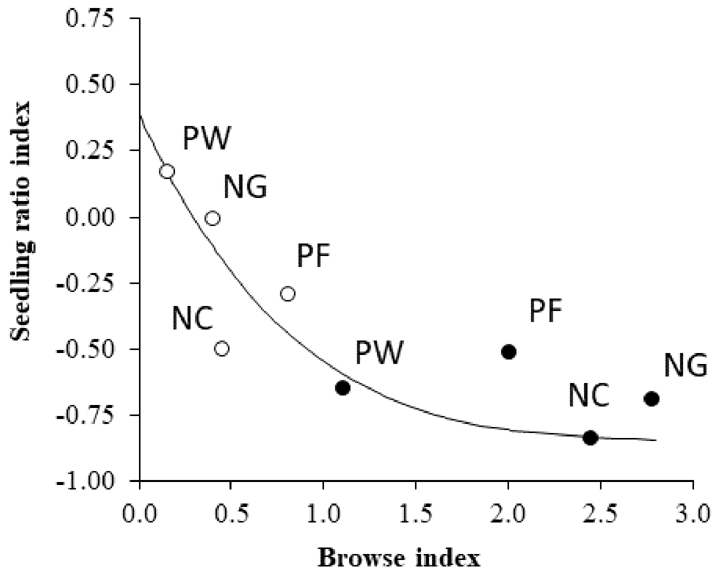

Figure 2. SRI and ungulate BIs from before and after commencement of ungulate control for preferred species from Nydia Saddle (New Zealand) canopy plots (NC), Nydia Saddle gap plots (NG), Pu'u Wa'awa'a (Hawai'i) woodland (PW) and Pu'u Wa'awa'a closed canopy forest (PF). BIs are site means and are back-transformed from those in Sweetapple & Nugent (2004) to produces values equivalent to the index described in this SRI method. Solid data points are pre-control data, and open points are two- and three-year post-control data from Pu'u Wa'awa'a and Nydia Saddle, respectively. The line is the regression line for preferred species in Figure 1. Adapted from Sweetapple & Nugent (2004).

Limitations and points to consider

This study supports the major assumption that species richness of 30–200 cm tall seedlings is (negatively) correlated with browsing ungulate abundance but richness of seedlings < 30 cm tall is not. That provides the explanation for SRIs of preferred and non-selected species tracking downward as ungulate abundance increases and provides confidence that this will occur across a wide range of forest types. This was confirmed by the measurement of SRIs in 43 different forests across two countries (Figure 1).

It is unknown to what extent the scatter of data points around the trend lines for all three preference classes is due to differing localised ungulate preferences, seasonal growth and dietary patterns, insufficient time for seedlings to respond to recent changes in ungulate abundance, or innate site differences due to local species mixes or other site factors. Therefore, it cannot be determined from the data to what extent the shape of the response curves (SRI vs pest abundance trend lines) will differ from site to site. Nevertheless, the strong correlations and modest levels of data scatter around the trend lines, particularly for avoided and preferred species, indicate these trend lines provide robust baselines against which local assessments can be compared.

Similar distributions of data points from Hawai‘i and New Zealand within all three preference classes, despite the different plot sizes used, further indicates the flexibility and robustness of the method.

The SRI response curves in Figure 1 are not linear; the magnitude of change in SRIs will not always match the scale of change in ungulate abundance. From a management perspective this is most significant for preferred species at high ungulate abundance. Little or no improvement in preferred-seedling populations can be expected until ungulates have been reduced to low levels. The SRI response curve is flatter for non-selected species, indicating they will be more responsive to ungulate abundance changes across a wide range of abundance. That possibly reflects the range of species preferences within this class, from near avoided to near preferred, and variable species mixes from site to site.

In contrast to the other two palatability classes, SRIs for avoided species responded positively when low abundance ungulate populations increased. This may be due to avoided species being released from competition with more palatable species at moderate and high ungulate abundance.

Each of the three response curves in Figure 1 is the summation of the response of many species. Individual species within any one of these groups are likely to differ in their response to changes in ungulate abundance reflecting their absolute palatability, abundance, and tolerance to browsing.

Preferred seedlings on open sites can respond rapidly to removal of ungulates while the same species respond slowly on adjacent sites with closed canopies. Randomly located SRI transects in forested areas will largely sample seedling populations under intact canopies, which will be slow to respond to ungulate control. It is important, therefore, to measure ungulate browse during SRI surveys, as they can indicate the effectiveness of control without having to wait several years for SRIs to fully respond.

References for case study A

Sweetapple, P.J.; Nugent, G. 2004: Seedling ratios: a simple method for assessing ungulate impacts on forest understories. *Wildlife Society Bulletin 32*: 137–147.

Case study B: SRI surveys of the Bryant Range (Nelson) following ungulate control

Synopsis

The Nelson City Council undertakes ungulate control in a water reserve in the Bryant Range that supplies domestic water to Nelson City. To quantify the utility of this control in protecting forest understoreys, and to inform future ungulate management, Nelson City Council commenced SRI monitoring within the reserve in 2013 and undertook further surveys in 2015 and 2018. Data from the three surveys was analysed to investigate trends in understory condition over 5 years of ungulate (red and fallow deer and goats) control to determine the required number of transects to detect spatial and temporal changes in SRIs and to optimise the SRI methodology for the study area (Sweetapple 2022).

Objectives

- To review the SRI protocol for efficient monitoring of ungulate impacts on forest understoreys in the Bryant Range.
- To undertake power analyses to determine the number of transects required to detect specified changes in SRI estimates.

Sampling design and methods

Data were collected from mixed beech (*Nothofagus*)-hardwood forests between 300 and 900 m elevation in the Bryant Range, Nelson. Sampling was stratified between areas on limestone substrate and those that were not. Data from a total of 22 SRI transects, each consisting of 20 plots at 20 m intervals, were analysed. Ten transects were on limestone substrate and 12 were on non-limestone substrate; however, only one limestone and nine non-limestone transects were measured and analysed in 2013 and 2015, while 12 different transects (nine limestone and three non-limestone) were measured in 2018. These are low–moderate diversity forests with seedling records (woody and tree fern species only) per plot averaging 6.1 and 7.1 on limestone and non-limestone transects, respectively.

Ungulate abundance was low across the whole period, reflecting sustained ungulate control before and during the 5-year study period. Mean BIs were 0.42–0.62 over the three surveys, and faecal pellet frequencies were 14.5% and 14.6% in 2015 and 2018, respectively (P. Cochrane, Nelson City Council 2021, pers. comm.).

The presence of short (< 30 cm) and tall (30–200 cm) seedlings was recorded on 49 cm radius plots nested in 141 cm radius plots, respectively. Target species were woody plants, including tree ferns, tall ground ferns, tall monocotyledons, and supplejack seedlings. Tall target species were those that would be expected to exceed 30 cm in height in the absence of ungulates. Seedling height was measured as the vertical standing height. Ungulate browse was scored using the categories in Table 3 (see 'Full details of technique and best practice').

Ungulate preference (avoided, non-selected, preferred) was assigned based on the data in Forsythe et al. (2002) for most species, but was based on the author's experience for species with limited or contradictory data. SRIs were calculated for each preference class and transect combination for each survey, and BIs were calculated (non-selected and preferred species combined) for each transect every survey. SRIs were also calculated for just woody species, tree ferns, and hen and chickens fern to investigate the impact of excluding ground ferns and monocotyledons.

A power analysis was conducted by plotting the LSD (calculated from the 'within groups sums of squares' and 'degrees of freedom': from ANOVA tables; see Sweetapple 2022 for further details), against sample size (3 to 30 transects). This identified the survey effort required to detect discrete differences in SRI estimates (e.g. an increase in SRI of 0.2) between surveys, or preference classes.

Results

Initial results indicated that kāmahi (*Pterophylla* (*Weinmannia*) *racemosa*) did not reflect its designation as a preferred species by Forsythe et al. (2022) and Sweetapple & Nugent (2004), with a mean SRI across the surveys of +0.55 compared to −0.40 for all other preferred species combined. This discrepancy was exacerbated by kāmahi dominating preferred-seedling records, particularly in 2013 and 2015, when they make up 55% of all preferred-seedling records. Therefore, Bryant Range SRIs for preferred species in 2013 and 2015 were about 0.5 higher than expected for preferred seedlings elsewhere in New Zealand (Figure 3). Re-assigning kāmahi as a non-selected species resulted in preferred-seedling SRIs in 2013–2015 closely matching expected values elsewhere (Figure 3), without affecting mean non-selected species SRIs (changes = 0.03–0.06) or precision (95% confidence levels decreased by ±0.0–0.03).

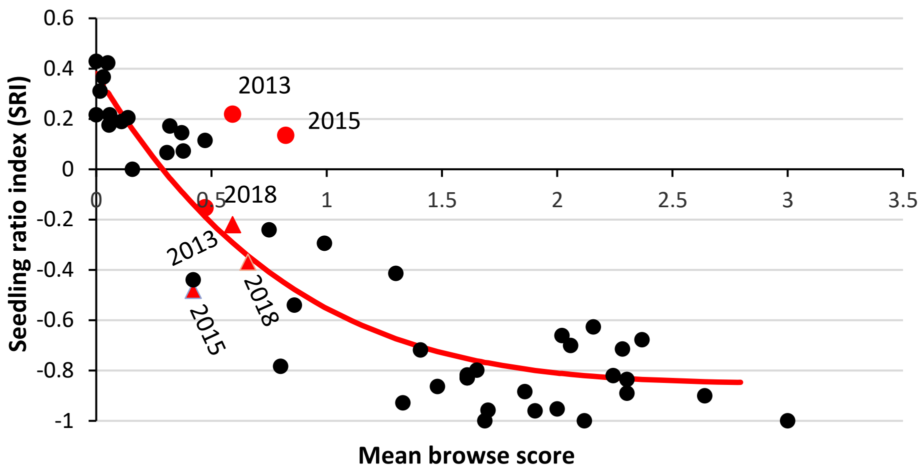

Figure 3. SRIs for preferred species plotted against mean BI for three Byrant Range surveys (red dots = kāmahi included; red triangles = kāmahi excluded) and for 42 surveys undertaken at other New Zealand locations with kāmahi included (black dots; unpublished data). The trend line is for preferred species from Sweetapple & Nugent (2004).

In contrast to the SRI, the BI for kāmahi (1.10) was similar to that for all other preferred seedlings (0.89) in the Bryant Range.

Preferred kanono (*Coprosma autumnalis* (*grandifolia*)) and māhoe (*Melicytus ramiflorus*) exhibited similar, but less extreme, mismatches between BI and SRI to kāmahi; both were low–moderately common (20–35 records), had high BIs (1.47–1.50), and relatively high SRIs (0.00 to +0.09). No adjustment was made to their preference class.

An average of 2,014 seedling records were recorded each survey. This total dropped by 29% to 1,434 when target species were reduced to just woody species and tree ferns. Excluding ground ferns, monocotyledons, and supplejack made no material difference to either SRIs or BIs, or the precision of their estimates, during any of the three surveys (Sweetapple 2022).

The results of the power analysis are presented in Figure 4 and show the number of transects needed to be measured to statistically detect varying sizes of change in SRI estimates. Larger sample sizes were required to estimate preferred species SRIs to the same precision as for non-selected and avoided species (Figure 4). For example, 10 transects in the Bryant Range will produce SRI estimates with LSDs of 0.28 and 0.15 for preferred and non-selected species, respectively.

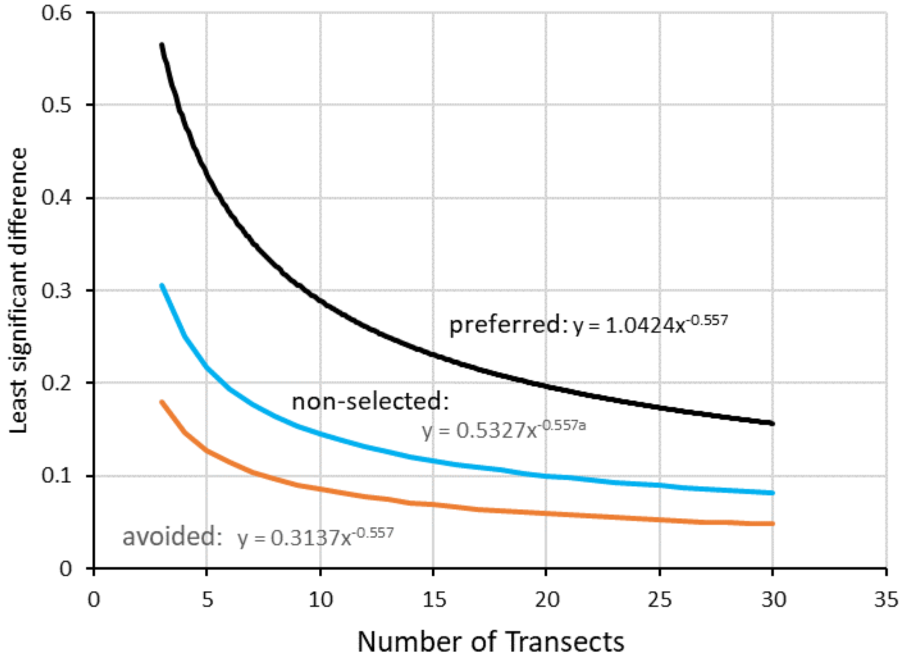

Figure 4. Power analysis of Bryant Range SRI data collected in 2013–2018. Each line plots the LSD (95% level) achieved against the number of transects measured, for comparing SRIs between surveys. The relationship is plotted separately for preferred (black line), non-selected (blue line) and avoided (orange line) species.

Limitations and points to consider

Kāmahi in the Bryant Range demonstrates the impact of a common species that has either an assigned preference class that is inappropriate to the area (does not reflect local ungulate preferences) or a unique regeneration strategy. Using the default 'preferred' class (Forsyth et al. 2002) produces preferred SRI estimates that appear too high for local ungulate abundance (BIs) compared with elsewhere (Figure 3), and an individual species-specific SRI much higher than all the other preferred species at this site. That default class may be erroneous because diet studies will overestimate dietary preference where leaf-fall is a significant contributor to what is consumed (e.g. kāmahi) and more so if leaf-fall is not accounted for in availability estimates (most studies) or if seedling foliage is of lower palatability than fallen adult foliage (e.g. horoeka/lancewood (*Pseudopanax crassifolius*), pōkākā (*Elaeocarpus hookerianus*), and possibly kāmahi; P. Sweetapple 1990–2024, pers. obs. while undertaking rumen content analysis).

Although the SRI for kāmahi and other species in the Bryant Range suggests kāmahi is a non-selected species there, its BI is similar to other preferred species there. This might be explained by a high resilience of kāmahi to ungulate browse, perhaps in combination with generally low ungulate abundance. Alternatively, browse intensity on kāmahi may have been overestimated (e.g. dieback on epicormic growth being incorrectly assigned to ungulate browse). A further possible explanation is that kāmahi seedlings predominantly establish on raised surfaces (moss rocks, stumps, logs, decaying spars) or as epiphytes on tree ferns (Sweetapple 1990–2024, pers. obs.), which might result in short seedlings being underrepresented. This latter possibility is supported by similar BI–SRI mismatches being observed for māhoe and kanono, both of which also frequently establish epiphytically (Sweetapple 1990–2024, pers. obs.).

Whatever the explanation, the dominance of kāmahi in records of preferred seedlings in the Bryant Range (> 50% of all preferred-seedling records) had a marked effect on preferred SRI estimates not seen elsewhere. Re-analysis of historical databases would help clarify the preference status of kāmahi. Calculating SRIs and BIs for very abundant species (e.g. those that make up > 30% of seedling records within a preference class) and for all other species in that class separately would avoid problems of abundant species with unusual results skewing results for the entire group.

The SRI method places emphasis on simplicity and efficiency of data collection. A major potential impediment to the efficient measurement of plots is the ability to quickly and accurately identify seedlings to species level, which is dependent on the level of training of field staff. Many of the hardest species to identify are ferns and graminoids (grass-like plants), and the exclusion of these species and other herbs and climbers had almost no impact on SRI and BI estimates or their precision. Their exclusion from the SRI field protocol would also substantially reduce the amount of data collected. Doing so in the Bryant Range would reduce the number of seedling records, and associated browse scores, by 29%. Excluding the same groups from SRI surveys in Taranaki (2023) reduced the number of seedling records by 58% (A. Whitehead, Department of Conservation, Taranaki, unpublished data). Restricting seedling records to tree ferns and woody species (and one or two special cases such as hen and chickens fern) appear to be an easy means to reduce field and data processing effort, without compromising data quality.

Analysis of Bryant Range data indicates that measuring 10 transects of 20 plots will provide the power required to detect small changes in SRI estimates for avoided (≥ 0.09) and non-selected (≥ 0.15) species and moderate changes in preferred (≥ 0.28) species. The apparent lower power for preferred species is not as problematic as it might seem because preferred SRIs are much more responsive than non-selected SRIs to changes in ungulate abundance at low to moderate densities. For example, Figure 1 (case study A) shows that reducing BI from 1.0 to 0.25 resulted in preferred and non-selected SRIs increasing by 0.55 and 0.25, respectively.

Power versus sample size will be site specific, but low-diversity sites require larger sample sizes than more diverse sites to achieve similar levels of power (Sweetapple & Nugent 2004). The beech forest of the Bryant Range is low–moderate diversity forest; therefore, greater power will likely be achieved for the same effort when surveying more diverse forest.

Power of preferred species SRI estimates is also likely to vary with ungulate abundance, being greatest at high and very low abundance and least at intermediated abundance. At sites with high ungulate abundance there will be very few tall, preferred seedlings nearly everywhere. At near-zero abundance sites there will be tall seedlings of preferred species at most sites where there are short, preferred seedlings. In both these cases all transects will give similar results providing good power. At sites with moderate ungulate abundance, tall, preferred seedlings will be more patchily distributed, reducing statistical power.

References for case study B

Forsyth, D.M.; Coomes, D.A.; Nugent, G.; Hall, G.M.J. 2002: Diet and diet preferences of introduced ungulates (Order: Artiodactyla) in New Zealand. *New Zealand Journal of Zoology 29:* 323–343.

Sweetapple, P. 2022: Evaluation of seedling ratio monitoring in the Nelson City Council Waterworks Reserve: Envirolink Grant 2233-NLCC121. Manaaki Whenua—Landcare Research contract report LC4162 (unpublished). 19 p.

Sweetapple, P.J.; Nugent, G. 2004: Seedling ratios: a simple method for assessing ungulate impacts on forest understories. *Wildlife Society Bulletin 32:* 137–147.

Full details of the technique and best practice

Setting a clear objective

The objective of the SRI measurement programme must be explicit, specifying parameters such as:

- Where and when the monitoring is to be undertaken
- The precision (and therefore sample size) required
- Whether it is a one-off survey to assess the current health of seedling populations to inform management or a series of surveys to assess trends or outcomes of a management intervention

Survey design

Study block location size and additional considerations

Firstly, describe the area that you want the SRI monitoring to represent—e.g. 'forested areas of *X* management unit in *Y* Conservation Area'. Following this, delineate the survey block boundary on a topographical map, using a GIS or other mapping application. Survey block location and size will depend on the objective; if a discrete management operation is to be monitored, the management unit boundary will usually define the study area. Where there is flexibility in choosing boundaries, large study areas are preferable. Densities of hunted deer populations in New Zealand forests are typically in the range of 2–7 per 100 ha, with seasonal home ranges of up to several hundred hectares (Nugent et al. 2021). Consequently, study areas of > 5,000 ha (the larger the better) are required to monitor areas containing more than just a few dozen individuals to minimise the impacts of unusual individual behaviour, and to encompass areas sufficiently large to cover differences in ungulate density due to preferred habitat selection (important when densities are low) and hunting pressure gradients around access points while minimising edge effects adjacent to different management regimes.

Non-treatment blocks will usually not be required because SRIs are consistent across habitat types with similar ungulate browse pressure. However, the effect of season on SRIs, if any, is unknown (see 'Survey timing' section below).

Where multiple blocks are to be compared to assess the impact of different management regimes or hunting pressure, they need to be sufficiently separated to ensure independence. All SRI transects in one management unit should ideally be > 10 km away from those in an adjacent unit, with an absolute minimum distance of > 2 km. Avoid locating transects within 1 km of a management unit boundary if that boundary coincides with a change in management regime (e.g. a poison block boundary).

Selection of transect locations

To avoid bias in design and in any resulting SRI estimates, the locations of SRI transects need to be determined via an objective process. Selecting transect locations subjectively is likely to result in unrepresentative transect distributions, which means that resulting SRI estimates are not applicable to the broader survey area.

If the survey area has habitat types that differ markedly in their attractiveness to the target species, it may be desirable to stratify sampling to ensure good coverage across all key habitats. This will require some ability to classify these habitats and define them spatially.

Spatially balanced sampling

There are several approaches that can be used to generate random locations for SRI transects. Best practice is to use spatially balanced sampling (Stephens & Olsen 2004). Two of the main spatially balanced sampling methods are generalised reverse tessellation stratified (GRTS) sampling (Olsen et al. 2012) and balanced acceptance sampling (BAS; Robertson et al. 2013). Both GRTS sampling and BAS produce an ordered list of sites that can be used to determine transect locations. Both methods provide for generating an 'oversample' consisting of additional sites over and above the sample size required for a study. An oversample is useful if a potential transect location is not feasible for some reason (e.g. a site is inaccessible or the habitat is unsuitable), in which case it can be discarded and a replacement site selected from the oversample. If the study site is part of a broader network of sites, there are advantages in considering if camera locations can be derived from a master sample of sites (van Dam Bates et al. 2018). The following section describes the process of establishing transect locations using BAS. It requires a working knowledge of the R programming language. Example code is provided.

Using BAS to determine transect locations

1. The first step involves preparing a spatial file that represents the survey block boundary. To do this we import a spatial file of the management unit boundary. SRI is a method that is only applicable to woody vegetation types so we also need to erase any non-forest areas from the spatial layer. We do this by importing a shapefile of indigenous forest classes for the area derived from the Land Cover Database[2] and intersecting it with our management units boundary. This approach can also be extended to include removing areas within the survey block boundary that aren't appropriate for monitoring, such as the need to avoid kauri forest in a kauri dieback area etc. The *xxx*? code for importing and intersecting these shapefiles is as follows:

```
 library(sf)
 library(spbal)
 library(dplyr)

#Import management unit
 shp <-st_read("management_unit.shp")
 #Convert to the NZTM coordinate system
 shp <-st_transform(shp,"+proj=tmerc +lat_0=0 +lon_0=173 +k=0.9996
+x_0=1600000 +y_0=10000000 +ellps=GRS80 +towgs84=0,0,0,0,0,0,0 +units=m
+no_defs")

#Import indigenous forest layer
 forest <- st_read("CNI_LCDB_forest.shp")
 #Convert to the NZTM coordinate system
 forest <-st_transform(forest,"+proj=tmerc +lat_0=0 +lon_0=173 +k=0.9996
+x_0=1600000 +y_0=10000000 +ellps=GRS80 +towgs84=0,0,0,0,0,0,0 +units=m
+no_defs")

#Intersect the indigenous forest layer with the management unit boundary
 shp_forest <-st_intersection(forest, shp)
```

2. Once the survey block boundary has been prepared, a set of sample points that can be used as the start points for SRI transects is generated. For this example, 20 SRI transects are required. However, 40 potential sample points are created to give 20 contingency points. This will give a list of 40 sample points with a hierarchical ordering of 1–40, shown by the attribute 'spbalSeqID' in Table 1. The *xxx*? code for generating 40 sampling points within a study area boundary is as follows:

[2] LCDB v5.0 – Land Cover Database version 5.0, Mainland, New Zealand | LRIS Portal. Available at https://lris.scinfo.org.nz/layer/104400-lcdb-v50-land-cover-database-version-50-mainland-new-zealand-deprecated/

```
#Load spbal library for generating BAS points
 library(spbal)

#Generate sample for survey block boundary
 sample_points <- spbal::BAS(shapefile = shp_forest,
 n = 40,
 boundingbox = NULL,
 seeds = NULL,
 verbose = FALSE)

#Add the coordinates to the table
 sample_points$sample$Easting <-st_coordinates(sample_points$sample)[,1]
 sample_points$sample$Northing <-st_coordinates(sample_points$sample)[,2]
```

Table 1. Transect start locations generated by BAS with the hierarchical ordering of locations shown in column 'spbalSeqID'. The two right-hand columns show the results of the desktop evaluation of the sampling points.

Site	spbalSeqID	Easting	Northing	Desktop evaluation	Accept/Reject?
1	1	1857916	5669040	OK	Accept
4	2	1850078	5665080	boundary	Reject
5	3	1860529	5672209	OK	Accept
6	4	1843547	5660327	OK	Accept
7	5	1853997	5667456	safety	Reject
15	6	1851874	5661119	feasibility	Reject
16	7	1846649	5668248	OK	Accept
18	8	1844037	5663496	OK	Accept
19	9	1854487	5670624	OK	Accept
23	10	1853181	5671681	OK	Accept
25	11	1858406	5666928	safety	Reject
28	12	1850568	5669304	OK	Accept
31	13	1852528	5665344	OK	Accept
35	14	1855140	5674849	proximity	Reject
37	15	1860365	5670096	OK	Accept
39	16	1853834	5659007	OK	Accept
40	17	1848609	5666136	OK	Accept
41	18	1859059	5673265	OK	Accept
42	19	1845996	5661383	OK	Accept

There will be occasions when surveying very large areas that cluster sampling may be desirable to reduce travel time between transects. Cluster sampling involves dividing the study area into subunits with transects assigned to a subset of those units. Transect start locations within each subunit can also be generated using spatially balanced sampling. Cluster and spatially balanced sampling is best left to the skills of a statistician.

A compass bearing will also need to be assigned to each sample location along which the transect will be established. The simplest option is to assign the same bearing to all points, usually one of the cardinal compass directions. Alternatively, a bearing (001–360°) can be randomly assigned to each point, although this may lead to more transects being rejected due to proximity to one another.

Random sampling

An alternative to spatially balanced sampling is random sampling, where the study area is gridded and grids cells or locations along grid lines are randomly selected to obtain sampling points. The advantage of this method is its simplicity, but the nature of random sampling means that the resultant distribution of sampling points will frequently be clumpy, which may lead to sampling biases if the distribution of browsing-animal impacts is unevenly distributed across the study area.

Discarding non-compliant transects

Once a list of potential transects is obtained, each will need to be assessed in terms of health and safety and feasibility of travel to and along them. Transect spacing and habitat will also need assessment. A desktop evaluation is initially undertaken with each transect assessed in sequential order listed in the ‘spbalSeqID’ column of Table 1, using the suggested rejection criteria in Table 2. If the location is feasible for establishing an SRI transect (i.e. can be accessed within a reasonable amount of time and has no apparent safety, habitat, or spacing issues), it is accepted and the next transect is assessed until the desired number is obtained.

Table 2. Rejection criteria. Suggested reasons for rejecting transect start point (adapted from Department of Conservation 2024).

Reason	Description	Desktop evaluation example	Field evaluation example
Safety	Likely to be unsafe terrain along the transect or on all feasible access routes to the start point.	Travel route or transect will intersect a river or large stream—i.e. likely to be an impassable barrier.	Travel route or transect passes through excessively steep or bluffy terrain that cannot be practically avoided.
Feasibility	Not feasible to complete the full transect within 1 day.	Over 1.5-hour walk (~3 km) from the access point (carpark, helicopter/boat landing or camp/hut) to the start point.	Access point is too far for the transect to be measurable within 1 day, based on field observations.

Boundary	Transect extends outside of the site boundary, or the transect is partially/ fully outside of forest.	GIS imagery shows that transect encounters non-forested areas.	Observations enroute or at the start point show that the transect will encounter non-forest habitat.
Proximity	Transect is within 200 m of other transects of the same method.	Transect is within 200 m of other planned or established transects of the same method.	Transect is likely to be within 200 m of other established transects of the same method.

The final list of accepted transects should contain the required number to meet sampling intensity requirements and at least 10 contingency transects to allow for further rejections, using the above criteria, when the locations are visited by field crew.

Sampling intensity

The number or transects measured will determine the precision of the SRI estimates obtained and, therefore, the power to detect statistical differences between indices within surveys (avoided vs non-selected vs preferred species SRIs), between areas, or over time (repeated surveys in the same area). Sample sizes will also depend on the number of strata to be measured and the desired effect size (how big of a difference between indices that you want to detect). Lastly, the number of transects required to meet these goals depends on the short seedling richness in the survey area; low-diversity forests require larger sample sizes.

The following recommendations are based on power analyses in Sweetapple (2022) and in Sweetapple & Nugent (2004).

- Recommended sampling intensity for most forests is 10 transects. This will detect differences (5% level) in SRI between surveys of about 0.15 for non-selected species and about 0.28 for preferred species in low–moderate diversity forests. Although power is lowest for preferred species, their SRIs cover a greater range of values than for non-selected species; therefore, detecting a significant change following effective ungulate control is just as likely, if not more so, than for non-selected species. Greater power will be obtained from forests with high seedling richness.
- Fifteen transects should be measured in very low diversity forests (e.g. high-altitude beech forests).
- An alternative to increasing the number of transects in low-diversity forests is to reduce the interval between plots to 10 m and increase the number of plots to 40 during subsequent surveys for all transects that have < 5 short seedling records of preferred species recorded during the initial survey.
- Larger sample sizes should be considered for very large surveys (> 20,000 ha), particularly where a range of ungulate densities across the area are expected.

Survey timing

- The extent to which seasonal effects (seasonal plant growth and ungulate dietary patterns) influence SRIs and BIs is unknown; therefore, to minimise possible seasonal effects, all transects are measured within a 30-day period, and that period is repeated for all survey remeasurements.
- Seedling populations may take several years to fully respond to a reduction in ungulate populations, but remeasurements should be undertaken immediately before and two years after the commencement of a control programme to determine if BIs are consistent with a recovering seedling population and that the preferred-species SRI is increasing. Adjustment to the control programme may be required if these results are not obtained.
- For trend monitoring once SRI goals have been achieved, re-surveys every 3–5 years will be sufficient for most management regimes.

Establishing transect starts

- Navigate to the pre-selected start point using a map, compass, and GPS.
- Choose a prominent tree as close as possible to the pre-selected start point.
- Start trees will be alive and sturdy enough to attach markers. Do not use crop trees in plantation forests.
- For new transects, relocate the start point if the original pre-selected one cannot be accessed (e.g. due to a bluff), or if there are no trees within 10 m of the original point. For repeat measurements mark a new line start on the nearest available tree when the original start tree cannot be found (e.g. due to a recent slip or windfall).
- Relocated start points for new transects will be established 50 m to the left or right (right angles to the transect bearing), as determined by a coin toss, of the original start point. If that point is also unsuitable, apply sensible 'business rules' to limit the need to abandon the start point. For example, try starting at 50 m, 100 m, then 150 m, then 50 m, 100 m, and 150 m in the opposite direction. If all six options are unsuitable, abandon the transect and use the next available contingency transect on the pre-determined ordered list. Transects will follow the original bearing from all relocated start points.
- Record all new, relocated, or re-marked GPS start point on a GPS unit, and on the SRI data sheet (Appendix A) tick the 'New start' box and record the reason for the new start in the transect notes. Use a logical and consistent naming protocol for the waypoint name (see Appendix B for an example).
- Permanently mark the start tree with a permolat cross or non-orange plastic track marker and record the GPS location if it differs from the pre-selected location.
- Hammer two nails into the marker to attach it to the tree. Nails should remain protruding by at least 2 cm to allow for tree growth.
- Scribe/scratch the survey/area identifier, transect number, bearing, and year on the marker, using a nail or other sharp device. Reinforce this with marker pen if required.

- For repeated measurements over time, use the same start points and bearings.

Rules for abandoning measurements

Situations may arise where an SRI transect is partially measured but cannot be completed within 1 day. If this occurs:

- Abandon the remainder of the line that cannot be completed in 1 day.
- Return on a different day to finish the incomplete transect only if it can be measured in addition to other transect measurements planned for that day.
- If the transect is not completed on a second day, record this deviation from standard protocol with a reason in the 'Transect notes' section of the SRI data sheet (Appendix A).
- If less than half of the transect was measured, measure an additional transect within the sampling location if time permits, using a contingency transect.

If a transect cannot be completed (e.g. for health and safety issues or a break in forest cover) and it cannot be turned (see rules for changing transect bearings in 'Impassable barriers' below), abandon the rest of the transect and follow the last two bullet points above.

Measuring transects

Use a compass and running line/hipchain/measuring tape to navigate to the first plot location, 20 m from the start point. To do this, fix the device to the ground or vegetation at the start point (base of the marker tree, facing the transect bearing) and run it out along the confirmed transect bearing. When the running line is taut, or measured distance is 20 m, insert the running line peg in the ground to mark the centre of the first plot centre. On transects with low species richness, consider using 10 m plot spacings to increase the number of plots from 20 to 40 per 400 m transect (see 'Sampling intensity' section above).

When the first plot is complete, navigate to and measure the next and all subsequent plots in the same manner. Figure 5 shows a schematic of the transect layout.

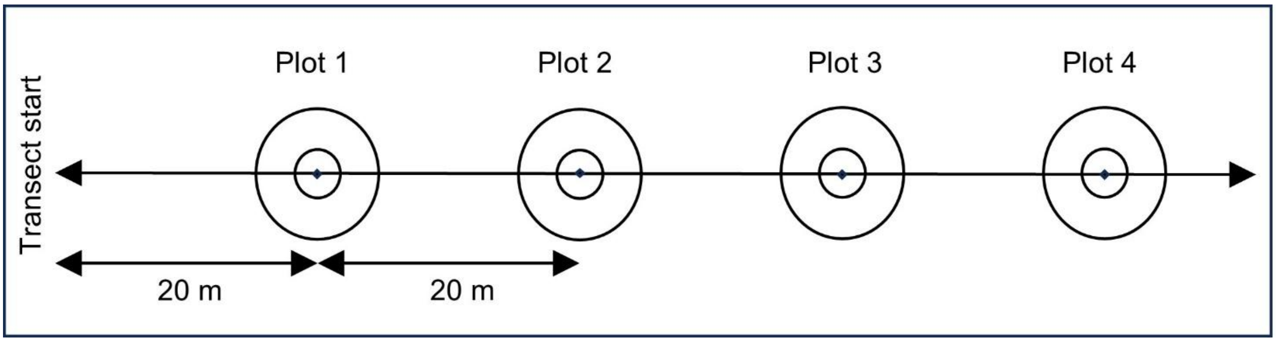

Figure 5. Transect layout for SRI measurement (not to scale; from Department of Conservation 2024).

Encountering barriers along transects

Sometimes barriers will be encountered along the transect bearing where it is not possible or inappropriate to place plots. These barriers are either passable (can be safely crossed) or impassable (cannot be safely crossed).

Passable barriers

Passable barriers include:

- Roads, tracks, permanent public camp, and hut sites, including their 20 m exclusion zones (ignore unofficial/illegal structures/temporary camp sites). The 20 m exclusion is measured along the shortest route to the track, road, or camp/hut site clearing, not along the line bearing.
- Temporary breaks in tall vegetation (≥ 2 m tall) such as grassland, subalpine, alpine, frost flat, or swamp vegetation.
- Water courses or permanent bodies of standing water that can be safely crossed.
- Temporary bodies of standing water ≥ 20 cm under tall vegetation. Do not measure any plot if any part of it is covered by water ≥ 20 cm.
- Any obstacle that cannot be safely crossed but can be bypassed without deviating more than 50 m off the lay of the line, returning to the line < 50 m from the last plot (e.g. bluffs, deep bodies of standing water).
- Fenced ungulate exclosure plots (do not enter or otherwise disturb even if the fence is broken).
- Impenetrable heavy windfall < 50 m across.

Passable barriers do not include tight or prickly vegetation, regenerating canopy gaps, or navigable windfall gaps; continue measuring plots through these areas.

Plots that fall within passable barriers are not measured. Continue to measure 20 m intervals along the transect bearing until the barrier is passed. For ungulate exclosure plots and heavy windfall, walk around to the far side of the barrier until the line of the original bearing is reached and measure 20 m to the next SRI plot along the original bearing. For all passable barriers, resume plot numbering from where you left off once the barrier is passed. Record location (plot number after which the barrier is encountered) and width of passable barriers in the transect notes on the SRI data sheet. Code as **LB-[plot number], [xx m]** (e.g. if a line is broken between plots 5 and 6 for approx. 25 m, then code as **LB-5, 25 m**).

A passable barrier is treated as an impassable barrier if the break in plots is longer than 50 m. If the barrier is assessed as clearly wider than 50 m when first encountered, then it can be treated as impassable without measuring. Accumulative passable barriers on a single transect must not exceed 100 m. Transects are ended once this limit is reached.

Impassable barriers

Impassable barriers include:

- Streams and rivers that cannot be safely crossed
- Bluffs, unstable slips and screes, or excessively steep terrain than cannot be safely navigated
- Breaks in tall vegetation > 50 m
- Survey area boundaries as defined in the 'Minimum attributes' section
- Where transects come within 200 m of another completed transect

The risk of encountering impassable barriers should be minimised by careful selection of start points and bearings during planning.

If you encounter an impassable barrier:

- Return to the previously measured SRI plot, then add or subtract 90 degrees from the original compass bearing.
- Follow the transect along the new bearing. Note all transect changes in the SRI data sheet (Appendix A).
- If you encounter another barrier or the transect comes within 200 m of another, repeat the process.
- Do not follow a bearing back towards the line start (i.e. the back bearing). If the transect cannot be continued without following the back bearing, it is considered a 'dead-end' and is ended.
- Save a waypoint for each plot at which there is a turning point (T) following the GPS point labelling protocol (see Appendix B) and record the new bearing for each turn and the reason for turning on the SRI data sheet.

If a transect runs into a dead-end before half of the plots have been completed, an additional transect should be established within the survey boundary if time permits, using one of the contingency transects.

Follow the turns and bearings recorded in the metadata from any previous measurements even if the barrier no longer exists.

Plot procedure

Delineating the plot boundaries

- Firmly push the search-radius (string/tape with a peg/spoke at one end and knots/markers at 49 cm and 141 cm from the peg) firmly into the ground at the plot centre (where the running line extended to when pulled tight). Where the centre peg is insecure due to hard ground conditions, it may be easier to use a builders measuring tape to define the plot boundaries.

- Plots consist of a 1.41 m radius search area (Figure 6). The search area is defined as any surface (soil, litter, rock, root-plate, dead and live standing stem, large woody debris, or moss/liverwort growing on these) that can be reached by the search string pulled tight. This means plants growing on these features are included. Dead and live stems are included to sample epiphytes. The string is passed either under or over objects suspended above the ground to achieve the greatest reach.
- Seedling heights are measured vertically.
- A synthetic string search radius (e.g. 3 mm paracord) can permanently stretch, or more commonly, shrink. Check the distances to each marker daily. Distances are measured from the centre of the centre peg.

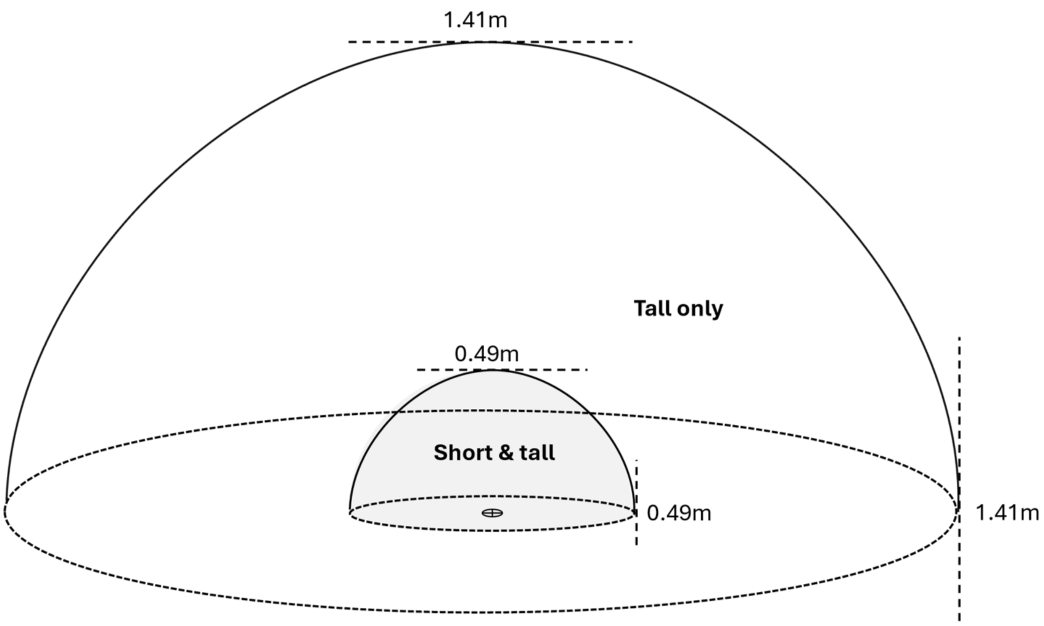

Figure 6 (not to scale). SRI is measured in a nested semi-spherical search area, centred on the peg attached to the running line. Short seedlings (< 0.3 m tall) are measured in a search area with a radius of 0.49 m. Tall seedlings (≥ 0.3 m and ≤ 2 m tall) are measured in a search area with a radius of 1.41 m.

Record short and tall seedling species

- Record all plot data on an SRI data sheet (Appendix A).
- Both horizontal and vertical searches are subdivided into **short**- and **tall**-seedling searches. **Short** seedlings are those < 30 cm tall, rooted on any surface within 49 cm of the plot centre. **Tall** seedlings are those ≥ 30 cm tall, rooted on any surface within 141 cm of the

plot centre. Systematically search a full circular sweep around the centre peg recording the names of all **target** species rooted within 49 cm of the centre (Figure 7). Tick the 'Short tier' column to the right of the plant name to indicate the presence of short seedlings (< 30 cm tall) and/or the 'Tall tier' column for seedlings 30–200 cm tall.

- Undertake a second full circular sweep, 49–141 cm out from the plot centre searching for **target** seedlings 30–200 cm tall (Figure 7). Record their names on new rows of the data sheet if not already recorded and tick the 'Tall tier' column. Use a builders measuring tape to confirm the heights of seedlings close to 30 or 200 cm tall.
- Include all seedlings (short and tall) that are rooted at least partially within their respective plots; i.e. it does not need to be fully, or even > 50% within the plot.

Do not record:

- The number of individual plants. Instead, only record a tick (✓) for each species in the 'Short tier' and/or 'Tall tier' columns.
- Seedlings that have only cotyledons (seedling leaves; the first pair of leaf-like lobes on recently germinated seedlings), even if you know what species it is. At least two proper leaves must be present, no matter how small they are.
- Dead plants.

Target species

Record any woody tree and shrub species that will likely attain heights of ≥ 100 cm (1 metre) in the absence of ungulates including:

- tree ferns (*Cyathea* and *Dicksonia* species that develop an upright trunk)
- nīkau palm (*Rhopalostylis sapida*)
- cabbage trees (*Cordyline* species)
- hen and chickens fern (*Asplenium bulbiferum/A. gracillimum*).

These can be rooted on the ground surface (clean or litter/moss/liverwort-covered soil, humus, and mineral surfaces such as sand, scree, and bedrock), or as epiphytes on standing or fallen stems/trunks of trees or tree ferns. This means that prostrate woody plants, mistletoes, climbers, grasses and grass-like plants, most ferns and monocotyledons (with the above exceptions), other herbaceous flowering plants, and non-vascular species are not recorded.

Identify most woody plants to species level and tree ferns to genus level, and hen and chickens fern (*Asplenium bulbiferum/A. gracillimum*). Small-leaved coprosmas, small-leaved pittosporums, hebes, *Carmichaelia*, and *Dracophyllum* need only be identified to genus level. *Coprosma* species are considered 'small-leaved' if they have leaves smaller than *Coprosma foetidissima*. *C. foetidissima* has consistently sized leaves and is a good baseline to assess if other *Coprosma* species are considered 'small' or 'large' leaved. Small-leaved *Pittosporum* species (*P. anomalum,* *P. divaricatum, P. obcordatum*, and *P. rigidum*) are grouped. *P. virgatum* and *P. pimeleoides* are localised, rare, and distinctive enough to be identified to species.

See Appendix C for information on how to record small- and large-leaved coprosmas, pittosporums, and *Asplenium bulbiferum/A. gracillimum*.

Note that this may differ from previous versions of the SRI method that included most ground ferns and some climbers that are free standing as seedlings. Hen and chickens fern (*Asplenium bulbiferum and A. gracillimum*) are included as a special case because they are widespread and common and are preferred species that, collectively, are scarce at some sites. See Appendix C for a list of target species for which preference classes are known. Other species meeting the above criteria are also recorded.

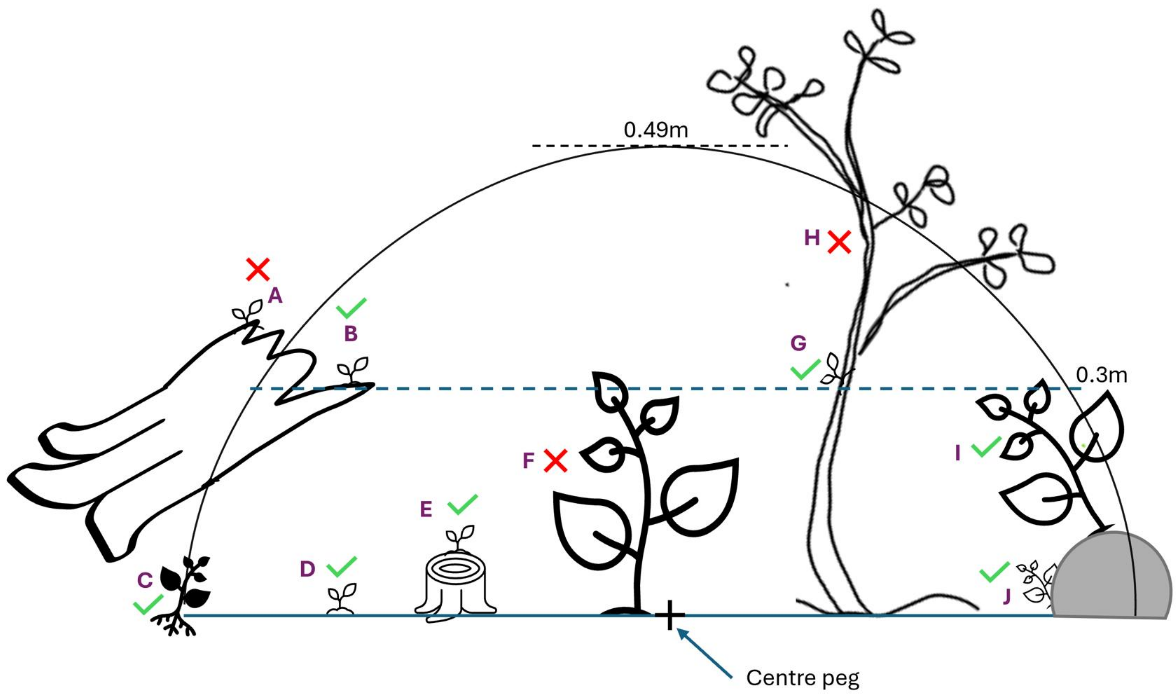

Figure 7. Plots for measuring short seedlings consist of a 3-dimensional search area with a radius of 0.49 m from the centre peg. The search area is defined as any surface (soil, litter, rock, root-plate, dead and live standing stem, large woody debris, or moss/liverwort growing on these) that can be reached by the search string pulled firm. Dead and live stems are included to sample epiphytes.

Record all target species < 0.3 m tall that are at least partially rooted within the search area. In this example, each letter represents a unique species. Species B, C, D, E, G, I, and J would be recorded in the 'Short tier' column. Note: G is an epiphyte, not a branch.

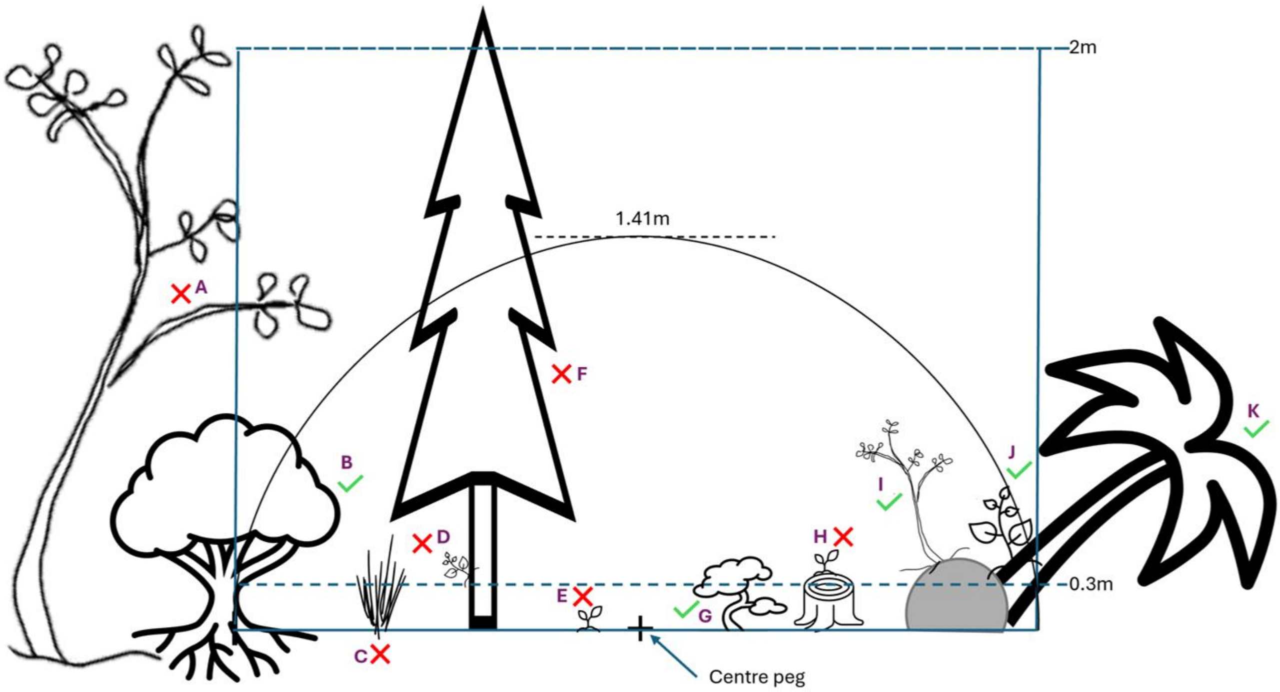

Figure 8. Plots for measuring tall seedlings consist of a 3-dimensional search area with a radius of 1.41 m from the centre peg. The search area is defined as any surface (soil, litter, rock, root-plate, dead and live standing stem, large woody debris, or moss/liverwort growing on these) that can be reached by the search string pulled firm. Dead and live stems are included to sample epiphytes.

Record all target species ≥ 0.3 m and ≤ 2 m tall that are at least partially rooted within the search area. In this example, each letter represents a unique species. Species B, G, I, J, and K would be recorded in the 'Tall tier' column. Note: C is a non-woody species.

Height measurements

Height is measured vertically (not perpendicular to the slope) from the base of the plant to the uppermost live foliage or shoot tip (not including flower or seed heads and their leaves), and as the plant naturally stands (rather than measuring the 'pulled up' or 'extended' height; Figure 9). On sloping ground, height is measured from the middle of the plant base, not from the uphill or downhill side. These standards are applied to both woody species and ferns, which differs from some previous SRI protocols where height of tree ferns was measured to the base of the fronds.

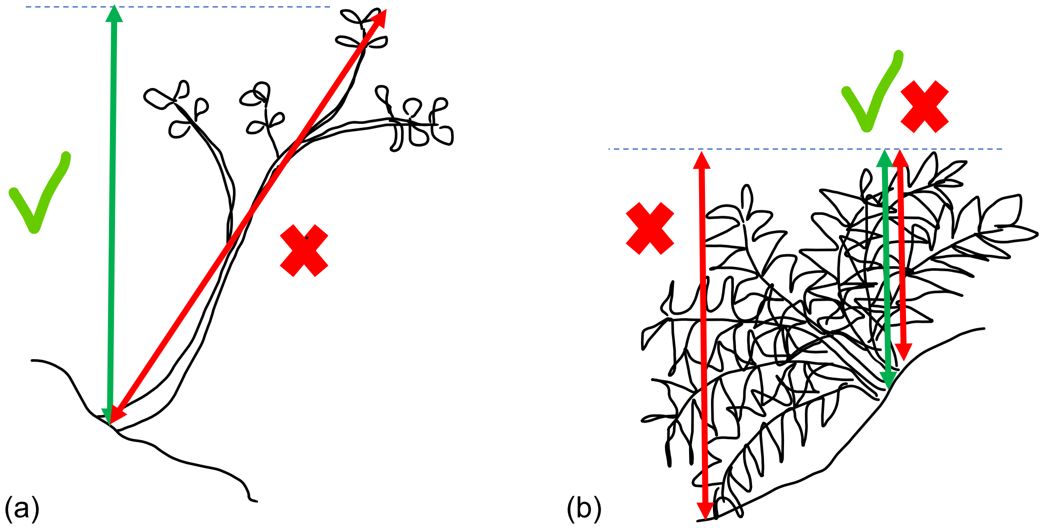

Figure 9. (Left) The height of plants is measured vertically, not perpendicular to the slope. (Right) Height is measured from the middle of the plant base to the uppermost live foliage or shoot tip (Department of Conservation 2024).

Ungulate browse scores

Browse scores are an optional part of the SRI method but are recommended. They help to interpret the SRI results, particularly when there has been a recent change in ungulate abundance and the SRIs have had insufficient time to fully adjust to that change.

Browse scores are measured on a browse plot defined as a 200 cm tall cylinder above the 1.41 cm radius seedling plot. The top of the browse plot is measured vertically from the ground surface. This excludes obstacles such as tree stumps, boulders, and steep banks that ungulates are unlikely to stand on (Figures 10 & 11). For such obstacles, the top of the plot is measured from the soil surface at the base of the obstacle.

Browse scores are assessments of the proportion of live branches present within the browse plot and that have been browsed by ungulates (Figures 12 & 13). Live branches are defined as the main (central) stem and all stems diverging from it that have at least 2 cm of live material, excluding leaves, from the stem tip to the point it arises from its ‘parent’ stem. Exceptions to this rule are whole fern fronds, individual *Cordyline* leaves and individual leaflets on nīkau palm fronds, which are all treated as individual branches. Live branches can have dead tips as long as > 2 cm of the branch remains alive.

This includes parts of plants not rooted on the plot but overhang the 1.41 m radius plot.

One browse score is recorded for all live branches and their foliage, combined, for each target species that has branch tips and/or foliage of plants > 15 cm tall within the browse plot. This includes epiphytes, and plants rooted outside the plot but with branch tips and/or foliage within the plot.

A branch is counted as browsed if at least one of its leaves and/or its terminus has been damaged by an ungulate. Ungulate browse is considered old if the branch has died back > 2 cm from the point of damage, or the damaged tip is calloused over. Old browse is ignored. Browse scores describe the proportion of eligible branches, with some recent ungulate damage. A five-point browse score, ranging from 0 to 4 (Table 3), is recorded for all target species with live shoots in the plot even if there is no browse observed (i.e. a score of 0).

Table 3. Browse score categories.

Browse score	Description
0	No recent ungulate browse observed
1	1–25% of shoots with some recent ungulate browse observed
2	26–50% of shoots with some recent ungulate browse observed
3	51–75% of shoots with some recent ungulate browse observed
4	76–100% of shoots with some recent ungulate browse observed

Browse is assessed for each of the same target species as for the short and tall seedling tiers that are present in the browse plot, with one exception. Because browse scores include epiphytes and overhanging plants, it is possible to record browse for target species that were not recorded in either of the seedling plots. In these cases, the new species name is recorded along with its browse score on a new row on the SRI data sheet, with a dash ('–') recorded in both the 'Short tier' and 'Tall tier' columns.

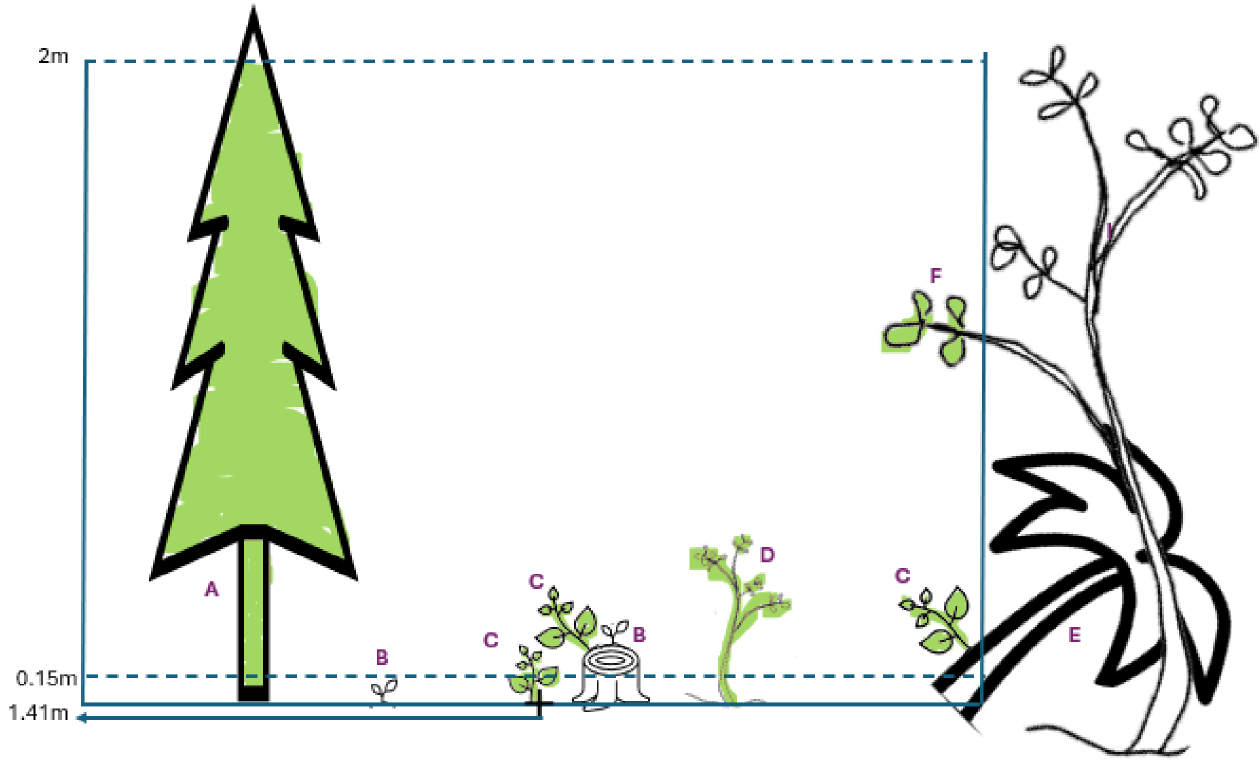

Figure 10. The area in which browse is assessed can be thought of as a 'cylinder'. The radius of the cylinder is the same as for measuring tall seedlings (1.41 m). Include all live branches within the browse cylinder from target species plants > 15 cm tall (green). Plants need not be rooted within the cylinder. In this example, where each letter represents a unique target species, browse scores are recorded for A, C, D, and F. Material shaded green is included while unshaded material is excluded from the browse score. E is not scored because it has no scorable material (foliage or branch tips) within the plot. The two shortest specimens of B are excluded because they are < 15 cm tall.

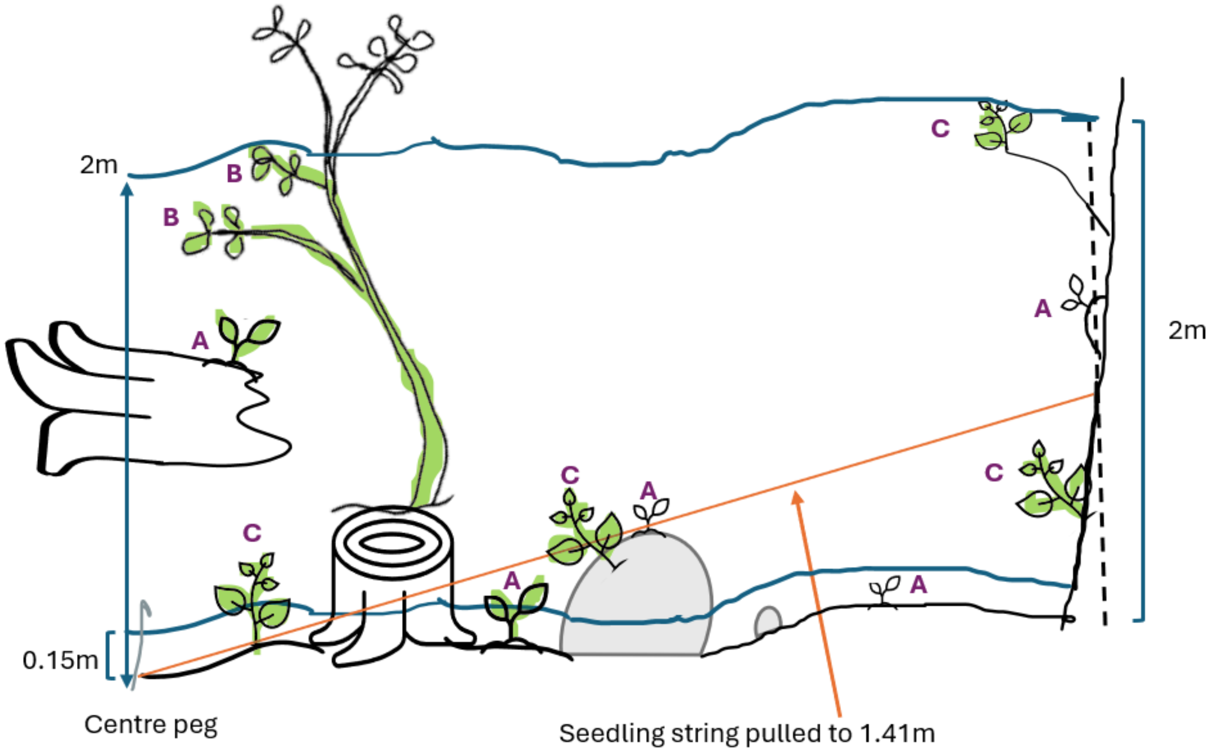

Figure 11. When there are large obstacles that deer are unlikely to stand on (e.g. boulders, stumps, and steep banks), measure the top of the browse cylinder from the soil level around these objects. In this example, where each letter represents a unique target species, browse scores are recorded for A, B, and C (assessing the foliage highlighted in green). The three smallest individuals of species A are excluded because they are < 15 cm tall.

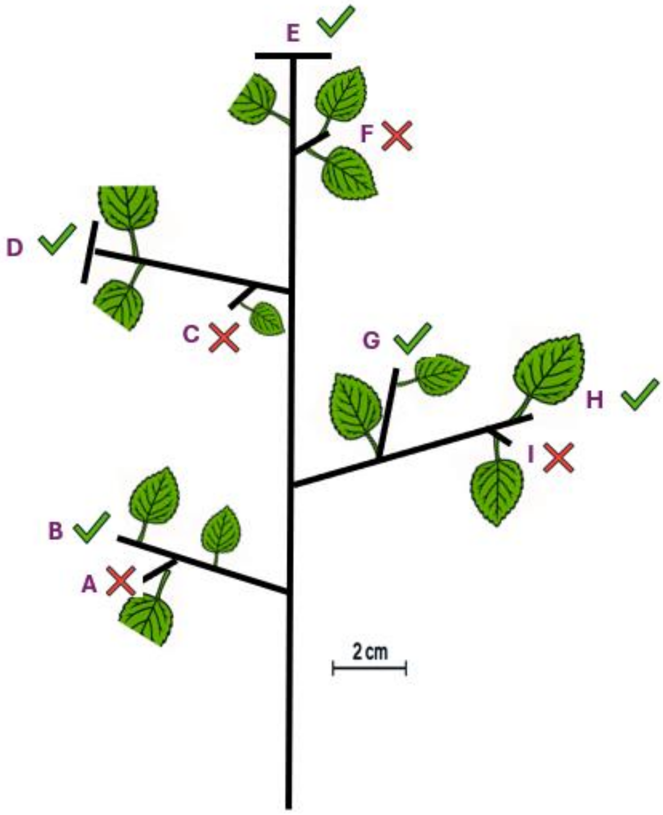

Figure 12. Interpretation of a browsed plant with simple leaves. Heavy lines are structural elements (main stem and branches) and browse damage. The 'T's at the end of some branches and half leaves indicate ungulate browse damage. Ticks and crosses beside branch labels indicate branches included and excluded, respectively, for browse assessment. The short branch spurs A, C, F, and I are not counted as eligible branches because they are < 2 cm long. The browsed leaf on A is not ignored but is assigned to branch B. There are 5 branches (B, D, F, G, and H) counted for browse assessment (i.e. > 2 cm long). Branches B, D, and E have varying amounts of browse damage, but are all treated as simply 'browsed'. If this plant was the only specimen of this species > 15 cm tall on the plot, the species would receive a browse score of 3 (3 out of 5 branches browsed = 60%: browse score = 3).

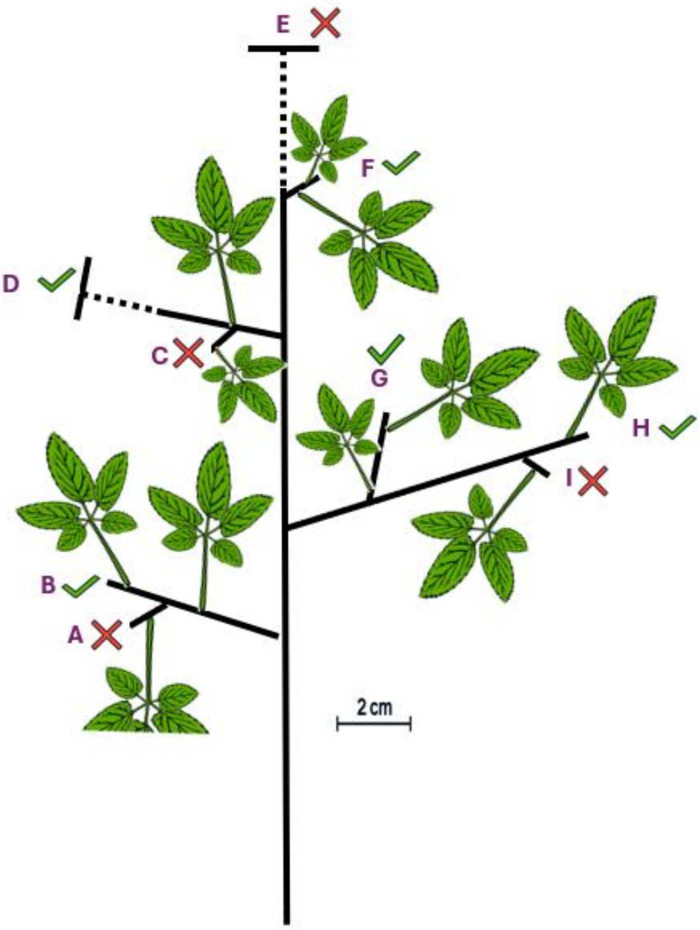

Figure 13. Interpretation of a browsed plant with compound leaves. Heavy lines are structural elements (main stem and branches) and browse damage. Light lines are leaf petioles. The dashed lines indicate dead parts of branches. The 'T's at the end of some branches and the half leaf (branch A) indicate ungulate browse damage. Ticks and crosses beside branch labels indicate branches included and excluded, respectively, for browse assessment. The short branch spurs A, C, and I are not counted as eligible branches because they are < 2 cm long. The browsed leaf on A is not ignored but is assigned to branch B. The top of the main stem above F is dead, meaning that F is now the top of the main stem and, therefore, is measured from its tip to the ground. There are 5 branches (B, D, F, G, and H) counted for browse assessment (i.e. > 2 cm long). Some petioles are > 2 cm long but are not counted as branches because leaves are not counted for browse assessment. Only one branch (B) is assessed as having recent browse damage. The browse damage on D is old (has dieback > 2 cm) and is not counted. If this plant was the only specimen of this species > 15 cm tall on the plot, the species would receive a browse score of 1 (1 out of 5 branches browsed = 20%: browse score = 1).

Counting of branches and browse damage is only practical when there are only a few small plants being assessed. In these cases, each branch and incidence of browse damage has a large bearing on the browse score. Where there are a large number of plants, or large plants being assessed, counting branches is impractical. Browse assessment then becomes a subjective estimate of the extent of browse damage. For example, if browse damage is present, does it affect more than 25%, 50%, or 75% of the branches present within the browse plot?

Identifying ungulate browse damage

Browse from ungulates, possums, and insects may be encountered on SRI plots in forest. Each type needs to be identified so that only ungulate browse is included.

- **Woody tree/shrub species:** Ungulate browse is characterised by truncated shoots with smoothly cut young shoots or older, thicker shoots with roughened ends, rather than damaged or missing leaves on intact stems. Where browse-damaged leaves are present they will usually be cleanly truncated, often with small clusters of more than one leaf and shoot truncated to the same length (Figure 14).
- **Ferns (including tree ferns):** Ungulate browse is characterised by truncated fronds, leaving either the lower part of the blade ('leafy' part) intact (Figure 15 (left)) or just the stipe (frond stem/petiole). Usually there will be several adjacent fronds truncated to about the same length. Ignore damage when just one frond is damaged as this is likely due to other causes.
- Fern fronds are sometimes bent and snapped off by wind, falling branches or other causes; if the snapped off end of the damaged frond is still attached or on the ground, it is not browsed.
- Browse that cannot be confidently identified as ungulate is included if it meets the criteria above for ungulate browse.

Identifying non-ungulate browse damage

- Possum browse on woody plant leaves is usually characterised by the remains of torn leaves on intact shoots. Basal parts of the leaf lamina usually remain on damaged leaves, often with the tattered remains of the bare or near-bare midrib extending beyond the basal remains (Figure 16).
- Possums will sometime shear off the whole leaf by biting through the base of the petiole (leaf stalk), dropping the rest of the leaf, and, often, damaging the adjacent shoot (e.g. *Pseudopanax* species and *Schefflera digitata*; Figure 17). This type of damage is usually easily identified by the presence of denuded shoots and cast leaves under the plant, with the petiole bases torn off. It can occur in combination with damaged leaves fitting the description above still attached to the plant.
- Truncated shoots caused by petiole-biting possums can superficially look like ungulate browse damage but are easily identified as caused by possums by the presence of dropped leaves with missing petiole bases, small patches of damaged bark behind the shoot truncation, and, sometimes, damaged shoots surrounded by undamaged leaves that are much longer than the damaged shoots (Figure 17).
- Possum browse on ground ferns is often characterised by a mix of intact and truncated pinnae (side leaflets; right-hand photo in Figure 15). These browse events usually occur while the frond is unfurling with the pinnae removed while they are still mostly tightly rolled, resulting in groups of heavily truncated pinnae amongst intact pinnae on the mature frond.

- Browse damage from insects typically has smooth wavy or semicircular margins that are finely milled (very fine individual bite marks lining the damaged margin; a lens can be useful to confirm). The scale of damage ranges from small holes or marginal scoops < 1 cm across to the entire lamina missing leaving just the midrib (Figure 18). Heavy insect browsing can superficially look like possum browse damage but is easily distinguished from the latter by the absence of torn margins.
- Occasionally, stem-boring insects will remove or kill the tips of fine shoots without damaging leaves and resemble very light ungulate damage. This is common in some years on tawa (*Beilschmiedia tawa*), an ungulate-avoided species.

Figure 14. Examples of ungulate browse on woody shrubs: (left) on a small-leaved divaricate shrub *Myrsine divaricata* (photo: G. Ledgard, in Department of Conservation 2024) and (right) on a large-leaved shrub *Griselinia littoralis* (photo: P. Sweetapple).

Figure 15. Examples of animal browse on ferns: (left) ungulate browse on *Polystichum vestitum* (inside red circles; photo: G. Ledgard in Department of Conservation 2024) and (right) possum browse on *Asplenium bulbiferum* (photo: Department of Conservation 2024).

Figure 16. Examples of possum browse damage on (left) māhoe (*Melicytus ramiflorus*) and (right) kāmahi (*Pterophylla racemosa*) pressed leaves. Material collected and photographed by P. Sweetapple.

Figure 17. Possum browse on *Pseudopanax arboreus* showing (left) truncated shoots after the removal petiole bases and shoot termini (note the patches of missing bark in the red circles) and (right) petiole bases of discarded leaves (photos: P. Sweetapple).

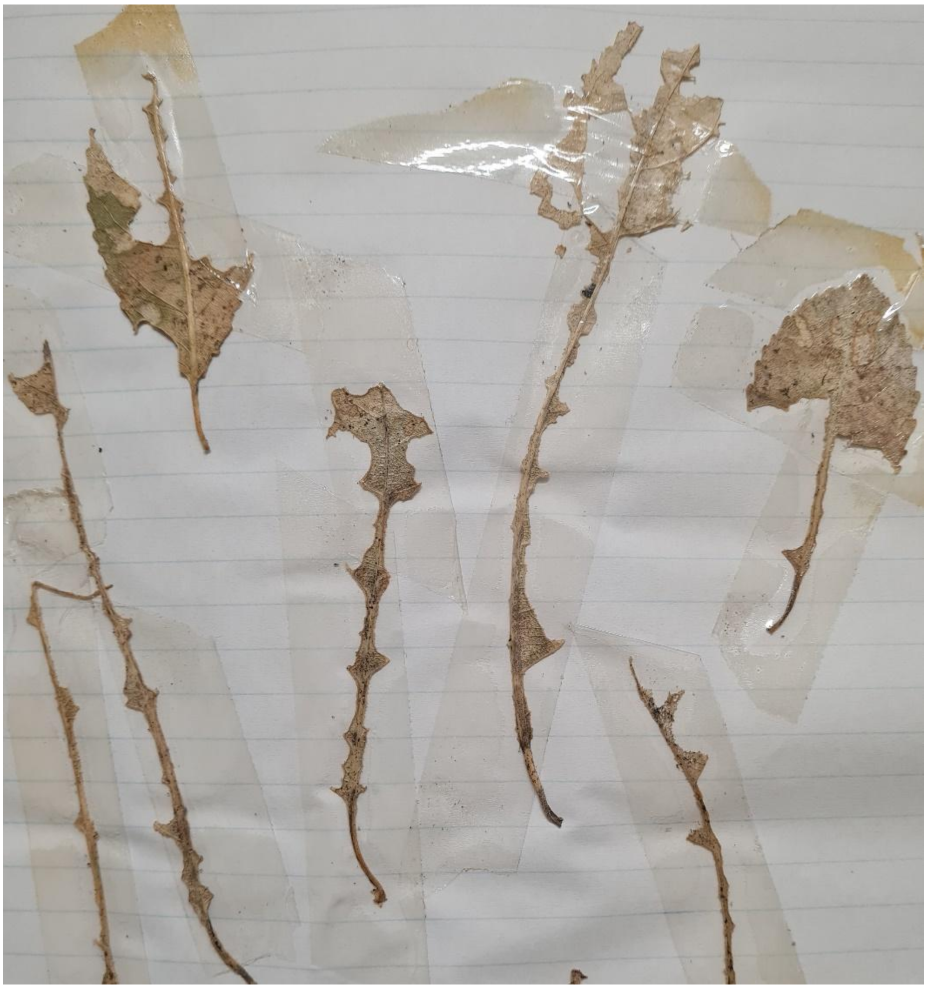

Figure 18. Pressed examples of insect-damaged māhoe (*Melicytus ramiflorus*) leaves. Material collected and photographed by P. Sweetapple.

Naming plant species

Plant species names follow the NVS (National Vegetation Survey Databank of New Zealand) six-letter code convention, which comprises the first three letters of the genus in upper case followed by the first three letters of the species in lower case (e.g. *Leptospermum scoparium* (mānuka) is shortened to LEPsco).

Name all small-leaved *Coprosma* and most small-leaved *Pittosporum* species (see Appendix D for full details) as 'COPsmall' and 'PITsmall', respectively, as though they are unknown at the species level. Record all large-leaved species of these genera to species level. The following are recorded to only genus level:

- *Carmichaelia* (CARMIC)
- *Dracophylum* (DRACOP)
- *Ozothamnus* (OZOTHA)
- *Veronica* (hebe) (VERONI)

For the two target *Asplenium* species (*A. bulbiferum* and *A. gracillimum*), either record to species level or group to 'ASPhenchick'.

Refer to Appendix C for a list of species and corresponding NVS codes and Appendix D for naming protocols.

Collecting or photographing unidentified plant specimens

Unidentified plants can be collected or photographed for later identification. Collecting or photographing and identifying plants is time consuming so can only be done if resources permit (a decision to collect or not is made during the planning stages of the survey). Collecting may be restricted to the more common unknown species, e.g. those recorded more than once on a transect or more than five times during a survey. This will have the added benefit of not over-collecting locally rare species. Quality photos can be taken in lieu of physical collections or to supplement collections but may be restricted by weather conditions and the low-light and close-up capabilities of available cameras. For plants that are collected or photographed:

- Clearly label with the SRI data sheet name (e.g. 'UNKhairy'), transect and plot number, date, and observer.
- Add a ©, ℗, or both after the name on the SRI data sheet to indicate if a specimen was collected (©) or photographed (℗).
- Identify the specimen using reference material and/or botanical experts as soon as practical after the survey and update the SRI data sheets with the correct names.

See Appendix D for full details of naming (including special cases), collecting, and photographing plants.

References and further reading

Department of Conservation. 2024: Seedling ratio index (SRI) field protocol: wild animal monitoring pilot 2023–2024. Draft version 8, February 2024 (unpublished). Department of Conservation. 25 p.

Forsyth, D.M.; Coomes, D.A.; Nugent, G.; Hall, G.M.J. 2002: Diet and diet preferences of introduced ungulates (Order: Artiodactyla) in New Zealand. *New Zealand Journal of Zoology 29:* 323–343.

Fraser, K.W. 1996: Comparative rumen morphology of sympatric sika deer (*Cervus nippon*) and red deer (*C. elaphus scoticus*) in the Ahimanawa and Kaweka Ranges, Central North Island, New Zealand. *Oecologia 105*: 160–166.

Gruner, I.; Hawcroft, A. 2024: Potential seedling ratios from permanent 20x20 forest plots. Department of Conservation internal report. 30 p.

Hurst, J.M.; Allen, R. 2007. A permanent plot method for measuring indigenous forests—field protocols. Manaaki Whenua—Landcare Research, Lincoln, New Zealand. 66 p.

Nugent, G.; Forsythe, D.M.; Latham, A.D.M.; Speedy, C.; Allen, R.B.; Asher, G.W.; Tustin, K.G. 2021: Family Cervidae. Pp. 447–514 in King, C.; Forsyth, D. (Eds): The handbook of New Zealand mammals. CSIRO Publishing.

Nugent, G.; Fraser, K.W.; Sweetapple, P.J. 1997: Comparison of red deer and possum diets and impacts in podocarp-hardwood forests, Waihaha catchment, Pureora Conservation Park. *Science for Conservation 50.* Department of Conservation, Wellington. 61 p.

Olsen, A.R.; Kincaid, T.M.; & Payton, Q. 2012: Spatially balanced survey designs for natural resources. In: Gitzen, R.A. et al. (eds.), Design and Analysis of Long-term Ecological Monitoring Studies. Cambridge University Press.

Robertson, B.L.; Brown, J.A.; McDonald, T.; Jaksons, P. 2013: BAS: Balanced Acceptance Sampling of Natural Resources. *Biom*, 69: 776-784.

Rose, A.B.; Burrows, L.E. 1985: The impact of ungulates on the vegetation. Pp. 210–234 in Davis, M.R.; Orwin, J. (Eds): Report on a survey of the proposed Wapiti area, West Nelson. Scion.

Stevens, D. L. Jr;, Olsen, A. R. 2004. Spatially Balanced Sampling of Natural Resources. *Journal of the American Statistical Association*. 99: 262 –278.

Sweetapple, P. 2022: Evaluation of seedling ratio monitoring in the Nelson City Council Waterworks Reserve: Envirolink Grant 2233-NLCC121. Manaaki Whenua—Landcare Research contract report LC4162.

Sweetapple, P.J.; Burns, B.R. 2002: Assessing the response of forest understoreys to feral goat control, with and without possum control. *Science for Conservation 201*. Department of Conservation, Wellington. 33 p.

Sweetapple, P.J.; Nugent, G. 2004: Seedling ratios: a simple method for assessing ungulate impacts on forest understories. *Wildlife Society Bulletin 32:* 137–147.

van Dam-Bates, P.; Gansell, O.; Robertson, B. L. 2018: Using balanced acceptance sampling as a master sample for environmental surveys. *Methods in Ecology and Evolution*. 9: 1718–1726.

Appendix A: SRI data sheet

Sampling location identifier		**Waypoint**	**Plot no.**	**Easting**	**Northing**	**Bearing** (°)	**Description of barrier**
Transect ID (e.g. 01)		Start	NA				Original start? ☐
Date Day 1 (DD/MM/YYYY)		End				NA	New start? ☐
***Date Day 2** (DD/MM/YYYY) (*if applicable)		Turn 1					
Total time (HH:MM)		Turn 2					
Measured by		Turn 3					
Recorded by		Turn 4					
Plot interval (✓)	**10 m** ☐ **20 m**☐	Turn 5					
Site size (m^2)		Turn 6					
Transect location and approach notes:							

Browse classes: 0 = no browse 1 = 1–25% 2 = 26–50% 3 = 51–75% 4 = 76–100%

Plot no.	**Species** (present in at least one tier)	**Short tier** < 0.30 m, 0.49 m radius (✓)	**Tall tier** 0.30–2 m, 1.41 m radius (✓)	**Browse score** 0.15–2 m, 1.41 m radius (score 0–4)

Plot no.	**Species** (present in at least one tier)	**Short tier** < 0.30 m, 0.49 m radius (✓)	**Tall tier** 0.30–2 m, 1.41 m radius (✓)	**Browse score** 0.15–2 m, 1.41 m radius (score 0–4)

Appendix B: Example of a GPS waypoint labelling convention

Naming waypoints needs to be consistent and contain essential identifying information to eliminate confusion and ease data handling. A suggested protocol is shown in Table 4 below. Each transect GPS point label consists of four elements: [Sampling location] [survey type (SRI)] [Transect number] and [additional point identifier (start/end/turning points)]. **Do Not Use spaces or underscores**. The concatenation of the different elements that make up the labelling system are illustrated in Table 4.

Table 4. GPS Waypoint Labelling Convention (adapted from Department of Conservation 2024)

Sampling location	Identified	Survey type	Identifier	Sampling unit	Identifier	Additional points	Identifier	Examples
Series of letters that must match the sampling location identifier provided. Do not include underscores or spaces when labelling waypoints.	e.g. KKCLEAB	Seedling ratio index	SRI	Transect	e.g. 01, 18. Number must match the waypoint provided.	Start points End points Turning points	START END T1, T2, etc.	KKCLEABSRI01START, KKCLEABSRI01END, KKCLEABSRI01T1
						Transport: Landing area Landing area Car parking	 HELILAND BOATLAND CARPARK	 KKCLEABHELILAND KKCLEABBOATLAND KKCLEABCARPARK
						Base	BASE	KKCLEABBASE
						Camp	CAMP	KKCLEABCAMP

For line breaks, code as **LB[plot numbers], [xx m]** (e.g. if a line is broken between plots 5 and 6 for approx. 25 m, then code as **LB5–6, 25 m**) in the transect notes.

Appendix C: Target plant species codes and preference classifications

Table 5. Target plant species codes and preference classifications (adapted from Forsythe et al. 2002).

Full name	Common name	Plot sheet species code	Preference group	Forsyth et al. 2002 data
Alectryon excelsus	tītoki	ALEexc	non-selected	ND
Alseuosmia macrophylla	toropapa	ALSmac	non-selected	−(1)*
Alseuosmia pusilla	small toropapa	ALSpus	avoided	−(2)
Alseuosmia turneri	–	ALStur	non-selected	−(1)
Aristotelia serrata	makomako/ wineberry	ARIser	non-selected	+(2), 0(1), −(1)
Asplenium bulbiferum/gracillentum	mouku/hen and chickens fern	ASPhenchick	preferred	0(3), −(1)*
Beilschmiedia tawa	tawa	BEItaw	avoided	−(2)
Brachyglottis repanda	rangiora	BRArep	non-selected	ND*
Carmichaelia spp.	*Carmichaelia* spp.	CARMIC	preferred	+(1)
Carpodetus serratus	putaputāwētā/ marbleleaf	CARser	non-selected	0(4), −(1)
Coprosma grandifolia	kanono	COPgra	preferred	+(1)
Coprosma foetidissima	Hūpiro/stinkwood	COPfoe	non-selected	+(2), 0(1)*
Coprosma lucida	shining karamū	COPluc	preferred	+(2)
Coprosma repens	taupata	COPrep	preferred	ND*
Coprosma robusta	karamū	COProb	preferred	ND*
Coprosma (small-leaved)	–	‘COPsmall’	non-selected	0(2), −(3)*
Coprosma tenuifolia	–	COPtef	preferred	+(1)
Cordyline spp.	*Cordyline* spp.	CORDYL	preferred	+(1)
Coriaria arborea	tutu	CORarb	avoided	ND*
Corokia cotoneaster	korokio	CORcot	non-selected	0(1)
Cyathea spp.	*Cyathea*	CYATHE	avoided	ND*
Dacrycarpus dacrydioides	Kahikatea/white pine	DACdac	avoided	−(1)
Dacrydium cupressinum	rimu/red pine	DACcup	avoided	−(2), 0(1)
Dracophyllum spp.	*Dracophyllum* spp.	DRACOP	avoided	−(1)

Full name	Common name	Plot sheet species code	Preference group	Forsyth et al. 2002 data
Dicksonia squarrosa/fibrosa	*Dicksonia*	DICSON	non-selected	0(3), −(1)
Elaeocarpus dentatus	hīnau	ELAden	non-selected	+(2)*
Elaeocarpus hookerianus	pōkākā	ELAhoo	avoided	+(1), 0(1)*
Fuchsia excorticata	kōukutuku/tree fuchsia	FUCexc	preferred	+(2), 0(2)*
Geniostoma ligustrifolium	Hangehange/ New Zealand privet	GENlig	non-selected	+(1), −(1)
Griselinia littoralis	pāpāuma/ broadleaf	GRIlit	preferred	+(5)
Hedycarya arborea	porokaiwhiri/ pigeonwood	HEDarb	non-selected	+(1), 0(1)
Knightia excelsa	rewarewa	KNIexc	avoided	ND*
Kunzea ericoides/robusta	kānuka	KUNeri	avoided	ND*
Leptecophylla juniperina	prickly mingimingi	LEPjun	avoided	0(1), 0(2)
Leptospermum scoparium	mānuka/tea tree	LEPsco	avoided	−(2)
Leucopogon fasciculatus	soft mingimingi	LEUfas	avoided	−(1)
Lophomyrtus obcordata	rōhutu	LOPobc	avoided	−(1)
Melicope simplex	poataniwha	MELsim	avoided	−(1)
Melicytus lanceolatus	māhoe wao/Narrow-leaved māhoe	MELlan	preferred	+(1)
Melicytus ramiflorus	mahoe/ whitey wood	MELram	preferred	+(3)
Metrosideros robusta	northern rātā	METrob	preferred	+(1)
Metrosideros umbellata	southern rātā	METumb	non-selected	0(1)
Myoporum laetum	ngaio	MYOlae	non-selected	−(1)
Myrsine australis	Māpou/red matipo	MYRaus	preferred	+(1), 0(1), −(1)
Myrsine divaricata	weeping māpou	MYRdiv	avoided	0(1), −(2)
Myrsine salicina	toro	MYRsal	non-selected	−(1)*
Neomyrtus pedunculata	rōhutu	NEOped	avoided	−(2)
Nestegis cunninghamii	black maire	NEScun	avoided	−(2)

Full name	Common name	Plot sheet species code	Preference group	Forsyth et al. 2002 data
Nothofagus (Fuscospora) fusca	tāwhairaunui/red beech	NOTfus	avoided	−(1)
Nothofagus (Lophozonia) menziesii	tawhai/silver beech	NOTmen	avoided	−(1)
Nothofagus (Fuscospora) solandri var. solandri	tāwhairaukiri/ black beech	NOTsol	avoided	−(1)
Nothofagus (Fuscospora) solandri var. cliffortioides	tāwhairaukiri/ mountain beech	NOTcli	avoided	ND*
Nothofagus (Fuscospora) truncata	tāwhairaunui/ hard beech	NOTtru	avoided	ND*
Olearia ilicifolia	hakeke/New Zealand holly	OLEili	avoided	−(1)
Olearia rani	tātaraheke	OLEran	non-selected	ND*
Olearia spp.	*Olearia* spp.	OLEARI	non-selected	+(1), 0(1), −(1)
Ozothamnus spp.	Ozothamnus spp.	OZOTHA	avoided	ND*
Pennantia corymbosa	kaikōmako/ duck's foot	PENcor	non-selected	+(1), 0(1), −(1)
Phyllocladus alpinus	alpine toatoa	PHYalp	avoided	ND*
Phyllocladus toatoa	toatoa	PHYtoa	avoided	ND*
Phyllocladus trichomanoides	tānekaha	PHYtri	avoided	−(1)
Piper (Macropiper) excelsum	kawakawa	PIPexc	avoided	ND
Pittosporum eugenioides	tarata/ lemonwood	PITeug	non-selected	−(1)*
Pittosporum (small-leaved)	–	'PITsmall'	avoided	ND*
Pittosporum spp.	–	PITTOS	non-selected	+(2), 0(1)
Pittosporum tenuifolium	kōhūhū	PITten	non-selected	−(1)*
Podocarpus laetus	Hall's tōtara	PODlae	avoided	0(2), −(1)*
Podocarpus totara	tōtara	PODtot	avoided	−(1)
Pectinopitys ferruginea	miro/brown pine	PECfer	avoided	−(3)
Prumnopitys taxifolia	matai/black pine	PRUtax	non-selected	0(2), −(1)
Pseudopanax arboreus	whauwhaupaku/ five-finger	PSEarb	preferred	+(2)

Full name	Common name	Plot sheet species code	Preference group	Forsyth et al. 2002 data
Pseudopanax colensoi	mountain five-finger	NEOcol	preferred	+(1)
Pseudopanax crassifolius	horoeka/ lancewood	PSEcra	non-selected	+(4), 0(2)*
Pseudowintera axillaris	horopito/lowland horopito	PSEaxi	avoided	ND*
Pseudowintera colorata	horopito/pepper tree	PSEcol	avoided	−(4)
Pterophylla racemosa	kāmahi	PTErac	preferred	+(3)
Quintinia serrata	tāwheowheo	QUIser	avoided	−(1)
Raukaua (Pseudopanax) anomalus	–	RAUano	avoided	−(1)
Raukaua edgerleyi	raukawa	RAUedg	preferred	+(1)
Raukaua simplex	haumakāroa	RAUsim	non-selected	+(1), 0(1), −(1)
Rhabdothamnus solandri	taurepo	RHAsol	avoided	ND*
Rhopalostylis sapida	nīkau/ nīkau palm	RHOsap	non-selected	ND*
Schefflera digitata	patē/seven-finger	SCHdig	preferred	+(3)
Sophora microphylla	kōwhai/South Island kōwhai	SOPmic	non-selected	0(1)
Ulex europaeus	gorse	ULEeur	non-selected	ND*
Urtica ferox	ongaonga	URTfer	avoided	ND*
Veronica (hebe) spp.	hebe	VERONI	avoided	+(1), −(1)*

Notes: Numbers and symbols in the Forsyth et al. (2002) data column give the number (in brackets) of studies that recorded the species as preferred (+), non-selected (0), or avoided (−). The asterisk (*) beside some data indicates the preference class listed in the preference class column was based on the author's personal experience rather than the Forsyth et al. (2002) or Sweetapple & Nugent (2004) data. These discrepancies arise in some cases due to the consumption of some plant species being dominated by windfallen leaves, especially when fallen leaves are more palatable than seedling leaves (e.g. *Pseudopanax crassifolius* and *Elaeocarpus hookerianus;* Nugent et al. 1997), resulting in over-estimates for the preference of those species. Other examples likely arise due to sparse data, which tend to under-estimate preference. Species preferences classes in this appendix may also not always align with classes in the NVS database. More research is needed to understand ungulate preferences in different regions.

Appendix D: Plant naming, collection, and photographing

Naming plant species

To record the different plant species present on plots, plants are named with current NVS six-letter codes. This ensures plants are named consistently and unambiguously according to one authority, as various resources (e.g. websites, books) can be outdated or contradictory. It is important to ensure correct NVS codes are used because using incorrect codes can create false information on biodiversity.

Six-letter NVS codes use the first three letters of the plant genus all in upper-case, and the first three letters of the plant species in lower-case. For example, *Leptospermum scoparium* (mānuka) is shortened to LEPsco. However, it is important to be aware that there are exceptions to avoid duplicates of six-letter codes. For example, *Pseudopanax colensoi* (mountain five finger) and *Pseudowintera colorata* (horopito) would have the same six-letter code following the standard rule. Here, NVS has specified the non-standard code of NEOcol for *P. colensoi*, while *P. colorata* is coded PSEcol.

If a plant cannot be reliably identified to the species level, the naming protocol is to record the first six letters (or entire genus if fewer than six letters) of the genus all in uppercase. However, there are some duplicates, so there are also several non-standard genus codes. For example, *Pseudopanax* = PSEUDO, but the NVS genus codes for *Pseudotsuga* and *Pseudowintera* are PSEUDT and PSEUDW, respectively.

A date-stamped list of NVS codes is available on request from nvs@landcareresearch.co.nz to provide to field teams before the beginning of the field season. This date-stamped list is used throughout the season to ensure consistent species naming.

To ease identification of difficult-to-separate species and reduce the number of plant samples that need to be taken for later identification, the SRI method lumps some of these species into groups that are identified by their genus only. The following group names are recorded just once per plot even if more than one species is recognised.

- Small-leaved *Coprosma* species ('COPsmall'). *Coprosma* species with leaves smaller than *Coprosma foetidissima* are recorded as 'COPsmall'. *Coprosma* species with large leaves (*Coprosma foetidissima* and larger-leaved *Coprosma* species) are identified to species.
- Small-leaved *Pittosporum* species ('PITsmall'). Most small-leaved *Pittosporum* species (*P. anomalum, P. divaricatum, P. obcordatum*, and *P. rigidum*) are grouped and recorded as 'PITsmall'. *P. virgatum* and *P. pimeleoides* are localised, rare, and distinctive enough to be identified to species. *Pittosporum* species with large leaves are identified to species level.

- *Dracophyllum* species (DRACOP). While mainly alpine and subalpine, there are several forest species of *Dracophyllum* whose seedlings can be difficult to separate. All *Dracophyllum* species are therefore recorded as 'DRACOP'.
- *Carmichaelia* species (CARMIC). Most native broom species are difficult to separate and, being a forest margin and scrub species, are uncommon in forest. They should all be recorded as 'CARMIC'.
- Hebes (*Veronica* species; VERONI). Most hebes are difficult to separate and, being alpine, subalpine, or forest margin species, are uncommon in forest. They should all be recorded as 'VERONI'.
- Hen and chickens fern includes two species (*Asplenium bulbiferum* and *A. gracillimum*) and are named 'ASPhenchick'.
- Unidentified large-leaved *Coprosma* and *Pittosporum* species will be given tag names 'COPlarge' and 'PITlarge', respectively, collected, then renamed once identified.
- When entering the tag names 'COPsmall', 'PITsmall', and 'ASPhenchick' into NVS Express, enter the tag names into the verbatim code field and genus names into NVS code (e.g. small-leaved *Coprosma* species are entered as 'COPsmall" in the verbatim code field and as 'COPROS' in the NVS code field).

Plants that cannot be identified to species level in the field (or genus level for the above groups), are named 'UNK' followed by a word or two that reflects a notable feature of the plant or the tentative genus.

Plant collection and photographing protocol

Collecting plants is time consuming and should be kept to a minimum. The SRI protocol has been designed with this in mind (e.g. most non-woody and climbing species are excluded and species within difficult-to-identify woody species groups are combined into groups such as 'small-leaved coprosmas'). If unsure of the identity of a target plant species on a plot and it has been decided to collect unidentified plants, collect a specimen or take high-quality photographs so that the identity can be checked later. Photos are also useful to supplement physical specimens if pressing plants does not adequately capture or preserve their growth habit or other identifying features, such as flowers.

Be aware of any regionally or nationally threatened species and ensure that your collecting activities do not contribute to the decline of local populations. Do not collect physical specimens if doing so would eliminate the species from the area; instead, take high-quality photos.

Naming and labelling specimens

1. Give each unidentified species a provisional 'tag name' that reflects a notable feature of the plant or the tentative genus or species name. Use this tag name on the data sheet and add a circled © symbol to indicate that this species was collected, and/or ℗ if it was photographed.

Choose a tag name you will remember if the same species occurs again on another plot on the same transect. You can then use the same tag name (again with ©, ℗, or both), but you do not need to make another collection or take another photograph. However, if there is any doubt that the species are the same, collect an additional specimen/take additional photographs and assign a new tag name. If the same species occurs on a different transect, make a new collection/take new photographs.

2. Label collected plant specimens using waterproof labels, ensuring the following fields are filled out:
    a. The tag name (e.g. 'PaleThinLf')
    b. Sampling location identifier and transect number
    c. Date collected
    d. Collector's name
    e. Any notable/descriptive features of the plant that are not visible in the specimen, e.g. growth form, height. If there are photos to accompany the physical specimen, make a note of the number of photos (e.g. 4 photos taken).

Collecting physical specimens

The specimen should include (where appropriate and as available) root, stem, leaves, flowers, fruits, and seeds. Collect plenty—make sure the specimen covers the range of characteristics of the plant, e.g. including various stages of growth. Only collect a physical specimen if the plant is reasonably abundant, and do not collect if taking a physical specimen will remove too much foliage for the pant to survive.

Ensure your collections are secure to avoid transporting plants (seeds or vegetative material capable of establishing) between sites. Use a field press (e.g. large, hard-covered book with absorbent pages) to store specimens. Plastic bags are acceptable for short-term storage of plants, but specimens need to be transferred to a field or large storage press as soon as possible to avoid them overheating and wilting or being squashed.

Photographs

Sometimes you may be unable to collect a physical specimen; for example, if the plant is too scarce or too small. It is acceptable to take high-quality photos of plants in lieu of physical specimens. Photos are also useful to complement physical specimens (i.e. collect physical specimens AND take photos of the same plant).

Best practice for photographing plants:

- Use a quality camera with macro function.
- Be clear and in focus!!!
- Fill the entire frame and have minimal background noise—placing a clipboard behind the plant can be useful here.

- Ensure lighting is adequate.
- Include a scale, e.g. a pencil or compass.

Important features to photograph:

- Leaf margins, veins, both upper and lower leaf surfaces
- Leaf and branch arrangement
- Overall growth habit
- Stems and/or bark
- Flowers, fruits, seeds

Check images while still in the field—for focus; clear representation of colours, patterns and textures; exposure; and that you have portrayed the critical features for identifying your plant. With digital cameras it is very easy to take more photos if needed.

Appendix E: DOC documents

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

docdm-323171	Animal pests: faecal pellet counts
doccm-146272	Standard inventory and monitoring project plan