Biodiversity Conservation Trust

Biodiversity Conservation Trust Ecological Monitoring Module

Operational manual | September 2024

CONTENTS

1 BACKGROUND AND CONTEXT

This document has been prepared as a companion to the BCT Ecological Monitoring Module (EMM) (BCT 2019). The EMM provides the framework, organisational context and ecological justification for the monitoring approach and methodologies presented here. The purpose of this document is to guide on-ground application of the EMM by BCT ecological staff, BCT partners and contractors, accredited assessors and landholders. Many of the methods described here borrow heavily from existing published material, which readers are encouraged to reference for further detail (open access sources cited wherever possible).

The scope of the EMM – and therefore this manual – includes all biodiversity values within conservation areas identified in all agreements administered by the BCT; i.e. conservation agreements (CAs; funded, partnership and offset), wildlife refuge agreements (WRAs), biodiversity stewardship agreements (BSAs) and other legacy agreements (i.e. Biobanking, Nature Conservation Trust, Registered Property Agreements and CAs and WRAs established under former legislation). For specific guidance on monitoring biodiversity values at BSA sites, see Section 3 (and BAM Operational Manual - Stage 3).

The objectives of the BCT's ecological monitoring module are:

1. to collect and analyse data to inform evaluation and reporting of ecological outcomes at site, regional and state scales, against relevant BCT objectives and demonstrate return on investment to the Board, Government, landholders and the wider community;
2. to enable evaluation of management effectiveness and test assumptions about improvement in biodiversity values, the security of those values, contribution to a 'no net loss' standard and the relationships between different indicators of ecological integrity, to inform adaptive program improvement;
3. to support broader evaluation of the outcomes of the *Biodiversity Conservation Act 2016* (BC Act); and
4. to collate and manage ecological data so that it is accessible, reliable, useful, and can support reporting requirements for the BCT Board, the Minister, and the community (e.g. informing the compilation of an aggregated ecological condition index [organisational KPI]).

1.1 CONCEPTUAL FRAMEWORK

The conceptual framework of the ecological monitoring program is described in detail in the EMM. In summary, monitoring of ecological values at BCT agreement sites should be guided by the following principles:

1. **Risk** – monitoring effort (i.e. frequency, density, precision) should be proportionate to the risk associated with not monitoring or not having access to the required data, and consequently failing to achieve program objectives (e.g. BSA sites are generally higher risk, given the requirement that biodiversity gain aligns with credit generation);

2. **Uncertainty –** monitoring effort and scientific rigour should be greater if/where the ecological outcomes of particular management interventions are more uncertain (e.g. feral predator control, nest box supplementation, grassy ecosystem restoration);
3. **Rate of (or potential for) change –** monitoring frequency should correspond to the estimated rate of, or potential for, ecological change or management response (e.g. lower condition sites being managed to significantly improve condition have a greater potential for short-medium-term change, therefore should be monitored more frequently than high condition sites, which are expected to have limited potential for improvement in response to management);
4. **Objectives –** ecological objectives should be defined, at least broadly, for all agreement sites and relevant zones, and monitoring prescriptions should be tailored to those objectives (e.g. biodiversity values with improvement objectives should generally be monitored more intensively than those with maintenance objectives);
5. **'Special' values –** biodiversity values for which standard plot-based metrics are not a suitable surrogate (e.g. threatened species populations) should receive targeted monitoring using a specific and appropriate method.

The above principles and the further guidance provided in this manual should be used to inform fit-for-purpose monitoring of any given agreement site. All sites and the ecological values they contain will differ, therefore there is a limit to how prescriptive this guidance can be without having a perverse effect. It is critical that BCT staff and accredited assessors apply their ecological expertise in combination with on-ground knowledge of particular sites when planning and implementing site-based monitoring.

2 PLANNING FOR MONITORING

2.1 PRIORITISING AGREEMENT SITES[1]

Agreement sites should be prioritised for monitoring investment based on the risk hierarchy described in the EMM. Monitoring ecological outcomes at BSA and offset CA sites is generally considered highest priority due to the risks associated with failing to adequately offset biodiversity losses, however, given that monitoring will be undertaken by accredited assessors (or otherwise qualified ecologists), these types of sites are not prioritised for monitoring by the BCT (with the exception of older agreements established prior to development of the EMM; see Table 1). The design and implementation of ecological

[1] This section is not relevant for accredited assessors or third parties implementing monitoring on BSAs or offset CAs.

monitoring at BSA and offset CA sites must still align with the guidance set out in this document.

Current condition state and expected change in biodiversity values as well as management objectives should also be considered when prioritising sites. In general, sites in higher condition, and with limited scope for positive ecological change (i.e. objectives related to maintenance, rather than improvement) should be a lower priority compared to sites in poorer condition with restoration activities aimed to improve biodiversity values.

Priorities for monitoring in any given year should be based on the above, as well as ensuring continuity of data collection, capturing baseline data for new agreements (ideally within 12 months of signing), and maximising efficiencies (e.g. aligning monitoring with planned site visits [within seasonal constraints] or monitoring close proximity sites in the same trip). It is expected that *all* agreement sites will be subject to some level of monitoring at some point in time (e.g. low priority sites may be scheduled for baseline monitoring within 10 years). Table 1 summarises the broad application of monitoring effort by agreement type, with site-specific details outlined in the next section (2.2).

Table 1: Monitoring approach and priorities for different agreement types

Agreement type	Sub-category	Priority (rank order) for BCT monitoring
BSA		n/a[1]
Offset CA (new)		n/a[2]
Legacy Biobanking / Offset CA	high priority[3]	2
	low priority	3
Funded CA		1
Partnership CA	grant-funded actions	2
	no funding	3
Legacy agreement[4]	grant-funded actions	2
	no funding	3
Control site		1

[1] Monitoring implementation contracted by landholder and funded via TFD (aligned to EMM with support from BCT)
[2] Monitoring implementation is the responsibility of the agreement-holder (aligned to EMM with support from BCT)
[3] As assigned by BCT, based on management objectives, monitoring history, status, biodiversity values
[4] Includes unfunded agreements established prior to 2017; e.g. Wildlife Refuges, Nature Conservation Trust agreements and Registered Property Agreements

2.2 DEVELOPING A SITE MONITORING PLAN

Every agreement site subject to ecological monitoring requires a monitoring plan. This document will guide implementation of monitoring at a site and contain sufficient detail to allow interpretation by a third party. For BSAs, the monitoring plan should be detailed in Section 7 of the Management Plan. Ideally, monitoring plans should be developed in a modular format, with relevant information organised by vegetation or management zone to enable digital storage of the information in a relational database (and linking to spatial data; e.g. zone polygons or plot points) (Table 2).

Table 2: Simplified site monitoring plan template (represents minimum information requirements), with example data

Zone	Target bio-diversity value	Area (ha)	Mngt intensity	Monitoring method	No. points	Spatial coords [1]	Monitoring Frequency	Baseline state[2]	Target state
001	*vegetation integrity*	*78.2*	*high*	*Floristic plots; full cover-abundance*; stem size assessment	*5*	*144.23, -32.81; 144.92, -32.17…*	*5 years*	*VI=57*	*VI=80*
002	*threatened flora X*	*14.1*	*moderate*	*Sampling via 10x10m plots; abundance estimate, condition, recruitment*	*3*	*144.92, -32.73; 144.51, -32.82…*	*3 years*	*162 mature plants; healthy condition; recruits present*	*>200 mature plants; recruits; healthy condition*
003	*threatened fauna Y*	*36.5*	*moderate*	*Baited arboreal remote cameras set for 30 days in Autumn*	*4*	*144.90, -32.55; 144.38, -32.02…*	*5 years*	*present*	*present*

Figure 1 summarises the stepwise process for developing a site monitoring plan, with reference to other sections of the document for more detail.

[1] Potentially not required if appropriate maps are attached
[2] Subject to change if new baseline data collected >2 years after original assessment

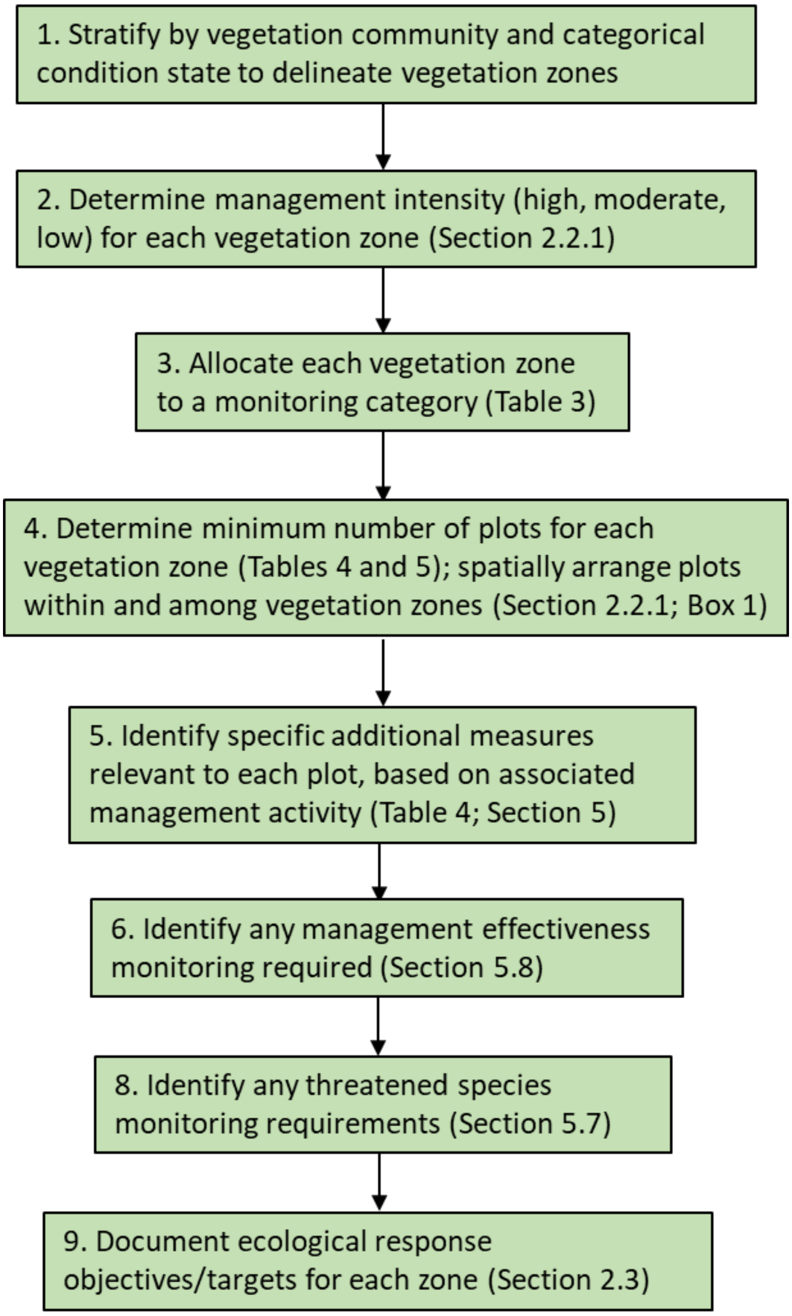

Figure 1: Process for stratifying an agreement conservation area, establishing locations for permanent monitoring plots and developing a site monitoring plan. See relevant sections in the text for more detail on each step.

2.2.1 Vegetation integrity plot stratification

The agreement area should be divided into 'vegetation zones' i.e. areas of the conservation area representing the unique combination of vegetation type (PCT for BSAs, Vegetation [Keith] Class for all other agreement types) and categorical condition state (Good, Moderate, Poor)[1], including all discontiguous patches (Figure 2a). The recommended number, type and monitoring frequency of plots for each vegetation zone can be determined with reference to Tables 3 and 4, and Figure 2a.

The overall monitoring effort (i.e. density x precision x frequency) appropriate for a given site should be proportionate to the site's expected magnitude and rate of ecological change. This expected change is generally a function of the initial condition state (i.e. high condition sites have relatively little potential for [positive] change) and the proposed management intensity (e.g. active restoration is likely to result in greater and more rapid and ecological change than natural regeneration). This principle should be applied to the design of monitoring prescriptions for agreement sites. Tables 3 and 4 provide guidance on the application of this approach to systematically design a monitoring program for any given site, one vegetation zone at a time.

Once the initial stratification by vegetation zone is complete, management zones (i.e. areas of equivalent management regime, including discontiguous patches) should be defined across the conservation area (this will already have been completed as part of the management plan). Depending on the type of agreement and the particular ecological values on-site, management zones may neatly nest within vegetation zones (or vice versa), or may intersect with vegetation zones in a haphazard way (e.g. due to fence lines; see Figure 2a, b). Irrespective, for each vegetation zone a 'management intensity' (high, moderate, low) category should be specified, applicable to the entire zone. If a vegetation zone includes multiple management zones of varying intensity, the categorisation should be based on the management zone representing the largest proportion of the vegetation zone.

The following examples provide some guidance on the determination of intensity categories for different management scenarios:

- ***High intensity***: active restoration actions (including all ARMAs[2] [BSAs]), 'restore' actions (funded CAs), some 'enhance' actions (funded CAs), 'high risk' grazing regimes (see 6.2.3), targeted (e.g. threatened species-focused) ecological burning, and most grant-funded actions on unfunded CAs[1]
- ***Moderate intensity***: all required management actions (BSAs), some 'enhance' actions (funded CAs), standard (vegetation type based) ecological burning, and 'moderate risk' grazing regimes
- ***Low intensity:*** all 'maintain' actions (funded CAs), and 'low risk' grazing regimes

Condition states should already have been determined through the process of delineating vegetation zones, generally at an earlier point in time (e.g. initial site assessment), however, there are various reasons why these data should be reviewed and confirmed prior to informing monitoring design. For example, extreme environmental conditions (e.g. drought) may have caused the initial assessment to be unrepresentative of condition state under 'typical' conditions, or time constraints contributed to reduced accuracy of vegetation mapping at initial assessment (including the potential for application of inappropriate vegetation condition benchmarks).

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[1] This aligns with the BAM definition. Other thematic categories (e.g. 'DNG' or 'weedy') should not be used
[2] May be some exceptions if/where predicted biodiversity gains are relatively small

Once management intensity and condition state are confirmed for each vegetation zone, Table 3 should be used to categorise each zone (A, B, C or D) for the purposes of designating a plot monitoring prescription (Table 4). Minimum plot densities for each vegetation zone can then be determined using Tables 4 and 5.

If/where a vegetation zone is completely overlapped by a single management zone, there are no further decisions with respect to plot allocation within the vegetation zone. For scenarios where a single vegetation zone is intersected by multiple management zones, the available plots (minimum number determined from Table 5) should be distributed within the vegetation zone, among management zones. This is to maximise the number of different management zones sampled, prioritising the highest intensity management zone (see Box 1).

Box 1: Plot allocation for complex intersection of vegetation/management zones

If a given vegetation zone is intersected by three different management zones with varying management intensity (i.e. Zone X = high, Zone Y = moderate, Zone Z = low), and the required number of plots is 5, then the allocations should be 2, 2 and 1 for Zones X, Y and Z, respectively. If the required number of plots was 4, then the respective allocations should be 2, 1 and 1 (Figure B1), if 3 plots, then 1, 1 and 1, if 2 plots, 1, 1 and 0, and if a single plot, then 1, 0 and 0. If management zone overlap is very small (<1ha), it does not require sampling within the vegetation zone. If overlapping management zones are different but with equivalent intensities, sampling priority within the vegetation zone should be based on relative size of overlapping areas.

In Figure B1, note that management zone 'X' has the smallest overlap with the vegetation zone, but is allocated two plots, rather than one, due to its higher management intensity than the other two zones.

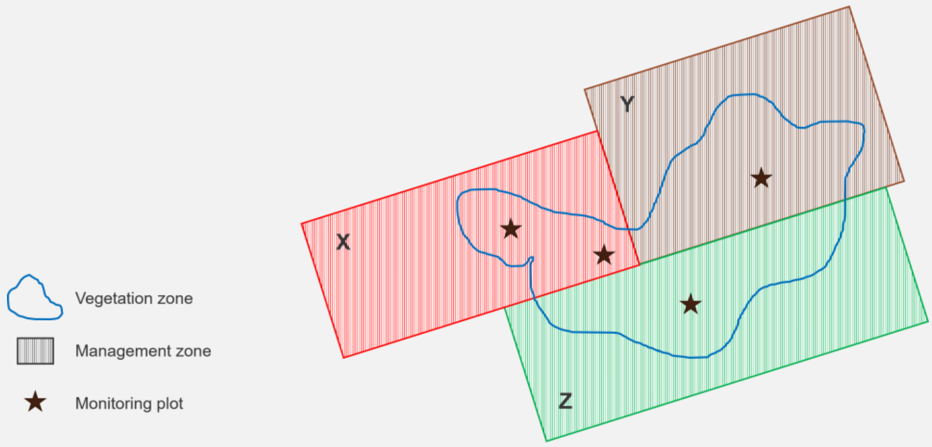


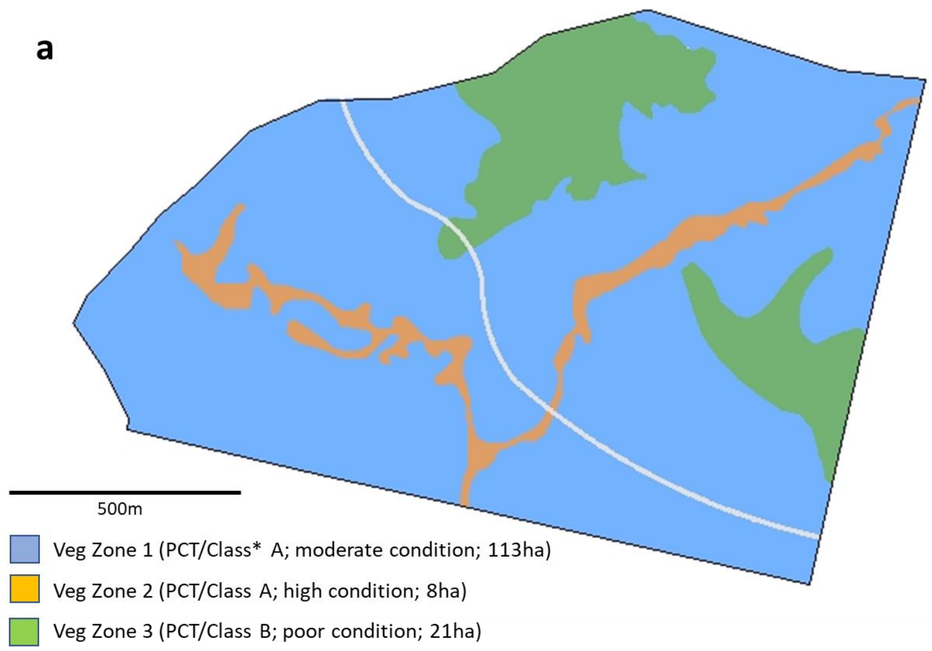
Figure B1: *Example scenario with three management zones of varying management intensity (High [X]; Moderate [Y]; and Low [Z]) overlapping a single vegetation zone, with recommend distribution of four plots allocated to the vegetation zone.*

Decisions with respect to the final arrangement and orientation of allocated plots within zones should be made on site at the point of plot establishment, with reference to finer-scale biophysical variation (see section 4.1).

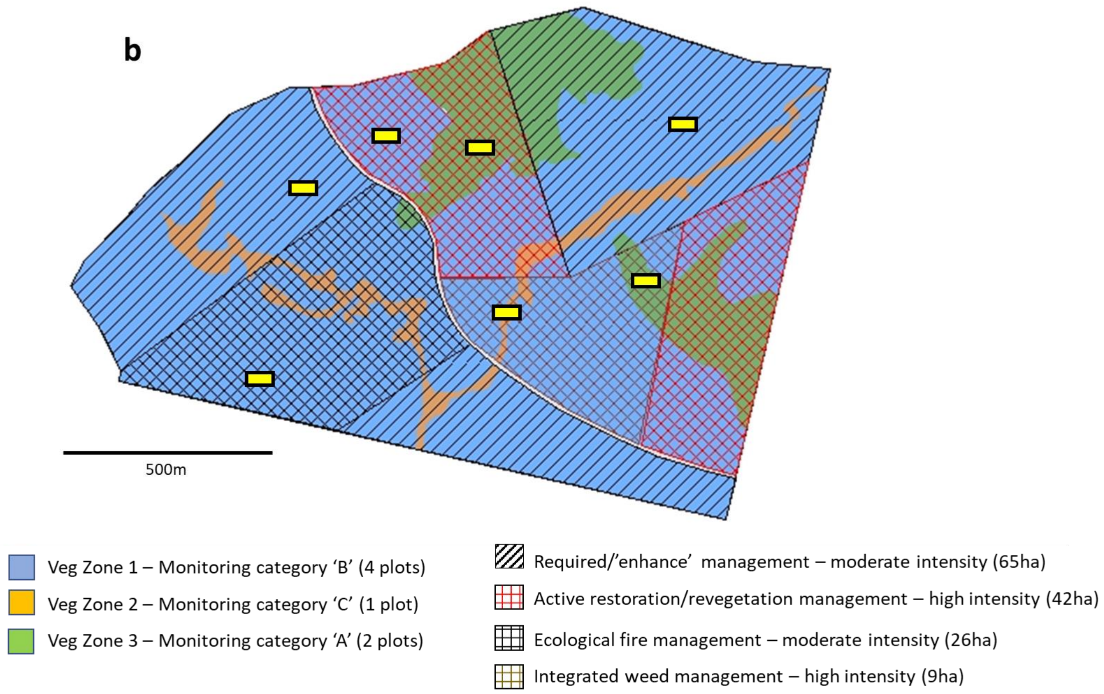
In scenarios where the total plot requirement for an agreement site is impractically high (e.g. >20), there may be justification for reducing the plot density by either; i) leaving very small (<2ha) zones unsampled, for sites with highly diverse vegetation (i.e. large number of vegetation zones), or ii) reducing plot density in very large zones, particularly if/where those zones represent *stratification groups*[1] that are already well sampled under the EMM.

Table 3: Monitoring categories related to variable condition states and management intensities, required for the definition of appropriate monitoring prescriptions via Table 4.

		Management intensity		
		HIGH	MODERATE	LOW[2]
Initial ecological condition state	HIGH (VI ≥ 70)	B[3]	C	D
	MODERATE (40 ≤ VI < 70)	A	B/C[4]	C
	POOR (VI < 40)	A	B	C



[1] Groups defined by the unique intersection of vegetation class, condition state and bioregion (see Section 7.1)
[2] Not relevant to BSAs
[3] Infrequent scenario, generally only applicable at BSA sites implementing very limited ARMA. 'High risk' grazing regimes (Table 13) should generally be assigned category 'A' irrespective of initial condition state
[4] Discretion should be applied in this scenario – i.e. for relatively lower condition (VI=40-55) and/or relatively more intensive management scenarios (including moderate risk grazing regimes), apply category 'B', otherwise category 'C'



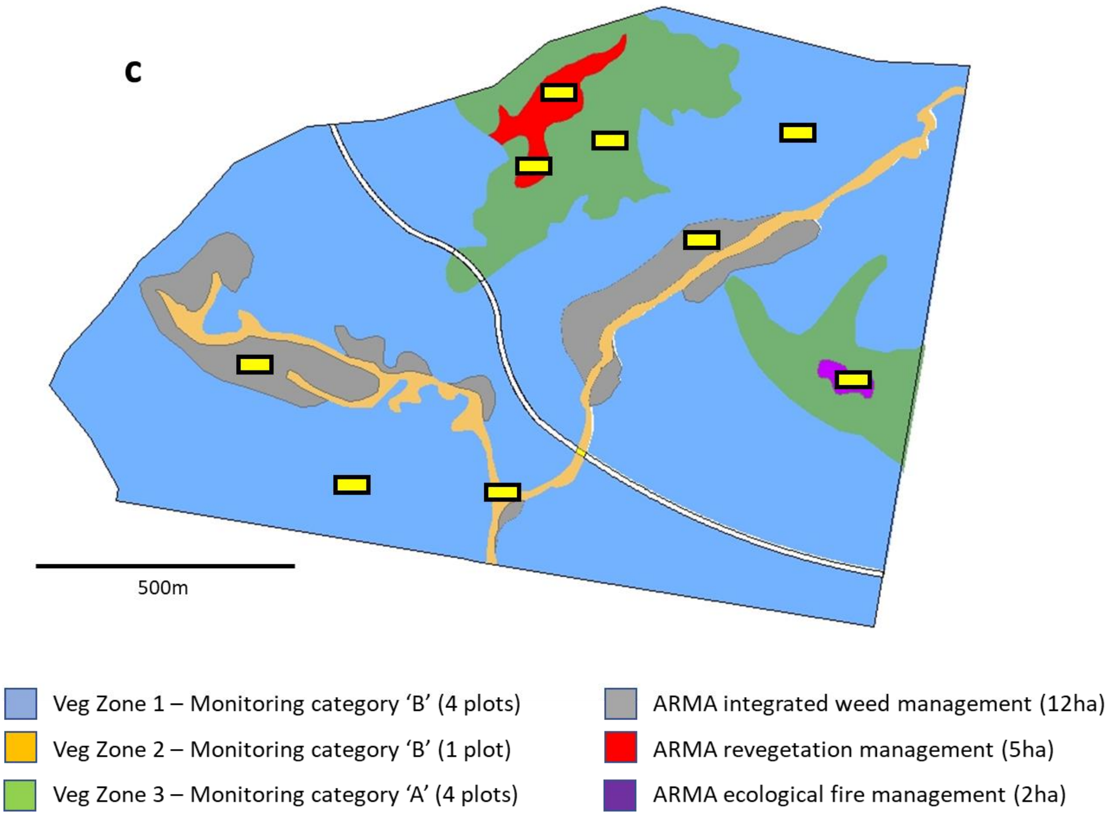


*Figure 2: Example conservation area maps, showing vegetation zones (a) and two different management zone arrangements relating to a typical CA (b) and BSA site (c) with stratified floristic plot (yellow rectangles) locations. *PCT for BSAs / Vegetation Class for CAs.*

Table 4: Recommended site monitoring prescriptions dependent on biodiversity values present and management regime. Legend: EB (ecological burning); FF (full floristic plot); MG (managed grazing[1]); NH (risk of overabundant native herbivores); RP (rapid floristic plot); RV (revegetation); VP (vertebrate pest management); WM (integrated / high threat weed management)

Agreement type	Category (Table 3)	Floristics (20x20m)		Function assessments (20x50m)[2]			Dung counts	Biomass exclosure	Other	Frequency
		Type	Density[3]	Tree stems	Point-intercept cover	Soil[4]				
BSA / Offset CA	**A**	FF	H	all plots	WM; EB; MG	MG; EB	MG; NH	MG; NH	Weed mapping (WM); Remote camera (VP)	2-5 yrs[5]
	B	FF	M	n/a	n/a	n/a	MG; NH	MG	n/a	5 yrs
	C	FF	L	n/a	n/a	n/a	n/a	n/a	n/a	5 yrs
Funded CA / High priority Biobanking	**A**	FF	M	all plots	WM; EB; MG	MG; EB	MG; NH	MG; NH	Weed mapping (WM); Remote camera (VP)	2-5 yrs[5]
	B	FF	M	RV; EB; MG	WM; EB; MG (1/zone)	MG; EB (1/zone)	MG; NH	MG; NH (1/ zone)	Weed mapping (WM)	5 yrs
	C	FF	L	RV; EB (1/zone)	n/a	MG (1/zone)	MG; NH (1/zone)	n/a	n/a	5 yrs
	D	FF	L	n/a	n/a	n/a	n/a	n/a	n/a	5 yrs

[1] Includes sites with grazing exclusion, where grazed prior to agreement establishment
[2] BAM function attributes should be collected at all plots as a minimum (litter included in soil assessment; regeneration, stem sizes classes and large trees included in tree stem assessment)
[3] Refer to Table 5
[4] Requirement dependent on vegetation formation (Table 9)
[5] Some higher risk scenarios (e.g. threatened species monitoring, revegetation, intensive grazing regimes) may require additional monitoring events (see 4.1)

Agreement type	Category (Table 3)	Floristics (20x20m)		Function assessments (20x50m)[2]			Dung counts	Biomass exclosure	Other	Frequency
		Type	Density[3]	Tree stems	Point-intercept cover	Soil[4]				
Voluntary (unfunded) CA / other legacy[1] agreements	A	FF[2]	1/veg class[3]	RV; EB (1/zone)	n/a	n/a	n/a	n/a	n/a	5 yrs
	B	FF[2]	1/veg class[3]	n/a	n/a	n/a	n/a	n/a	n/a	10 yrs
	C	FF[2]	1/veg class[3]	no	no	no	n/a	n/a	n/a	10 yrs
	D	RP	1/veg class[3]	no	no	no	n/a	n/a	n/a	10 yrs
Control sites	All	FF	n/a	all	all	some[4]	all	potential[5]	n/a	5 yrs

[1] Includes agreements established prior to 2017; e.g. wildlife refuges, Nature Conservation Trust agreements and Registered Property Agreements
[2] If/where constrained by time or staff expertise, replace with Rapid plots (RP)
[3] If/where time-constrained, sample the three largest vegetation zones only
[4] As required, dependent on vegetation formation (Table 9)
[5] If/where required as control for biomass assessment array on nearby agreement site (on-site control plots not feasible)

Table 5: Recommended density of monitoring plots based on vegetation zone area and required sampling intensity.

Vegetation zone* area (ha)	Recommended number of plots/zone**		
	High (H)	Moderate (M)	Low (L)
<2	1	0	0
>2-5	2	1	1
>5-20	3	1	1
>20-50	4	2	1
>50-100	5	3	2
>100-250	6	4	3
>250	7	5	4

**Based on PCT for BSAs and Vegetation Class for all other agreement types. **Number of plots should be increased for vegetation zones exhibiting significant heterogeneity (e.g. to sample PCTs within heterogenous Vegetation Classes, foot slopes/ridges or variation in soil depth), if occurring within a single zone.*

2.3 MANAGEMENT OBJECTIVES AND TARGET-SETTING

Predictions of how biodiversity will respond to management, are critical to informing outcome evaluations, monitoring methods and adaptive management (Bakker et al. 2000; Lindenmayer *et al.* 2006; Burgman *et al.* 2012). Management objectives (i.e. ecological response targets) need to be defined for all biodiversity assets (e.g. vegetation/management zones) within conservation areas, for all agreement sites. To be meaningful and useful for evaluation, outcome targets should have the following characteristics:

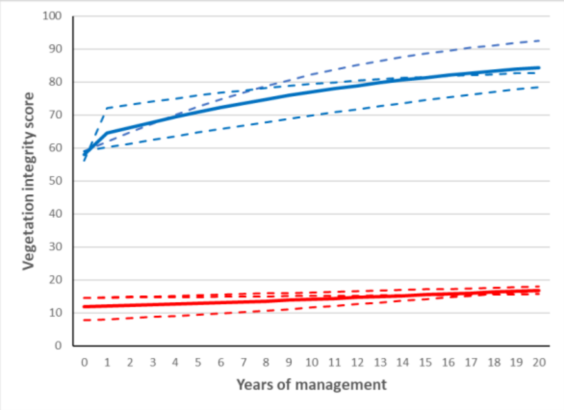
- defined based on a valid reference (e.g. control, conceptual model, benchmark state, baseline assessment)
- expressed in the same units and metric being monitored (e.g. count, score, % cover), and with the same level of precision (e.g. 'poor, moderate, high' / 0-100)
- consistent with the intensity of management and realistic ecological response (e.g. stable condition [maintenance management] / improving condition [restoration management])

Guidance on appropriate targets for specific vegetation communities, species or management scenarios is available from various sources (Table 6), which should be interpreted in the site-specific context to which it is being applied. Given the inherent uncertainty in most ecological systems, outcome targets should generally incorporate a confidence interval, i.e. a specified range of acceptable values.

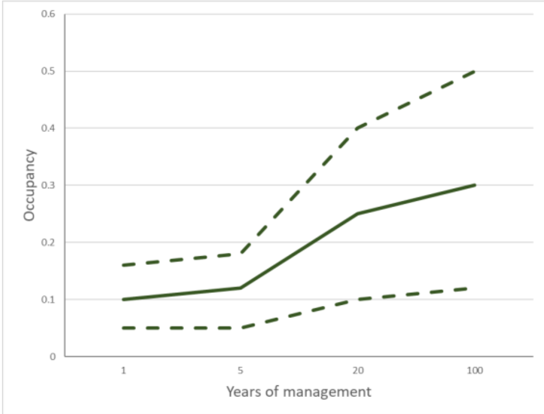
To ensure that outcome targets are useful for informing management, they should facilitate regular evaluation aligned to a management review schedule. This requires the development of short (e.g. 5 years) and long-term (e.g. 20+ years) outcome targets, based on an understanding of how the system is expected to respond to management (Figure 3). The short-term target should reflect expected biodiversity response given the elapsed time and management intensity, and enable evaluation of whether management is 'on track' to meet the long-term target. The long-term target should be defined based on the ultimate objective of management (i.e. benchmark or equilibrium/climax successional state), with a corresponding time period reflecting realistic response to the proposed management regime. Note that outcome targets may not necessarily equate to an improved condition state. For example, target state may equal current state if/where the management objective is maintenance, and in some scenarios target state may reflect a decline (if the decline is less severe than would be predicted under a no-management [counterfactual] scenario).

Table 6: Relevant information sources for guidance on target-setting

Biodiversity value / management scenario	Target-setting guidance / sources
High condition site with maintenance management.	Set lower condition threshold (e.g. 10% below baseline/control state) below which is concerning and should trigger management review.
Assisted regeneration following stock exclusion.	Targets expressed in terms of upper vegetation strata attributes initially, then evidence of regeneration of the ground layer. BAM gain prediction for the relevant vegetation community (Figure 3a).
Moderate condition site being managed for improvement towards benchmark.	BAM gain prediction for the relevant vegetation community (Figure 3a).
Vertebrate pest control.	Activity rate / detection is constantly held at very low value.
Targeted management of a threatened plant population currently suppressed by weed infestation.	Increase in area of occupancy / abundance proportional to area of weed removal; can refer to BAM gain model for relevant species group.
Habitat supplemented with nest-boxes targeting a threatened arboreal mammal.	E.g. *minimum of 20% occupancy (breeding) of nest-boxes across the site by the target species, within 5 years.*



a) BAM predicted gain in vegetation integrity under (required) management for an example regional vegetation class (Western Slopes Grassy Woodland in the South Western Slopes bioregion, with 'moderate' starting conditions [all attributes median value]) (solid blue line), associated structure, composition and function components (broken blue lines), with 'poor' starting conditions (all attributes 25% of benchmark) (solid red line) and associated structure, composition and function components (broken red lines) (OEH 2020).



*b) Predicted increase in occupancy of the long-nosed potoroo (*Potorous tridactylus*) with comprehensive management of threats (e.g. foxes), based on structured expert elicitation (Mayfield et al. 2019).*

*Figure 3: Example response-to-management models which may be used to inform the development of short and long-term outcome targets. *Note that these types of continuous models are not necessary for target-setting, provided there is a reasonable ecological basis for determining target values.*

2.3.1 Active restoration targets for BSA sites

Rigorous and frequent monitoring of the outcomes of active restoration management actions (ARMAs) at BSA sites is important for two reasons; i) credit yields are significant and the risk of failure is high; and ii) the long-term effectiveness of active restoration techniques in most ecosystems is uncertain (Maron *et al.* 2012). Although the BAM does account for these risks (e.g. via a weighting on predicted gains), monitoring will enable testing of the adequacy of these measures, as well as informing improvement of the underlying gain models.

Long-term (i.e. 20-year) vegetation integrity targets for management zones with proposed ARMAs can be generated by the BAM calculator and are generally included in a Biodiversity Stewardship Site Assessment Report (BSSAR), as they inform credit generation. In order to evaluate progress towards these targets and facilitate adaptive improvement of the management plan, interim (i.e. short-term) targets are required for each relevant management zone, timed to align with management plan reviews – i.e. years 5, 10 and 15. These targets should be developed for all floristic attributes being actively restored, or when related to integrated weed management, for those attributes expected to respond significantly to the planned weed removal. Targets should be expressed as a range; the upper values reflecting a trajectory towards the target determined by the assessor (i.e. *Future value with active restoration gain*), and the lower values reflecting a trajectory towards the equivalent value with the *final risk weighting* applied (i.e. *Future value with offset [after restoration]*) (Figure 4; Table 7).

This represents a target range which is practical and meaningful for periodic evaluation – i.e. observed values below the lower limit (Figure 4; red lines) indicate a risk of failing to achieve the biodiversity gain required to fulfil the offset obligation, and provide a trigger for adjusting management settings. Observed values at or above the upper limit (Figure 4; green lines) indicate that management is on track to generate additional biodiversity credits at Year 20.

For simplicity, biodiversity response to management can be assumed to be linear over the projected 20-year period (i.e. gain in attribute value for each 5-year interval is 25% of the total gain). The exception being revegetation management (ARMA), where most (estimated 80%) of the gain in *composition* condition can be expected to occur in the first five years (i.e. due to immediate establishment of target species richness at planting stage) (Figure 4a; Table 7).

Interim targets (ranges) for active restoration management (native vegetation and habitat management; integrated weed management) and required management, for any attribute, can be calculated using data readily available from the BAM Calculator and site assessment, including:

- *Current value* (assessment) (*C*);
- *Future value with offset* (BAM-C) (*FO*);
- *Future value with active restoration gain* (assessor) (*FA*);
- *Future value with offset (After restoration)*[1] (BAM-C) (*FW*);

using the calculations shown in Table 7.

Table 7: Recommended methods for calculating interim targets for different vegetation management scenarios and attributes at BSA sites.

Management type (attributes)	Range (upper / lower limit)	Year 5 target	Year 10 target	Year 15 target	Year 20 target
ARMA revegetation (composition)	Upper	$C + ((FA\text{-}C) * 0.8)$[2]	*FA*	*FA*	*FA*
	Lower	$C + ((FW\text{-}C) * 0.8)$	*FW*	*FW*	*FW*
ARMA revegetation (structure, function)	Upper	$C + ((FA\text{-}C) * 0.25)$	$C + ((FA\text{-}C) * 0.5)$	$C + ((FA\text{-}C) * 0.75)$	*FA*
	Lower	$C + ((FW\text{-}C) * 0.25)$	$C + ((FW\text{-}C) * 0.5)$	$C + ((FW\text{-}C) * 0.75)$	*FW*
ARMA weed management (all)	Upper	$C + ((FA\text{-}C) * 0.25)$	$C + ((FA\text{-}C) * 0.5)$	$C + ((FA\text{-}C) * 0.75)$	*FA*
	Lower	$C + ((FW\text{-}C) * 0.25)$	$C + ((FW\text{-}C) * 0.5)$	$C + ((FW\text{-}C) * 0.75)$	*FW*
Required management	n/a	$C + ((FO\text{-}C) * 0.25)$	$C + ((FO\text{-}C) * 0.5)$	$C + ((FO\text{-}C) * 0.75)$	*FO*

[1] Risk weighting (0.3) applied to predicted gain based on assessor's manually adjusted target value (generally benchmark)
[2] Assumes 80% 5-year survivorship of plantings (Wilkins *et al.* 2003)

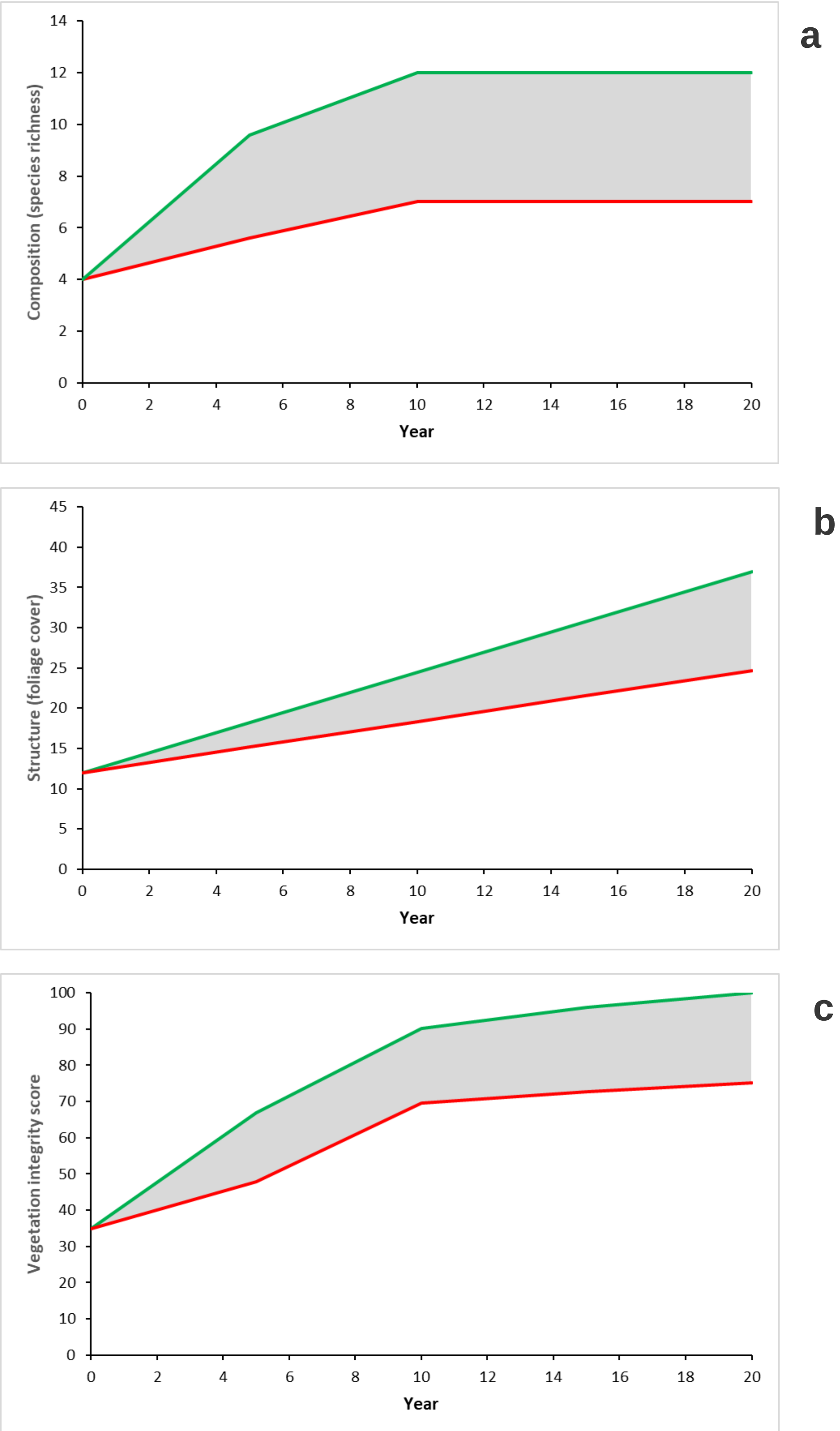


Figure 4: Example scenarios of predicted response to active restoration management under the BAM, for shrub composition (a), shrub structure (b) and vegetation integrity score (c). Scenario is PCT 1590 in the Hunter subregion with 70% native vegetation cover and 0% high threat weed cover. Plots show incremental biodiversity gain under an achieving benchmark scenario (green lines), and equivalent scenario with risk weighting applied (red lines). Grey shading represents target range for outcome evaluation at any time point – i.e. management is 'on track' to meeting long-term target.

For other types of ARMAs (e.g. habitat enhancement, hydrology management) long-term and interim targets should be developed based on site and management-specific considerations, ideally in consultation with a relevant expert on the focal system or target species. For example, if nest-boxes or other artificial hollows are being erected with the aim of expanding a species polygon, targets should be specified with reference to proportional occupancy or density of target species (and ideally, non-target and/or invasive species) in the restored (added) areas of habitat.

3 MINIMUM REQUIREMENTS FOR BIODIVERSITY STEWARDSHIP SITES

The following section provides guidance specifically for accredited assessors developing BSA applications[1] and associated management (monitoring) plans, and should be read in conjunction with the BAM Operational Manual - Stage 3. The BCT will provide support to accredited assessors, as required, in developing a fit-for-purpose monitoring prescription consistent with this guidance. The EMM is intended to be a flexible framework – departure from the guidance is acceptable if and where justified, consistent with EMM principles, and in consultation with the BCT.

3.1 VEGETATION INTEGRITY PLOT MONITORING

- Permanent, full floristic plots (i.e. 20x20m; cover and abundance estimates for all species present) with additional measures (applicable to 20x50m plot) as relevant must be established within each vegetation zone (PCT x condition state), at a density specified by Tables 3, 4 and 5, following the process outlined in Section 2.2.1 (i.e. dependent on the size, condition state and management intensity of each vegetation zone). Note – additional measures (beyond full floristics) are generally only required in ARMA zones.
- Plot locations used for the original BAM assessment (or a subset thereof) may be used as sites for establishing permanent monitoring plots, assuming that the sites align with the stratification criteria. For zones requiring fewer monitoring plots than the original assessment, a subset of sites should be selected randomly, ensuring that the selected plots are broadly representative of the zone.
- For the purposes of interpreting Table 3:
    - Active restoration management actions (ARMA) = *high* management intensity

[1] Requirements applicable only to BSA applications received from February 2021

- Required management actions = *moderate* management intensity
- *Moderate* condition x *moderate* management intensity = category ‘*B*’

- Targets for active restoration should be developed for all ARMA zones (and are recommended for all zones) as per Section 2.3.1. Targets are required for all attributes being actively restored (i.e. where *Future value with active restoration gain* has been ‘unlocked’ and amended by the accredited assessor).
- Plot monitoring frequency for the first 20 years of the agreement should be every 5 years (i.e. monitoring events at year 0[1], 5, 10, 15 and 20). Floristic data collected as part of the initial assessment informing the BSSAR may contribute to the baseline monitoring data set, if this is within 2 years, and if the site has not been subject to significant disturbance in the intervening period (e.g. fire, drought, emergent pest/weed impact). For ARMA zones that have a predicted VI gain of >25 (*Future value with offset [after restoration]*) or are subject to a ‘high risk’ grazing regime, additional monitoring events at years 2 or 3 and 7 or 8 are required. In limited scenarios (i.e. high condition, low management intensity), a reduced monitoring frequency may be acceptable if properly justified.
- From year 21 onwards, plot monitoring should continue at half the frequency (i.e. every 10 years) and half the density (i.e. 50% of plots per zone should be randomly selected for continued monitoring [where only one plot has been allocated to a zone, that plot should continue to be monitored]).
- Threatened species monitoring effort should remain the same (i.e. intensity of each survey event), but frequency can reduce by half as per plot monitoring.
- If any additional biodiversity credits are generated at year 20 (or subsequent reassessment event), monitoring for the relevant vegetation zones should continue at the same frequency and density (as had occurred in years 0-20) for the next 20 years.
- If/where the site configuration (e.g. narrow linear or small discontiguous patches with high edge:area ratios) and/or adjacent land-use (e.g. cropping) pose a significant risk of edge effects on biodiversity values, an increased frequency and/or density of monitoring may be required to detect any impacts early (this is by negotiation with the BCT).

[1] Year 0 = baseline; defined as the year the agreement becomes active

3.2 SPECIES CREDIT SPECIES MONITORING

Targeted monitoring of all threatened species populations that generate species credits is generally required at all relevant BSA sites. The objective and design of this monitoring should follow the guidance provided in Section 5.7. Appendix 1 provides additional species-specific guidance for a subset of threatened species that frequently generate species credits (or are likely to occur at development sites). In particular, threatened species monitoring should be designed:

- to assess or adequately sample the entire species polygon;
- to meet the objective of detecting presence on site for fauna species and estimating population size, area of occupancy and/or condition for flora species;
- to meet an additional objective of detecting population growth (e.g. via increased abundance or area of occupancy) if/where ARMA is being applied to increase the size of the species polygon; and
- with a frequency appropriate to the species' life-history and population dynamics (e.g. more frequent for short-lived or irruptive species or linked to trigger events [e.g. fire, rain] for obligate [e.g. disturbance-responding] species) – see Table 11 or Appendix 1.

For flora species assessed by count, a full population census is not required for very large populations/sites, however sampling design should be sufficient to generate a relatively accurate estimate of abundance. Similarly, for species assessed by area, it is important that sampling design is adequate and representative (this may be achieved using a two-phase grid-based systematic survey approach, as per the BAM Flora Survey Guide, Section 4.4.1). Wherever plots are used for threatened flora monitoring, they should be permanent - marked and mapped as per vegetation integrity plots (circular plots [e.g. 10 m radius] marked with a single star picket at the centre are generally recommended).

Although targeted monitoring beyond the species polygon is not specifically required, it is important to record any observations of the target species made on the subject land, either while traversing the site as part of other monitoring activity, or during vegetation integrity plot surveys, as evidence of colonisation.

For sites where species credits are generated specifically for breeding habitat (e.g. buffer area around a nest-tree) for dual credit species:

- no monitoring is required if/where there are ≤ 2 nest-sites generating credits; and
- for sites with >2 nest-sites generating credits, all potential nest trees within the credit-generating area should be monitored for breeding activity annually (e.g. via nest watches, nest contents inspections or remote cameras).

As per vegetation integrity plot monitoring, threatened species monitoring should continue in-perpetuity, with the frequency reduced by half (e.g. from 5-yearly to 10-yearly). Intensity should generally remain the same, unless it can be reduced without dropping below minimum detectability required to minimise false negatives.

3.3 MANAGEMENT EFFECTIVENESS MONITORING

It is a requirement of BSA landholders to monitor and report annually on the implementation of management actions (Performance Measures). In addition to this, direct monitoring of management effectiveness – in terms of reduction in extent or severity of the threat to biodiversity values (e.g. pests/weeds) – is required in particular scenarios involving more intensive management or greater uncertainty (i.e. ARMA). Specifically:

- assessing the utilisation of any habitat resource supplementation (e.g. artificial hollows, coarse woody debris, frog ponds) targeting particular species (see 5.3);
- weed cover mapping associated with integrated weed management (see 5.2.2);
- assessing grazing impacts where strategic stock grazing is allowed within a conservation area (see 5.2.3); or
- direct monitoring of vertebrate pests, if/where their management is part of a strategic approach beyond the scope of required management (e.g. targeted control of predators to protect an identified threatened prey species) (see 5.2.5).

3.4 DATA MANAGEMENT

Ecological monitoring data should be collected in formats consistent with Field Data Sheets in Appendix 2. Primary data should be provided to BCT in a digital format following collection. Digital field data collection tools and data standards are being developed to support EMM and will be published when available Accredited assessors can be request more information about data standards by contacting the BCT at info@bct.nsw.gov.au or making an enquiry at https://www.bct.nsw.gov.au/make-an-enquiry .

Floristic data submitted to BCT systems will be transferred to Bionet (Flora Survey Module) on behalf of accredited assessors, fulfilling NSW Scientific Licence holder obligations.

3.5 MONITORING PLAN

A Monitoring Plan should be developed as part of the BSA Management Plan (Section 7), submitted along with a BSSAR. This plan should generally conform to the structure provided in Table 2, with an appropriate level of detail. The plan should outline – by management or vegetation zone (whichever is appropriate) – information on the target biodiversity values, management actions, biodiversity objective (target; see also 3.3.1), monitoring methods, number and location of monitoring points (e.g. vegetation integrity plots) and resurvey frequency.

The BSA Management Plan Template has been updated (November 2021) to accommodate this additional information.

3.6 TOTAL FUND DEPOSIT CALCULATION

The total cost of implementing a BSA monitoring plan consistent with the guidance in this document, in-perpetuity, should be calculated using appropriate contractor rates (for an accredited assessor or similarly qualified ecologist) and appropriate time allowances for monitoring activities (including planning, travel and data quality assurance) and included in the TFD. This should include the cost of a baseline monitoring event in Year 1 (which may not be required if original BAM assessment can be used [<2 years old]).

Given that the TFD calculator currently has some functional limitations that affect the way in-perpetuity activities can be itemised, a work-around is required to ensure that EMM-related items are costed accurately. Figure 5 provides a detailed example of the recommended method for organising TFD items related to the EMM.

Management action costs	Timing			Estimated annual cost ($)		
	Start year	End year	Frequency		1	2
EMM - vegetation integrity plot monitoring - baseline	1	1	1	12,000	12,000	
EMM - vegetation integrity plot monitoring - active period	5	15	5	10,000	0	
EMM - vegetation integrity plot monitoring - perpetuity	20		10	5,000	0	
EMM - vegetation integrity plot monitoring - year 20 top-up	20	20	1	5,000	0	
EMM - threatened species X monitoring - baseline	1	1	1	6,000	6,000	
EMM - threatened species X monitoring - active period	3	18	3	5,000	0	
EMM - threatened species X monitoring - perpetuity	20		5	5,000	0	
Other recurring costs						

Figure 5: Example TFD calculator table showing recommended breakdown and layout of EMM-related items. The calculator form does not currently allow for a 'Start year' > 20, requiring the in-perpetuity items to start in Year 20, which requires a further adjustment to the Year 20 event cost ('top-up'). Note: the total present value for all payments related to the items in this example is $107,778.

If on development and costing of the monitoring plan the associated component of the TFD is considered unreasonable or likely to significantly impact the viability of the BSA, accredited assessors are encouraged to contact the BCT to negotiate amendments aimed at reducing projected costs while maintaining the rigour and value of the proposed monitoring.

3.7 EXCLUSIONS

Accredited assessors or landholders are ***not*** responsible for:

- establishment or monitoring of control sites; or
- data analysis and reporting[1] (BCT will prepare a report for each BSA summarising ecological outcomes and evaluation against targets, timed to inform the 5-year management plan review process)

[1] There is no change to existing obligations with respect to annual reporting on management plan implementation

4 VEGETATION INTEGRITY PLOTS

4.1 ESTABLISHING PERMANENT MONITORING PLOTS

Once the required number of plots per vegetation and management zone is confirmed via desktop review, permanent plot locations should be established in the field (e.g. walking a random distance into the zone, or selecting a subset of existing assessment sites), with the aim of capturing a representative sample of the ecological variation present within each zone. This variation may include condition (e.g. piosphere, topography, floristics [e.g. PCTs within particular vegetation classes with high intrinsic variability such as swamp forests]), and may necessitate establishing more plots than required by the desktop stratification. Plots should not be located in or near ecotones, vehicle tracks and their edges, or other disturbed areas that are readily distinguishable from the broad condition state of the vegetation zone. Where separate areas of land are mapped into a single vegetation zone, the plots should be located across the separate areas, while being representative of the zone. Generally, the long axis of plots should be oriented across a slope, with the exception of those used for Landscape Function Analysis (LFA; see *4.5.1*), which should be oriented down-slope.

All plots should be permanently marked using two sturdy posts (~1500mm; e.g. star picket with cap) erected at the 0m and 50m points on the midline transect (see Figure 6), with the bearing from the 0m post recorded. A waypoint should be recorded at the 0m post location and the plot should be allocated an alpha-numeric identification code that encodes both the identity of the property (or control site) and the plot, and is unique across the BCT's ecological monitoring program (a *Monitoring Point ID* will be allocated automatically if data are entered directly using the BCT system). It is important for the quality and utility of the data collected, that plots are laid out identically each time the plot is reassessed in the future.

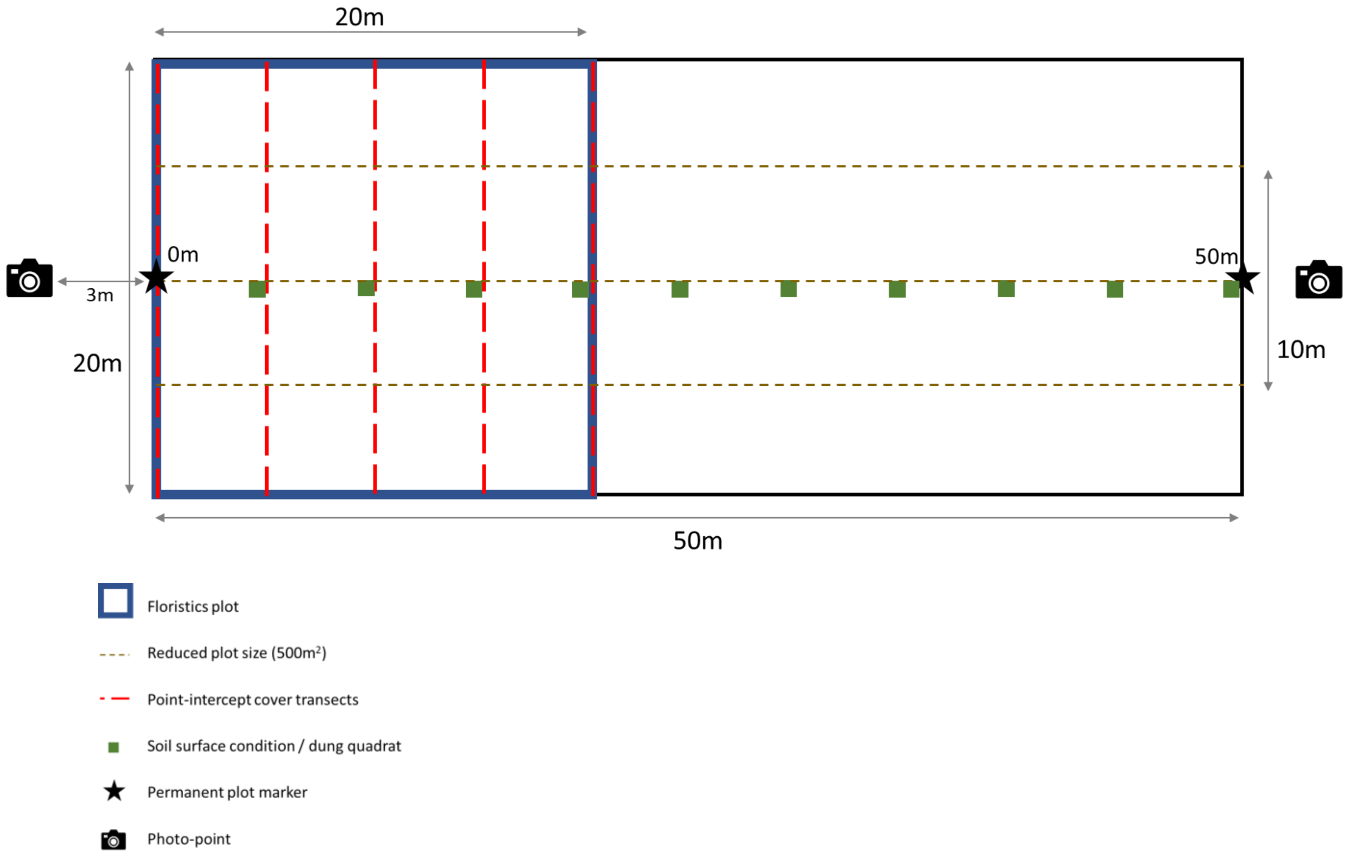


Figure 6: Layout for 20x50m floristic (vegetation integrity) plot and sub-plots.

4.2 FLORISTIC MEASURES

When implementing 'full floristic' plots (FF), the following data must be collected for *all* vascular plant species found to occur within the 20x20m plot:

- Full scientific name (*Genus, species*, and subspecific epithet if known)
- Estimated % foliage cover[1] of each species with individuals rooted in or overhanging the plot. Cover should be recorded in decimals if less than 1% (0.1, 0.2, 0.3…), or whole numbers up to 5% (1, 2, 3…), or to the nearest 5% where greater than 5% cover (5, 10, 15…)[2]
- Estimated abundance of each species, using the following intervals: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 200, 300, 400, 500, 600, 700, 800, 900, 1000, 2000, 3000, etc.
- Whether the species is native, exotic, or high threat exotic

[1] percentage of the plot covered by a vertical projection of all attached plant material, regardless of whether it appears alive or dead, of all individuals of a species. This includes leaves, stems, twigs, branchlets and branches, and any canopy overhanging the plot, even if the stem is outside the plot.
[2] Note: 1% cover equates to $4m^2$

If insufficient plant material is present for identification to species level, genus name can be recorded, providing it can be discriminated from other species of the same genus occurring within the plot (e.g. '*Eucalyptus sp.1*').

For a 'rapid' floristic plot (RP), the method is analogous except that summed cover and species richness are recorded by growth form (as per BAM) instead of species (i.e. a full species list is not required).

It is important that the data from every vegetation integrity plot assessment are sufficient to inform calculation of a *BAM Vegetation Integrity* (VI) *Score*. Therefore, as a minimum (in additional to structure and composition attributes described above), function attributes should be assessed within the 20x50m plot as per the BAM, i.e.:

- Litter cover (already recorded if implementing SSCA)
- Number of tree stem size classes (already recorded if implementing tree density and size distribution assessment)
- Number of large trees (already recorded if implementing tree density and size distribution assessment)
- Total length of fallen logs

4.3 PLANT SPECIMEN COLLECTION

Collection of plant specimens from monitoring sites for submission to the National Herbarium of NSW is recommended for two purposes:

- to confirm species identification where this is uncertain; and
- to contribute to the Herbarium's physical collection and voucher data set, informing taxonomy, systematics, conservation and ecological research.

Given time and resourcing constraints, specimen collection is not a requirement, but should be undertaken if and where feasible. The recommended priorities for collection, in priority order, are:

1. species requiring ID confirmation
2. threatened or (generally or locally) rare species (including exotics)
3. species representative of the site, in under-sampled landscapes[1]
4. species representative of the site, in other landscapes

4.3.1 Specimen collection and submission

Any plant specimens should be collected from within the 20x50m monitoring plot, then shipped to the Herbarium, following the protocols outlined here:

- Collect specimens in flower and/or fruit, ideally 25-40cm long and up to 26cm wide (approximate size of a tabloid newspaper)

[1] Generally west of the Great Dividing Range; alternatively, regions or species with few vouchered specimens (identified via PlantNET)

- When pressing, carefully spread out structures (i.e. leaves, flowers) so that diagnostic features are clearly evident
- Long and narrow specimens, such as grasses and sedges, can be folded up to three times at the time of pressing
- With smaller plants (e.g. grasses, rushes, sedges, irises and lilies), collect one or more entire plants, including underground parts (i.e. bulbs, corms, rhizomes) still attached to aerial parts of plant
- For delicate plants (e.g. orchids, small algae), store fresh material inside a sealed plastic bag, and add paper towel, moistened with methylated spirit, to the plastic bag, then ensure that the sample is shipped immediately. Alternatively, make a spirit collection
- For information (including on making a wet/spirit collection) see, *How to Collect Plants* (Royal Botanic Gardens Sydney, 2005)
- Samples should be clearly labelled with the following:
    - BCT Monitoring Point ID; GPS coordinates
    - Collectors name
    - Date
    - Locality description (e.g. agreement/reserve name)
    - Vegetation Class and bioregion
    - habit – dimensions, bark type (important in eucalypts) flower/fruit colour, abundance
    - any information on characters and field observations that cannot be observed from the pressed specimen
    - good quality photographs of delicate plants like orchids (taken from a front and side view), or of the whole plant (e.g. showing the form of a tree) or bark type etc
    - scientific licence number (or note, ‘*scientific licence not required – DPIE staff implementing BCT Act*’)
- Samples should be shipped to:

  Botanical Information Service
  National Herbarium of New South Wales
  Australian Institute of Botanical Science
  Royal Botanic Gardens & Domain Trust
  Mrs Macquaries Rd, Sydney
  NSW 2000

5 ADDITIONAL MEASURES

Following the hierarchical design of the EMM (p.10), all monitoring plots across the program will include a standard assessment of floristic structure, composition and function attributes as outlined in Section 4, with a subset of plots to include one or more additional measures, dependent on risk, uncertainty, management regime and target biodiversity values (varying by agreement and/or zone; Table 4). The resultant data sets can inform analyses of relationships between basic floristic attributes and more complex indicators, enabling improvements to monitoring efficiency by enhancing program breadth without requiring intensive monitoring at every site.

5.1 POINT-INTERCEPT COVER MEASURE

This assessment provides a more objective and repeatable measure of vegetation structure, generally applied when relatively greater or more rapid ecological change is expected in response to management - particularly within the lower strata. Analysis of these data against matching projective foliage cover estimates will also provide a useful calibration of the latter method, as well as a test of the influence of inter-observer (estimation) error.

Within the 20x50m plot, two cover assessments – one 'lower stratum' and one 'upper strata' – are recorded at each of 100 points (i.e. 200 data points). For each intercept assessment, one of the following categories should be recorded:

- Native vascular plant (living)
- Exotic vascular plant (living)
- Litter (lower stratum only)
- Cryptogram (lower stratum only)
- Log / standing dead / coarse woody debris
- Rock / water (lower stratum only)
- Bare ground (lower stratum only) / no intercept (upper strata only)

For the lower stratum, at each point, cover category is assessed based on the material intercepting the vertical line between the ground and 1 metre height, closest to the 1 metre point (i.e. only one category to be recorded if there are multiple intercepts between the ground and 1m). For the upper strata, at each point, two values are recorded: i) cover category, assessed based on the first material intersecting a vertical line upwards from 1m height at each point; and ii) which sub-stratum the intercept occurs within:

- 1-3m
- 3-5m
- >5m

As for the lower stratum, only one cover category is recorded for each point (e.g. if there are intercepts at 1-3m and 3-5m, only the 1-3m intercept is recorded).

Configuration of the 100 points within the 20x50m plot may follow one of the following methods, dependent on ease of application:

- 1m intervals along 5 x 20m transects within the 20x20m subplot (preferred)
- 0.5m intervals along the length of the 20x50m plot midline (50m)
- 5m either side of the 20x50m plot midline transect at 1m intervals
- 0.5m intervals along 10 x 5m transects within a 5x5m subplot (this method should only be used in very dense vegetation where alternative methods are infeasible, and the assessor is confident that vegetative cover is relatively homogenous across the 20x50m plot

The specific method used should be recorded and the same method used for all future re-surveys of the plot.

To maximise accuracy, precision and efficiency, the recommended technique and equipment for implementing this assessment is using a rigid pole marked at 1m height, with a laser distance measurer attached, as shown in Figure 7. The pole is used to determine the lower stratum intercept and the laser distance measurer returns the exact value of the intercept height (or no intercept). An optional addition to this device is a small spirit level, which helps to ensure that the pole is perpendicular to the ground at each intercept point. Alternatively, upper strata intercepts may be assessed visually, by looking vertically through a tube with crosshairs affixed, while standing at each point (noting that this method is likely to be more subjective).

Note on application: when assessing upper strata, rapid observation of the distance reading is preferable to taking time to ensure the pole is precisely vertical, as this may bias results towards overestimating cover (i.e. subconsciously preferentially recording a distance reading over an 'error' [no cover] reading). It is also important not to forget to add the height above ground of the laser origin, when calculating upper strata intercept height.

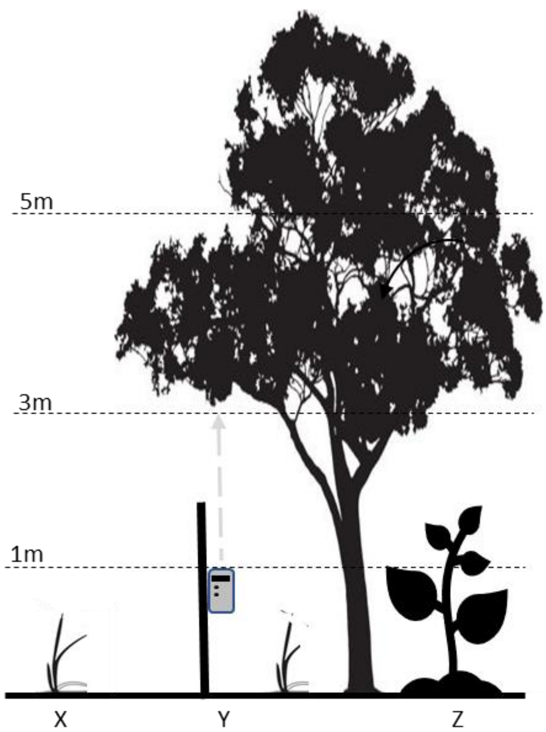


Figure 7: Recommended equipment set-up for taking point-intercept cover measures. Assessment at point 'X' should be; lower='native vascular plant' / upper='no intercept' (>5m); point 'Y'; lower='bare ground' / upper='native vascular plant' (3-5m); point 'Z'; lower='native vascular plant' / upper='native vascular plant' (1-3m)

5.2 TREE DENSITY AND SIZE DISTRIBUTION

Assessing the density of plant stems across size classes, within species, provides detailed quantitative data on the vegetation community structure and function. Importantly, it provides information about age structure, recruitment of canopy species and disturbances that may impact the future provision of habitat resources such as hollows. This assessment is most relevant for (treed) systems likely to experience disturbance to recruitment (e.g. grazing in wooded areas), where management is expected to generate significant change in the density and size distribution of trees (e.g. active revegetation), and where large trees represent a critical habitat resource (e.g. koala habitat).

Record the tally (count) of the total number of trees with stems originating within the 20x50m plot (excluding those with stems originating outside of the plot with foliage inside the plot), for each species separately, by stem size class (Table 8). For multi-stemmed (e.g. mallee) species, each individual should be counted once, based on the largest stem (stem join must be observable above ground). 'Trees' should include all species allocated to the tree growth form group (BAM Appendix 4). Tree stem size should be measured at 1.3m above ground height (high side of slope), referred to as 'diameter at breast height over bark' or DBH, and classes are: <1, 1-5, 5–9, 10–19, 20–29, 30–49, 50–79, and >80cm DBH. For stems <1.3m high, stem diameter at ground level should be used instead of DBH.

In some systems – generally wet sclerophyll forests or rainforests – plots may contain a large number of smaller tree species which occupy the midstorey and would not be considered 'structurally dominant' in the context of the local vegetation community (e.g. *Glochidion ferdinandi, Acacia dealbata or Jagera pseudorhus var. pseudorhus*). For these scenarios, to maximise efficiency, these types of species may be omitted from data collection – i.e. the list of tree species recorded for this component should be limited to those which appear to be 'structurally dominant' at the site (e.g. forming part of the canopy, *Eucalyptus sp.*). This exception to the standard method is justified based on the purpose of this particular component, which is primarily for assessing demographic and successional dynamics of functionally important and ecosystem-structuring (i.e. canopy-forming) species.

In addition to each tree species, the total number of trees (all species combined) containing at least one hollow – >5cm diameter and >1m above ground – should be recorded for each stem size class, as well as the number of standing dead (>5cm DBH). Any observable evidence of trees in poor health or degraded condition should be recorded as a qualitative "condition-affected" category, by species, for any stem size class (e.g. '*dieback'*, '*senescence'*, '*disease'*) (Table 8).

Evidence of different types of regeneration should be identified and recorded based on the primary regeneration category observed (e.g. seedlings, persistent lignotubers, mature [e.g. epicormic] resprouting) for each species, across all stem size classes, the default being '*seedling*' (Table 8).

If/where trees <20cm DBH are estimated to be very numerous (i.e. >>50) within the 20x50m, the plot size for assessment of the <1, 1-5, 5-9 and 10-19cm classes may be reduced. In this scenario, plot size should be reduced by incrementally reducing plot width to 10, 5 or 2.5m, dependent on estimated stem density (i.e. with the aim of recording approximately 50+ trees/plot), while maintaining 50m plot length (i.e. reducing plot area to 500, 250 or 125m^2, respectively). For example, if the 20x50m plot is roughly estimated to contain 200 trees <20cm DBH, this would justify reducing the plot size for assessment of these classes to 250m^2 (i.e. 5x50m). The relevant plot size used for the <20cm classes must be recorded, and the same plot size must be used for all subsequent site resurveys.

Table 8: Example data schema for tree species density and size class assessment

Stem size (cm DBH) / Species / type	<1	1-5	5-9	10-19	20-29	30-49	50-79	>80	Primary regen type[1]	Condition-affected category
***Plot size*[2]**	*5m (250m^2)*				**20m (1000m^2)**					
Spp. X	*48*	*33*	*39*	*19*	*8*	*5*	*0*	*4*	*seedling*	*dieback*
Spp. Y	*24*	*41*	*28*	*23*	*6*	*0*	*9*	*1*	*seedling*	*disease*
Spp. Z	*39*	*27*	*20*	*11*	*0*	*7*	*3*	*0*	*mature resprout*	*senescent*
***Hollows*[3]**	*n/a*	*n/a*	*n/a*	*0*	*0*	*0*	*5*	*8*	*n/a*	*n/a*
Standing dead	*n/a*	*n/a*	*n/a*	*0*	*0*	*0*	*1*	*0*	*n/a*	*n/a*

5.3 SOIL FUNCTION

The Landscape Function Analysis (LFA) and incorporated Soil Surface Condition Assessment (SSCA) methods presented here are based directly on Tongway and Hindley (2004). These methods focus on understanding the movement and retention of nutrients on the soil surface, therefore are most useful when applied to systems and management regimes where these processes are most dynamic. For example, they are likely to be of limited benefit in high condition, dense forests with very high litter cover, but are extremely useful for assessing improvement in drier or more open systems, particularly where changes to the ground layer are of interest (e.g. grazing management, post-disturbance [fire, erosion], major rehabilitation) (Table 9).

[1] E.g. seedlings (default), persistent lignotubers, mature (e.g. epicormic) resprouting
[2] Default = 20m width; reducible to 10, 5 or 2m for classes <20cm only
[3] Count of trees (all species) with hollows >5cm diameter and >1m height

Table 9: Guidance on the application of soil condition assessments by NSW Vegetation Formation

Vegetation Formation	Recommended application of soil function assessment[1]
Alpine Complex	SSCA[2]
Arid Shrublands (Acacia sub-formation)	LFA[3]
Arid Shrublands (Chenopod sub-formation)	LFA
Dry Sclerophyll Forests (Shrub/grass sub-formation)	SSCA
Dry Sclerophyll Forests (Shrubby sub-formation)	SSCA
Forested Wetlands	Not applicable
Freshwater Wetlands	Not applicable
Grasslands	SSCA
Grassy Woodlands	SSCA
Heathlands	Not applicable[4]
Rainforests	Not applicable[4]
Saline Wetlands	Not applicable
Semi-arid Woodlands (Grassy sub-formation)	SSCA
Semi-arid Woodlands (Shrubby sub-formation)	SSCA
Wet Sclerophyll Forests (Grassy sub-formation)	Not applicable[4]
Wet Sclerophyll Forests (Shrubby sub-formation)	Not applicable[4]

5.3.1 Landscape Function Analysis

Application of the full LFA method is appropriate for a limited set of scenarios (see Table 9), particularly those where there is an expectation of significant change to the size and distribution of 'patches' (i.e. productive areas of groundcover with the capacity for water and nutrient retention, such as grass tussocks, litter or coarse woody debris) across the ground

[1] If/where management regime dictates (see Table 4)
[2] Soil surface condition assessment (see 4.5.2)
[3] Landscape function analysis (see 4.5.1)
[4] May be applicable at highly degraded or disturbed sites

layer (see Tongway and Hindley 2004 for more details). This will maximise the cost-effectiveness of soil function data collection, given the significant additional time required to implement the transect component of LFA compared to the SSCA only (see 4.5.2).

The decision to implement LFA must be made at the point of establishment of the (20x50m) plot and baseline data collection. When implementing LFA, the midline 50m transect (and therefore the plot) must be oriented directly downslope, ideally positioning the plot to capture the maximum slope in the immediate vicinity of the planned plot location. If the slope is very low to flat, then the orientation is not so critical. Once the plot and midline transect have been established, the distribution, size and distance between 'patches' are measured and recorded (Figure 8).

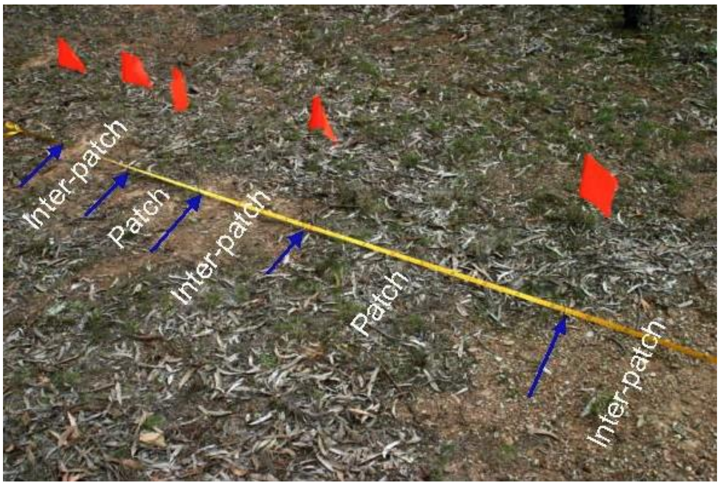


Figure 8: Image showing delineation of patch and 'inter-patch' boundaries (Tongway and Hindley 2004; reproduced with permission).

Patches are long-lived features defined by their tendency to accumulate resources by obstructing or diverting water, topsoil and organic matter down slope and/or collecting/filtering material from runoff. Patches can be comprised of physical features, such as furrows or bays created by active land-forming processes, or biological features such as plants or fallen logs. Typically, patches become a combination of both, over time.

Patch assessment along the 50m transect includes the measurement of three parameters which characterise the functional status of the soil:

1. number of obstructions to overland flow per unit length of transect (number and length of patches);
2. obstruction width per unit length of transect (patch width); and
3. mean distance, and range, between obstructions, per unit length of transect (inter-patch distance).

Figure 9 illustrates how these parameters should be measured in the field and Table 10 outlines the data collection required to quantify the transect.

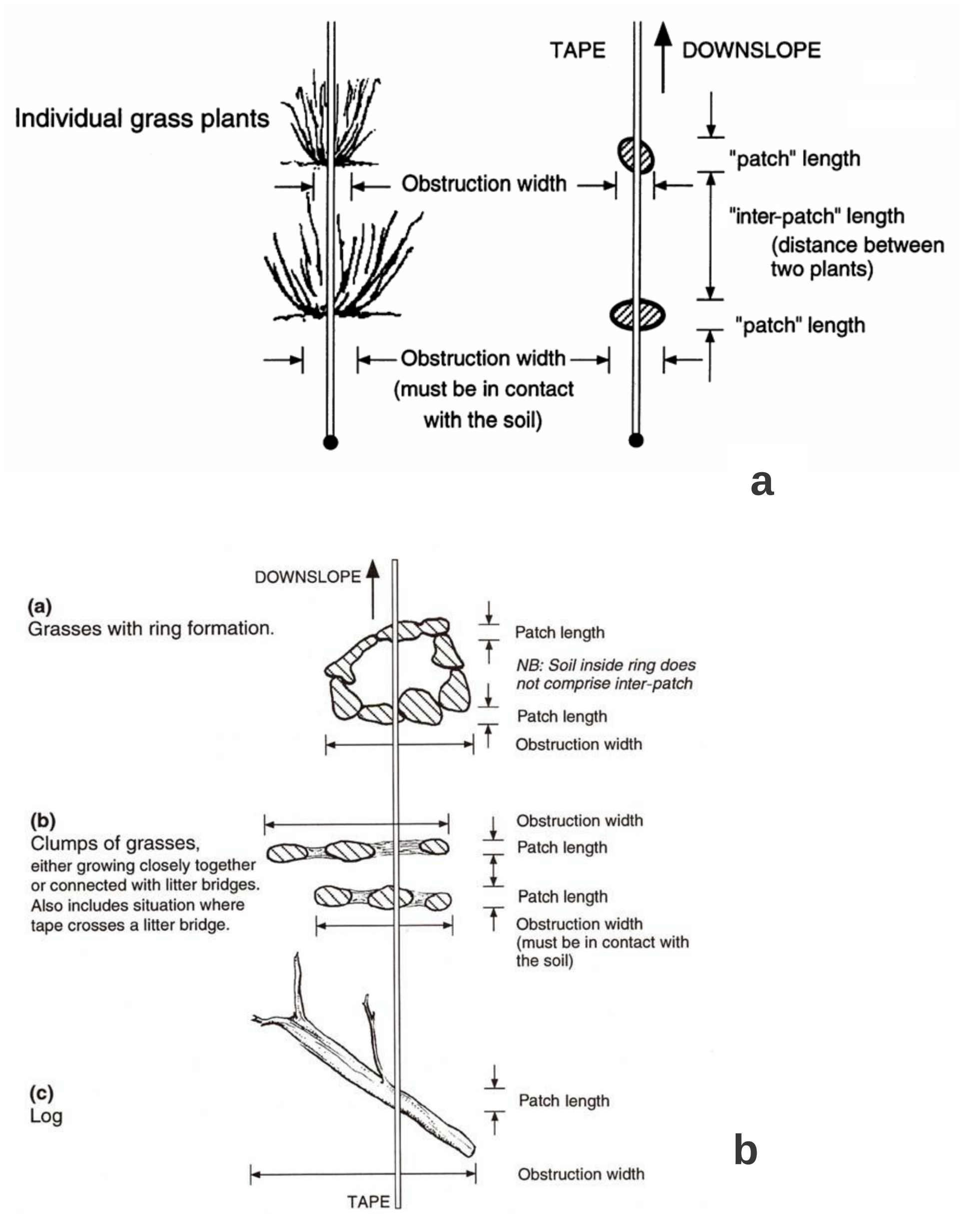


Figure 9: Diagrammatic representation of the method for defining and measuring patches of a) individual grass tussocks and b) other patch types (Tongway and Hindley 2004; reproduced with permission).

The following points provide some guidance on the identification and definition of patches and inter-patch areas:

- Deposition of alluvium or litter is a common identifying factor in helping to recognise patches.
- The minimum plant butt size for inclusion in the data is 1 cm.
- All measurements of grass plants for obstruction width and cover length are taken to and from the edge of the grass tussock, ignoring any soil hummock.
- Measure the obstruction width at right angles to the transect line, i.e. on the local contour – this is the maximum width of the patch.
- Measure the patch length along the transect line.

- Measure patch length and width at about 1 cm height above the ground level (as though in an overland flow situation).
- Patches can be simple (i.e. a single plant, rock or branch), or complex (i.e. a heterogeneous mix of different elements).
- Not all landscapes have a patch/inter-patch organization. As grasslands become denser, there comes a point when litter and soil are no longer mobilized and transported by flowing water. The patch is then a large area comprised of a sward made up from a large number of functionally linked plants acting as a single unit rather than a series of isolated individuals as is the case with sparse tussock grasslands.
- If there is no evidence of soil or litter transport between or around grass butts, then a sward or very large patch (resource retaining zone) exists. Litter may be present, but should show no evidence of movement. An ideal time to observe this is just after a rainfall/run-off event to judge the extent of litter and alluvium movement.
- Inter-patch areas are characterized as a zone where resources such as water, soil materials and litter are freely transported either downslope when water is the active motive agent or downwind when aeolian processes are active.
- Different types of inter-patch are possible, for example “bare crusted soil” or “bare stony soil”.

5.3.2 Soil Surface Condition Assessment

SSCA involves the rapid assessment of several (mostly categorical) simple visual indicators within ten 0.25m^2 (0.5x0.5m) quadrats, within the 20x50m plot. Different combinations of these indicators are aggregated to create three indices of soil condition – *stability, infiltration* and *nutrient cycling.* SSCA can be implemented as a component of LFA or as a standalone assessment (more common). The spatial sampling technique – i.e. how the quadrats should be arranged within the larger plot – will depend on which of the above scenarios applies:

1. **SSCA as a component of LFA –** quadrats should be arranged along the 50m midline transect, each centred on a different (previously defined) patch or inter-patch area (preferably larger than the quadrat, where possible), stratified relative to the proportional length of patch and inter-patch for the transect, placed randomly once those conditions have been met. For example, if total patch length = 33.82m (remaining inter-patch length = 16.18m), then the estimated proportion patch (to the nearest 10%) = 70%, and therefore 7 quadrats should be positioned over patches and 3 over inter-patch areas.

2. **SSCA as a standalone assessment –** ten quadrats should be placed evenly along the 50m midline transect, immediately adjacent to right side (facing down the transect from the 0m point) of the transect, with the upper left corner of each quadrat aligned to the 5, 10, 15…50m points on the transect, respectively, as shown in Figure 6. An alternative arrangement may be used, to complement the specified arrangement of litter assessment under the BAM, where quadrats are

positioned 5m from the midline transect, five on each side, evenly spaced along the 50m length.

Within each quadrat, the following indicators should be assessed visually, and a score recorded. See Table 10 for visual assessment category descriptors and data collection requirements.

Table 10: Soil Surface Condition Assessment (SSCA) visual indicators and interpretation of categories for assessment

Indicator	Assessment categories / data requirement				
Plant foliage cover	% foliage cover of perennial vegetation <0.5m (nearest 5%)				
Plant basal cover	% basal cover of perennial vegetation (nearest 5%)				
Litter – cover	Estimate and record % cover within quadrat (nearest 5%)				
Litter – depth	Estimate average depth across quadrat (nearest 1mm)				
Litter – origin	*local* = 1.5	*transported* = 1.0			
Litter – incorporation	*nil* = 1.0	*slight* = 1.3	*moderate* = 1.7	*extensive* = 2	
Cryptogam cover	% cover cryptogram / biocrust (nearest 5%)				
Crust brokenness	*no crust* = 0	*extensively broken* = 1	*moderately broken* = 2	*slightly broken* = 3	*intact crust* = 4
Erosion severity	% surface impacted by erosion (eroded area)				
Deposited materials	% cover (abiotic) deposited material (if volume spread across quadrat)				
Surface roughness	<3mm = 1	3-8mm = 2	9-25mm = 3	large depressions with base = 4	very large depressions > 100mm = 5
Surface resistance	*loose, sandy* = 1	*easily broken* = 2	*moderately hard* = 3	*very hard / brittle* = 4	*non-brittle / mulching* = 5
Crust stability	*N/A* = 0	*very unstable* = 1	*unstable* = 2	*moderately stable* = 3	*very stable* = 4
Texture	*clay* = 1	*clay loam / sandy clay* = 2	*loam* = 3	*sand* = 4	

Plant foliage cover

The objective is to assess the degree to which physical surface cover and projected plant cover ameliorate the effect of raindrops impacting on the soil surface. Assess the projected percentage cover of perennial vegetation to a height of 0.5m, plus rocks >2cm, woody material >1cm in diameter or other long-lived, immoveable objects. Ephemeral herbage and litter should be excluded from this indicator.

Plant Basal Cover[1]

The objective is to estimate the “basal cover” of perennial grasses, trees and shrubs. This indicator assesses the contribution of the below-ground biomass of perennial vegetation to nutrient cycling and infiltration processes. Grass cover for example, is assessed by summing the butt areas of perennial grasses (annual plants are excluded) within the quadrat.

Litter

The objective is to assess the cover, depth, origin and incorporation of plant litter. “Litter” refers to all dead or detached herbage, leaves, stems, twigs, fruit etc.

- Cover – estimated % cover of litter within the quadrat (nearest 5%, or 1% where <5%)
- Depth – estimated average litter depth (mm) across the quadrat (i.e. if spread equally across quadrat)
- Origin – categorised as either *local* (derived from plants growing in close proximity to the quadrat and showing no signs of transport/deposition by wind or water flows) or *transported* (has clear signs of being washed or blown to the current location)
- Incorporation - the degree of decomposition and extent of humification, darkening and integration of the litter and soil layers

Cryptogam Cover

The objective is to assess the cover of cryptogams visible on the soil surface. “Cryptogam” is a generic term that includes algae, fungi, lichens, mosses and liverworts. Fruiting bodies of mycorrhizae would be included. When these are present, they indicate soil surface stability and elevated levels of available nutrients in the surface layers of soil. The soil surface may need close inspection to assess the presence of cryptogams. Adding a little water and observing the “greening” of cryptogams over a period of 10 –20 seconds can be very useful. Some cryptogams are “detached” from the soil surface after long periods of desiccation, but cover is assessed normally.

Where the soil surface is clearly mobile, e.g. loose sands; “naturally active”, e.g. self-mulching clays or has an extensive deep litter cover, no habitat for cryptogams exists and a score of zero should be recorded. In rare cases, lichens can grow on sandy soils, or on undisturbed self-mulching clays. Where this is observed, the cryptogam indicator must be

[1] Tongway and Hindley (2004) specify that overstory foliage cover should be included in this indicator, however, these data will be derived from the complementary floristic data set for the purposes of analyses.

assessed. If there is no observable soil crust, cryptogam cover should be scored as zero, as they require a stable surface to grow.

Crust Brokenness

The objective is to assess to what extent the surface crust is broken, leaving loosely attached soil material available for erosion. A crust is defined as a physical surface layer that overlies sub-crust material. Soils with physical crusts in good condition are crusts that are smooth and conforms to the gentle undulations in the soil surface. These good condition crusts yield little soil material in a runoff event.

Polygonal cracking of the crust without curled edges is not considered broken and scores the maximum value. Typically, sections of crust are lost, forming a micro-crater that may be filled with loose alluvium. Both the area of and severity of broken crust should be assessed. A score of zero should be applied to: loose, sandy soil; self-mulching (surface crumb-structure) soils; or soil under high permanent perennial plant cover (no crust present, typical in the wet dry tropics).

Erosion Severity

The objective is to assess the severity of recent/current soil erosion i.e. soil loss from within the quadrat. Erosion in this context refers to accelerated erosion caused by the interaction of management and climatic events, rather than the background levels of geologic erosion. This is assessed as the estimated % cover of eroded surface within the quadrat. The erosion type (i.e. rills/gullies, terracettes, sheeting, scalding or pedestalling) can be noted as additional information.

Deposited Materials

The objective is to assess the nature and amount of alluvium transported to and deposited within the quadrat. The alluvium generally comprises silts, sands and gravels. The amount or volume of deposited material is more important than the simple cover, it is important to consider total quantity (volume) within the quadrat. Hummocking is an indication of the movement large quantities of materials by wind. It is not to be confused with pedestalling which is the eroding away of material around plants and other objects. It is most often associated with adjacent scalding.

Surface Roughness

The objective is to assess the surface roughness for its capacity to capture and retain mobile resources such as water, propagules, topsoil and organic matter. This should be measured by placing a straight edge (e.g. ruler) on the soil surface and estimating the height (mm) of the largest depression created by surface unevenness. Surface roughness may be due to soil surface microtopography which retain flowing resources (e.g. depressions, gilgais) or to high grass plant density such that water flows are highly convoluted at the 5cm horizontal scale. High surface roughness slows outflow rates, permitting a longer time for infiltration and may comprise a safe site for the lodgement of propagules and litter. Roughness created by hoof or paw prints, animal scratchings or other similar disturbances should be included in the assessment.

Surface Resistance

The objective is to assess the ease with which the soil can be mechanically disturbed to yield material suitable for erosion by wind or water. This assessment should generally only be done on dry soil, as all moist soils are soft (although an educated estimate may be possible having previously observed the site under dry conditions). A very hard soil surface implies high mechanical strength, but very low infiltration, due to low porosity and massive crusting or hard setting. Descriptions of the nature of the surface:

- *Loose sandy surface*: Surface is not crusted, easily penetrated by finger pressure to about second knuckle joint. Sub-surface is non-coherent.
- *Surface easily broken*: Surface is easily penetrated with finger pressure (to about first knuckle joint). Surface may have a weak physical crust and sub-crust is sandy.
- *Moderately hard surface*: Surface has a physical crust and moderately hard, needing a plastic tool (e.g. pen-top) to pierce, breaking into fragments or powdering; the subcrust is coherent.
- *Very hard and brittle surface*: Needs a metal implement to break the surface, forming amorphous fragments or powder. The sub-crust is also very hard, coherent and brittle.
- *Non-brittle surface*: this shows some “springiness” when pressed with finger, typically an organic layer, or is a surface with a self-mulching clay; or is under a dense perennial grass sward (i.e. not just an isolated plant).

Crust Stability

The objective of this test is to assess the stability of natural soil fragments to rapid wetting using a ‘Slake Test’. Stable soil fragments maintain their cohesion when wet, implying low water erosion potential. The test is performed by gently immersing air-dry soil fragments (approximately 1cm^3) in water and observing the response over a period of approximately one minute. Water quality is important – saline water is unsuitable. The fragment can be obtained with a chisel or knife blade, breaking the fragment with the fingers to the appropriate size, and the soil crust must remain uppermost after immersion. Some soils high in organic matter may float in the water – usually these are stable (maximum score). Soils that do not permit coherent fragments to be picked up and tested (e.g. loose sands) should be scored as zero. Do not test moist soil – where possible, take a sample and allow it to air-dry before testing (the duration required to complete remaining assessments within the plot should be sufficient). This test is only required once for the 20x50m plot (with the result entered for each of the ten quadrats, for analysis).

Description of each category:

- *Not applicable:* No coherent fragments available (e.g. sand)
- *Very unstable*: Fragment collapses in less than 5 seconds

- *Unstable:* Fragment substantially collapses in 5-10 seconds; a thin surface crust remains; >50% of the sub-crust material slumps
- *Moderately stable*: Surface crust remains intact with some slumping of the sub-crust but <50%
- *Very stable*: Whole fragment remains intact with no swelling

Texture

The objective of this test is to classify the texture (i.e. silt, clay, sand and loam composition) of the surface soil, and relate this to permeability. This indicator only requires assessment once per 20x50m plot, as it is highly unlikely to vary over small spatial scales. The method has been simplified for application here, so as not to require a pedologist's moist bolus test. A rapid assessment of soil texture by feel and sight should be used to assign the site to one of four aggregated categories (see Table 10).

5.4 SOIL CHEMISTRY

It is recommended that a soil sample be taken from a subset of sites where SSCA or LFA is being implemented, or where management regime is likely to affect soil health (e.g. grazing exclusion), to be sent for chemical analysis (generally applicable to sites being monitor by BCT staff only, not BSAs). Sampling density should be one per relevant vegetation zone, with a maximum of three samples per agreement site, with repeat samples taken every 10 years. A single, composite soil sample from a depth of 0-10cm ('A' horizon) should be sampled from each site (plus an additional core sample specifically for bulk density analysis [see below]), as this layer's chemistry (fertility) is likely to provide the most useful information with respect above-ground plant productivity (Delgado-Baquerizo *et al.* 2017).

The purpose of this sampling is to link aspects of soil chemistry related to soil health/fertility to above-ground measures of biodiversity condition, as well as testing the efficacy of SSCA and LFA as reliable indicators of soil quality. In addition, these data will be critical to understanding the relationship between biodiversity outcomes and production outcomes in agricultural systems more broadly.

5.4.1 Sampling method

The aim is to collect a composite topsoil sample weighing approximately 500g, plus an additional core sample (~100g; for bulk density analysis) representing soil condition at the site (vegetation integrity plot within zone), package the samples and send to the lab for chemical analysis and archiving.

The following steps should be followed for sample collection and processing:

1. Select five of the ten 0.5x0.5m quadrats used for SSCA (capturing variation in soil surface condition within the 20x50m plot), identifying a point immediately adjacent (outside; to avoid influencing SSCA data) to each quadrat, for soil sampling.
2. At each of the five points; remove any vegetation residues, grass or litter from the soil surface, then using a shovel, trowel or core, dig to a depth of 5cm and remove an approximately 100g sample of soil from the 0-10cm layer (if the sample is being collected from an area of exposed soil [e.g. a cut face or bank], dig back the face until you reach unexposed soil).
3. Ensure that a composite sample of at least 500g has been collected, put the sample in a calico sample bag, seal the bag and place this in a second sample bag; clearly label the outer bag with:
    - *"BCT EMM"*
    - Monitoring Point ID
    - Sample ID
4. At one of the five sampling sites, collect a single additional sample using a 6cm diameter core: take a precise core sample (ensuring no air pockets in the sample) trimmed to exactly 10cm depth, from the opposite side of the quadrat to the first subsample. Bag and label this sample as above, separate to the composite sample, with the additional label – "*Bulk density*"[1].
5. Record the following data associated with the sample (i.e. in digital form or hard copy):
    - Monitoring Point ID
    - Sample ID
    - Date
    - Collector name
    - Sample upper depth (i.e. *0m*) and lower depth (i.e. 0*.05m*)
    - Spatial coordinates
6. Once returned from the field, air-dry the sample for 24-48 hours before sealing. Store in a cool, dry place, for no more than 4 weeks, before shipping to the lab for analysis.
7. Post/courier samples to:
   Soil and Water Environmental Laboratory - DPIE
   c/o Yanco Agricultural Institute
   2198 Irrigation Way East, Yanco
   NSW 2703

[1] Soils with near surface vertic properties and high volume expansion/linear shrinkage (i.e. cracking clays: Prairie Soils; Black Earths; Grey, Brown and Red Clays) – identifiable via cracking / forming friable aggregated clay surface crumb when dry, and commonly found on inland basalt derived slopes and plains – should not be sampled for bulk density.

5.4.2 Chemical analyses

Initially, each soil sample will receive a basic suite of tests, including the following:

- Moisture content
- Electrical conductivity
- pH (H_20) and $CaCl_2$
- Salinity ($CaCl_2$)
- Total organic carbon (LECO)
- Total nitrogen (LECO)
- Phosphorous (Colwell)
- Bulk density

The samples will then be archived, with the potential to conduct additional tests in the future, should they be required to answer specific questions.

These data can be used not only to inform evaluation of state and change in soil health/fertility at agreement sites and its relationship to biodiversity condition, but to assess relative soil condition compared to other equivalent sites in the landscape via the existing NSW Government data set held in the *eSPADE* repository.

5.4.3 Phytophthora testing

Dependent on certain risk factors, as well as feasibility, collection of an additional soil sample at a limited subset of sites should be considered for the purpose of testing for the presence of *Phytophthora cinnamomi* (or similar pathogens, e.g. *P. multivora*). The following scenarios are likely to warrant testing:

- if evidence of disease or dieback is observed and the source is uncertain (particularly where 'indicator' species [e.g. *Xanthorrhoea*] are affected)
- in ecosystems which are at higher risk of *P. cinnamomi* infection, i.e.
  - located in coastal, escarpment or tablelands regions;
  - characterised by a heath understorey;
  - sites adjacent to human disturbance (e.g. roads and tracks);
  - areas of poor drainage or open textured soil; and/or
  - in close proximity to known infected areas (particularly down slope).

To collect a soil sample, first scrape away the organic layer and then using a trowel dig to around 10cm, ensuring to sample as much root material as possible. Take multiple samples from within the drip line of trees or shrubs – preferentially sampling individuals with symptoms typical of *Phytophthora* (wilting, yellowing and dieback) – and combine into a zip-lock bag (ideally 3-4 cups of soil per composite sample). There is no need to refrigerate samples, but they should not be exposed to direct sunlight or high temperatures.

Samples should be labelled with ‘*BCT EMM*’, Monitoring Point ID, Site Name, observer’s name and date, and the online form completed with matching information. Samples should then be shipped to:

Plant Disease Diagnostic Unit
The Royal Botanic Gardens & Domain Trust
Mrs Macquaries Rd
Sydney NSW 2000

5.5 DUNG ASSESSMENT

Quantification of the volume and type of dung present is particularly important for sites where total grazing pressure may have significant impacts on biodiversity values. This includes agreement sites with strategic grazing permitted within conservation areas, sites with abundant native herbivores or sites with significant populations of feral herbivores.

Dung assessments are to be implemented as part of the vegetation integrity plot monitoring regime if/where required (see Table 3). Quantity of cattle dung should be assessed within the 20x20 floristic plot, all other species’ dung should be assessed within the 10 x 0.25m^2 quadrats used for SSCA (if soil function assessment applied; 5 x 1m^2 BAM litter plots, if not). The associated species name is recorded, with the total number of pellets or pats, tallied within the plot/quadrat, using the intervals; 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 20, 30, 40, 50, 100, 200 etc, for each species separately. Extremely desiccated (old) dung should be excluded from the count.

5.6 PHOTO-POINTS

Two photos are to be taken at each vegetation integrity plot during each resurvey event, by BCT staff or accredited assessor, and annually in the intervening years by the landholder (submitted with annual report). One photo should be taken from the 0m end, down the transect length, standing 3m back from the 0m marker post and positioning the camera’s field of view such that bottom of the frame aligns with the (20m) edge of the plot and the marker post is in the centre (Figure 10). This procedure should be repeated for the second photo at the 50m end of the transect, aiming the camera back up the length of the transect (towards the 0m point).

Ideally, the image file should be digitally stamped with identifying information (e.g. Plot ID, Agreement ID, date)[1] at the point of creation and storage (e.g. using a BCT system). If this is not possible, a photo-board should be attached to each sighter post with this information clearly displayed.

[1] Not required if image is captured using EMM mobile data collection tools.

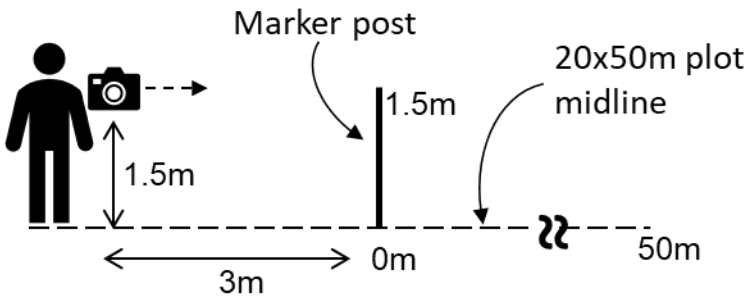


Figure 10: Setup for taking a photo-point at a vegetation integrity plot. Setup is repeated in reverse at 50m point.

5.7 THREATENED SPECIES MONITORING

Targeted monitoring of all *focal* threatened species populations identified at high priority agreement sites (i.e. BSAs and funded CAs) is required. Focal populations, in this context, are defined as:

- Sites generating species credits (at BSAs, legacy Biobanking agreements; or sites within Offset CAs identified specifically as offsetting threatened species loss)
- Sites established via a targeted threatened species (e.g. koala) tender, SoS priority sites, or populations identified via other means and considered important by relevant experts (funded CAs)

The design of any targeted monitoring program for a threatened species on an agreement site should be based on the objective and question(s) to be answered. Given the scale of most agreement sites (relative to the scales at which population dynamics are operating and the size of fauna species' home ranges), the objective of monitoring threatened species populations within conservation areas should be:

- For flora species – to assess population size, distribution, condition and recruitment dynamics, and population change in response to management if/where significant change is expected (e.g. under active restoration) (for some [e.g. annual, obligate, assessed by area under BAM] species, presence, area of occupancy and/or habitat condition may be more appropriate indicators)
- For fauna species – to confirm presence and quantify habitat condition, and if appropriate and feasible, quantify activity/density and/or utilisation of habitat resources (the latter in particular for active restoration scenarios (e.g. provision of nest-boxes or coarse woody debris)

Monitoring methods and indicators should align with those described in the relevant species' conservation project under the *Saving our Species* program (SoS) or the relevant BAM survey guidelines (accessible here), including the *Flora Species with Specific Survey Requirements* database. Table 11 provides some general guidance on appropriate monitoring methods for different species functional groups. Appendix 1 provides species-specific recommended monitoring methods for a subset of threatened species most likely to occur on agreement sites. Sampling density should be proportional to the size of the site / population size and relate to the objective – for plot or transect-based flora monitoring, see Keith (2000) for guidance on sampling design.

For some species, direct monitoring of individuals (either abundance or occupancy) may not be feasible, in which case a surrogate (e.g. abundance/condition of a habitat feature or resource) may be monitored, as long as the chosen surrogate is ecologically valid (i.e. it is a reliable indicator of population size or viability). For management scenarios where fauna (or flora in some cases, e.g. translocation) habitat is being actively restored, with an expectation that the target species will colonise restored habitat (e.g. increasing the area of a species credit polygon with active restoration management actions at a BSA site), monitoring should be designed to assess change in area of occupancy.

Threatened ecological communities (TECs) should be monitored according to their condition and management intensity, as per other vegetation communities, except for where the relevant SoS conservation project specifies particular important indicators which are relevant to assessing attributes specific to that TEC (e.g. groundwater-dependent communities).

Table 11: Recommended generic monitoring methods and indicators for different threatened species groups (taxonomic and/or functional). This represents general guidance only, is not prescriptive, and should only be referred to in lieu of any available species-specific guidance (i.e. from sources cited above).

Species group	Monitoring method(s)	Frequency[1]	Primary indicator
Arboreal mammals	Spotlighting, remote camera, passive acoustic recording	5-yearly	presence / absence; activity
Ground-dwelling mammals	Remote camera; trapping; indirect detection (e.g. scats)	5-yearly	presence / absence; activity
Amphibians	Aural/visual survey, passive acoustic recording, tadpole search	5-yearly	presence / absence
Reptiles	Pitfall trapping, artificial habitat (e.g. tiles), manual survey (e.g. walking transects)	5-yearly	presence / absence
Birds (passerine)	20 min / 2 ha visual survey, fixed walking transects, passive acoustic recording, call playback, breeding activity assessment (e.g. hollows)	5-yearly	presence / absence
Bats	Passive acoustic detection (e.g. Anabat, Audiomoth)	5-yearly	presence / absence
Raptors	Nest observation, aural-visual surveys (e.g. owls)	5-yearly (annual for	presence / absence; breeding activity

[1] Higher frequency monitoring may be required if/where more rapid change in populations or habitat components is expected (e.g. following disturbance)

		nest observation)	
Trees	Population census (small population); sample abundance plots/transects; condition assessment; stem size class counts; recruitment assessment (e.g. seedling survival, flowering)	5-yearly	abundance; area of occupancy; condition
Shrubs	Population census (small population); sample abundance plots; condition assessment; size class counts; recruitment assessment (e.g. seedling survival, flowering)	3/5-yearly	abundance; area of occupancy; condition
Forbs	Population census (small population); sample cover/abundance plots; condition assessment; size class counts; recruitment assessment (e.g. seedling survival, flowering)	3-yearly	cover; abundance; area of occupancy
Grasses	Sample cover (tussock density if feasible) plots/transects; condition assessment (e.g. browsing/grazing pressure)	3-yearly	cover; abundance; area of occupancy
Orchids	Population census; sample abundance plots (if large); flowering density; individual condition	annual	abundance; reproduction

5.7.1 Koala monitoring

Koalas (*Phascolarctos cinereus*) are a special case among threatened species, given that there have been multiple tender rounds targeting koala habitat under the BCT's Conservation Management Program, and they often trigger offset requirements under the BOS. Monitoring of both habitat condition and occupancy is required for all BSAs generating koala species credits as well as funded CAs resulting from a targeted koala tender.

Koala habitat condition can be adequately monitored via application of full floristic plots along with tree stem counts by size class (see 4.4), with the additional designation of '*Preferred Koala Feed Tree'*[1] / '*non-feed tree'* recorded for each species in the stem count data (can be attributed post-fieldwork). These plots should be stratified by PCT x condition

[1] Region-specific; either locally determined or based on the NSW Koala Habitat Information Base

state within areas of identified koala habitat (varying from the default stratification by vegetation class for CAs), at ‘Moderate’ density (Table 4).

Given the typical size of conservation areas and the size and distribution of koala home ranges (10-400ha, varying by region; Goldingay and Dobner 2014; L. Wilmott *unpub.*), the predominant objective of monitoring koala populations on BSAs and funded CAs should be ongoing detection of presence. There are several frequently employed methods for monitoring koala occupancy; including scat detection (by human observers or detector dogs), spotlighting and acoustic recording. The recommended method likely to be suited to most agreement sites is passive detection via acoustic recording, e.g. using technology such as songmeters (e.g. SM4) or *Audiomoths* (Hill *et al.* 2019). Benefits of this method compared to alternatives in this context, include; cost-effectiveness (larger sampling area for lower cost per unit time), objectivity (detection probability is not subject to inter-observer error), improved detectability (Law *et al.* 2020) and simplicity (small/simple [e.g. Audiomoth] units can be mailed to landholders for application).

The method relies on the detection of koala (generally male) bellows at night, which can be identified via a semi-automated process using recognition software (Towsey *et al.* 2012) to confirm presence/absence at a site. Units should be placed within the target habitat, fixed to a tree (~1.5-1.8m height) and enclosed in waterproof housing. Available evidence suggests that using this method (for a single recording unit), detectability of koala presence in a low-density population is maximised (90-99%) after 4-7 nights (Hagens *et al.* 2018; Law *et al.* 2020), therefore the recommended minimum period of deployment is 7 nights (dusk-dawn) continuous recording (10 nights is the likely maximum without battery and SD card replacement). This period should be increased – i.e. second 7-night deployment – in wet (>2mm/night), hot (>35°C) or windy conditions, or if recording sites are on ridges or steep topography, given these factors are known to reduce detectability (Ellis *et al.* 2011; Law *et al.* 2020). For very large sites (>100ha) where a sampling approach is taken (see 5.7.1.1 below), and when Audiomoths are used, these should be deployed for 12 nights to maximise detectability.

Where battery life is a constraint, daily recording hours should be reduced to 10pm-2am (highest frequency of bellowing activity; B. Law *unpub.*) to extend the number of days deployed. Conservation area size (and proximity of recorders to boundary) should be considered in relation to recorder detection range, to minimise false positives (e.g. detecting bellows from beyond the boundary) – Audiomoths are not recommended for sites <4ha[1]. Koala occupancy monitoring using this (or other passive audio recording) method should be implemented in August – December (during breeding; Ellis *et al.* 2011; Law *et al.* 2020), every 2-3 years, with a repeat survey after 12 months if presence is not detected in any given monitoring event. This frequency may be reduced to every 5 years following 8 monitoring events (i.e. 20 years).

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[1] Songmeters (~300m detection range) are not recommended for sites <25ha, unless sensitivity is manually reduced

5.7.1.1 Detector density

Detector units (e.g. songmeters, Audiomoths) should be deployed evenly spaced throughout koala habitat within the site. The density of units should be sufficient to ensure a high probability of detecting koalas if they are present (i.e. minimise false negatives). The following guidance is based on an analysis of available data sets from multiple passive acoustic koala monitoring projects in NSW which have applied a systematic grid design (Gonsalves & Law 2021).

For sites <50ha, deployment of detectors should aim to capture all (or a large proportion) of the survey area within the detectable range of at least one unit (i.e. saturation approach). This equates to approximately one songmeter (SM4) per 30ha (assuming 300m detection range) or one Audiomoth per 5 ha (assuming 100-150m detection range) up. For sites 50-100ha, 1-2 songmeters or 3-6 Audiomoths (depending on conditions) should be deployed.

For sites >100ha, a sampling approach should be taken with reference to Figure 11 for minimum spatial sampling effort (detector density), under ideal conditions. For example, at a 500ha site, the minimum recommended number of detector units is either 3 songmeters or 9 Audiomoths, while for an 800ha site the recommendation is either 4 songmeters or 12 Audiomoths. The significantly lower densities recommended for larger sites relative to smaller sites are justified in the context of the monitoring objective – in this case detecting presence/absence within a conservation area – given the increasing probability of intersecting multiple koala home ranges with increasing area. The guidance presented here is not appropriate for application where the survey objective is to quantify occupancy at the patch scale or to estimate population size.

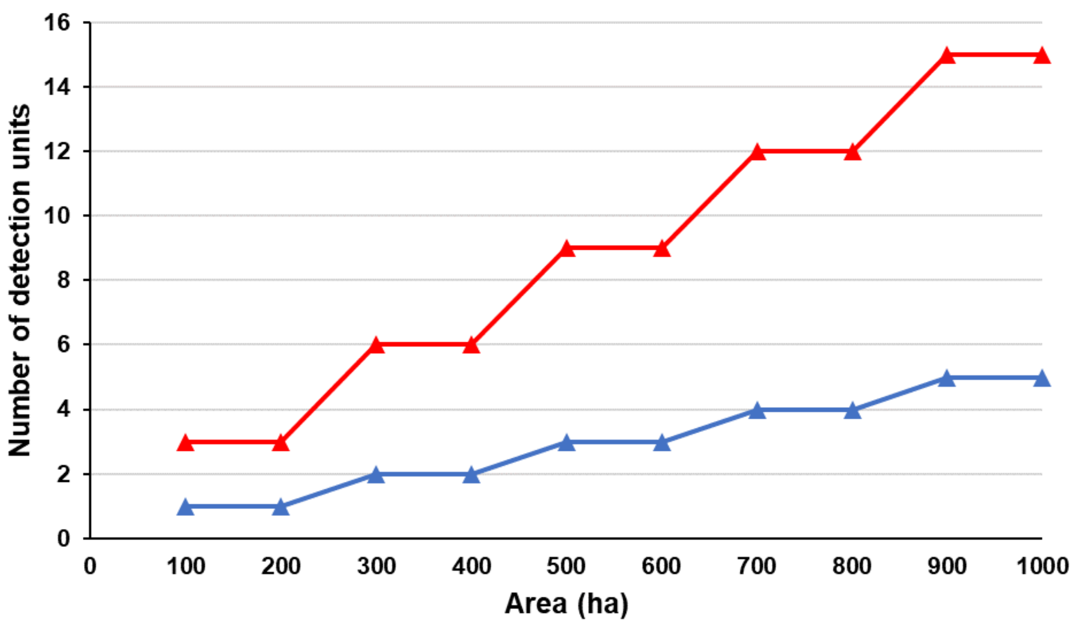


Figure 11: Recommended minimum densities for deployment of passive acoustic detectors – either songmeters (SM4) (blue triangles) or Audiomoths (red triangles) – for monitoring koala occupancy under ideal conditions. Reproduced from Gonsalves & Law (2021).

It is important to note that the densities recommended above are appropriate under ideal detection conditions, and should be increased (one additional songmeter or three additional Audiomoths) for any of the following scenarios likely to reduce koala detectability:

- surveying on hotter (>30°C) nights closer to the end of the breeding season (late December;
- surveying on upper slopes and ridges (particularly in southern NSW);
- surveying during rainfall or high winds (additional survey nights are recommended over increased detector density); or
- survey site is subject to unavoidable noisy conditions (e.g. streams/ponds with calling frogs, busy roads).

5.8 MONITORING MANAGEMENT EFFECTIVENESS

5.8.1 Revegetation

Revegetation may be undertaken at BSAs as an Active Restoration Management Action (ARMA) or at funded CAs as a 'Restore' management action, in alignment with the BCT Restoring Native Vegetation Guidelines . Monitoring the outcomes of site restoration via revegetation is crucial to its success, given the uncertainty inherent in the practice and the often significant investment (Maron *et al.* 2012; Lindenmayer 2020). Also, because of the expectation of significant ecological response (i.e. biodiversity gain) to revegetation, it warrants relatively greater monitoring density, frequency and precision.

Floristic monitoring plots should be established prior to planting within the revegetation management zone, stratified as per Section 2.2.1, and including tree stem counts by species and size class (see Section 5.2).

Supplementary measures required to track short- and medium-term progress, in addition to those outlined in Table 4, in the first 10 years post-planting, include:

- Germination (estimated % of planted; for direct seeding)
- Survivorship of all planted species (or functional groups, for diverse plantings)
- Seed set (woody shrubs and small trees; year 5+)
- Qualitative assessment of any disturbance impacts (e.g. browsing, trampling)

These attributes should be assessed for all plants/revegetated area for smaller plantings, or using an appropriate sampling method for larger plantings – e.g. 'Latin squares' (see Box 2), with timing and frequency as outlined in Table 12. Rapid qualitative assessment of survivorship (i.e. to identify any major issues) should occur as part of annual compliance visits (mandatory for BSAs and funded CAs).

Box 2: Revegetation monitoring – 'Latin squares' method

This monitoring method is most useful for larger plantings structured in rows (e.g. rip lines). The method is designed to eliminate bias related to environmental factors (i.e. which may vary by row or landscape position). The 6x6 square design illustrated in Figure B2 can be used to sample 1/3 of the planting (as shown), or alternatively, 1/6 (e.g. 'A' squares only) or 1/2 (e.g. 'A', 'C' and 'F' squares only), depending on available resources and required precision – both increasing with increased sampling effort.

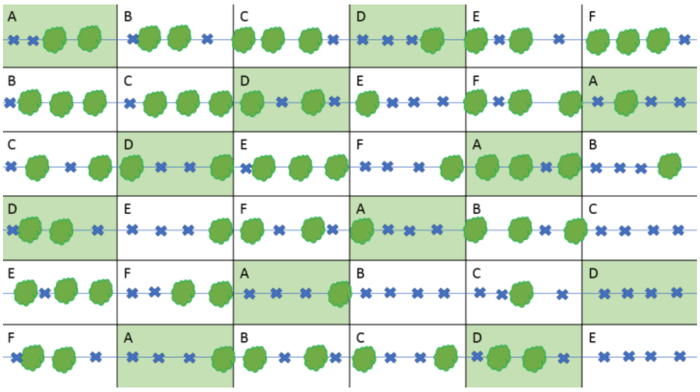


Figure B2: *A 6x6 Latin square design sampling 1/3 of the planting (green shaded squares). Opaque green blobs represent surviving plants, blue 'X's represent dead stems or failed planting.*

Table 12: Timing of monitoring events and indicators for revegetation management zones in first 10 years post-planting

Monitoring component	Years post-revegetation					
	0	1	2/3	5	7/8	10
Germination						
Survivorship						
Full floristics (cover/abundance)						
Stem density / size distribution						
Seed set						
Disturbance assessment						

Monitoring of all indicators measured at year 10 should continue at 5-yearly intervals until restoration targets (e.g. for cover and richness by growth form) have been met. See section 5.3 for further guidance on target-setting for restoration management.

5.8.2 Weed management

Monitoring the outcome of weed management is most critical when management is targeting high threat weeds and a significant improvement in ecological condition is expected (e.g. when undertaken as an ARMA at BSA sites or an 'enhance' or 'restore' action at a funded CA site [i.e. 'high intensity' management]). The state (extent and severity) of weed infestation and response to management over time should be quantified via mapping of weed cover classes if and where appropriate.

Patches or areas of similar foliage cover of the same 'weed type' targeted for management should have polygonal boundaries mapped. Weed types may reflect an infestation of a single weed species or suite of weed species (e.g. 'Blackberry'; 'Exotic perennial grasses'; 'Small-leaved Privet and associated species'; 'HTE and environmental weeds' etc) receiving a similar control method and exhibiting similar native vegetation community resilience. Cover should be scored using standard foliage cover classes; *Very Low* (<1%); *Low* (1-10%); *Moderate* (11-30%); *High* (31-60%); and *Very High* (>60%). Zones with highly dispersed and/or consistently patchy weed distributions may be mapped as a single weed type class, representing average cover. Weed mapping should occur immediately prior to initiation of management activity (baseline), then every 2-3 years during the primary control phase, then every 5 years during maintenance. Targets in terms of cover should be defined for each weed type (polygon) separately, at years 5, 10, 15 and 20. Management effectiveness should be evaluated based on reduction in cover for each polygon compared to the baseline (reference) state, and against defined targets.

Floristic plots should be positioned – as far as is feasible – in locations that are broadly representative of the average weed cover for the management zone and that will be targeted for management early in the life of the agreement (to maximise opportunity for assessing native vegetation response). It is not necessary to sample all weed cover classes within a zone (i.e. no additional plots beyond the recommendation from Table 5).

5.8.3 Grazing pressure

The level of effort applied to monitoring the biodiversity outcomes of stock grazing allowed within conservation areas should be proportional to the risk of a poor (i.e. worse than expected) biodiversity response. Table 13 categorises this risk, based on four key factors known to mediate grazing impacts on biodiversity (Dorrough *et al.* 2004; Eldridge *et al.* 2017). This should be used to inform the development of a monitoring prescription for each relevant (managed grazing) zone, using Tables 3 and 4 (additional guidance below).

Table 13: Determining risk associated with managed stock grazing within conservation areas

				Mean Annual Rainfall[1]					
				400-600mm			>600mm		
				Grazing duration (allowed days/year)					
				7	28	90	7	28	90
Land & soil capability	1-3	Significantly altered grazing regime?[2]	yes						
			no						
	4-6		yes						
			no						
	7-8		yes						
			no						

Legend: Red cells = High risk = 'High' management intensity (Table 3)
Orange cells = Moderate risk = 'Moderate' management intensity
Green cells = Low risk = 'Low' management intensity

Note: *If the paddock or management zone is in good condition, with no signs of over-grazing (e.g. lack of grazing-sensitive species), then the identified risk category can be reduced one level (e.g. High – Moderate or Moderate – Low).*

5.8.3.1 Measuring biomass

Biomass exclosures arrays (Figure 11) should be used to assess the impacts of total grazing pressure and the relative impacts of different sources of grazing pressure (i.e. stock, native herbivores, feral herbivores), in conjunction with other monitoring methods (e.g. vegetation condition assessment, dung assessment, SSCA, remote cameras). This approach is recommended for higher risk managed grazing scenarios and/or where impacts of feral or overabundant native herbivores or the effectiveness of their control is uncertain.

The objectives of monitoring biomass using exclosures, are:

1. To ensure that the observed total grazing pressure is consistent with the expected outcome of the approved (and reported) grazing regime;
2. to inform adaptive changes to the regime as required; and
3. to contribute to a program-wide assessment of the impacts of managed/strategic grazing on biodiversity; or

[1] Managed grazing is generally not allowed at sites with <400mm average rainfall; if/where this occurs, the 'High risk' category should always be applied.
[2] Is the proposed grazing regime under agreement significantly different than it was prior to the agreement being established?

4. To isolate the relative impacts of grazing by stock from those of native/feral herbivores; and
5. assess the effectiveness of native/feral herbivore control methods to inform management decisions (i.e. whether to commence or adaptively change native/feral herbivore management).

At relevant sites, an array comprising a single exclosure and associated control plot(s), all of equal size, should be established as illustrated in Figure 11c. Exclosure design may vary dependent on feasibility and paddock size – if a smaller exclosure (e.g. Figure 11a) is being used, it is recommended that 2-3 arrays are established per site, in order to sample observable variation in the paddock (e.g. vegetation type, dominant grass species, proximity to water points). If a larger exclosure (e.g. comprised of 4 x 8, 10, 12 or 14ft gates; Figure 11b) is being used, only a single array is required per site. For agreement sites with several different grazing regimes operating within a single conservation area, implementing biomass monitoring in all relevant paddocks may be prohibitively resource intensive. In these scenarios, a subset of sites (e.g. 2-3) with the highest risk grazing regimes should be selected for biomass monitoring.

Arrays should be positioned away from waterpoints (>100m in Eastern and Central Division, >1km in Western Division) and areas of stock congregation (e.g. sheep camps, treed areas). Mesh size should be smaller at the base of the exclosure, if rabbits are likely to impact the site. If a control paddock is not available within the agreement site, then a nearby equivalent site (e.g. existing control plot site on public tenure) may be used, with the permission of the relevant land manager.

The assessment involves recording ground cover (%) and average sward height (cm) the exclosure/quadrat, followed by cutting, drying and weighing all (or a sample) of the living (green) vegetation, using the following procedure:

1. Use a ruler to measure sward height at 5 (centre and 20cm towards the centre from each corner; 1m^2 quadrats) or 10 (evenly spaced along the two diagonals; gate exclosures) points, and record the mean (cm);
2. Visually estimate and record total foliage cover (%);
3. For 1m^2 exclosures/quadrats, use grass cutting shears (battery or hand operated) to cut all plant matter within the quadrat as close to the ground surface as practical, without cutting into the soil, leaving about a 1cm stubble (i.e. emulate a hard grazing situation), trim any grass blades hanging outside of the quadrat and discard;
4. For larger exclosures/quadrats, randomly sub-sample the area using 3 x 1m^2 quadrats representative of the observed vegetation structure and composition, before applying Step 3;
5. Collect all the plant matter (excluding dead matter) within the quadrat(s) into a bag and label appropriately;
6. Weigh and record ‘wet’ sample (to nearest g), then place in a microwave on *high* for approximately 30 seconds – 1 minute, ensuring to include a small glass of water

inside the microwave to minimise fire risk, take out, let moisture steam off, then re-weigh;

7. Repeat until the sample no longer loses weight;
8. Weigh ‘dry’ sample and record.

A baseline assessment should occur at the initiation of the management regime for the target paddock (i.e. agreement establishment or erection of herbivore fencing), with re-assessment to coincide with the frequency of other planned monitoring activities at the agreement site (maximum 5 years).

Observed biomass in the exclosure can be compared to both control quadrats at each assessment event, to assess grazing pressure over the intervening period. In Figure 11c, the difference in biomass between *X* and *Y* represents the total grazing pressure within the assessment paddock, the difference between *X* and *Z* represents the background grazing pressure attributable to feral/native herbivores, and the difference between these two derived values represents grazing pressure attributable to stock.

Interpretation of these data should inform management decisions with respect to appropriate grazing frequency/intensity and/or native herbivore control measures.

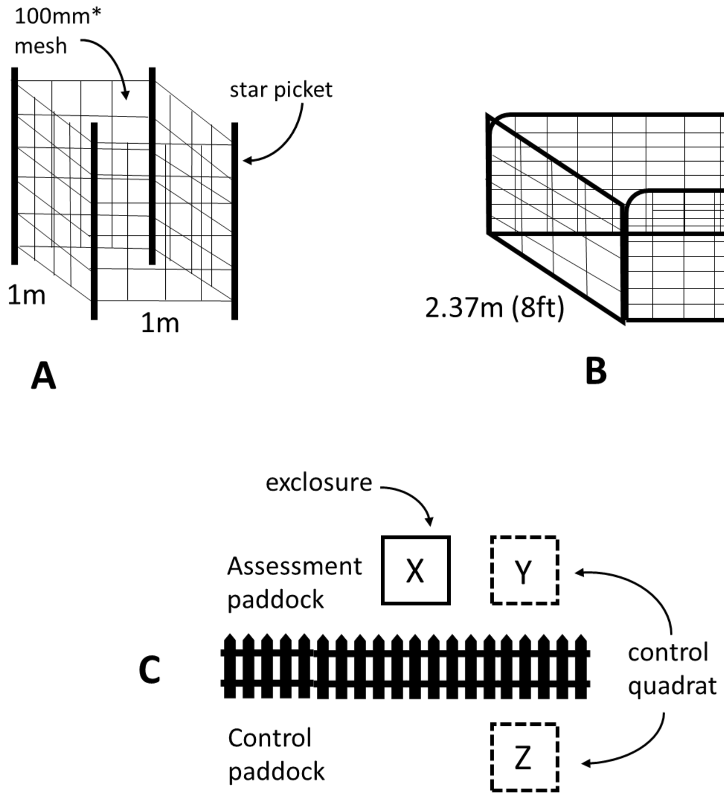


*Figure 11: Example biomass exclosure designs; smaller (A) and larger (B), and arrangement of exclosure and control quadrats (C) for monitoring. Control quadrats (‘Y’ and ‘Z’) should be permanently marked (e.g. using a fibreglass post in the north-east corner) if possible, or accurate waypoints taken if not. The ‘assessment paddock’ represents either a paddock with managed grazing or a paddock with fencing designed to exclude or reduce native herbivore density. *Smaller mesh size (e.g. 31mm) should be used close to the ground to exclude rabbits*

5.8.4 Post-fire recovery

The impacts of fire on biodiversity are significant and important for land managers to understand when managing sites in the recovery phase. In particular, the impacts of the Summer 2019/20 bushfires were extensive, affecting 45% of total conservation area across all agreement types. A targeted monitoring program designed to collect fine-scale data on the response of biodiversity to (unmanaged) fire would require significant time and resources, and is therefore beyond the scope of the BCT's ecological monitoring program. The primary objective of the EMM, with respect to fire, is to understand its *long-term* impacts on ecological condition.

Fire impact (i.e. burnt vs unburnt) will *not* be used as an additional stratification layer at the site or regional scales, given the consequent increase in plot requirements and the added complexity created by future bushfires. Rather, fire (except for planned ecological burning; see below) will be treated similar to any other disturbance event impacting biodiversity condition, with relevant variables – i.e. time-since-fire, fire frequency and burn intensity (see Table 10) – recorded and incorporated as covariates in any relevant analyses.

There are three main sources of fire likely to impact agreement sites; unmanaged (i.e. wildfire/bushfire), managed hazard-reduction burns and managed ecological (or cultural) burns. For the purposes of this manual, monitoring following unmanaged and hazard-reduction burns should follow a similar approach (given that these scenarios are not planned for in terms of permanent monitoring plot arrangement, and neither has an expected ecological benefit requiring evaluation).

5.8.4.1 Unmanaged fire

If an agreement site is significantly fire-affected at the time of planning monitoring, burnt sites should not be explicitly stratified nor avoided when positioning permanent plots. For sites affected by unmanaged fire following the establishment of permanent monitoring plots, the proportion of plots in recently burnt vegetation is expected to approximate the proportion of the conservation area that is fire-affected (on average, over large spatial and temporal scales). The first monitoring event following fire should include an additional fire severity assessment at each fire-affected plot, recording the following categorical data per plot:

- fire severity (Table 14)
- scorch height above ground (m)

and the following per stratum (ground layer, shrubs, sub-canopy, tree):

- % cover of living vegetation (apply data from floristic structure assessment)
- % cover of vegetation scorched (brown) but not fully consumed by fire
- % cover of vegetation that would have been fully consumed by fire

using cover classes; 'low' (<30%), 'moderate' (30-70%) and 'high' (>70%).

These data may be used to validate the state-wide fire extent and severity mapping (FESM) as well as providing contextual information (along with time since fire) for analysing change in ecological condition.

If a monitoring plot location is fire-affected after establishment, subsequent monitoring events for 5 years post-burn should apply tree stem assessment and SSCA, if not already implemented for the plot.

Table 14: Fire Extent and Severity Mapping (FESM) – severity classes for field validation assessment

Severity class	Description	% foliage fire affected
0 = Unburnt	Unburnt surface with green canopy	0% canopy and understory burnt
1 = Burnt Grassland	Burnt grassland or open grassy woodland. Unburnt canopy (if present)	100% grassland burnt; 0% canopy burnt (if present)
2 = Low	Burnt understory with unburnt canopy	>10% burnt understory, >90% green canopy
3 = Moderate	Partial canopy scorch	20-90% canopy scorch
4 = High	Complete canopy scorch (+/- partial canopy consumption)	>90% canopy scorched, <50% canopy consumed
5 = Extreme	Complete canopy consumption	>50% canopy biomass consumed

5.8.4.2 Ecological burning

If/where an ecological burn is planned for a management zone, the type and density of monitoring plots should follow Table 3. If burning is being implemented solely to maintain the recommended fire frequency for the vegetation community (e.g. every 7 years), then this should be classified as 'moderate intensity' management for the purposes of monitoring design. If burning is strategically targeting a particular species (e.g. threatened species) and/or a particularly ecological response (e.g. stimulating recruitment), then this should be classified as 'high intensity' management. In the latter case, additional measures should be established specifically to monitor for the desired outcome (e.g. reproduction immediately following burn).

5.8.5 Vertebrate pests

Monitoring vertebrate pest activity directly is important in some circumstances, in particular, where there is uncertainty in the best approach to management and/or there is significant investment in management. A targeted monitoring program for threatened vertebrate pests should only be established if/where pest management is classified as 'high intensity' in the context of this document (e.g. ARMA, 'restore' or 'enhance' actions). Generally, monitoring focused on the impacted biodiversity value is sufficient to evaluate management effectiveness. The primary objective of monitoring vertebrate pests should be to inform management decisions in the short-medium term. For example, to identify the source (pest species) of any biodiversity impacts to guide control method, or to evaluate the efficacy of a given control method or intensity to guide adaptive changes.

It is also important to ensure that the scale of monitoring (i.e. maximum property-scale, by definition, for agreement sites) is equivalent to the scale of management. In most cases, optimal management of vertebrate pests should be coordinated at the landscape scale (e.g. via a strategic program coordinated by Local Land Services [LLS]), in which case property-scale monitoring is unlikely to be useful.

5.8.5.1 Herbivores

If feral (e.g. pigs, goats, deer) or overabundant native (i.e. macropods) herbivores are the target of a ('high intensity') control program or are suspected to be significantly impacting biodiversity within a conservation area, targeted monitoring of activity using remote cameras may be justified, in line with the considerations outlined above. If the objective is to determine background density / activity rate, a camera array (~500m spacing) across the conservation area for 2-3 weeks is appropriate. If the objective is to diagnose the source of disturbance impacts within a particular management zone, one or more cameras should be positioned within the target asset (e.g. threatened plant population). Meek *et al.* 2012 and 2015 provide additional, specific guidance on the deployment of remote cameras for detection of various species.

In this context it is important that remote camera monitoring should be implemented (and the resulting data interpreted) in conjunction with related methods for detecting herbivore presence and impacts; i.e. dung counts, biomass exclosures, groundcover assessment and qualitative observations of disturbance (e.g. plant browsing, soil pugging), made during annual compliance visits.

5.8.5.2 Predators

Given the home range size of feral and introduced vertebrate predators (e.g. red fox = 250-2100ha; Carter *et al.* 2012), direct monitoring of these species via remote cameras is generally unlikely to provide meaningful data at the scale of a single agreement site. Generally the only context in which this type of threat monitoring may be warranted is where an identified critical population (see 5.1) of a threatened prey species is the focus of a targeted predator control program at the site (i.e. the objective of the entire control effort is to protect the population on site, rather than the site being included within a broader, landscape-scale control program). In this scenario, unbaited cameras should be set up in an array throughout the identified habitat for as many days as feasible (at least 30), annually, to determine an incursion rate. A generalised recommended array design to assess predator incursion rate (related to risk of predation), is 10 cameras evenly spaced across a 5ha area[1]. This monitoring should be implemented alongside direct monitoring of the focal threatened species population, in order to investigate any relationship between predator management effectiveness and population dynamics.

5.8.6 Habitat supplementation

If/where, as part of active restoration management, habitat is being supplemented with a critical resource with the objective of improving or supporting local fauna (or particular threatened species) populations, this intervention requires targeted monitoring designed to evaluate the efficacy of the intervention.

Table 15 provides some generalised examples of the types of monitoring that may be implemented in these scenarios.

Table 15: Recommended monitoring approaches for evaluating the effectiveness of habitat supplementation

Supplementation type	Recommended monitoring approach
Erecting nest-boxes or manually (chainsaw) creating tree cavities for hollow-dependent birds or mammals	Visual inspection and identification of contents (i.e. target/non-target species; other evidence of use) of all nest-boxes annually for the first 5 years, then every 3 years.
Replacement of logs, rocks or other coarse debris as cover for reptiles or small mammals	Installation and regular (2-3 years) monitoring of tiles or permanent pitfall traps to detect target species occupancy
Artificial wetlands or frog ponds	Passive acoustic (e.g. Audiomoth) surveys or regular (2-3 years) spotlight surveys within habitat area

[1] Specific design should be dependent on site and target species characteristics (see Meek *et al.* 2012 and discuss with BCT staff)

6 ADAPTIVE MONITORING

The monitoring regime for a site should be reviewed alongside the management plan at regular intervals (e.g. every 5 years; mandatory for BSAs). The appropriateness and efficacy of monitoring specifications (i.e. methods, intensity, frequency) should be evaluated with reference to the data collected to that point, as well as any changes to management. As a general rule, the intensity and frequency of monitoring can be reduced once the target biodiversity under management reaches target (e.g. benchmark) state. The precision and frequency of monitoring should also be increased in response to any significant disturbance (e.g. fire) to the site.

Table 16 provides guidance on how monitoring should be amended in response to various changes to ecological conditions or management, generally identified as part of the (e.g. 5-yearly) management plan review.

Table 16: Recommended amendments to monitoring in response to changed management scenarios

Scenario	Recommended change to monitoring
Biodiversity value under management improves to target state (e.g. benchmark condition)	Reduce plot density, precision and monitoring frequency to align with prescription for relevant monitoring prescription category aligned with the updated condition state (Tables 3 and 4)
Site is affected by fire (planned or unplanned)	Apply some additional measures (tree stem counts and SSCA) to affected plots, if not already being implemented, for following planned monitoring events for 10 years post-burn
New disturbance impacts to biodiversity values are identified, suspected to be from vertebrate pests	Install short-term remote cameras to monitor pest activity for the purposes of diagnosis and informing additional management requirements
Change to grazing regime in managed grazing zone	Install biomass exclosure and quadrat array, if not already in place
Monitoring indicates that management is currently *not* on track to meet long-term outcome targets	Monitoring should be adjusted (increased precision and frequency) and targeted to measure the response to any adaptive changes in management regime

7 CONTROLS

Controls are important for any ecological monitoring program, and are required to properly attribute inputs (i.e. investment, management activity) to their associated outcomes (i.e. state and change in biodiversity values). In the context of the EMM, controls (or counterfactuals) are critical to inform outcome evaluation for three scenarios in particular:

a) demonstrating if and how much observed improvement in biodiversity condition can be attributed to BCT investment in management;
b) if/where declines in biodiversity condition are observed, associated with variation in environmental conditions (e.g. drought), demonstrating marginal benefits (e.g. reduced severity of decline) attributable to management; and
c) quantifying the value of averted biodiversity loss (reduction in risk of total loss) associated with establishing an agreement – critical for sites with high initial biodiversity condition (i.e. where value derived from condition improvement is minimal).

7.1 ECOLOGICAL CONDITION CONTROL SITES

The optimal design of controls for a monitoring program would include one biophysically matched control (plot) paired to every monitoring plot within conservation areas, located on the same property, outside of the conservation area. This approach is unlikely to be feasible or cost-effective, due to both the significant resource demand associated with the large number of additional monitoring plots, as well as the likely difficulty of identifying enough appropriate sites on every property. Instead, the program design will be to establish control site samples – i.e. for each stratification group, as required, a sample of control plots will be monitored[1]. Stratification groups are defined as the unique combination of Vegetation Class, baseline condition state (*poor*, *moderate*, *good*) and bioregion (IBRA).

The requirement for a control site sample for any given stratification group, is based on the total number of plots (and associated hectares) representing the group that are established at agreement sites and the number of plots likely to be required to detect expected change in ecological condition (at the stratification group scale; i.e. statistical power). Each of these factors will set a lower threshold – i.e. number of plots and associated conservation area below which it is cost-ineffective to establish matched controls and sample size with adequate statistical power, respectively – to guide the design of the control plot monitoring program.

The timing of collecting baseline (and resurvey) data from control sites will be aligned – as much as feasible – with baseline data collection at agreement sites for the same stratification groups. Given continual establishment of BCT agreements, however, it would not be practical to achieve consistent timing across all sites for all stratification groups.

[1] Coordinated by the BCT. While control sites will inform evaluation of outcomes at BSA sites, BSA landholders (or accredited assessors on their behalf) are not required to establish or collect data at these sites.

Efforts will made to ensure that baseline data collection for most agreement sites occurs within 2 years of relevant control sites, and that seasonal consistency is also considered.

7.2 POWER ANALYSES

The number of plots required to ensure sufficient statistical power to detect expected change in monitored biodiversity attributes was estimated at two scales – within stratification group and at the program (state-wide) level. Detailed methods and results are presented in Appendix 3.

7.2.1 Within stratification group

The median lower and upper estimates for minimum plot requirement per stratification group was 5 and 14 plots, respectively, across all groups (Figure 12), which is generally considered achievable for a program of this size. If/where cumulative plot sample size targets are impractically large for any given region, steps can be taken to reduce the requirement while maintaining statistical rigour, such as merging similar stratification groups (e.g. poor and moderate condition state groups with equivalent vegetation and bioregion, or groups from neighbouring bioregions with equivalent vegetation and condition states), if/where ecologically valid.

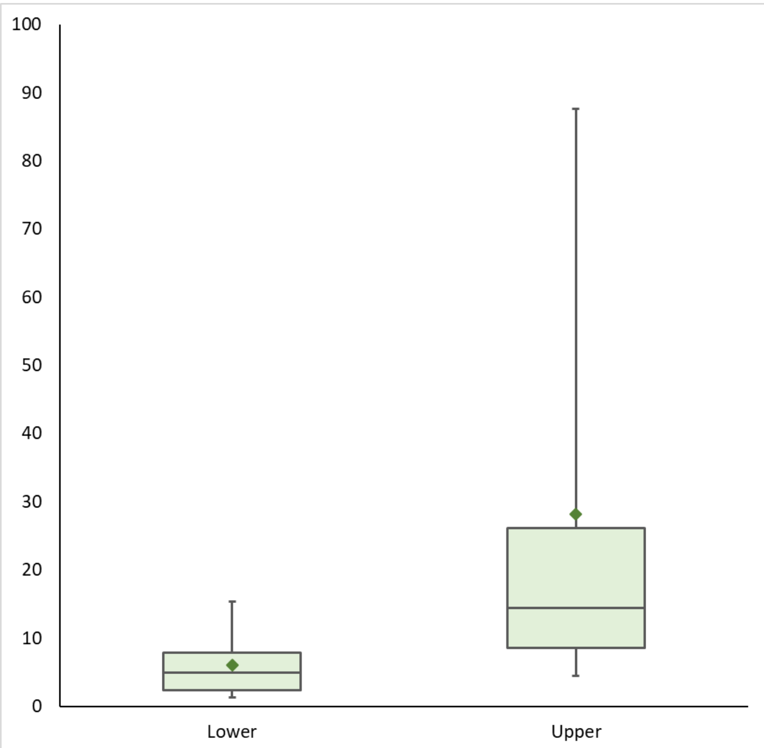


Figure 12: Distribution of estimated minimum plot sample sizes (upper and lower) for all stratification groups, from power analysis. Boxes represent interquartile range (midline = median), lower and upper whiskers = 5th and 95th percentiles, dark green diamonds = mean. Disaggregated results presented in Appendix 3.

7.2.2 Program scale

To answer questions about change in ecological condition at the program scale, a quantitative analysis of aggregated plot data will be conducted by the BCT, which controls for various sources of variation (e.g. related to vegetation community, condition state, bioregion, collection date and potentially other environmental factors [e.g. rainfall]). Therefore, separate power analyses using an appropriate method (generalised linear mixed models) were conducted to estimate required plot sample sizes to inform evaluation at this scale.

Minimum sample sizes required to achieve reliable statistical power (~80%) decreased with increasing effect size (i.e. expected change in condition - assumed proportional to years of management), as expected. Total number of plots required to answer program-level questions is likely to be approximately 250, 100 and 50, at 10, 15 and 20 years, respectively. Power to detect effects after 5 years is likely to require significantly more plots (~1000), which is close to the maximum number of plots likely to be monitored state-wide (Figure 13). These aggregated (across floristic attributes) results exclude *Tree species richness*, as it represented a significant outlier – unlikely to exhibit detectable change over timeframes less than 20 years (with the likely exception of revegetation management; see Appendix 3).

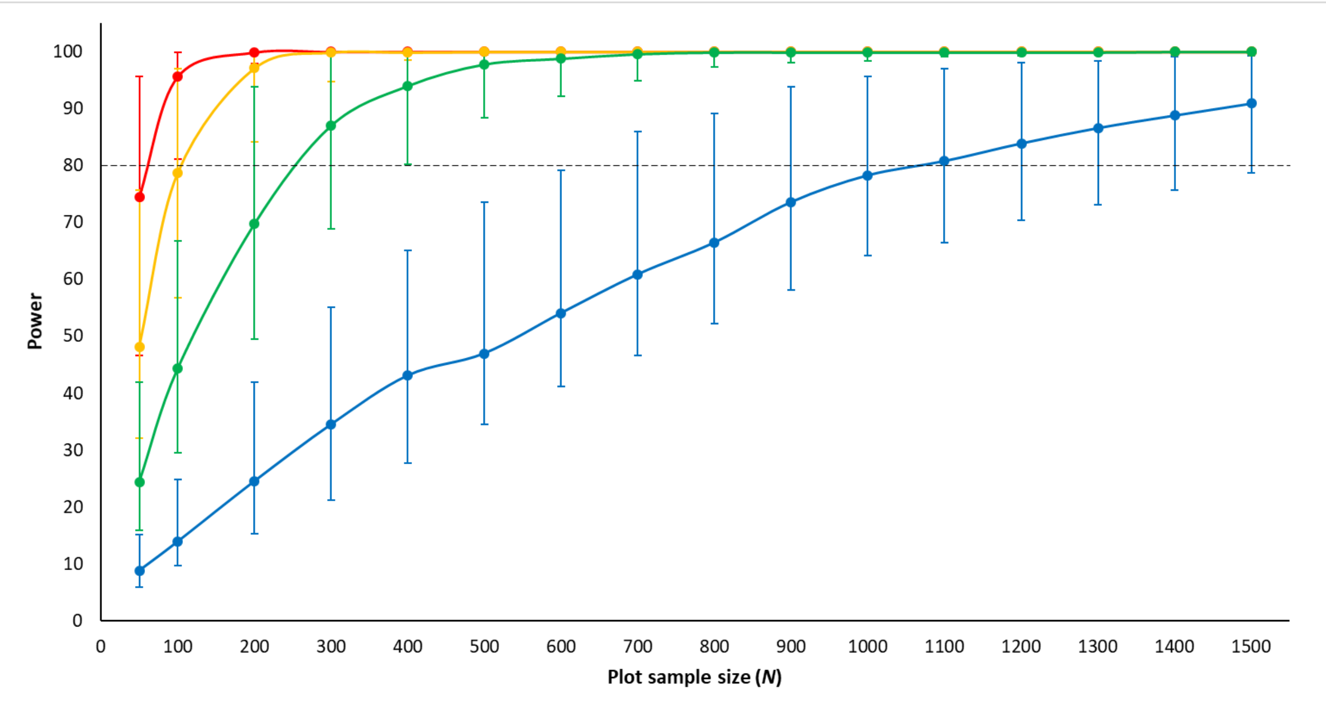


Figure 13: Estimated statistical power associated with a range of sample sizes, from simulated Generalized Linear Model power analysis, for four effect sizes representing 25% (blue line), 50% (green line), 75% (yellow line) and 100% (red line) of the effect size observed in the original model (i.e. predicted 20-year change), aggregated across five floristic attributes (median + maximum 95% confidence intervals).

7.3 ESTABLISHING CONTROL SITES

Control sites – i.e. permanent vegetation integrity monitoring plots (Figure 6) – will be established and regularly monitored by BCT staff, using the measures and methods outlined in Section 2.2.1. To act as a valid control for evaluation of ecological outcomes at agreement sites, selected sites should represent a valid counterfactual or 'business as usual' scenario. This should be ensured by selecting sites that – to an extent that is feasible – are biophysically matched, likely to be continually accessible, have stable management over the long term, and have land use consistent with agreement sites prior to agreement establishment. Therefore, control sites will be established, predominantly on public land (particularly National Parks and Wildlife [NPWS] estate and Travelling Stock Reserves [TSR]), but may also be established on private land if/where appropriate (e.g. on an agreement-holder's property, outside of the conservation area).

The following criteria will also be used to guide the selection and establishment of monitoring sites:

- use of the site has been approved by the landholder or land manager;
- the site can be allocated to a required stratification group;
- it is generally accessible by BCT staff (with appropriate permissions); and
- is not subject to 'active' biodiversity management (e.g. pest/weed control).

Multiple control plots may be established within the same reserve (TSR or NPWS), however, to avoid biasing the control site samples with site-level effects, there should be no more than 3 plots per stratification group per reserve, and these plots should be >500m apart. Control plots should be distributed within a bioregion, to the extent practicable, in alignment with the distribution of agreement sites in the matched stratification group (e.g. if all agreement sites containing vegetation zones in a given stratification group are clustered in a particular area, then control plots should be established predominantly in the same area). Similarly, timing of monitoring control sites and agreement sites in the same stratification group should align as much as is practicable.

With respect to accessing control sites, it is important that relevant local land managers' (e.g. LLS or NPWS) permission is sought prior to each visit. Also, when on-site, and particularly when visiting multiple sites within a day, it is critical that staff employ appropriate hygiene protocols to minimise the spread of plant and animal pathogens (see DPIE Hygiene Guidelines).

Given the expansion model of BCT programs (i.e. increasing the portfolio of agreements year-on-year), the control site monitoring program will be dynamic, with additional sites incorporated as part of new stratification groups as these become required to match those sampled at new agreement sites. This process should also be dynamic with respect to adaptively informing monitoring design at new agreement sites, particularly with respect to plot densities. If and when the plot target for a given stratification group has been met for both agreement and control sites, there is a reduced requirement for additional plots to inform program-scale evaluation. In this scenario, the required site plot density may be a reduced from the recommendations provided in Table 5, thereby moderating the resource requirements of an expanding program.

8 QUANTIFYING MANAGEMENT EFFORT

In order to properly analyse and evaluate management effectiveness, it is critical that inputs, such as the amount of effort invested in management actions ('Performance Indicators' for BSAs), are monitored and reported accurately and comprehensively. Management effort should be quantified using the same indicators and units of measure, to allow for aggregation and quantitative analysis of these data. In addition, recording the spatial extent of management effort (e.g. management/vegetation zone, paddock) is critical to ensuring these data can be linked to the relevant ecological outcome data (e.g. plot locations).

Processes to capture management effort data are already in place for BSA and CA sites (i.e. annual reporting obligations), which are fit-for-purpose from a compliance perspective, but require some amendments to maximise their utility for quantitative analysis. Proposed amendments include standardisation of indicators as outlined in Table 17 below and digitising reporting and integration with BCT data management systems. The BCT plans to introduce such changes in future refinements of the EMM.

Table 17: Proposed standards for quantifying and reporting management effort

Management action type	Method	Reporting data[1]	
		Indicator(s)	Units
weed control	patchy weeds / spot spraying / maintenance	control time	person-hours
	dense infestation removal	control area	hectares; person-hours
vertebrate pest control	baiting	bait station density; baiting duration; treatment area	count; baiting days; hectares
	trapping	trap density/time; individuals caught	number traps; hectares; days number/species caught

[1] Per implementation event (i.e. additionally report number of events per year)

	shooting	control time; number shot	person-hours; count
grazing management	all stock grazing	stock density; stock type; grazing period and timing (per paddock)	number head; species; diary (i.e. specific days in)
revegetation	tubestock	planting density	number seedlings; hectares
	direct seeding	seeded area	hectares
native herbivore management	vegetation manipulation / fencing / watering point removal	control type	n/adays active
artificial hollow supplementation	nest-box installation / chainsaw or drilled hollows	method; supplementation density	count; hectares
coarse woody debris supplementation	addition of logs or rocks	supplementation density	lineal metres (logs); tonnes (rocks); hectares
ecological thinning	selective removal of stems to benchmark density	number stems removed; density remaining (by size class)	count; hectares
ecological burning	targeted to stimulate species reproduction / maintenance of optimal vegetation community fire regime	objective; treatment area; severity	hectares; qualitative severity scale

9 DATA COLLECTION AND MANAGEMENT

Rigorous data management protocols are critical to ensuring that data collected under the EMM are quality-assured, accessible, interpretable and secure. This applies to all ecological data collected as part of any BCT program, either by BCT staff or others (e.g. accredited assessors). Central to supporting such protocols are information systems, including databases and associated applications for data collection and management (Figure 14). Data standards are being developed along with digital forms to replace paper datasheets (Appendix 2). These resources will ultimately be made available to stakeholders implementing the EMM to ensure data is captured in a consistent way and consolidated in a centralised system to support analysis.

All relevant ecological data collected as part of the EMM (with the exception of sensitive material) will ultimately be made publicly available via an appropriate platform (e.g. Bionet or SEED portal), in line with the NSW Government's Open Data Policy.

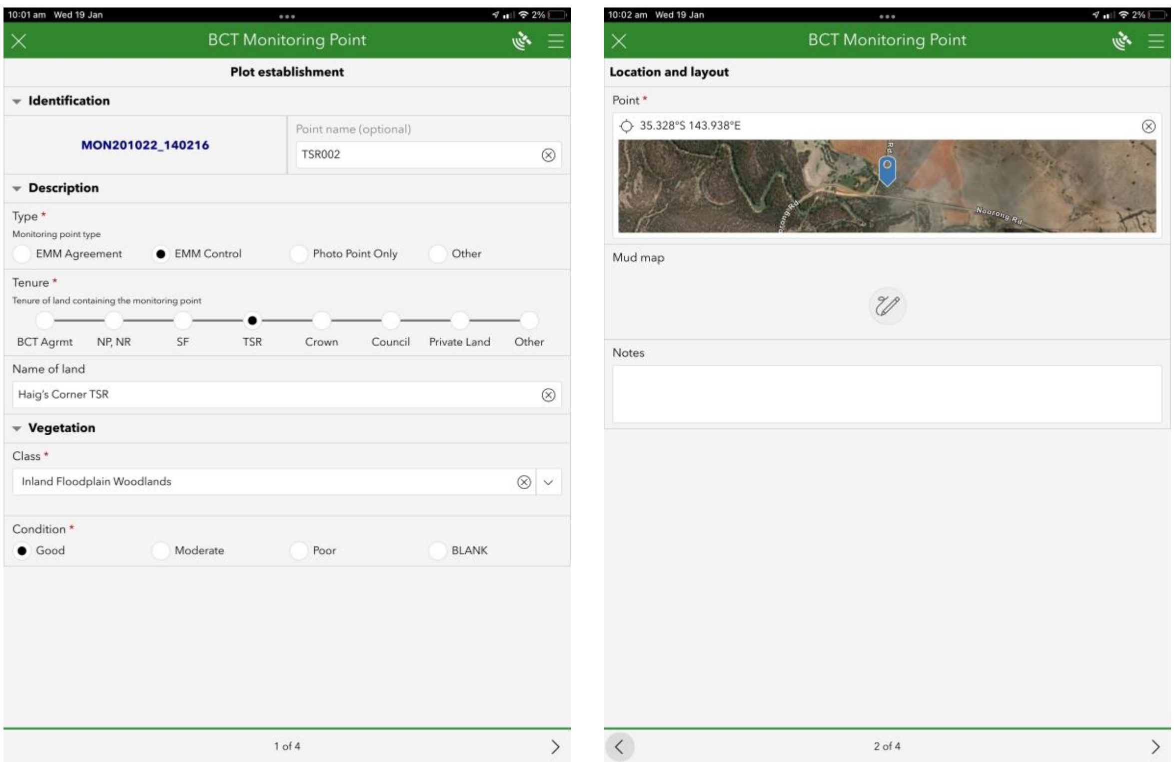


Figure 14: Screen shot of a draft digital form developed for the establishment of 'Monitoring Points' (ArcGIS Survey123 software platform).

9.1 DATA MODEL

The EMM data model, underpinning the enterprise database and data collection tools, is centred around “Monitoring Points” – which specify spatial locations within agreement or control sites associated with some type of monitoring effort and stratification group, and are generally fixed for the life of the program (Figure 15). A data set of associated observations/measures is built by linking different monitoring types (e.g. floristic plot, SSCA, remote camera, biomass exclosure) at different time points (e.g. Year 0 [baseline], 5, 10, 15, 20) to each monitoring point, which is also linked to associated site/zone data (e.g. tenure, land use, management implementation).

Organising data in this way enables efficient and automated quantitative analyses, evaluation and reporting.

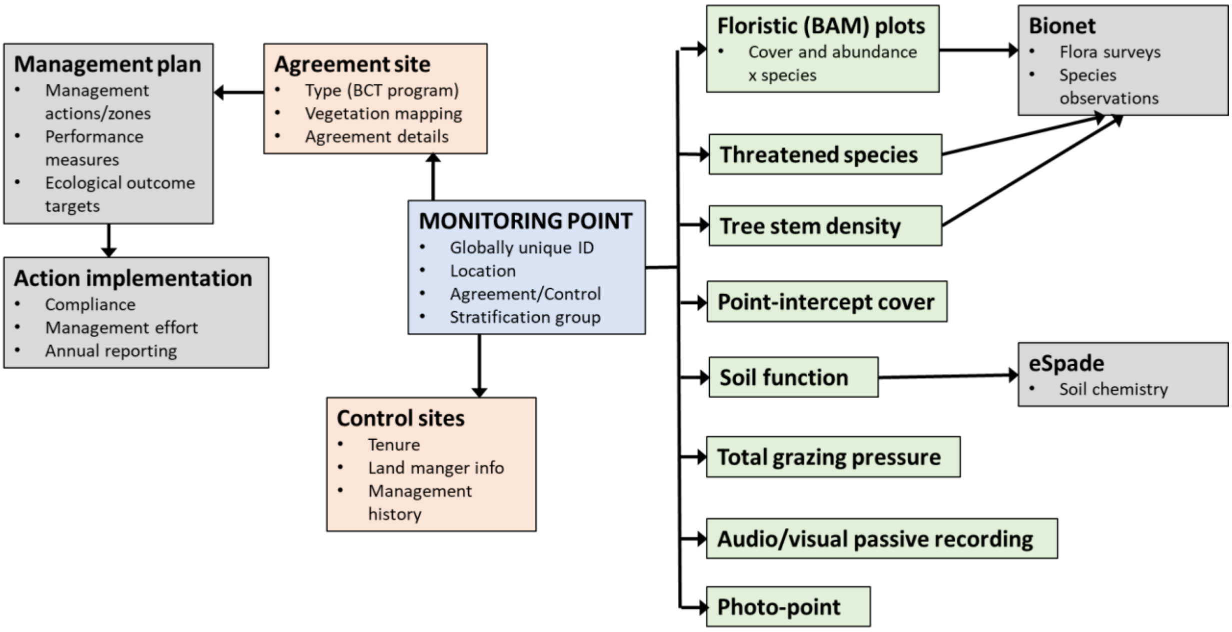


Figure 15: BCT ecological monitoring data model (illustrative summary)

10 REFERENCES

Bakker JP, Grootjans AP, Hermy M and Poschlod P (2000). How to Define Targets for Ecological Restoration? – Introduction. *Applied Vegetation Science* **3**: 3-6.

Borm GF, Fransen J and Lemmens WAJG (2007). A simple sample size formula for analysis of covariance in randomized clinical trials. *Journal of Clinical Epidemiology* **60**: 1234-1238.

Burgman M, Lowell K, Woodgate P, Jones S, Richards G and Addison P (2012). An endpoint hierarchy and process control charts for ecological monitoring, in eds. Lindenmayer D and Gibbons P, *Biodiversity Monitoring in Australia*, CSIRO Publishing, Collingwood, Victoria.

Carter A, Luck GW and Mcdonald S (2012). Ecology of the red fox (*Vulpes vulpes*) in an agricultural landscape. 2. Home range and movements. *Australian Mammalogy* **34**:175–187.

Delgado-Baquerizo M, Powell JR, Hamonts K, Reith F, *et al*. (2017). Circular linkages between soil biodiversity, fertility and plant productivity are limited to topsoil at the continental scale. *New Phytologist* **215**: 1186–1196.

Dorrough J, Yen A, Turner V, Clark SG, Crosthwaite J and Hirth JR (2004). Livestock grazing management and biodiversity conservation in Australian temperate grassy landscapes. *Australian Journal of Agricultural Research* **55**: 279-295.

Eldridge DJ, Delgado-Baquerizo M, Travers SK, Val J and Oliver I (2017). Do grazing intensity and herbivore type affect soil health? Insights from a semi-arid productivity gradient. *Journal of Applied Ecology* **54**: 976–985.

Ellis W, Bercovitch F, FitzGibbon S, Roe P, Wimmer J, Melzer A and Wilson R (2011), Koala bellows and their association with the spatial dynamics of free-ranging koalas. *Behavioural Ecology* **22**: 372−377.

Goldingay RL and Dobner B (2014). Home range areas of koalas in an urban area of north-east New South Wales. *Australian Mammalogy* **36**: 74-80.

Gonsalves L and Law B (2021). *Preliminary assessment of the influence of effective sampling area on male koala detection probability across a range of sites and a gradient of koala densities*. Report prepared for the NSW Department of Planning, Industry and Environment.

Green P and MacLeod CJ (2016). SIMR: An R package for power analysis of generalized linear mixed models by simulation. *Methods in Ecology and Evolution* **7**: 493-498.

Hagens SV, Rendall AR and Whisson DA (2018). Passive acoustic surveys for predicting species’ distributions: Optimising detection probability. *PLoS ONE* **13**: e0199396.

Hill AP, Prince P, Snaddon JL, Doncaster CP, Rogers A (2019). AudioMoth: A low-cost acoustic device for monitoring biodiversity and the environment. *HardwareX* **6**: e00073.

Keith DA (2000). Sampling designs, field techniques and analytical methods for systematic plant population surveys. *Ecological Management & Restoration* **1**: 125-139.

Law B, Gonsalves L, Bilney R, Peterie J, Pietsch R, Roe P and Truskinger A (2020). Using Passive Acoustic Recording and Automated Call Identification to Survey Koalas in the Southern Forests of New South Wales. *Australian Zoologist* **40**: 477-486.

Lindenmayer DB, Franklin JF and Fischer J (2006). General management principles and a checklist of strategies to guide forest biodiversity conservation. *Biological Conservation* **131**: 433-445.

Lindenmayer D (2020). Improving restoration programs through greater connection with ecological theory and better monitoring. *Frontiers in Ecology and Evolution* **8**: 1-8.

Maron M, Hobbs RJ, Moilanen A, Matthews JW, Christie K, Gardner TA, Keith DA, Lindenmayer DB and McAlpine CA (2012). Faustian bargains? Restoration realities in the context of biodiversity offset policies. *Biological Conservation* **155**: 141-148.

Mayfield H, Rhodes J, Evans M and Maron M (2019). *Guidelines for estimating and evaluating species' response to management.* A report to the Saving our Species program. NSW Government, National Environmental Science Program Threatened Species Recovery Hub.

Meek PD, Ballard G and Fleming P (2012). *An Introduction to Camera Trapping for Wildlife Surveys in Australia*. PestSmart Toolkit publication, Invasive Animals Cooperative Research Centre, Canberra, Australia.

Meek PD, Ballard GA and Fleming PJS (2015). The pitfalls of wildlife camera trapping as a survey tool in Australia. *Australian Mammalogy* **37**: 13-22.

OEH (2020). *Biodiversity Assessment Method*. Office of Environment and Heritage, NSW.

R Core Team (2013). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna, Austria.

Tongway D and Hindley N (2004). *Landscape Function Analysis: Methods for monitoring and assessing landscapes, with special reference to mine sites and rangelands.* CSIRO Sustainable Ecosystems, Canberra.

Towsey M, Planitz B, Nantes A, Wimmer J and Roe P (2012). A toolbox for animal call recognition. *Bioacoustics*: *The International Journal of Animal Sound and its Recording* **21**: 107–125.

Wilkins S, Keith DA and Adam P (2003). Measuring Succes: Evaluating the Restoration of a Grassy Eucalypt Woodland on the Cumberland Plain, Sydney, Australia. *Restoration Ecology* **11**: 489-503.

APPENDIX 1: THREATENED SPECIES POPULATION MONITORING – RECOMMENDED METHODS

The methods described below come from a variety of sources, however, generally align with the prescribed method used for monitoring the species' critical populations under the *Saving our Species* program (SoS), and/or the relevant BAM survey guidelines. These recommendations should be used to guide the development of monitoring protocols for focal populations of threatened species occurring on BCT agreement sites, tailored to the specific requirements and management objectives of the target site.

Scientific Name	Common Name	Recommended monitoring method
Acacia ausfeldii	Ausfeld's Wattle	Full population census for small (<100 individuals) populations, or sample the area of occupancy using 20x20 m plots, stratified by plant density zones. Count individuals by age/size class, assess individual reproductive status and condition. Conduct monitoring August - October, every 3 years. Note: Use flowers and/or pods to identify, as species can be confused with *A. verniciflua.*
Acacia baueri subsp. aspera	Lonely Wattle	Full population census for small (<100 individuals) populations, or sample the area of occupancy using 20x20 m plots, stratified by plant density zones. Count individuals by age/size class, assess individual reproductive status and condition, and soil moisture. Conduct monitoring February - March, every 3 years. Note: Species is cryptic, may require multiple surveys, 1 month apart.
Acacia bynoeana	Bynoe's Wattle	Full population census for small (<100 individuals) populations, or sample the area of occupancy using 20x20 m plots, stratified by plant density zones. Count individuals by age/size class, assess individual reproductive status and condition, and vegetative state. Conduct monitoring December - February, every 3 years.
Acacia pubescens	Downy Wattle	Full population census for small (<100 individuals) populations, or sample the area of occupancy using 20x20 m plots, stratified by plant density zones. Count individuals by age/size class, assess individual reproductive status and condition. Conduct monitoring in November (while fruiting), every 3 years.
Acacia terminalis subsp. Terminalis	Sunshine Wattle	Full population census for small (<100 individuals) populations, or sample the area of occupancy using 20x20 m plots, stratified by plant density zones. Count individuals by age/size class, assess individual reproductive status and condition. Conduct monitoring February - October, every 3 years.
Aepyprymnus rufescens	Rufous Bettong	Establish a remote camera array on a grid covering the habitat area, with cameras spaced at 100-500 m, depending on size of the site. Cameras should be baited with peanut butter, honey, oats and vanilla essence and active between dusk and dawn for at least 7 consecutive nights (preferably 14).
Aldrovanda vesiculosa	Waterwheel Plant	Assess total number of individuals (combined amount of individual plants present within a discrete population, excluding daughter shoots still attached to the parent stem) as well as an index of biotic potential (assessed by averaging the number of daughter shoots per parent plant for the entire population, or a representative sample), a categorised assessment of ecosystem quality (weed invasion, the presence of filamentous algal blooms, waterbird numbers, the abundance of herbivorous fish, hydrological variation). When Aldrovanda is particularly abundant and counting all plants would be impractical, apply the above method to a 1x1 m plot placed in a representative location within the population.

Ammobium craspedioides	Yass Daisy	Full population census for small (<100 individuals) populations, or sample the area of occupancy using 5x5 m plots, stratified by plant density zones. Count individuals, assess individual reproductive status and condition. Conduct monitoring December - February, every 3 years.
Anthochaera phrygia	Regent Honeyeater	Ground visual survey conducted by species expert, consisting of 5-minute point counts recording the abundance of regent honeyeaters at a site of 50 m radius. Points should be distributed throughout suitable habitat, with a minimum spacing of 150 m. Ideally, use one-minute of audio-enhanced regent honeyeater call playback at the beginning of each point survey. Conduct surveys late July to mid-September and/or early October to early December.
Aprasia parapulchella	Pink-tailed Legless Lizard	Conduct monitoring in early spring (late August - early October), ideally, surveys should be conducted in the days following rainfall and when maximum temperatures do not exceed 25°C., and in the early morning. The method involves turning and replacing at least 500 rocks (of a size easily handled) and checking for A. parapulchella or sloughed skin. If the habitat area contains <500 rocks, then turn all appropriately sized rocks. If it contains >500 rocks, then sample 500 rocks from across the area using 10x10 m representative plots. Habitat suitability should also be assessed by estimating % foliage cover of large tussock grass species.
Asperula asthenes	Trailing Woodruff	Use belt transects with square plots randomly placed along the length of the transects, of different sizes, to match the area of occupancy of the population - i.e. 10x30 m transect with 5x5 m plots (larger sites) or 4x12m transect with 2x2 m plots (smaller sites) - to adequately sample the population. In each plot, record count and % foliage cover of A. asthenes individuals, individual reproductive state and condition, % foliage cover of other native species and % foliage cover of exotic species.
Asterolasia beckersii	Dungowan Starbush	Count all individuals (i.e. full census; generally small populations) and estimate population area of occupancy. Record age class (adult/juvenile) of each individual - juveniles defined as <50 cm height, and presence of flowers and/or fruit. Assess any evidence of grazing or browsing on individuals. Conduct monitoring every three years in October.
Burhinus grallarius	Bush Stone-curlew	Use call (e.g. duetting) playback - 30 seconds playback followed by 5 min listening - at multiple locations sampling the area of known habitat, conducted between 1 hour post-dusk and 1 hour pre-dawn. High confidence in detecting individuals (via return calls or visually) should be achieved by repeating this method on three different nights.
Caladenia concolor	Crimson Spider Orchid	Count all flowering individuals occurring at the site and record condition of each. Conduct monitoring in October-November, annually.
Caladenia tessellata	Thick Lip Spider Orchid	Count all individuals and assess reproductive capacity of each. Conduct monitoring in September-November, annually.
Callocephalon fimbriatum	Gang-gang Cockatoo	In breeding habitat (higher altitude forests and woodlands), identify potential nesting sites (hollows >20 cm diameter and >20 m height) and observe for signs of breeding activity (e.g. nestling calls, adult visitation; Spring-Summer) for minimum 3 hours per nest site, on three different days (or until presence detected).
Calyptorhynchus banksii samueli	Red-tailed Black-Cockatoo (inland subspecies)	Identify potential nesting sites (hollows >10 cm diameter and >2 m height) and observe for signs of breeding activity (e.g. nestling calls, adult visitation; May-July, September-December) for minimum 3 hours per nest site, on three different days (or until presence detected).
Calyptorhynchus lathami	Glossy Black-Cockatoo	Ideally use at least two of the following four methods to determine presence on site: i) watering point surveys (human observer or remote camera) at one or more appropriate sites within the habitat area, ii) chewings transect surveys within stands of mature Allocasuarina; iii) Birdlife Australia standard 20 min / 2 ha surveys sampling the habitat area; or iv) confirmation of active breeding hollows (via remote camera or direct observation) during breeding season (July- August)
Cercartetus nanus	Eastern Pygmy-possum	Ideally, erect 'trap tubes' (temporary nest-boxes) at an approximate density of 20/ha throughout the habitat area, checking for occupancy weekly over a four-

		week period OR use traditional spotlight survey technique - minimum two nights, undertaken by observer with expertise in this species
Chalinolobus dwyeri	Large-eared Pied Bat	Use acoustic detectors (e.g. Anabat) appropriately spaced throughout habitat area, recording for at least 4 nights (dusk-dawn) in November - January.
Chamaesyce psammogeton	Sand Spurge	For small populations (<150 individuals), conduct parallel traverses across habitat area (between high water mark and 20m up dune profile) to identify and count all individuals, recording size class and reproductive status. For larger populations, adequately sample the entire habitat area using randomly located 2x5 m plots, recording the same attributes.
Crinia tinnula	Wallum Froglet	Conduct 4 aural-visual surveys along 500 m transects adequately sampling breeding habitat area or 14 days (continuous 24-hour recording) of acoustic recording, to detect presence. Monitoring can be any time of year following flooding rains.
Cryptostylis hunteriana	Leafless Tongue Orchid	Count and tag all known plants in the population annually in December - February, during flowering. Additionally record number of flowers and flowering stage for each plant.
Cyperus aquatilis	Water Nutgrass	Adequately sample the habitat area using 5x5 m permanent plots, recording presence/absence within each plot, every three years when flowering (September-February) or following significant disturbance event (e.g. fire).
Daphnandra johnsonii	Illawarra Socketwood	Count all stems >2 m height, allocating each to a height class (2-5 m or >5 m) and recording presence/absence of fruit. Estimate the total number of stems/suckers <2 m. For larger populations/sites, sample using 20 x 20 m plots, assessing stem density using the above method. Conduct monitoring every 3 years in February-April (fruiting period).
Dasyornis brachypterus	Eastern Bristlebird	Method should follow Bain and French (2009, Wild. Res. 36, 516-52); walking line transects in the first two hours after dawn, recording any birds seen or heard following call playback (5 min), at a minimum density of 3 km of transect / 100 ha. Surveys should take place October - December, on two separate, closely occurring (e.g. consecutive) days.
Delma impar	Striped Legless Lizard	The primary survey method should involve the installation and checking of artificial shelter sites (i.e. corrugated steel or roofing tiles). Tiles should be installed at least three months prior to planned monitoring (i.e. June, for spring monitoring). Tiles should be arranged in arrays of 50 (5x10) with five metre spacing between tiles, preferably positioned on a northerly aspect. Two arrays should be used for sites <2 ha in size, one array/3 ha for sites 2-30 hectares, and 10 arrays for sites >30 ha, adequately sampling the habitat area. Tiles should be checked 2-4 times per month, spaced at least a week apart (avoid checking in when >28°C.
Dichanthium setosum	Bluegrass	Sample the habitat area using 1x1 m plots, stratified by D. setosum density (focusing only on high density areas if site is large). Assess tussock abundance per plot, as well as recording seed set and any evidence of disturbance.
Digitaria porrecta	Finger Panic Grass	Estimate total population size and % cover by adequately sampling the habitat area using 10x50 m transects stratified by density class.
Dillwynia glaucula	Michelago Parrot-pea	Sample population using either 5 m radius circular plots or 1x10 m belt transects. Record number of plants per height class (<20, 20-50, 51-100, >100 cm). Record flowering/fruiting status of each plant, as well as browsing disturbance (e.g. 'light', 'moderate', 'heavy', 'hedging effect').
Diuris aequalis	Buttercup Doubletail	Full population census for small (<100 individuals) populations, or sample the area of occupancy using 5x5 m plots. Count all individuals within each plot, assess number flowering and individual condition. Conduct monitoring late October - mid November, annually.
Diuris arenaria	Sand Doubletail	Full population census for small (<100 individuals) populations, or sample the area of occupancy using 5x5 m plots. Count all individuals within each plot, assess number flowering and individual condition. Conduct monitoring in September, annually.

Diuris tricolor	Pine Donkey Orchid	Full population census for small (<100 individuals) populations, or sample the area of occupancy using 5x5 m plots. Count all individuals within each plot, assess number flowering and individual condition. Conduct monitoring September - November, annually.
Eucalyptus aggregata	Black Gum	For small populations - count, tag and map all adults, assign each to stem size class and count/estimate total number of recruits. In addition, note incidences of disease, dieback or significant disturbance (e.g. browsing of recruits). For larger populations, adequately sample the area of occupancy using 20x20 m plots and record equivalent details on all individuals rooted within plots.
Eucalyptus benthamii	Camden White Gum	For small populations - count, tag and map all adults, assign each to stem size class and count/estimate total number of recruits. In addition, note incidences of disease, dieback or significant disturbance (e.g. browsing of recruits). For larger populations, adequately sample the area of occupancy using 20x20 m plots and record equivalent details on all individuals rooted within plots.
Eucalyptus cannonii	Capertee Stringybark	For small populations - count, tag and map all adults, assign each to stem size class and count/estimate total number of recruits. In addition, note incidences of disease, dieback or significant disturbance (e.g. browsing of recruits). For larger populations, adequately sample the area of occupancy using 20x20 m plots and record equivalent details on all individuals rooted within plots.
Eucalyptus glaucina	Slaty Red Gum	For small populations - count, tag and map all adults, assign each to stem size class and count/estimate total number of recruits. In addition, note incidences of hybridisation, disease, dieback or significant disturbance (e.g. browsing of recruits). For larger populations, adequately sample the area of occupancy using 20x20 m plots and record equivalent details on all individuals rooted within plots.
Eucalyptus rubida subsp. barbigerorum	Blackbutt Candlebark	Adequately sample the population using 50x50 m plots, counting all individuals within stem size classes (including recruits) in each plot, every 3 years.
Genoplesium baueri	Bauer's Midge Orchid	Count and tag all known plants in the population annually in January-February, during flowering. Additionally record number of flowers and flowering stage for each plant
Grevillea juniperina subsp. juniperina	Juniper-leaved Grevillea	Install permanent line transects (1 per 20 ha) adequately sampling the habitat area. Count all intersecting individuals and record age class of each. Conduct monitoring in January-February, every three years.
Grus rubicunda	Brolga	Survey potential breeding habitat (swamps) within the key breeding period (September-October) for two hours in the morning and two hours in afternoon, on days separated by at least a week, until presence / breeding activity is detected. A key indicator of active breeding is a pair observed split (i.e. one foraging, one on the nest), or together during change over, often in the middle of the swamp.
Heleioporus australiacus	Giant Burrowing Frog	Conduct aural-visual surveys along 500m transects adequately sampling the habitat area, between September and May and tadpole searches (10min/50m^2) between February and May. Transects should run through areas of native vegetation located within 300 metres of suitable breeding habitat. Surveys should be completed within one week of heavy rainfall (>50 mm in 24 hours, >100 mm in 3 days). Tadpole searches are completed within areas of identified suitable breeding waterbodies, surveying at night when tadpoles are most active.
Hibbertia fumana	Hibbertia fumana	Adequately sample the area of occupancy using 2x2 m plots. Within each plot, record individual condition, age structure and evidence of disturbance to plants or substrate. Also assess total extent and density, during flowering (October - December), annually.

Hoplocephalus bungaroides	Broad-headed Snake	Establish permanent transects throughout suitable habitat (i.e. rocky outcrops). At each outcrop, snakes should be searched for by carefully lifting all moveable rocks and other shelter structures (e.g. logs, large pieces of bark) on rock substrate and inspecting crevices and spaces underneath boulders using a torch. Snakes found underneath rocks that have been lifted are captured and returned after the rock has been carefully repositioned. The number of snakes found, as well as the number of suitable rocks (i.e. >15 cm diameter, fitting snuggly on substrate) inspected, should be recorded. Surveys should be undertaken during fine weather to maximise species detection and to minimise accidental damage to bushrock, which can be fragile when wet. In addition, weather conditions should be recorded, as well as any evidence of disturbance to habitat (e.g. bushrock removal). Monitoring should occur every 3 years in September.
Indigofera baileyi	Bailey's Indigo	Install permanent plots (5x5 m) capturing all significant patches of *I. Baileyi* within the habitat area. Count all stems and qualitatively assess recruitment, in each plot. Conduct monitoring every three years or following any significant disturbance event (e.g. fire).
Lasiopetalum joyceae	Lasiopetalum joyceae	Population should be adequately sampled using plots or strip transects (10x25 m). Within each plot, record total numbers of plants, and counts of individuals per life stage, height class, reproductive status and condition. Monitoring should occur annually if feasible (3-yearly if not) in summer when fruiting, and following any planned or unplanned fire.
Lindernia alsinoides	Noah's False Chickweed	For smaller populations - sample each different, visually homogenous stand of vegetation dominated by native ground cover species, with little or no shrub and tree recruitment, which currently supports a population of L. alsinoides, using 1x1 m quadrats. Count all individuals within quadrats and qualitatively score each quadrat as either; majority of plants appear vigorous or majority of plants appear unhealthy (e.g. foliage diseased, yellow, senescent). For large populations, sample the entire area of occupancy using a 25x25 m grid, with 1x1 m quadrats placed at each intersection point (data collection as above).
Litoria aurea	Green and Golden Bell Frog	Use timed visual encounter surveys (VES) assisted by call playback, over four nights, per site, between September and March, ensuring to adequately sample the full area of habitat (i.e. wetland area). Record sex and life stage of individuals observed, if possible. In addition, if feasible, monitor water quality (i.e. pH, conductivity, total dissolved salts, salinity, temperature).
Litoria brevipalmata	Green-thighed Frog	Conduct aural-visual surveys along a 500m transects, combined with tadpole searches (10 min/50m2), adequately sampling the habitat area, between spring and autumn and within 24 hours of a significant rain event.
Litoria littlejohni	Littlejohn's Tree Frog	Conduct aural-visual surveys along a 500m transects adequately sampling the habitat area, or use passive acoustic recorders (active for 14 days) to sample a similar area. Supplement with tadpole surveys (10 min / 50m2) in open water throughout the habitat area. Monitoring should be conducted between July and November, every three years.
Meridolum corneovirens	Cumberland Plain Land Snail	Conduct diurnal meandering transects (1 hour / ha) within all suitable habitat, overturning (and returning) potential refugia (e.g. coarse woody debris, non-natural debris, leaf litter, bark accumulations, grass tussocks and sedge clumps). If diurnal surveys fail to detect the species, conduct nocturnal surveys, using a random meander, spotlighting the ground and other low objects for active snails. Nocturnal surveys should be undertaken between dusk and dawn the night following rainfall, with a moist ground layer, high (>75%) humidity and temperature >12°C (minimum 2 nights, following separate rainfall events). It is recommended that empty shells are collected and live snails photographed, for expert identification.
Micromyrtus minutiflora	Micromyrtus minutiflora	Adequately sample the habitat area using 50m linear transects (i.e. separated by approximately 500m). For each transect, record % cover (i.e. summed plant intercept length) and count, and for each individual M. minutiflora, record height, condition, growth stage (seedling, juvenile, adult, standing dead) and adult reproductive status (flower buds, flowering, fresh fruit, no breeding event, old fruit, seeds). Monitor June - March, every three years.

Mixophyes iteratus	Giant Barred Frog	Conduct aural-visual surveys throughout the habitat area, between October and March. Species can be detected from both call (irregular) and eyeshine when active at night.
Myotis macropus	Southern Myotis	Use acoustic recorders to adequately sample the habitat area, for a minimum of 4 nights, between October and March. Recorders should be placed preferably over pools of water along creeks or rivers, particularly in flat or areas of low relief, if present. Where relevant, conduct roost search (30 min per feature), including any bridges, tunnels, culverts or other structures identified as potential breeding habitat, identifying and recording observations of bats or signs of bats (e.g. guano).
Paralucia spinifera	Purple Copper Butterfly	Establish permanent 20 m wide transects sampling the habitat area (i.e. available Bursaria spinosa subsp. lasiophyll). Monitor in September-October, 10am-2pm on sunny days with minimal wind and no rain. Observer should walk slowly along the transect lightly tapping vegetation where possible and monitoring for activity. Survey should be repeated on multiple days, separated by at least one day, up to 5 times or until a presence is confirmed. Ideally, in addition, record larval abundance in 5x5 m plots as well as extent and condition of Bursaria.
Persoonia nutans	Nodding Geebung	Adequately sample habitat area using 2x25 m belt transects, count all individuals, assess condition and flowering/seed set for each stem, for each transect. Conduct monitoring in March and/or November, every three years
Petaurus norfolcensis	Squirrel Glider	Spotlight transects adequately sampling the habitat area, conducted by observer(s) with experience and expertise surveying for the species, repeated over at least 2 nights, or until presence detected; OR remote cameras (e.g. Reconyx Hyperfire) baited and mounted in habitat trees with an approximate spacing of 500 m, active for 7 nights.
Phascogale tapoatafa	Brush-tailed Phascogale	Use remote motion-sensitive cameras, erected high (>2 m) in trees and focused on an attractant (punctured sardine tin and honey), to detect presence. Multiple cameras should be placed to adequately sample the habitat area, active for 3-5 nights during winter and/or spring.
Phascolarctos cinereus	Koala	See Section 5.7.1
Pimelea curviflora var. curviflora	Pimelea curviflora subsp. curviflora	Adequately sample the habitat area using 2x2 m plots, counting all individuals, and assigning height classes and reproductive status to each. Monitoring should occur in spring or summer (flowering or fruiting) every 3 years, or following significant disturbance event (e.g. fire, slashing, soil disturbance).
Pimelea spicata	Spiked Rice-flower	Use 25 m line transects to adequately sample the habitat area, recording the total number of P. spicata along each transect, as well as general condition, reproductive status and height for each individual.
Pomaderris pallida	Pale Pomaderris	Use a method appropriate to the local abundance and distribution: i) Default - adequately sample the habitat area using 5 m radius circular plots, counting all individuals and allocating to height classes (<20, 20-50, 51-100, 101-200, >200cm), recording general browsing intensity (none, light, moderate, heavy) and % cover of high threat weeds. ii) High density populations - as above, but with 2.5m radius plots. iii) Small clusters of riparian ramets - as above, with all plants in sub-populations monitored. Suitable for small clusters of riparian ramets.
Pomaderris reperta	Denman Pomaderris	Full population census for small (<100 individuals) populations, or sample the area of occupancy using 5x5 m plots, stratified by plant density zones. Count individuals, assess individual reproductive status, condition, age/size class, as well as vegetation structure. Conduct monitoring September - November, every 3 years.
Pomaderris walshii	Carrington Falls Pomaderris	Count all known individuals within suitable habitat (full census), searching relevant riparian zones 30m either side of tributaries containing known plants or in proximity to known plants. For each counted individual, record height, canopy width, stem number, stem basal diameter, breeding status and condition.

Pommerhelix duralensis	Dural Land Snail	Conduct diurnal meandering transects (1 hour / ha) within all suitable habitat, overturning (and returning) potential refugia (e.g. coarse woody debris, non-natural debris, leaf litter, bark accumulations, grass tussocks and sedge clumps). If diurnal surveys fail to detect the species, conduct nocturnal surveys, using a random meander, spotlighting the ground and other low objects for active snails. Nocturnal surveys should be undertaken between dusk and dawn the night following rainfall, with a moist ground layer, high (>75%) humidity and temperature >12°C (minimum 2 nights, following separate rainfall events). It is recommended that empty shells are collected and live snails photographed, for expert identification.
Pseudophryne australis	Red-crowned Toadlet	Use call playback (observing male response) and aural-visual surveys, adequately sampling throughout the habitat (and potential habitat) area. Monitoring can occur any time of year, following sufficient rainfall to stimulate activity. Surveys should not be conducted if three significant rain events (>50 millimetres of rain in 24 hours) have occurred in the previous two months, nor during periods of heavy rainfall.
Pterostylis gibbosa	Illawarra Greenhood	Adequately sample the habitat area using 1x1, 2x2 or 5x5 m plots, dependent on population size/area. Within each plot count number of individuals, condition and reproductive state (seedling [<2 leaves], mature rosette [>2 leaves], flowering plant, aborted plant [stem damage]) and number of plants with capsule.
Pterostylis ventricosa	Pterostylis ventricosa	Sample the habitat area adequately using 5x5 m plots. Within plots, count total number of plants (flowering stems, flowers and rosettes; if a flowering stem also has a rosette, only count the stem. This also allows the calculation of the flower:stem ratio). Quantify occupancy by overlaying a 20x20 m grid across the full habitat area, placing a 2.5m radius circular plot at the centre of each grid square to be searched for orchids over approximately 1 to 2 minutes, recording count for each. Monitoring should occur annually during the flowering period (late March - early April), although climatic conditions may vary this. A reconnaissance trip is recommended to confirm flowering time (the species forms a rosette of leaves following flowering, although not all individuals will flower each year).
Pultenaea parviflora	Pultenaea parviflora	Sample the habitat area using 2x25 m permanent plots; count individuals and assess population age/size class structure within plots. Conduct monitoring late spring - early summer (during flowering).
Solanum celatum	Solanum celatum	Sample the population with an appropriate number of permanent 10 x 10 m plots across the habitat area, counting all individuals within each plot and recording the following attributes for each individual: standing height (cm), flowers (0=none, L=1-5, M=6-20, H=>20), fruit (0=none, L=1-5, M=6-20, H=>20), every 3 years in January-February.
Swainsona recta	Small Purple-pea	Install permanent plots (5x5 m) capturing all significant patches of *S. recta* within the habitat area. Count all stems and qualitatively assess recruitment, in each plot. Conduct monitoring every three years during spring (flowering), or following any significant disturbance event (e.g. fire).
Swainsona sericea	Silky Swainson-pea	Install permanent plots (5x5 m) capturing all significant patches of *S. sericea* within the habitat area. Count all stems and qualitatively assess recruitment, in each plot. Conduct monitoring every three years during spring (flowering), or following any significant disturbance event (e.g. fire).
Synemon plana	Golden Sun Moth	Survey for species' presence using 10x50 m belt transects, adequately sampling the total habitat area, between October and December, every three years. Focus searches in foraging habitat - i.e. native wallaby grasses (*Rytidosperma sp*), Chilean needlegrass (*Nassella nessiana*) or Serrated Tussock (*Nassella trichotoma*).
Thersites mitchellae	Mitchell's Rainforest Snail	Conduct diurnal meandering transects (1 hour / ha) within all suitable habitat, overturning (and returning) potential refugia (e.g. coarse woody debris, non-natural debris, leaf litter, bark accumulations, grass tussocks and sedge clumps). If diurnal surveys fail to detect the species, conduct nocturnal surveys, using a random meander, spotlighting the ground and other low objects for active snails. Nocturnal surveys should be undertaken between

		dusk and dawn the night following rainfall, with a moist ground layer, high (>75%) humidity and temperature >12°C (minimum 2 nights, following separate rainfall events). It is recommended that empty shells are collected and live snails photographed, for expert identification.
Todiramphus chloris	Collared Kingfisher	Conduct 2 ha (50x400 m) / 2 min surveys, separated by 400 m, adequately sampling the habitat area, recording any individuals seen or heard within the survey area.
Triplarina nowraensis	Nowra Heath Myrtle	Adequately sample the habitat area using 20x20 m plots. Within each plot, assess cover and abundance of *T. nowraensis*, as well as other competing native and exotic species. In addition, for T. nowraensis individuals, record condition and note presence of flowers, fruit or reshooting, as well as general presence of seedlings in the plot. Assess for evidence of disturbance or disease (e.g. myrtle rust).
Tympanocryptis pinguicolla	Grassland Earless Dragon	Assess presence and density of dragons using 'shelter tubes' (artificial burrows made from PVC pipe; 31 mm diameter x 142 mm) lined with brown paint and sand, slipped inside an outer sleeve that is buried vertically in the ground (trimming 20cm radius of surrounding vegetation to ground level). Grids of shelter tubes spaced at 10 m intervals (e.g. 7x8 matrix) should be used to sample the habitat area, with 100 m between grids, as required. Individuals caught should be classified as juvenile (<28 mm SVL), subadult (28-38 mm) or adult (>38 mm).
Uvidicolus sphyrurus	Border Thick-tailed Gecko	Conduct systematic search across the habitat area, using a torch to inspect sheltering sites (e.g. under rocks), in the first three hours of darkness, for multiple days. In addition, conduct systematic spotlight surveys on the ground in rocky and woodland habitat, to detect eye shine. Monitoring should be undertaken November to February, every three years.
Veronica blakelyi	Veronica blakelyi	Count all individuals and assign age/size class to each, estimate area of occupancy and local density. For <5 cm DBH individuals, record whether recruit or resprouting adult. Conduct monitoring December - February.
Zieria citriodora	Lemon Zieria	Sample the habitat area using 2x2 m or 5x5 m plots (as appropriate to capture individual patchiness), counting all plants within each plot and allocating each to a growth stage (i.e. adult [reproductive material present], juvenile, or seedling. In addition, record estimate of average height of (native and exotic) plants considered to be competing with Z. citriodora. Conduct monitoring every three years in August - February.
Zieria granulata	Illawarra Zieria	Sample the habitat area using 2x2 m or 5x5 m plots (as appropriate to capture individual patchiness), counting all plants within each plot and allocating each to a growth stage (i.e. adult [reproductive material present], juvenile, or seedling). In addition, record estimate of average height of (native and exotic) plants considered to be competing with *Z. granulata*. Conduct monitoring every three years in November - February.
Zieria murphyi	Velvet Zieria	Sample the habitat area using 2x2 m or 5x5 m plots (as appropriate to capture individual patchiness), counting all plants within each plot and allocating each to a growth stage (i.e. adult [reproductive material present], juvenile, or seedling. In addition, record estimate of average height of (native and exotic) plants considered to be competing with *Z. murphyi*. Conduct monitoring every three years in September - November.

APPENDIX 2: FIELD DATA SHEETS

Full-floristic (BAM) plot

Start Time:	End Time:	MP ID	Agmt/Ctrl	Recorders	
Date	_ _ / _ _ / _ _				
Zone	Datum	**Site Name**		**Plot dimensions**	
Easting	Northing	**IBRA region**	In m	**Plot bearing**	Magnetic °
Vegetation Class / Condition State					Confidence:

Growth Form	*Genus and species name*	N , E or HTW	Cover	Abund	Voucher
	1				
	2				
	3				
	4				
	5				
	6				
	7				
	8				
	9				
	10				
	11				
	12				
	13				
	14				
	15				
	16				
	17				
	18				
	19				
	20				

BAM Attribute (1000 m^2 plot)	
DBH	**Present?**
80 + cm	
50 – 79 cm	
30 – 49 cm	
20 – 29 cm	
10 – 19 cm	
5 – 9 cm	
< 5 cm	
Length of logs (m)	Tally space

Dung assessment											
1 x 1 m or 0.5 x0.5 m (SSCA) plots											**Count cow pats (400 m^2 plot)**
Species	**Count pellets**										

BAM Attribute (1 x 1 m plots)	Litter cover (%)					Bare ground cover (%)					Cryptogam cover (%)					Rock cover (%)				
Subplot score (% in each)																				
Average of the 5 subplots																				

Point-intercept cover assessment

MP ID:		Point arrangement / method[1]	
Recorder(s):		Assessment equipment / technique[2]	
Date:			

Cover category	Lower: <1m		Upper: 1-3m		Upper: 3-5m		Upper: >5m	
	Tally	Count	Tally	Count	Tally	Count	Tally	Count
Native vascular plant								
Exotic vascular plant								
Litter								
Cryptogam								
Log / coarse debris								
Rock / water								
Bare ground / no intercept								

[1] 1m intervals along 5 x 20m transects within 20x20m plot (preferred); 0.5m intervals along 50m midline transect; 1m intervals along 2 x 50m transects 1m either side of midline; 0.5m intervals along 5 x 5m transects in 5x5m subplot
[2] Pole/laser; pen tip; boot; other

Tree stem density assessment

Site ID:		**Plot width (DBH <20cm)**[1]	20m	10m	5m	2m
Recorder(s):		**Date:**				

DBH class (cm) / Species / type	<1	1-5	5-9	10-19	20-29	30-49	50-79	>80	Primary regen type[2]	Condition-affected category[3]
No. hollows										
No. standing dead										

[1] Variable for DBH size classes <1, 1-5,5-9 and 10-19cm only; all size classes >20cm to be assessed within 20x50m plot
[2] Seedlings, persistent lignotubers, mature resprouting (e.g. epicormic)

[3] If/where observable evidence of stem loss/degradation (e.g. dieback [drought, BMAD], disease, logging, browsing)

Soil surface condition assessment (SSCA)

Site ID:		Date:		Recorder(s):	

Indicator	Assessment categories / data requirement					Scores (Quadrat #)									
						1	2	3	4	5	6	7	8	9	10
Plant foliage cover	% foliage cover of perennial vegetation <0.5m (nearest 5%)														
Plant basal cover	% basal cover of perennial vegetation (nearest 5%)														
Litter – cover	Estimate and record % cover within quadrat (nearest 5%)														
Litter – depth	Estimate average depth across quadrat (nearest 1mm)														
Litter – origin	*local* = 1.5		*transported* = 1.0												
Litter – incorporation	*nil* = 1.0	*slight* = 1.3	*moderate* = 1.7	*extensive* = 2											
Cryptogam cover	% cover cryptogram / biocrust (nearest 5%)														
Crust brokenness	*no crust* = 0	*extensively broken* = 1	*moderately broken* = 2	*slightly broken* = 3	*intact crust* = 4										
Erosion severity	% surface impacted by erosion (eroded area)														
Deposited materials	% cover (abiotic) deposited material (if volume spread across quadrat)														
Surface roughness	<3mm = 1	3-8mm = 2	9-25mm = 3	large depressions with base = 4	very large depressions >100mm = 5										
Surface resistance	*loose, sandy* = 1	*easily broken* = 2	*moderately hard* = 3	*very hard / brittle* = 4	*non-brittle / mulching* = 5										
Crust stability	*N/A* = 0	*very unstable* = 1	*unstable* = 2	*moderately stable* = 3	*very stable* = 4										
Texture	*clay* = 1	*clay loam / sandy-clay* = 2	*loam* = 3	*sand* = 4											
Dung count – sheep[1]															
Dung count – macropod															
Dung count – goat															
Dung count – pig															
Dung count - other	**Species**														

[1] Cattle dung should be assessed within the 20x20m floristic plot

APPENDIX 3: POWER ANALYSES

METHODS

For both sets of analyses, variance was estimated using the NSW Vegetation Condition Benchmarks (cover and richness raw data v1.2) and change over time was estimated using gain and averted loss models described in the BAM.

Within stratification group

First, each plot in the benchmark data set was allocated to a stratification group (Vegetation Class x bioregion [IBRA] x condition state), with condition state based on a calculated (modified) BAM VI score (composition and structure only) categorised as *Poor* (<40), *Moderate* (40-75) or *Good* (>75). All plots allocated to stratification groups with <20 plots were removed, as were any replicate (resurvey) plots (i.e. all data points represented independent sites).

A subset of six attributes were selected to represent floristic variation: *Grass Cover, Shrub Cover, Tree Cover, Grass Richness, Shrub Richness* and *Tree Richness*. A future (Year 20) value for each attribute for each plot was calculated using three different methods, dependent on plot condition state, attempting to model broadly typical trajectories under management for each group:

- Poor condition – future value assuming active restoration, using BAM Equations 23, 24 and 27, simulating (normal distribution) landscape native vegetation cover and high threat weed cover;
- Moderate condition – future value assuming required management, using BAM Equations 23 and 24, simulating (normal distribution) landscape native vegetation cover and high threat weed cover values;
- Good condition – future value without an agreement (averted loss), using BAM Equation 20, simulating (normal distribution) values for annual probability of decline based on ranges provided in BAM Table 8

A trajectory of decline was applied to good condition sites, not because this is expected under BCT management, but given the predominant management objective of maintaining condition (improvement is unlikely), detecting significant decline in condition should be the focus of any monitoring for this group.

Effect sizes were calculated for each stratification group using the Year 0–Year 20 gain, which were then used to estimate the minimum required sample size (number of plots) to achieve adequate (i.e. β=0.8, α=0.05) statistical power for each group separately, using the formula: $n = 2(Z_{1\text{-}\alpha/2} + Z_{1\text{-}\beta})^2 * \sigma^2 / (\mu_{20}\text{-}\mu_{0})^2 + 1$ (Borm *et al.* 2007). A single 'confidence interval' for required sample size for each stratification group was approximated by taking the 25th and 75th percentile values of the group of six estimates (floristic attributes).

Program (state-wide) scale

Power analysis by simulation, applied to linear mixed models, using the package *simr* (Green and MacLeod 2016; R Core Team 2013) was employed to estimate statistical power (α=0.05) to detect an effect of management at agreement sites on the same six floristic attributes, compared to controls, for a range of sample and effect sizes. The data set informing the model was a modified version of that used above. Only plots from stratification groups currently represented at agreement sites were retained (*n*=33 groups), and 10 plots were randomly selected from each group to represent *Treatment* sites, with Time 1 (Year 20) values calculated as above. *Control* site data were synthesised by simply replicating Time 0 *Treatment* site data to represent Time 0, and simulating Time 1 values via random variation along a normal curve with a median of the Time 0 value and a standard deviation of 50% of the appropriate BAM averted loss value for the growth form (BAM Equation 20; Table 8 [low risk land]; no weightings).

The full data set represented an orthogonal design with 33 stratification groups x 10 plots per group x 2 treatment groups x 2 time steps (*n*=1,320).

Six different models were fitted, each with a different floristic attribute value as the response variable, *Treatment* and *Time* as fixed effects and *Plot ID* nested within *Stratification group* as random effects (Vegetation Class, condition state and bioregion were not modelled separately given it was not critical to understand their independent effects in this instance; *Plot ID* was removed from the *Tree Richness* response model to avoid over-fitting). A Gaussian distribution was used for the three models with structure attribute response variables and a Poisson distribution (log link) was used for those with composition attribute responses (appropriate for count data; simulated values were transformed to integers). For all models *simr* was used to manually adjust the within *Treatment*Time* sample size (*n*=330) to 2000 as well as the effect size, to estimate power for all combinations of 21 sample sizes (50, 100, 200…2000) and four effect sizes equivalent to 25%, 50%, 75% and 100% of the observed effect size from the data (assumed to approximate expected effect sizes at years 5, 10, 15 and 20 of management, respectively).

RESULTS

Within stratification group

The table below shows the upper and lower estimated minimum plot requirements for each stratification group separately, from the power analyses. Only those stratification groups represented by ≥20 plots in the VIS data set are included. Plot requirements for other groups should be based on a valid surrogate group (e.g. same vegetation class x bioregion with different condition state, similar vegetation class in the same bioregion or same vegetation class in a neighbouring bioregion) included in the table. The *Priority* column is based on *Total hectares* (protected under agreement [funded CAs and BSAs]) – i.e. groups with >500ha are designated ‘High’, 200-500ha ‘Moderate’ and <200ha ‘Low’. Ideally, the minimum number of plots per stratification group (if/where required) should be 5 (i.e. for groups with lower minimum plot requirement <5, the target sample size should be 5). Where time/resources are limited, stratification groups with a total area within agreement sites of <50ha do not require controls. This assessment is likely to change as new agreements are established by the BCT year-on-year.

Stratification group attributes			Total hectares	Priority	Minimum plot requirement (power analysis)[1]	
IBRA	Vegetation Class	Condition state			lower	upper
Mulga Lands	Sand Plain Mulga Shrublands	Moderate	23415.01	High	n/a	n/a
Darling Riverine Plains	Riverine Chenopod Shrublands	Good	7031.13	High	3	32
Brigalow Belt South	Sand Plain Mulga Shrublands	Moderate	5858.25	High	n/a	n/a
Darling Riverine Plains	North-west Floodplain Woodlands	Moderate	3781.11	High	11	22
Darling Riverine Plains	Floodplain Transition Woodlands	Moderate	3253.59	High	12	24
NSW South Western Slopes	Inland Rocky Hill Woodlands	Moderate	3134.97	High	7	22
NSW South Western Slopes	Western Slopes Dry Sclerophyll Forests	Moderate	2648.30	High	9	19
Riverina	Inland Floodplain Woodlands	Moderate	2570.95	High	13	39
Darling Riverine Plains	Semi-arid Floodplain Grasslands	Moderate	2548.44	High	9	17
Brigalow Belt South	Western Peneplain Woodlands	Moderate	2522.39	High	10	20
NSW South Western Slopes	Western Slopes Grassy Woodlands	Moderate	2467.14	High	10	27
Sydney Basin	Central Gorge Dry Sclerophyll Forests	Moderate	2294.95	High	5	9
NSW North Coast	North Coast Wet Sclerophyll Forests	Moderate	2069.41	High	7	14
NSW South Western Slopes	Western Slopes Dry Sclerophyll Forests	Good	1959.70	High	3	8
Nandewar	North-west Slopes Dry Sclerophyll Woodlands	Moderate	1954.93	High	7	14
NSW South Western Slopes	Upper Riverina Dry Sclerophyll Forests	Moderate	1892.93	High	9	21
Brigalow Belt South	Inland Saline Lakes	Moderate	1861.97	High	n/a	n/a
Cobar Peneplain	Inland Rocky Hill Woodlands	Moderate	1684.39	High	7	15
NSW South Western Slopes	Upper Riverina Dry Sclerophyll Forests	Good	1521.18	High	2	7
Mulga Lands	Stony Desert Mulga Shrublands	Moderate	1519.62	High	n/a	n/a
New England Tablelands	Northern Tableland Dry Sclerophyll Forests	Good	1510.24	High	2	3
Cobar Peneplain	Western Slopes Dry Sclerophyll Forests	Moderate	1393.52	High	7	17
NSW North Coast	Hunter-Macleay Dry Sclerophyll Forests	Good	1337.20	High	1	4
Riverina	Inland Riverine Forests	Moderate	1312.50	High	11	49
Brigalow Belt South	North-west Slopes Dry Sclerophyll Woodlands	Moderate	1299.37	High	8	19
New England Tablelands	Northern Tableland Dry Sclerophyll Forests	Moderate	1271.36	High	5	10
Brigalow Belt South	Subtropical Semi-arid Woodlands	Good	1251.51	High	n/a	n/a
Darling Riverine Plains	Inland Riverine Forests	Good	1185.63	High	4	17
Cobar Peneplain	Western Peneplain Woodlands	Moderate	1133.26	High	9	17
NSW North Coast	Hunter-Macleay Dry Sclerophyll Forests	Moderate	1032.41	High	7	17
South Eastern Highlands	Temperate Montane Grasslands	Moderate	1025.13	High	11	42
Brigalow Belt South	Western Slopes Grasslands	Poor	999.02	High	n/a	n/a
New England Tablelands	New England Grassy Woodlands	Moderate	992.52	High	7	16

[1] "n/a" indicates insufficient plots available to inform a power analysis, therefore a surrogate group (e.g. different condition state, neighbouring IBRA or ecologically similar vegetation class) should be used to inform control plot requirement

New England Tablelands	New England Dry Sclerophyll Forests	Moderate	958.00	High	5	10
Darling Riverine Plains	Riverine Chenopod Shrublands	Moderate	935.39	High	11	44
Darling Riverine Plains	North-west Floodplain Woodlands	Good	932.14	High	4	10
South Eastern Highlands	Southern Tableland Dry Sclerophyll Forests	Moderate	911.63	High	6	12
Darling Riverine Plains	Inland Riverine Forests	Moderate	894.92	High	12	24
Riverina	Inland Floodplain Shrublands	Moderate	865.01	High	21	52
Darling Riverine Plains	North-west Floodplain Woodlands	Poor	863.43	High	2	561
Riverina	Riverine Plain Grasslands	Moderate	781.39	High	20	43
South Eastern Highlands	Western Slopes Dry Sclerophyll Forests	Moderate	772.53	High	n/a	n/a
Cobar Peneplain	Inland Rocky Hill Woodlands	Poor	760.31	High	2	28
South Eastern Highlands	Western Slopes Grassy Woodlands	Poor	749.68	High	n/a	n/a
Riverina	Riverine Chenopod Shrublands	Moderate	719.20	High	19	34
NSW South Western Slopes	Southern Tableland Dry Sclerophyll Forests	Moderate	716.03	High	6	19
NSW South Western Slopes	Inland Rocky Hill Woodlands	Good	682.21	High	2	5
Cobar Peneplain	Floodplain Transition Woodlands	Moderate	646.68	High	13	33
New England Tablelands	New England Grassy Woodlands	Good	642.20	High	2	5
Darling Riverine Plains	Riverine Plain Woodlands	Poor	640.28	High	n/a	n/a
Riverina	Inland Floodplain Woodlands	Good	608.15	High	3	10
South Eastern Highlands	Central Gorge Dry Sclerophyll Forests	Poor	590.74	High	n/a	n/a
Darling Riverine Plains	Inland Floodplain Woodlands	Moderate	569.37	High	n/a	n/a
NSW North Coast	North Coast Wet Sclerophyll Forests	Good	560.84	High	2	6
NSW South Western Slopes	Western Slopes Grassy Woodlands	Good	529.19	High	3	13
Darling Riverine Plains	North-west Plain Shrublands	Moderate	522.08	High	8	54
Riverina	Riverine Plain Grasslands	Good	518.81	High	2	6
Sydney Basin	Sydney Hinterland Dry Sclerophyll Forests	Moderate	510.76	High	6	10
NSW South Western Slopes	Western Slopes Grassy Woodlands	Poor	486.36	Moderate	3	29
South Eastern Highlands	Western Slopes Grassy Woodlands	Moderate	476.89	Moderate	n/a	n/a
NSW North Coast	Northern Hinterland Wet Sclerophyll Forests	Moderate	474.73	Moderate	6	13
NSW North Coast	Coastal Freshwater Lagoons	Poor	463.23	Moderate	n/a	n/a
Darling Riverine Plains	Riverine Plain Woodlands	Moderate	463.13	Moderate	14	34
NSW North Coast	North-west Slopes Dry Sclerophyll Woodlands	Moderate	452.35	Moderate	3	7
Brigalow Belt South	North-west Floodplain Woodlands	Good	448.39	Moderate	n/a	n/a
NSW South Western Slopes	Western Slopes Grasslands	Moderate	447.83	Moderate	32	69
Darling Riverine Plains	Riverine Chenopod Shrublands	Poor	439.98	Moderate	4	136
Darling Riverine Plains	Gibber Transition Shrublands	Moderate	439.95	Moderate	n/a	n/a
South Eastern Highlands	Temperate Montane Grasslands	Good	430.50	Moderate	3	73
NSW South Western Slopes	North-west Floodplain Woodlands	Moderate	405.91	Moderate	n/a	n/a

Nandewar	Western Slopes Dry Sclerophyll Forests	Moderate	395.60	Moderate	7	14
NSW South Western Slopes	Floodplain Transition Woodlands	Moderate	384.29	Moderate	9	19
Brigalow Belt South	Western Slopes Grassy Woodlands	Moderate	378.48	Moderate	21	42
Sydney Basin	Sydney Hinterland Dry Sclerophyll Forests	Good	358.77	Moderate	1	4
NSW South Western Slopes	Inland Riverine Forests	Moderate	352.43	Moderate	14	29
NSW South Western Slopes	Inland Riverine Forests	Good	346.58	Moderate	n/a	n/a
Darling Riverine Plains	Semi-arid Floodplain Grasslands	Good	336.24	Moderate	3	18
New England Tablelands	Western Slopes Grassy Woodlands	Moderate	326.86	Moderate	16	35
New England Tablelands	North-west Slopes Dry Sclerophyll Woodlands	Moderate	322.42	Moderate	6	13
Riverina	Inland Riverine Forests	Good	286.44	Moderate	3	60
Darling Riverine Plains	Inland Floodplain Shrublands	Moderate	282.06	Moderate	13	36
South Eastern Highlands	Southern Tableland Grassy Woodlands	Good	275.17	Moderate	3	8
South Eastern Highlands	Southern Tableland Grassy Woodlands	Moderate	258.92	Moderate	8	16
Brigalow Belt South	Western Slopes Grassy Woodlands	Good	256.28	Moderate	3	10
Darling Riverine Plains	Inland Floodplain Woodlands	Good	255.40	Moderate	n/a	n/a
Brigalow Belt South	Floodplain Transition Woodlands	Moderate	248.50	Moderate	11	20
Riverina	Riverine Plain Woodlands	Moderate	248.03	Moderate	n/a	n/a
South Eastern Queensland	Northern Hinterland Wet Sclerophyll Forests	Good	241.86	Moderate	2	8
Darling Riverine Plains	Floodplain Transition Woodlands	Poor	240.73	Moderate	4	113
Brigalow Belt South	Riverine Chenopod Shrublands	Moderate	223.01	Moderate	n/a	n/a
NSW South Western Slopes	Inland Riverine Forests	Poor	216.48	Moderate	1	7
South Eastern Highlands	Tableland Clay Grassy Woodlands	Moderate	205.97	Moderate	12	28
South Eastern Highlands	Temperate Montane Grasslands	Poor	187.27	Moderate	3	79
South Eastern Highlands	Central Gorge Dry Sclerophyll Forests	Moderate	186.14	Moderate	5	10
Darling Riverine Plains	Western Peneplain Woodlands	Moderate	171.01	Moderate	9	31
South Eastern Highlands	Upper Riverina Dry Sclerophyll Forests	Moderate	168.82	Moderate	7	13
Darling Riverine Plains	Floodplain Transition Woodlands	Good	168.56	Moderate	3	9
NSW North Coast	Northern Hinterland Wet Sclerophyll Forests	Good	167.30	Moderate	2	6
Sydney Basin	Coastal Valley Grassy Woodlands	Moderate	162.14	Moderate	7	16
NSW South Western Slopes	Floodplain Transition Woodlands	Good	159.44	Moderate	3	7
Brigalow Belt South	Western Slopes Grassy Woodlands	Poor	158.19	Moderate	5	164
Brigalow Belt South	Pilliga Outwash Dry Sclerophyll Forests	Moderate	151.39	Moderate	6	12
New England Tablelands	New England Dry Sclerophyll Forests	Good	148.83	Moderate	2	5
New England Tablelands	North-west Slopes Dry Sclerophyll Woodlands	Good	148.18	Moderate	1	4
NSW South Western Slopes	Riverine Plain Woodlands	Moderate	143.70	Moderate	n/a	n/a
South Eastern Queensland	Clarence Dry Sclerophyll Forests	Good	143.60	Moderate	2	6

South Eastern Highlands	Tableland Clay Grassy Woodlands	Good	134.55	Moderate	3	8
NSW South Western Slopes	Riverine Plain Grasslands	Good	132.73	Moderate	n/a	n/a
Riverina	Inland Floodplain Swamps	Moderate	130.25	Moderate	18	29
South Eastern Highlands	South East Dry Sclerophyll Forests	Moderate	129.69	Moderate	4	8
South Eastern Highlands	Southern Escarpment Wet Sclerophyll Forests	Moderate	126.76	Moderate	6	12
NSW South Western Slopes	Western Slopes Grasslands	Good	112.96	Moderate	n/a	n/a
Nandewar	Western Vine Thickets	Moderate	112.25	Moderate	n/a	n/a
Brigalow Belt South	North-west Floodplain Woodlands	Moderate	102.81	Moderate	13	33
Sydney Basin	Southern Tableland Wet Sclerophyll Forests	Moderate	102.06	Moderate	7	15
South Eastern Highlands	Southern Tableland Wet Sclerophyll Forests	Moderate	99.48	Low	8	16
Sydney Basin	Southern Escarpment Wet Sclerophyll Forests	Moderate	99.06	Low	5	12
Sydney Basin	Coastal Freshwater Lagoons	Good	98.60	Low	n/a	n/a
South Eastern Queensland	North Coast Dry Sclerophyll Forests	Good	98.10	Low	n/a	n/a
NSW North Coast	Coastal Swamp Forests	Moderate	97.79	Low	11	21
Sydney Basin	Coastal Valley Grassy Woodlands	Good	97.65	Low	2	4
NSW South Western Slopes	Western Slopes Dry Sclerophyll Forests	Poor	96.59	Low	n/a	n/a
NSW North Coast	Northern Hinterland Wet Sclerophyll Forests	Poor	95.00	Low	1	4
Riverina	Riverine Sandhill Woodlands	Moderate	94.74	Low	21	115
NSW North Coast	Coastal Swamp Forests	Poor	93.79	Low	3	447
Nandewar	Dry Rainforests	Moderate	91.35	Low	5	17
Darling Riverine Plains	North-west Alluvial Sand Woodlands	Moderate	90.17	Low	8	16
Sydney Basin	North Coast Wet Sclerophyll Forests	Moderate	89.61	Low	6	11
NSW South Western Slopes	Inland Floodplain Swamps	Moderate	88.98	Low	n/a	n/a
Brigalow Belt South	Western Slopes Dry Sclerophyll Forests	Moderate	88.07	Low	7	14
New England Tablelands	Northern Montane Heaths	Moderate	87.85	Low	7	21
Sydney Basin	Coastal Valley Grassy Woodlands	Poor	85.86	Low	2	10
NSW North Coast	Coastal Swamp Forests	Good	82.60	Low	2	6
Brigalow Belt South	North-west Floodplain Woodlands	Poor	80.15	Low	n/a	n/a
NSW South Western Slopes	Riverine Sandhill Woodlands	Poor	78.50	Low	n/a	n/a
Brigalow Belt South	Brigalow Clay Plain Woodlands	Moderate	77.82	Low	9	18
NSW South Western Slopes	Western Peneplain Woodlands	Good	77.15	Low	n/a	n/a
Darling Riverine Plains	Inland Floodplain Woodlands	Poor	75.98	Low	n/a	n/a
South Eastern Queensland	North Coast Wet Sclerophyll Forests	Good	75.15	Low	2	6
Nandewar	Western Slopes Grassy Woodlands	Moderate	74.25	Low	13	27
Cobar Peneplain	Floodplain Transition Woodlands	Poor	74.20	Low	n/a	n/a
South Eastern Highlands	Western Slopes Grasslands	Good	73.05	Low	n/a	n/a
Brigalow Belt South	Floodplain Transition Woodlands	Poor	72.22	Low	n/a	n/a
Brigalow Belt South	Inland Riverine Forests	Poor	70.99	Low	n/a	n/a

Sydney Basin	Southern Tableland Dry Sclerophyll Forests	Moderate	70.63	Low	5	12
NSW South Western Slopes	Floodplain Transition Woodlands	Poor	63.28	Low	3	23
Sydney Basin	Hunter-Macleay Dry Sclerophyll Forests	Moderate	63.26	Low	7	14
Darling Riverine Plains	Inland Floodplain Swamps	Good	59.60	Low	3	27
Brigalow Belt South	Western Peneplain Woodlands	Poor	59.44	Low	n/a	n/a
South Eastern Queensland	Coastal Valley Grassy Woodlands	Moderate	59.29	Low	n/a	n/a
South Eastern Highlands	Montane Lakes	Good	55.49	Low	n/a	n/a
NSW South Western Slopes	Upper Riverina Dry Sclerophyll Forests	Poor	53.40	Low	n/a	n/a
NSW South Western Slopes	Inland Floodplain Swamps	Poor	53.35	Low	n/a	n/a
Sydney Basin	Coastal Floodplain Wetlands	Moderate	52.32	Low	11	24
NSW South Western Slopes	Riverine Plain Grasslands	Moderate	51.50	Low	34	126
NSW South Western Slopes	Inland Floodplain Swamps	Good	51.38	Low	n/a	n/a
NSW South Western Slopes	Riverine Chenopod Shrublands	Poor	49.45	Low	n/a	n/a
NSW North Coast	Northern Warm Temperate Rainforests	Moderate	49.37	Low	8	18
New England Tablelands	New England Grassy Woodlands	Poor	48.63	Low	3	12
Riverina	Floodplain Transition Woodlands	Moderate	47.78	Low	20	73
Sydney Basin	North-west Slopes Dry Sclerophyll Woodlands	Moderate	47.30	Low	7	14
Sydney Basin	Cumberland Dry Sclerophyll Forests	Moderate	46.53	Low	5	12
New England Tablelands	Temperate Montane Grasslands	Moderate	46.12	Low	n/a	n/a
Sydney Basin	Sydney Coastal Dry Sclerophyll Forests	Moderate	44.21	Low	5	9
Sydney Basin	South Coast Sands Dry Sclerophyll Forests	Moderate	38.20	Low	6	14
NSW South Western Slopes	North-west Slopes Dry Sclerophyll Woodlands	Moderate	37.13	Low	n/a	n/a
Sydney Basin	Coastal Swamp Forests	Moderate	36.84	Low	11	23
South Eastern Highlands	Southern Tableland Grassy Woodlands	Poor	35.92	Low	2	9
New England Tablelands	Tableland Clay Grassy Woodlands	Moderate	35.72	Low	8	22
NSW North Coast	Dry Rainforests	Moderate	35.50	Low	8	15
South Eastern Queensland	Coastal Swamp Forests	Moderate	35.12	Low	9	18
Brigalow Belt South	Riverine Plain Woodlands	Poor	32.79	Low	n/a	n/a
Brigalow Belt South	Riverine Chenopod Shrublands	Poor	32.70	Low	n/a	n/a
NSW South Western Slopes	Western Slopes Grasslands	Poor	31.20	Low	5	30
Sydney Basin	Coastal Floodplain Wetlands	Good	31.16	Low	2	6
Darling Riverine Plains	Riverine Plain Woodlands	Good	30.72	Low	n/a	n/a
New England Tablelands	Tableland Clay Grassy Woodlands	Good	28.99	Low	n/a	n/a
Sydney Basin	North Coast Wet Sclerophyll Forests	Poor	26.84	Low	2	16
NSW South Western Slopes	Southern Tableland Wet Sclerophyll Forests	Moderate	26.83	Low	n/a	n/a
Sydney Basin	Dry Rainforests	Moderate	26.40	Low	6	12
South Eastern Highlands	Eastern Riverine Forests	Moderate	25.86	Low	n/a	n/a

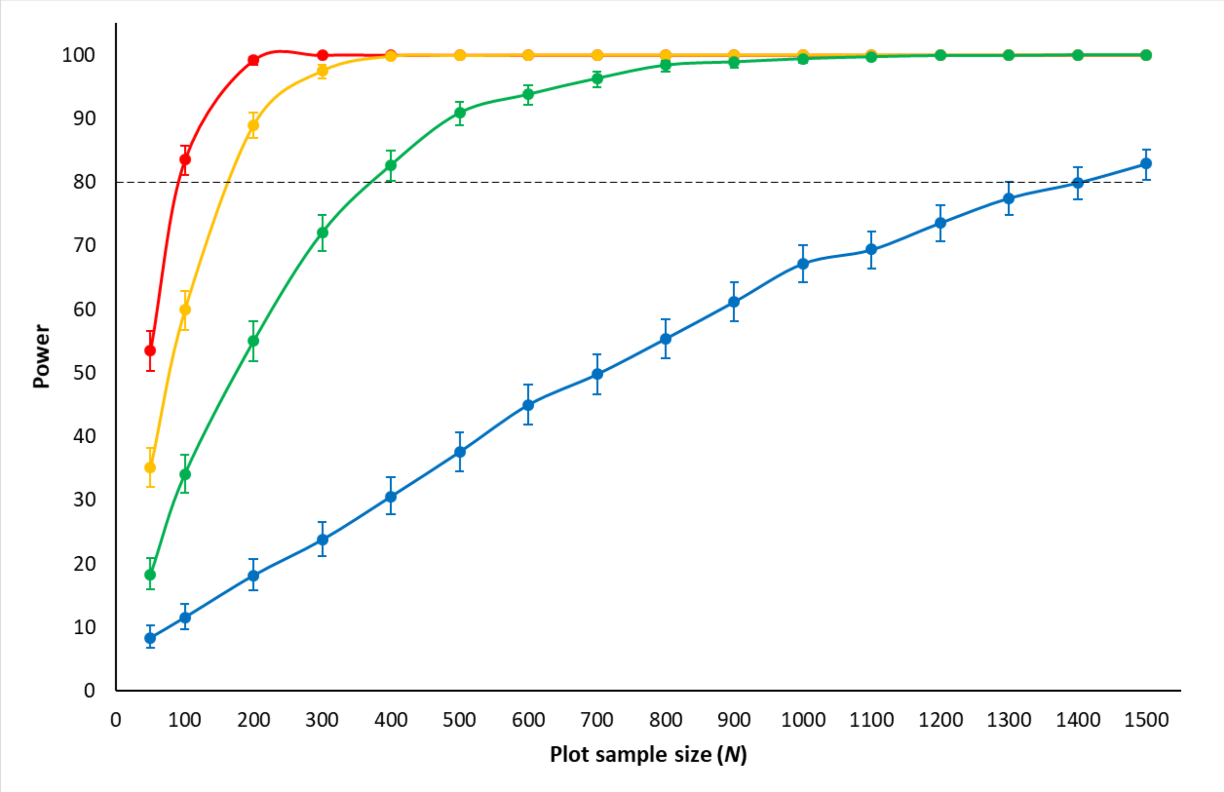
South Eastern Queensland	Coastal Swamp Forests	Good	25.35	Low	3	7
Riverina	Riverine Sandhill Woodlands	Poor	24.24	Low	2	38
NSW North Coast	Subtropical Rainforests	Moderate	24.13	Low	7	19
Brigalow Belt South	Inland Floodplain Shrublands	Poor	24.05	Low	n/a	n/a
Sydney Basin	Southern Warm Temperate Rainforests	Moderate	23.45	Low	5	33
NSW North Coast	Coastal Valley Grassy Woodlands	Moderate	22.51	Low	8	18
NSW North Coast	Hunter-Macleay Dry Sclerophyll Forests	Poor	21.23	Low	n/a	n/a
Sydney Basin	Southern Lowland Wet Sclerophyll forests	Good	19.80	Low	n/a	n/a
Nandewar	Western Slopes Grassy Woodlands	Good	19.54	Low	3	11
Nandewar	Inland Riverine Forests	Moderate	19.49	Low	n/a	n/a
NSW North Coast	Coastal Floodplain Wetlands	Good	18.88	Low	n/a	n/a
Sydney Basin	Sydney Sand Flats Dry Sclerophyll Forests	Moderate	18.77	Low	5	10
South Eastern Queensland	Northern Gorge Dry Sclerophyll Forests	Good	17.40	Low	n/a	n/a
Darling Riverine Plains	North-west Alluvial Sand Woodlands	Good	17.30	Low	n/a	n/a
Riverina	Riverine Chenopod Shrublands	Good	17.16	Low	2	7
Riverina	Floodplain Transition Woodlands	Good	16.88	Low	n/a	n/a
NSW South Western Slopes	Western Peneplain Woodlands	Moderate	16.49	Low	n/a	n/a
South Eastern Highlands	Tableland Clay Grassy Woodlands	Poor	15.79	Low	3	15
South Eastern Highlands	Southern Tableland Dry Sclerophyll Forests	Good	15.75	Low	3	7
New England Tablelands	Northern Montane Heaths	Good	15.48	Low	n/a	n/a
NSW North Coast	Western Slopes Grassy Woodlands	Moderate	14.69	Low	5	38
Nandewar	Western Vine Thickets	Moderate	14.56	Low	n/a	n/a
South Eastern Queensland	Northern Hinterland Wet Sclerophyll Forests	Moderate	14.20	Low	5	10
Nandewar	Western Slopes Grassy Woodlands	Poor	14.03	Low	4	67
New England Tablelands	New England Dry Sclerophyll Forests	Poor	13.89	Low	2	8
NSW North Coast	Saltmarshes	Moderate	13.29	Low	15	58
Darling Riverine Plains	Inland Floodplain Swamps	Moderate	13.01	Low	8	14
Sydney Basin	Coastal Floodplain Wetlands	Poor	12.60	Low	1	88
Riverina	Inland Floodplain Swamps	Good	12.39	Low	n/a	n/a
Darling Riverine Plains	Western Slopes Grasslands	Moderate	12.36	Low	n/a	n/a
Brigalow Belt South	Western Slopes Dry Sclerophyll Forests	Poor	12.00	Low	4	12
Brigalow Belt South	Eastern Riverine Forests	Moderate	11.98	Low	22	50
Sydney Basin	Northern Hinterland Wet Sclerophyll Forests	Moderate	11.66	Low	6	12
Darling Riverine Plains	Inland Riverine Forests	Poor	11.47	Low	5	67
NSW North Coast	Coastal Floodplain Wetlands	Poor	11.05	Low	n/a	n/a
NSW South Western Slopes	Southern Tableland Grassy Woodlands	Moderate	10.23	Low	7	38
Brigalow Belt South	Brigalow Clay Plain Woodlands	Good	10.17	Low	n/a	n/a
NSW North Coast	Dry Rainforests	Good	9.76	Low	2	7

NSW South Western Slopes	Inland Floodplain Woodlands	Moderate	9.68	Low	n/a	n/a
Sydney Basin	Northern Warm Temperate Rainforests	Moderate	9.47	Low	5	25
Nandewar	North-west Slopes Dry Sclerophyll Woodlands	Good	9.28	Low	2	7
New England Tablelands	Eastern Riverine Forests	Moderate	9.24	Low	8	18
Brigalow Belt South	Semi-arid Sand Plain Woodlands	Moderate	9.13	Low	n/a	n/a
Sydney Basin	Cumberland Dry Sclerophyll Forests	Poor	9.03	Low	n/a	n/a
Brigalow Belt South	Brigalow Clay Plain Woodlands	Poor	8.79	Low	n/a	n/a
South Eastern Highlands	Dry Rainforests	Moderate	8.60	Low	4	12
South Eastern Highlands	Southern Escarpment Wet Sclerophyll Forests	Poor	8.58	Low	n/a	n/a
NSW North Coast	Northern Warm Temperate Rainforests	Good	7.96	Low	3	9
South Eastern Highlands	Southern Tableland Dry Sclerophyll Forests	Poor	7.71	Low	3	11
Sydney Basin	Southern Tableland Wet Sclerophyll Forests	Poor	6.89	Low	n/a	n/a
Riverina	Riverine Chenopod Shrublands	Poor	6.56	Low	n/a	n/a
Sydney Basin	North-west Slopes Dry Sclerophyll Woodlands	Poor	6.20	Low	n/a	n/a
Riverina	Riverine Plain Grasslands	Poor	5.95	Low	6	197
Riverina	Riverine Sandhill Woodlands	Good	5.60	Low	4	16
Brigalow Belt South	Pilliga Outwash Dry Sclerophyll Forests	Poor	5.50	Low	1	20
Sydney Basin	Southern Tableland Grassy Woodlands	Moderate	5.49	Low	n/a	n/a
New England Tablelands	Northern Escarpment Dry Sclerophyll Forests	Moderate	5.45	Low	8	18
South Eastern Queensland	Subtropical Rainforests	Good	5.44	Low	3	10
South Eastern Queensland	Eastern Riverine Forests	Poor	5.10	Low	n/a	n/a
NSW South Western Slopes	Riverine Plain Woodlands	Poor	4.94	Low	n/a	n/a
Brigalow Belt South	Eastern Riverine Forests	Poor	4.83	Low	n/a	n/a
Brigalow Belt South	North-west Slopes Dry Sclerophyll Woodlands	Poor	4.24	Low	3	50
Sydney Basin	Southern Escarpment Wet Sclerophyll Forests	Poor	4.09	Low	n/a	n/a
NSW South Western Slopes	Southern Tableland Dry Sclerophyll Forests	Poor	4.04	Low	n/a	n/a
Sydney Basin	Coastal Freshwater Lagoons	Poor	3.80	Low	n/a	n/a
Nandewar	Inland Rocky Hill Woodlands	Moderate	3.76	Low	n/a	n/a
New England Tablelands	Northern Tableland Wet Sclerophyll Forests	Moderate	3.74	Low	7	16
NSW North Coast	Coastal Floodplain Wetlands	Moderate	3.60	Low	15	99
Sydney Basin	Coastal Swamp Forests	Good	3.35	Low	2	5
New England Tablelands	Montane Bogs and Fens	Poor	3.17	Low	3	60
NSW North Coast	Sydney Coastal Dry Sclerophyll Forests	Moderate	2.93	Low	4	14
Sydney Basin	Sydney Hinterland Dry Sclerophyll Forests	Poor	2.86	Low	1	5
NSW South Western Slopes	Riverine Sandhill Woodlands	Moderate	2.81	Low	n/a	n/a
Sydney Basin	Dry Rainforests	Poor	2.81	Low	n/a	n/a
Sydney Basin	Coastal Swamp Forests	Poor	2.74	Low	2	86
South Eastern Highlands	Western Slopes Grassy Woodlands	Good	2.50	Low	n/a	n/a

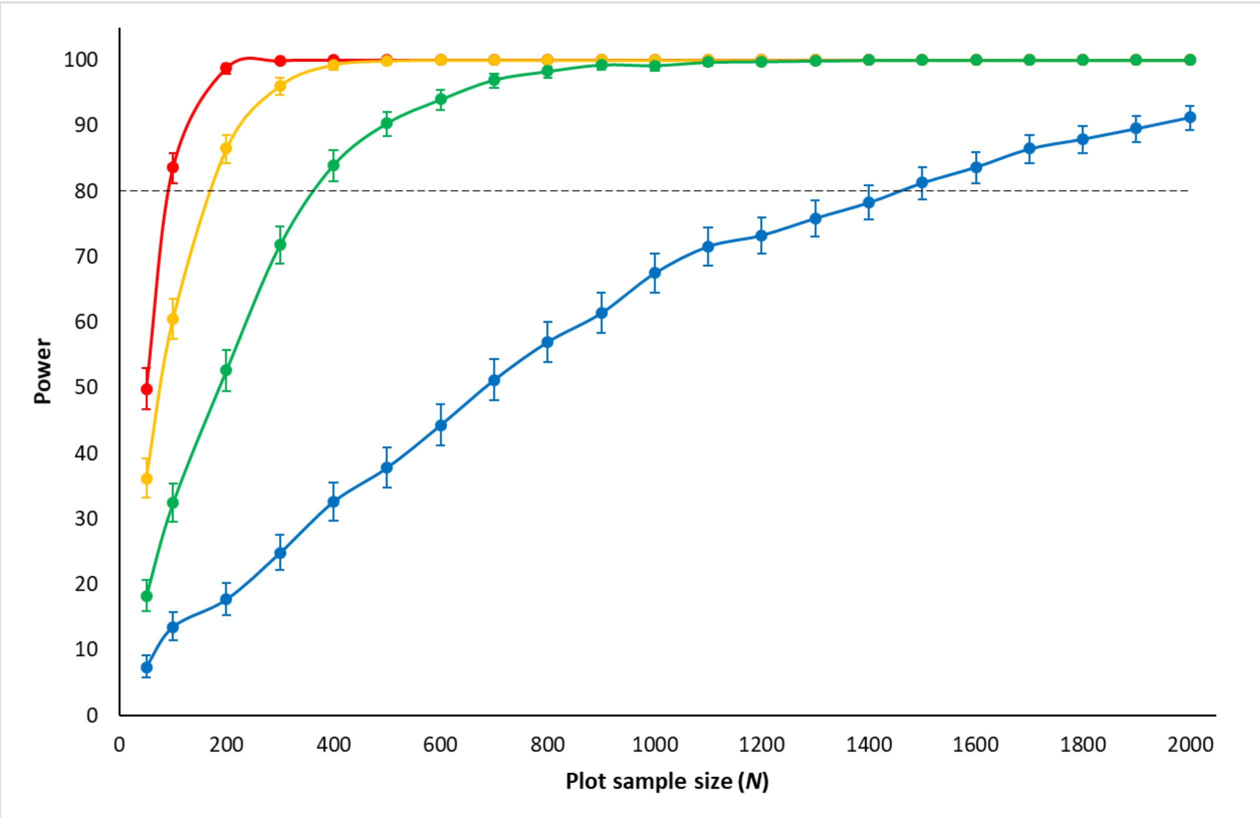
NSW South Western Slopes	Inland Floodplain Shrublands	Good	2.33	Low	n/a	n/a
Sydney Basin	Hunter-Macleay Dry Sclerophyll Forests	Poor	2.18	Low	n/a	n/a
South Eastern Highlands	Upper Riverina Dry Sclerophyll Forests	Poor	2.15	Low	n/a	n/a
Brigalow Belt South	Western Vine Thickets	Moderate	2.12	Low	6	13
NSW North Coast	Northern Warm Temperate Rainforests	Poor	1.99	Low	n/a	n/a
NSW North Coast	Northern Montane Heaths	Poor	1.96	Low	n/a	n/a
Nandewar	Western Vine Thickets	Poor	1.94	Low	n/a	n/a
NSW North Coast	Dry Rainforests	Poor	1.86	Low	n/a	n/a
New England Tablelands	Montane Bogs and Fens	Moderate	1.74	Low	11	85
New England Tablelands	Dry Rainforests	Moderate	1.70	Low	n/a	n/a
NSW South Western Slopes	Inland Rocky Hill Woodlands	Poor	1.50	Low	n/a	n/a
NSW South Western Slopes	Eastern Riverine Forests	Moderate	1.46	Low	n/a	n/a
Sydney Basin	Sydney Sand Flats Dry Sclerophyll Forests	Poor	1.37	Low	n/a	n/a
Sydney Basin	Subtropical Rainforests	Moderate	1.26	Low	6	16
NSW South Western Slopes	Southern Tableland Dry Sclerophyll Forests	Good	1.08	Low	2	4
NSW North Coast	Northern Montane Heaths	Moderate	0.97	Low	5	13
Sydney Basin	Sydney Coastal Dry Sclerophyll Forests	Good	0.87	Low	2	5
NSW North Coast	Coastal Heath Swamps	Good	0.70	Low	n/a	n/a
NSW North Coast	Mangrove Swamps	Moderate	0.57	Low	n/a	n/a
NSW North Coast	Coastal Dune Dry Sclerophyll Forests	Good	0.50	Low	2	6
Sydney Basin	Central Gorge Dry Sclerophyll Forests	Poor	0.48	Low	1	14
Sydney Basin	Eastern Riverine Forests	Moderate	0.46	Low	13	32
Nandewar	North-west Slopes Dry Sclerophyll Woodlands	Poor	0.42	Low	2	4
NSW North Coast	Mangrove Swamps	Good	0.30	Low	n/a	n/a
South Eastern Queensland	Subtropical Rainforests	Moderate	0.20	Low	7	22
Sydney Basin	Sydney Coastal Dry Sclerophyll Forests	Poor	0.19	Low	2	4
Sydney Basin	Coastal Freshwater Lagoons	Moderate	0.08	Low	8	22

Program (state-wide) scale

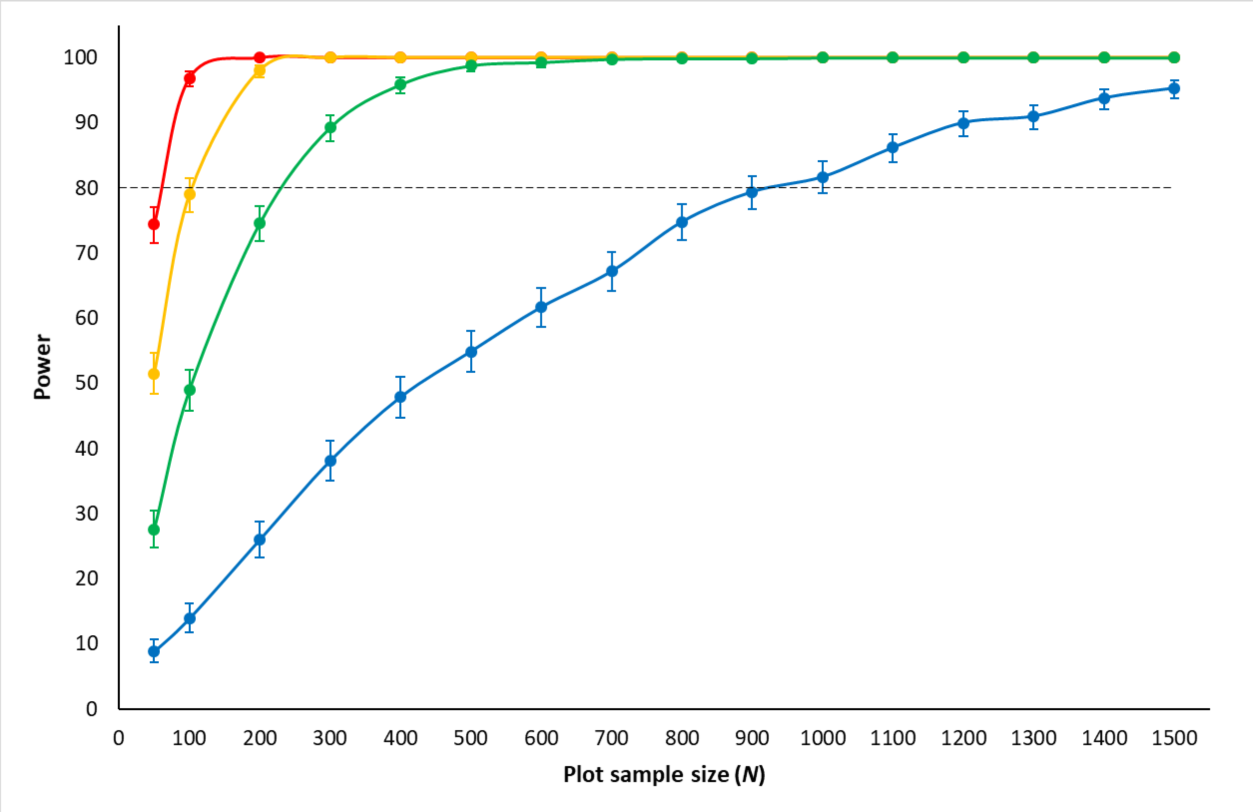
The plots below show estimated power (±95% confidence interval) for a range of sample sizes from the simulated Generalized Linear Model power analysis, for four effect sizes representing 25% (blue line), 50% (green line), 75% (yellow line) and 100% (red line) of the effect size observed in the original model (assumed to reflect 5, 10, 15 and 20 years of management, respectively), for each of six floristic attributes, separately.



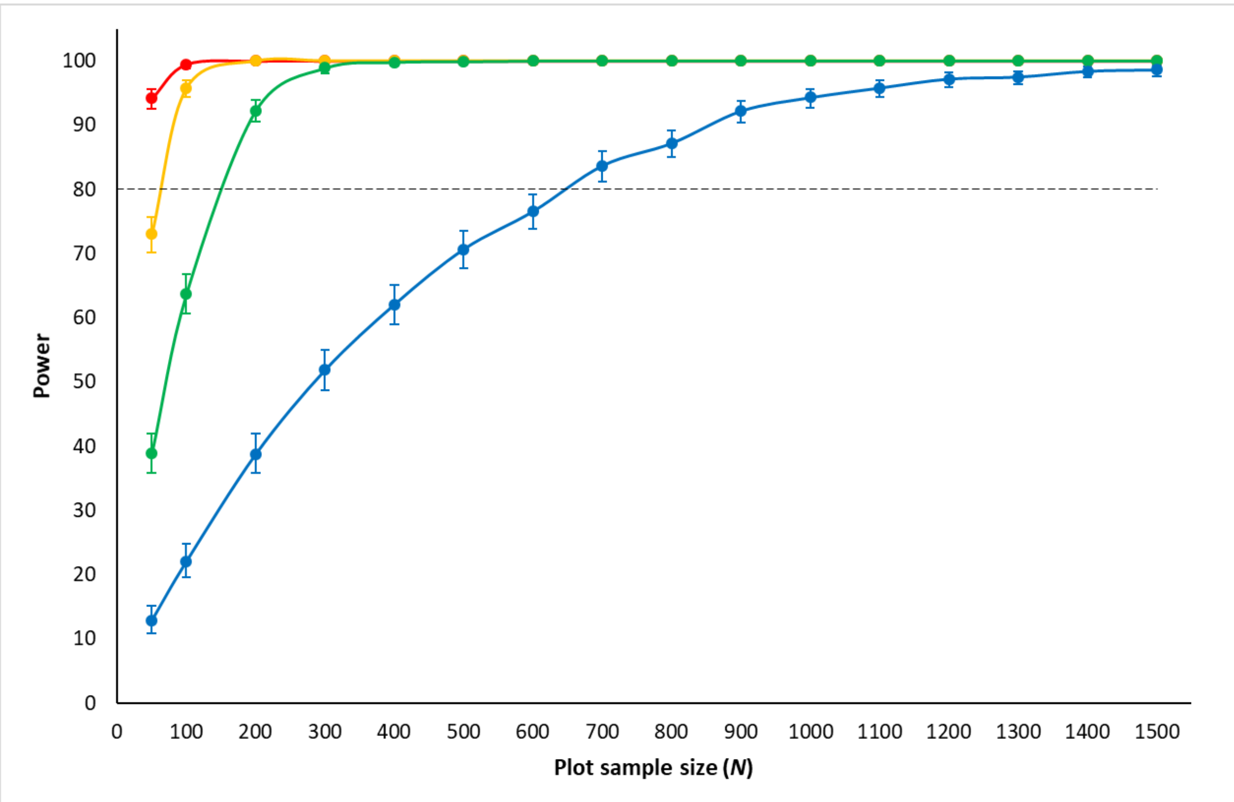
Grass cover



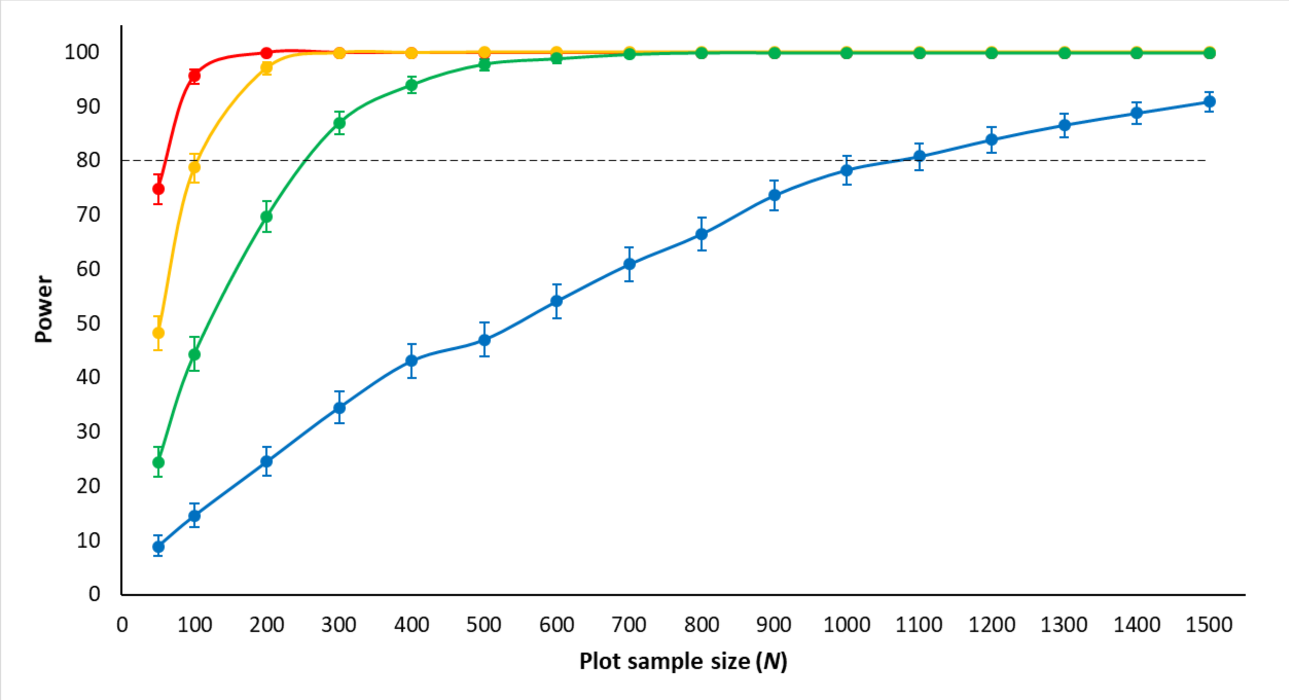
Shrub cover



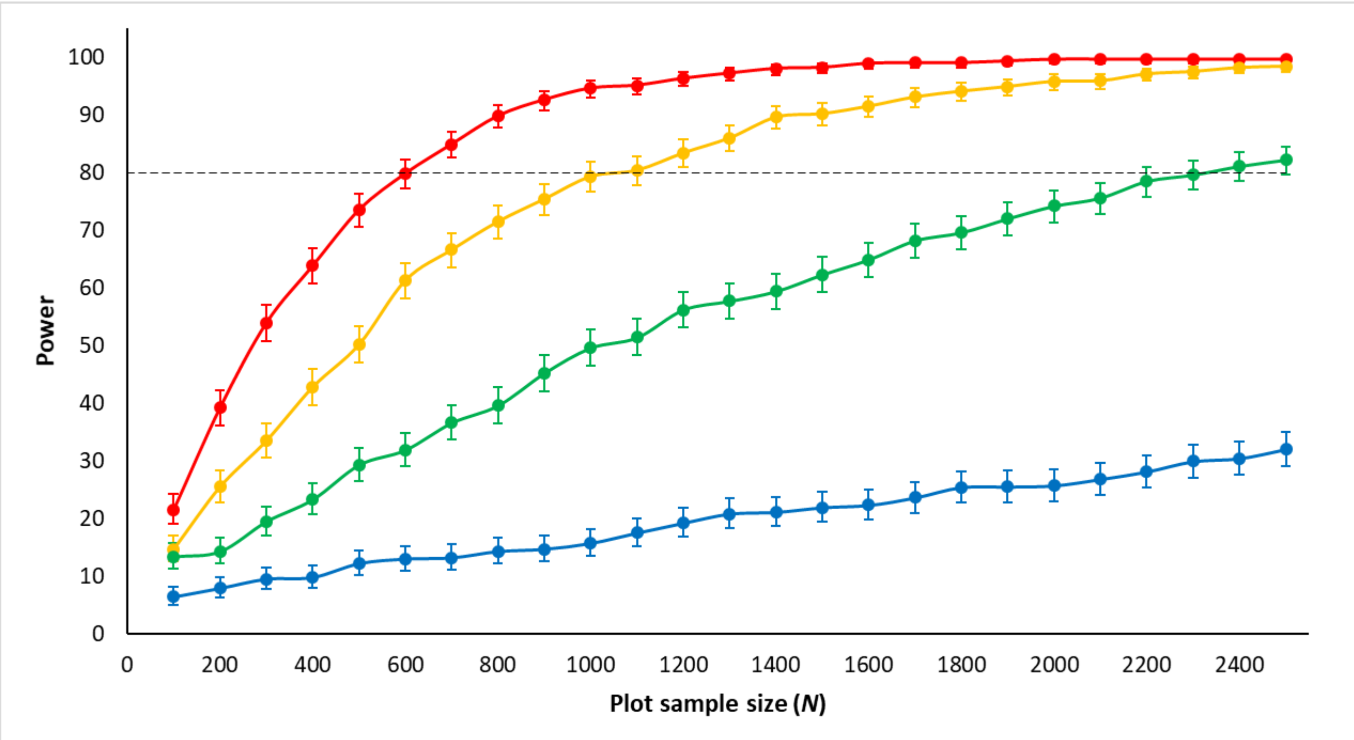
Tree cover



Grass richness



Shrub richness



Tree richness

APPENDIX 4: FIELD EQUIPMENT LIST

REQUIRED

- Mobile device (e.g. tablet) with latest versions of ArcGIS Field Maps, Collector and Survey123 installed
- Hard-copy data sheets (backup)
- External battery pack
- 2 x star pickets or 1500mm fibreglass posts
- 2 x 20m tape
- 1 x 50m tape
- Survey flags
- 0.5x0.5 lightweight quadrat
- DBH tape
- Compass
- Water for bolus test
- Ruler
- Rigid pole (e.g. dowel) marked at 1m and 1.3m
- Laser distance measure (e.g. DeWalt DW033)
- Collection bags and jewellers' tags or envelopes (plant specimens)
- Calico sample bags (soil)
- Shovel, trowel or soil core (6cm diameter x 10cm depth)
- First aid kit

OPTIONAL

- 1 x 100m tape
- Flagging tape
- Binoculars
- Small spirit level (for point-intercept tool)
- GPS (backup)
- Plant ID reference materials