SAVING OUR SPECIES

Saving our Species Monitoring, Evaluation and Reporting

Guidelines for conservation projects

Cover photo: Long nosed potoroo (*Potorous tridactylus*), potoroo trapping, Barren Grounds (Michael Van Ewijk/OEH)

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Introduction

The Saving our Species program (SoS) has a clear overarching objective: 'To maximise the number of threatened species and ecological communities that are secure in the wild in NSW for 100 years'. To evaluate the program against this objective, the Office of Environment and Heritage (OEH) has developed a comprehensive framework that:

- links investment in projects with their outcomes
- covers short-term, medium-term and long-term timeframes
- facilitates monitoring of projects and evaluation of program effectiveness and efficiency.

As part of this framework, there is a logic that describes the assumed outcomes of implementing species and ecological community conservation projects and the monitoring that needs to be done to test those assumptions (see Figure 1).

Monitoring, evaluation and reporting (MER) for conservation projects under SoS is informed by this logic and by the following guiding principles:

- transparency – values, decisions and priorities are clearly justified and communicated to all stakeholders and the community
- objectivity – decisions and priorities are based on consistently applying an evidence-based approach
- scientific rigour – the collection, analysis and use of data is rigorous and decisions are based on the best available evidence
- cost-effectiveness – investment decisions are based on maximising expected return in terms of outcomes, relative to cost
- adaptive learning – opportunities for learning that improves management effectiveness are taken wherever possible.

This framework also complements and will contribute to the broader OEH environmental monitoring, assessment and reporting program, including the Biodiversity Baseline Assessment.

The purpose of this document is to provide SoS stakeholders and those implementing SoS conservation projects with a consistent approach to MER. By following these guidelines:

- monitoring the outcomes of conservation management actions will be rigorous and effective
- evaluation of outcomes will be consistent and applicable at a range of scales
- reporting will be clear and meaningful to government and the community, given their substantial investment in threatened species conservation.

Under SoS, every threatened species is allocated to a management stream based on their ecology and management requirements. Threatened ecological communities are allocated to one of two different categories – 'range-restricted' or 'widespread'. Each management stream has a specific objective, performance indicators and a monitoring approach to ensure conservation projects achieve their objectives (see Table 1).

Irrespective of management stream, the primary focus of MER for SoS conservation projects is to evaluate the response of a species or ecological community to management at the site(s) of investment.

Having accurate data on the status of all threatened species and ecological communities across their NSW range would be ideal, but this is not realistic in a resource-limited environment. Therefore, in general, the scope of monitoring for conservation projects has been restricted to answering the question: ‘is the target species, ecological community, habitat or threat responding to conservation management as expected at focal sites?’ Reflecting this scope, this document is focused on MER for conservation projects wherever they target specific sites.

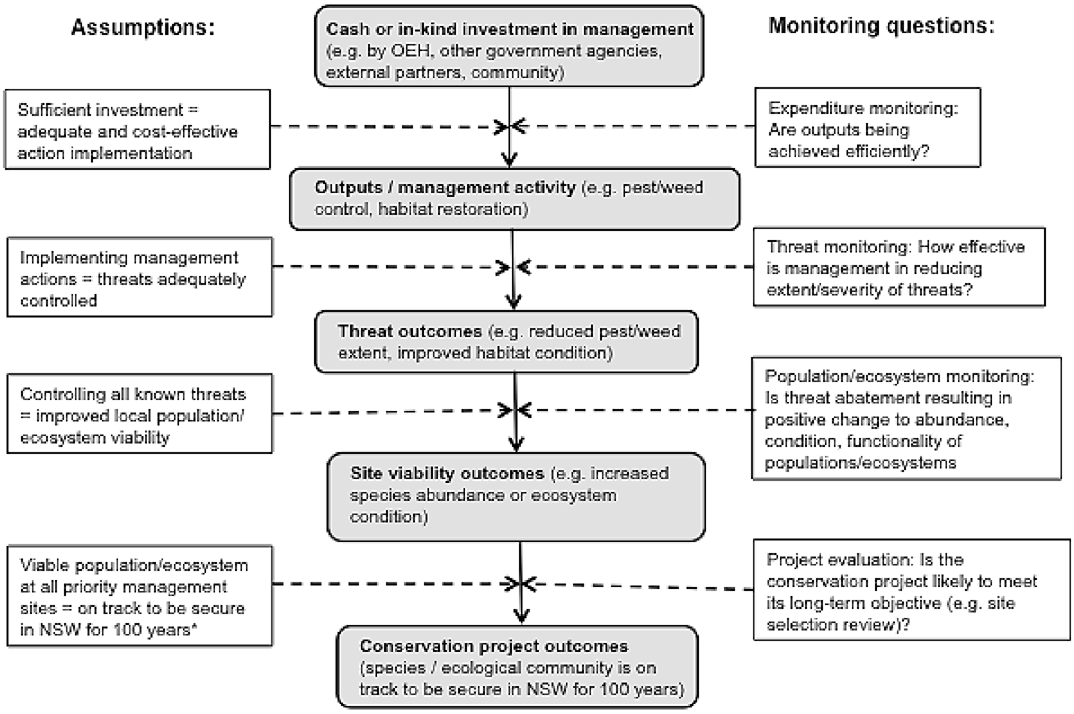

Figure 1 Logic guiding the site-based monitoring and evaluation of SoS conservation projects

*Includes the additional assumption that the selection of management sites is comprehensive and adequate (e.g. in terms of number, distribution and representativeness) to secure the species/TEC in the long-term.

Table 1 SoS management stream objectives, performance indicators and monitoring approach

BC Act = *Biodiversity Conservation Act 2016*; EPBC Act = *Environment Protection and Biodiversity Conservation Act 1999*.

Management stream	Management objective(s)	Performance indicator(s)	Monitoring approach
Site-managed	Maintain a 95% probability of having a viable population in the wild in 100 years (i.e. secure), and ensure that the species' status under the BC Act does not decline	Number of management sites where (sub)populations are responding as expected, and critical threats are being controlled	Targeted monitoring of population and threat outcomes at all management sites
Landscape-managed	To maximise the viability of the species and its habitat by strategically investing in priority locations and management actions and working in partnership with stakeholders across NSW	Proportion of species' habitat managed for conservation, number of important (sub)populations responding positively to management and having critical threats controlled	Desktop assessment of statewide indicators (e.g. proportion of habitat protected) and targeted monitoring of threats and populations at important sites
Iconic	Equivalent to either the site-managed or landscape-managed objective(s) as appropriate	Equivalent to either the site-managed or landscape-managed performance indicators, as appropriate	Equivalent to either the site-managed or landscape-managed monitoring approach, as appropriate
Data-deficient	Address critical knowledge gaps with respect to the species' ecology and threats, allowing for the development of an effective conservation project	Species' reallocation from the data-deficient stream to another stream (e.g. site-managed) based on improved knowledge informing development of a conservation project	Targeted survey/monitoring as appropriate to address critical knowledge gaps
Partnership (range-restricted & widespread)	To secure strategically important populations of the species in NSW	Number of important (sub)populations responding to management as expected, and critical threats are being controlled	Targeted monitoring of populations and threats at management sites (working in consultation with relevant partner jurisdictions also managing the species)
Keep watch	Species is secure or on track to be secure in NSW for 100 years without ongoing targeted investment	Status and trend of key populations and threats to those populations across NSW	Risk-based prioritisation of population and threat monitoring to test assumptions about secure status

Management stream	Management objective(s)	Performance indicator(s)	Monitoring approach
Threatened Ecological Communities (range-restricted & widespread)	To maximise the viability of the TEC in NSW	Number of management sites where critical threats are being controlled and the TEC extent, biotic and abiotic components, processes and function are responding positively to management	Targeted monitoring of threats and indicators related to essential ecosystem elements at all management sites
Key Threatening Processes	Reduce the current and future impacts of Key threatening processes (KTPs) on priority biodiversity values, including threatened species and ecological integrity, in NSW	Improvement in knowledge and effectiveness of KTP management; reduction in KTP risk to biodiversity and ecological integrity; extent, severity and impacts of KTPs on high-value biodiversity assets	As per site-managed for biodiversity asset protection activities; as appropriate for other response types (see *SoS KTP Strategy*)

Monitoring, evaluation and reporting for Threatened Ecological Communities

Monitoring, evaluation and reporting of outcomes for Threatened Ecological Community (TEC) conservation projects under SoS will align broadly with the approach and principles outlined for species. However, given the significant differences to species and inherent complexities associated with ecological communities, additional specific guidance is required to ensure a consistent and rigorous approach to TEC MER across the program.

Ecological communities are naturally occurring collections of native plants and animals, their environment and the interactions between them, occupying particular locations. There are over 100 ecological communities listed as threatened in New South Wales on the Schedules of the *Biodiversity Conservation Act 2016*.

The criteria for assessing ecological communities as threatened (i.e. at risk of collapse in NSW) are closely aligned with those developed for the IUCN (International Union for. Conservation of Nature) Red List of Ecosystems (Bland *et al.* 2017). SoS conservation projects for TECs are divided into two categories; **range-restricted** (developed in a similar way to those for site-managed species, and **widespread** (similar to landscape species) (see the SoS *Threatened ecological communities strategy* for more detail)).

An important difference between TECs and species that has the potential to significantly influence management decisions, is uncertainty around the definition of the management unit. Species' taxonomies – with some exceptions – are generally agreed and stable through time and space, allowing management foci (i.e. populations/individuals) to be clearly delineated.

In contrast, TECs are defined by the NSW Scientific Committee via Scientific Determinations with some flexibility, to accommodate variation in observable characteristics (e.g. transitional states). This can lead to conflicting interpretations between various experts and managers. For the purposes of SoS (and these guidelines), a TEC will be defined – at any given point in time – by its SoS conservation project and its associated mapped management sites.

The viability (security from extinction) of a species in New South Wales is a function of the viability of a number of critical populations of that species across its NSW range. Similarly, the viability (security from collapse) of an ecological community in New South Wales is a function of the viability of a number of patches of that community across its NSW range. The key differences – in terms of monitoring and evaluating outcomes – are related to; the response variables selected for monitoring (i.e. indicators in lieu of species populations); how those indicators are measured; and how the indicators are evaluated and interpreted in relation to the viability of any given patch of ecological community.

Designing and implementing a rigorous TEC monitoring program that allows for meaningful evaluation of ecosystem viability and management response to inform decision-making is difficult (Keith *et al* 2017), but achievable if best practice is followed.

The guidance presented in this document is generally applicable to both species and TECs, with some elements specific to TECs (these sections are identified accordingly).

The International Union for. Conservation of Nature Red List approach

The IUCN (International Union for. Conservation of Nature) Red List of Ecosystems provides a suitable framework for linking the viability of ecological communities to 'essential elements' that explain variation in risk (Keith *et al* 2013), and in turn linking those elements to measurable indicators (Figure 2). By using this framework to inform monitoring, evaluation and reporting on outcomes, SoS TEC projects that adhere to a rigorous monitoring design should be able to demonstrate response to management in terms that align with the program's high-level objectives; i.e. maximising viability (long-term security from collapse) in New South Wales. Also, there is additional benefit in aligning with the global standard for ecosystem risk assessment.

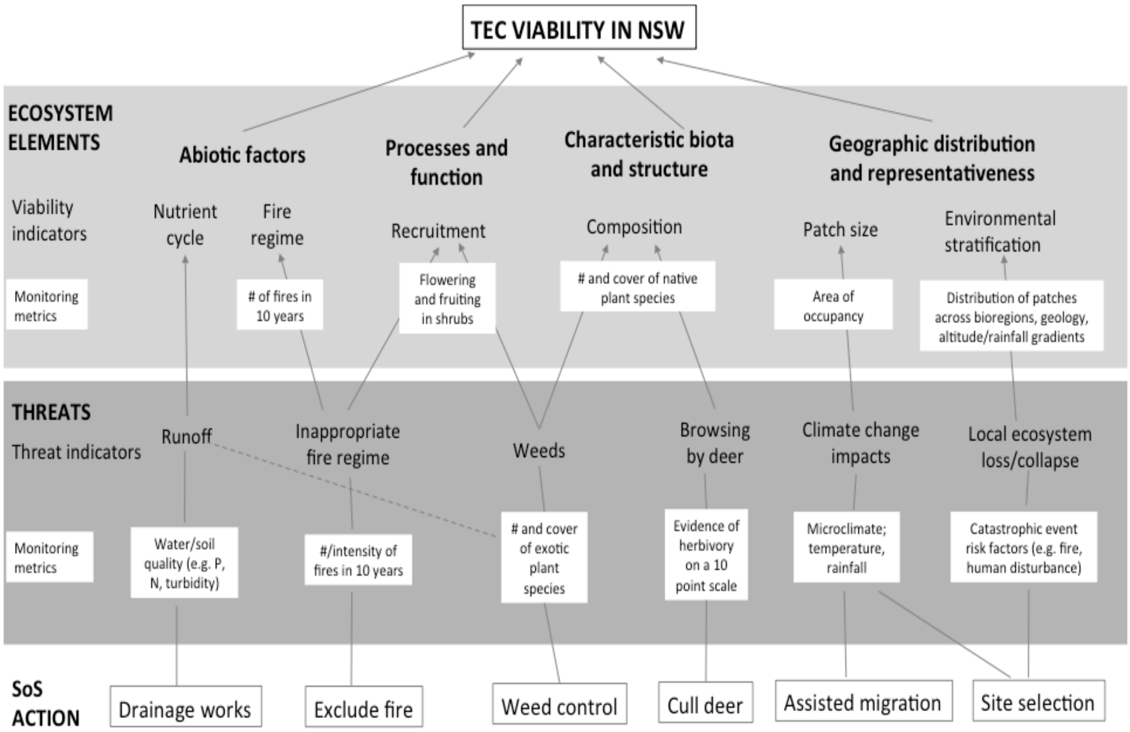

Figure 2 **Application of the IUCN Red List of Ecosystems theoretical framework to TEC monitoring under SoS. Indicators and monitoring metrics are examples only, for additional examples, see Keith *et al* 2013; Tables 4 and 5**

Monitoring

There are three main reasons for monitoring the outcome of conservation projects under SoS:

1. To provide evidence used to inform the community and government on the status of threatened species and ecological communities and how the implementation of conservation projects has affected this status.
2. To enable evaluation of the effectiveness of conservation projects and the return on investment in terms of time, budget and other resources.
3. To facilitate adaptive learning, thereby increasing ecological and operational knowledge that can be applied by all stakeholders in threatened species management.

Implementing site-based monitoring

The predominant method for collecting data to evaluate the effectiveness of SoS conservation projects is **site-based monitoring**. This type of monitoring is relevant for projects for species in the site-managed, landscape-managed, iconic and partnership management streams, as well for ecological communities. Monitoring should be designed to answer the questions posed in Figure 1; i.e.:

- Are outputs being achieved efficiently?
- How effective are conservation actions in reducing the extent and severity of threats?
- Is threat control leading to increased species survival, reproduction or population growth (i.e. population viability) or increased ecosystem extent, condition or function (i.e. ecosystem viability)?

Table 2 on the next page summarises the types of monitoring questions that SoS conservation project monitoring should be designed to answer, regarding each action, threat and species population/ecological community at a site, aligning with the logic described in Figure 1.

The first step in identifying specific indicators and metrics to monitor for a particular project should be the development of a process model. A process model is simply an explicit representation of our best understanding of the system – a predictive logic illustrating how the different elements (e.g. species, threats, environmental factors) interact with each other and are expected to respond to management and other disturbances (Rumpff *et al.* 2011; see Figure 3).

A process model can be used to inform the selection of appropriate indicators to answer the questions outlined in Table 2 (e.g. invasive species density, habitat condition). Once indicators have been selected, associated metrics can be identified, based on their cost-effectiveness, feasibility and sensitivity to change (e.g. goat density versus browsing index as potential metrics for an indicator of the threat of goats).

For species or threats that are cryptic, difficult or not cost-effective to monitor directly, the use of surrogates is recommended (e.g. habitat condition/extent). This may include the use of co-occurring species as indicators (e.g. monitoring 1-2 easily detectable species as indicators for multiple other species in the same assemblage). It is important that any surrogate used has been sufficiently validated (e.g. in a peer reviewed study), is ecologically defensible in the context, and is similarly sensitive to management as the target species.

Threat monitoring

The most important indicator of management success is ultimately the response of species populations (or ecosystem health/extent), however, monitoring the independent dynamics of threatening processes is also crucial for three main reasons:

1. Threats generally respond to management on a shorter timeframe than species populations or ecosystem health, which facilitates reporting on project outcomes more regularly (i.e. using the traffic light system under SoS (see Reporting)).
2. The shorter response time also provides an early warning system to trigger adaptive changes to management – if required – before impacts on species/ecosystems become severe.
3. Data on threat outcomes can provide important diagnostic information – e.g. if all identified critical threats are observed to be under control but population monitoring indicates continuing decline, this reveals a problem with our understanding of the system and should trigger a project review.

In some systems, disturbance may be an important process that promotes viability; a threat alters the disturbance regime in a way that reduces viability. Similarly, predation may be an inherent process that promotes viability, and a threat may change the predation dynamics. Threats should be monitored where they are critical for understanding viability of the population/ecosystem and/or are expected to change in response to management.

In some cases, indicators for threat outcomes may be indistinguishable from indicators of population/ecosystem viability (e.g. indicators of vegetation clearing impacts will be measures of spatial extent, distribution and/or connectivity, which are also fundamental characteristics of an ecological community). Ideally, however, the extent and severity of threatening processes should be measured independently of higher level indicators. This will allow for more rigorous evaluation of management effectiveness, by identifying the most important drivers of population viability and how they are responding to management.

Finally, some threats may not be meaningful to monitor because their impacts are self-evident (e.g. habitat loss due to development), however, an assessment of their status in terms of severity, extent or impact is still meaningful for reporting purposes.

The most important considerations are that the monitoring:

- can effectively answer the questions required (e.g. Table 2), based on the stated objective of monitoring for a project
- considers the characteristics of the species, ecological community, site or threat
- methods are scientifically rigorous.

The checklist on the next page describes all steps that must be taken when planning a conservation project to ensure monitoring is relevant and meaningful.

MER design and implementation checklist for SoS conservation projects

This checklist should be used when planning to implement a SoS conservation project, to ensure that the MER aligns with the SoS framework and will deliver meaningful data.

1. Review the project and clearly identify the target species or ecological community, the threats to be managed on each site and the number of sites to be monitored.	❑
2. Identify all active project partners and ways in which information on expenditure and outcomes will be collected and managed.	❑
3. Confirm the guiding objective of the monitoring program, based on the level of uncertainty in the system – i.e. simple monitoring to report status and progress against targets or adaptive management approach focusing on learning about the system (see page 10).	❑
4. Develop a process model of the system (i.e. predictive logic illustrating how the different elements (e.g. species, threats, environmental factors) interact with each other and are expected to respond to management) (see page 10).	❑
5. Based on the process model, select indicators for each threat and population/ecosystem-level outcomes, and appropriate monitoring metrics.	❑
6. Determine the most appropriate and cost-effective method – i.e. sampling design, effort, frequency – for detecting change in response to management, for each of the chosen indicators. If the design is complex or takes an adaptive management approach, consult with a statistician or biometrician.	❑
7. Based on the process model and relevant data and expert opinion on the system, develop predicted response to management curves for each indicator, and from those curves derive annual and long-term targets (see page 18).	❑
8. Write a monitoring plan for the project, including all the information above and following the guidelines and template provided at Appendix B. Have the monitoring plan peer reviewed by an appropriate person and save the final version in the *Documentation* section of the conservation project in the SoS database.	❑
9. Implement the monitoring regime, regularly reviewing the methods and adaptively changing as appropriate (while ensuring that changes do not reduce the integrity of long-term datasets).	❑

Table 2 Summary of conservation project monitoring methods and objectives and targets

What is to be monitored and in what timeframe	Monitoring question	Monitoring metric examples	Objective	Example of outcome targets	
				Annual	Long-term (ultimate)
Activity/output (short-term)	What is the quantity of each output produced?	Various (e.g. number of hectares or kilometres to be restored, number of days spent on project)	Outputs are sufficient to address threats	8 hectares of habitat restored	2 hectares of habitat restored annually from year 5 of project onwards
Threat (medium-term)	What is the local severity, extent or impact on species/ecosystem viability?	Density of pests or weeds, species survival, salinity or soil moisture	The severity and extent of the threat is reduced to a level at which species populations can survive/reproduce and ecosystems can function adequately	Reduce area of high-density weed occupancy to less than 20 hectares	Reduce area of high-density weed occupancy to less than one hectare within 10 years
Site/population (long-term)	What is the size, extent, condition or functionality of the species (sub) population or ecological community at the site?	Species abundance, demography, or habitat condition; viability indicators for ecological communities (see Fig. 2)	Species (sub)population trend or ecosystem viability indicators at the site are stable or increasing	Increase population to more than 50 mature stems and more than 100 recruits; increase functioning community patch size to 30ha	Increase population to more than 250 mature stems within 20 years; increase functioning community patch size to 100ha within 20 years
Project	How many management sites have viable species populations or ecosystems?	Aggregate assessment of each site's viability based on all indicators	Species is secure in the wild in NSW for 100 years	All sites are on track to be secure – i.e. populations/ecosystem indicators are responding as expected to management	All sites are secure without ongoing management within 20 years

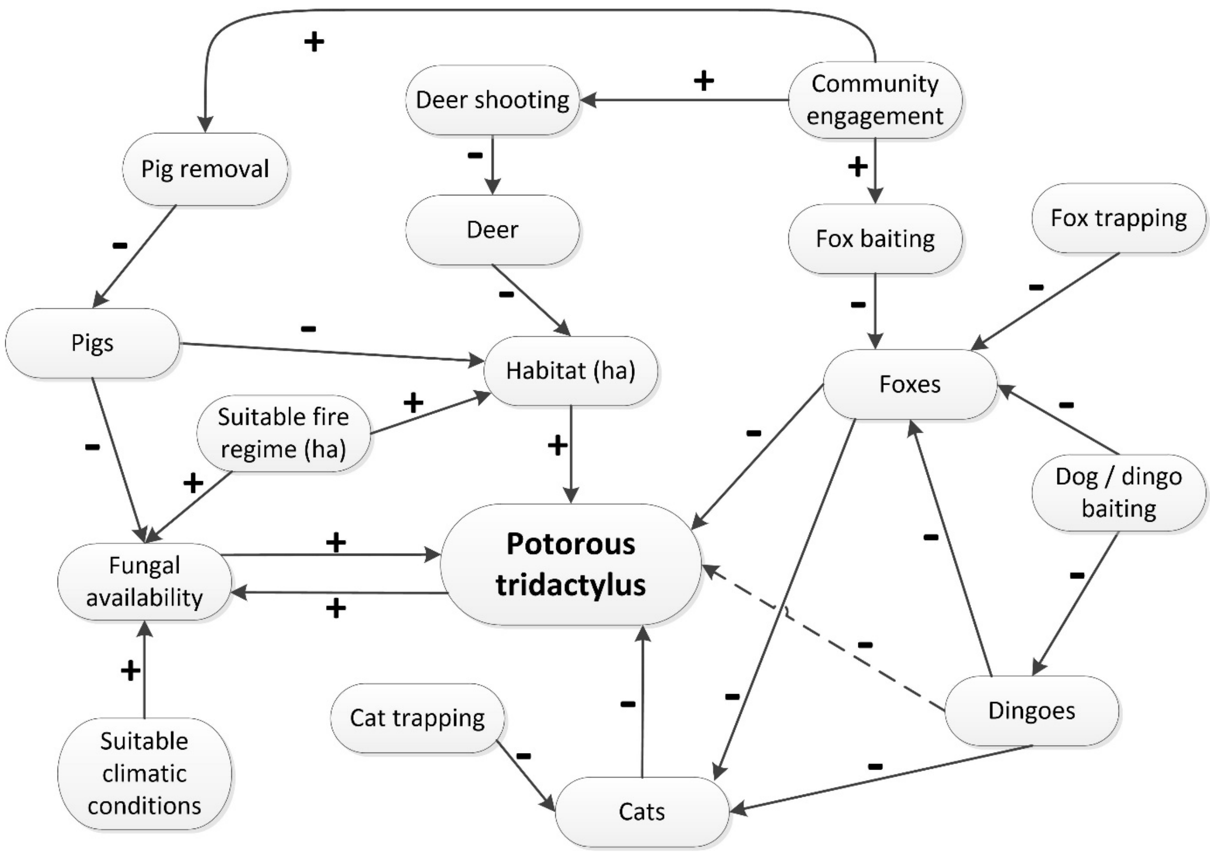

Figure 3 An example process model for the Long-nosed potoroo (*Potorous tridactylus*)
Arrows indicate interactions between different elements and +/- symbols indicate the predicted effect of an increase (in abundance/intensity) in the element at the arrow's origin on the element at the arrow's destination. More complex models may encode each link with additional information about the strength of the relationship, associated uncertainty and/or whether particular drivers are manageable or not. Documentation of assumptions and definitions (not shown here) is also integral to the model.

Decisions about which particular indicators and metrics to use are made by those responsible for project management (i.e. Project Coordinators), informed by the ecological characteristics of the species or ecosystem in question. Monitoring regimes must balance the trade-off between rigour and cost – i.e. the design should be sufficient to answer the monitoring questions outlined in Table 2 adequately while minimising cost.

Where there is uncertainty about which drivers determine population or ecosystem viability, or which threats are the most critical to manage (this should be evident when developing the process model), monitoring may take an adaptive management approach.

The decision of whether or not to take an adaptive management approach is a significant one, as it will influence the design (and cost) of the entire monitoring regime. Therefore, the broader objective of monitoring (i.e. simply monitoring outcomes to report on status and management effectiveness and track progress against targets, versus adopting an adaptive management approach to learn about the system and resolve critical uncertainties inhibiting effective management) should be stated clearly at the beginning of every conservation project monitoring plan (see Appendix B).

When to use adaptive management

The process of evaluating conservation project outcomes should inform project planning on a regular basis, even if learning about the species, ecosystem or threats is a secondary objective of monitoring (McCarthy & Possingham 2007).

For most conservation projects this will involve implementing a single management approach based on the best available information, monitoring the outcomes of that approach at priority management sites only (i.e. without control sites), and evaluating those outcomes carefully to inform adaptive changes. This may be the most appropriate monitoring regime for several reasons; e.g. the species' distribution is so restricted that control or replicate sites are simply not available, or the system is well understood and an effective management approach has been demonstrated, so there is little value in additional learning. Primarily, though, adaptive management comes at a cost premium – either financial (e.g. additional monitoring of control sites, replication) or via foregone conservation outcomes (e.g. impacts at non-treatment sites, reduced efficacy of sub-optimal techniques).

These additional costs reduce opportunities for investment in other conservation projects under SoS, which seeks to maximise outcomes across all threatened species and ecological communities. Therefore, adaptive management should proceed only where the likely benefits outweigh the cost.

An active adaptive management approach is recommended wherever there is high uncertainty in the system under management. This uncertainty may be related:

- i to the basic ecology of the system (i.e. what are the important environmental drivers, what are the dynamics of processes like competition and predation)
- ii the relative effectiveness of different threat-abatement techniques (e.g. mechanical versus chemical weed control)
- iii the effects of threat-abatement on the focal species or ecosystems.

If/where this uncertainty is inhibiting effective management or reducing confidence in the value of management investment, an approach should be adopted consistent with the OEH adaptive management position statement. This is particularly important if the proposed expenditure on management is high over the foreseeable future, given the increased risk of this investment cost outweighing the associated benefits.

When designing an adaptive management program, it is recommended that advice is sought from a statistician or biometrician or a manager with experience in applying successful adaptive management on the ground. This is to ensure that the design is sufficiently rigorous and powerful enough to answer the questions it is required to.

Scale of monitoring

The spatial scale of any SoS monitoring program should be determined by the scale of the associated conservation project (i.e. size, number and distribution of management sites), which may be different to the total range of the species/TEC in New South Wales.

In some instances, it may be appropriate to measure particular indicators at a scale that differs to the target management site (e.g. environmental water availability at the catchment scale). Within sites, the size, density and distribution of sampling units (e.g. vegetation survey plots) should be sufficient to capture variation across relevant environmental (e.g. edaphic, altitudinal, disturbance) gradients, randomised where possible and in fixed locations (e.g. permanent plots) to allow repeat observations through time, where possible (Lindenmayer *et al* 2015).

Monitoring of control sites (without management and/or without threatening processes) is recommended under an adaptive management approach – but may not be feasible or cost-effective for all projects (McDonald *et al* 2016).

The frequency of monitoring is not prescribed but should be based on the expected rate of change of populations or TEC indicators, species' life-histories, disturbance regime and/or threat dynamics, as appropriate.

Under SoS annual reporting on outcomes is required, however, the traffic light system allows for reporting on the status of indicators that are measured less frequently (see *Reporting*). Also, monitoring frequency may not be consistent across all indicators – e.g. invasive species density may require annual monitoring, while patch size may change on a decadal timescale so can be monitored less frequently – and for some indicators may not be required at all (e.g., if the system has come to an equilibrium or a threat, has been effectively abated; Hooper *et al* 2016).

Attempts should be made to ensure that the frequency and timing (e.g. season) of monitoring particular indicators remains consistent through time to maximise the integrity of longitudinal data (Lindenmayer *et al* 2015), however, monitoring regimes should also be flexible enough to measure responses to stochastic disturbance events as appropriate (e.g. immediate and more frequent post-fire monitoring).

Monitoring threatened ecological communities

The principles guiding monitoring of threatened ecological community projects under SoS are identical to those for species, with a few exceptions. As with species projects, monitoring should be designed to test each assumption in the program logic (i.e. to detect indicator change and compare observed change with predicted; Figure 1). Monitoring of expenditure, outputs and threat outcomes remains the same.

Monitoring of populations is replaced by monitoring indicators related to the four essential ecosystem elements contributing to viability (Figure 2). These four elements describe and categorise the attributes of TECs that are susceptible to degradation by threats, which are also sensitive to management intervention. Therefore, assessing aggregate change in these elements via appropriate indicators informs evaluation of the state and change in a TEC's long-term viability (risk of collapse). Ideally, at least one indicator for each element should be monitored as part of all TEC monitoring programs.

The four elements include:

1. **Geographic distribution/representativeness** – this refers to both the management site scale (i.e. patch size, area of occupancy, fragmentation) as well as the landscape (entire TEC project) scale (i.e. extent of occurrence, number and location of management sites, stratification of sites across the community's known environmental space). The importance of maximising ecosystem extent, minimising fragmentation and maximising the number of disjunct 'locations' (Bland *et al.* 2017) is well documented. Stratification across environmental space (i.e. representativeness) could be based on bioregions, latitude, altitude, edaphic/geological variation, temperature/rainfall gradients or some sort of multivariate composition, as appropriate. This is an important contributor to long-term viability because maximising representation is likely to maximise genetic variation, which subsequently maximises adaptive capacity (particularly important under climate change). In practice, this element should be addressed primarily by the selection and definition of management sites as part of project development. However, TEC extent and number and size of patches are likely to be important indicators, which should be assessed in the context of representativeness (e.g. if a particular patch of TEC is lost, did it represent unique floristic variation, how has that affected total extant diversity?) Such indicators are unlikely to change significantly in the short-term;

however, they are important to monitor for the purposes of assessing status, informing risk-based management decisions and documenting long-term change.

2. **Characteristic biota and structure** – this refers to the living attributes that are critical to the viability of the TEC; including species composition, diversity, functionally important species and vegetation structure. These are often the indicators that are most likely to be affected by threats and are most likely to change in response to SoS management.
3. **Processes and function** – this refers to interactions between living components and between living and non-living components of the system that are crucial to sustaining the TEC in the long-term. These may include pollination, recruitment, competition, succession, trophic cascades and hydrological processes. These types of indicators are likely to be affected by changes in disturbance regimes (e.g. fire).
4. **Abiotic factors** – these are the non-living attributes or processes that are critical to viability of the TEC. Examples include fire regime, hydrological regime, rainfall or nutrient cycling. Although these types of indicators may not change over short timeframes, monitoring is important, particularly for those factors that are likely to be impacted or disrupted by known threats (e.g. human-induced disturbance to natural flow regimes).

TEC monitoring design and indicator selection

The design of the monitoring component of a TEC project under SoS should be based on an ecosystem risk assessment (Keith 2015 and references therein) and a conceptual/process model of the system (Rumpff *et al* 2011; see Burns *et al* 2015; Figure 3). The risk assessment may not necessarily be a formal assessment but should involve a systematic diagnosis of the key drivers of the system – including threatening processes – and how they relate to the essential elements outlined above. This process can inform the development of an explicit conceptual model, which can subsequently be used to select the most appropriate indicators and metrics.

Monitoring design – in terms of method, spatial scale, replication, frequency and precision – should consider:

- repeatability of methods and potential for observer bias (Gorrod *et al* 2013)
- stratification across all different domains of interest (e.g. land tenure, threatening processes) (Keith *et al* 2017)
- if using multi-metric ‘condition’ or ‘integrity’ indices, their appropriateness and relationship to indicators that are of ultimate interest for evaluation purposes (Lamb *et al* 2009; Oliver *et al* 2014; Brown & Williams 2016)
- whether there is sufficient statistical power to detect change/management response (Magurran *et al* 2010)
- if using surrogates, the validity of those surrogates for representing biodiversity or other indicators of interest (Lindenmayer & Likens 2011; Westgate *et al* 2017)
- opportunities for maximising cost-efficiency by cost-sharing with or contributing to other projects (e.g. monitoring co-occurring populations of threatened species or threatening processes relevant to multiple projects)

On-ground methods

Wherever possible it is important that SoS contributes to statewide data sets to enhance their coverage and utility, and to maximise the benefits associated with SoS investment. Therefore, if/where SoS TEC monitoring regimes include plot-based measures, it is recommended that the methods employed for collection, interpretation and storage of these data are aligned with other statewide OEH programs undertaking site-based vegetation assessment (e.g. biodiversity offsets and private land conservation under the Biodiversity Conservation Trust). Specifically, following the *Biodiversity Assessment Method* (OEH 2017), if/where it is feasible to do so without compromising data quality or cost-effectiveness.

Ensuring scientific rigour and best practice governance

For monitoring data to be useful and reliable, it is important that all monitoring be scientifically rigorous. OEH's standards for scientific rigour are articulated in the Scientific Rigour Position Statement, which states that scientific activities such as monitoring should have 'appropriate design… ensuring the people involved have relevant skills and experience' and 'peer review of the design before implementation'.

The governance framework for SoS conservation projects (available to project stakeholders via the Help menu in the SoS database) will help to ensure that monitoring protocols are rigorous by:

- having project coordinators, in consultation with relevant species experts, design individual monitoring plans that are species, TEC and site-specific
- having monitoring plans peer reviewed by appropriate colleagues or other species/threat management experts
- having the Species Technical Group (STG) review proposed monitoring plans for projects receiving significant funding (i.e. >$50,000 p.a.).

In addition, the following principles have been developed to guide the design of monitoring methods and ensure a level of standardisation if and where feasible:

- monitoring questions must be clearly defined and linked to the management objective/s, i.e. how is the species or threat responding to management
- the factors to be monitored must be clearly defined (e.g. proportion of sampling points where the species was detected on camera over a one-week sampling interval, number of breeding pairs recorded annually) and demonstrably related to the species or threat being monitored, e.g. distribution or abundance
- where feasible and appropriate, monitoring should have sufficient statistical power to detect meaningful change, e.g. the capacity to differentiate between a declining, stable or increasing population within an appropriate timeframe (Mahon et al*.* 2011)
- detectability of a trend or response to management should be proportionate to the cost, and this cost-effectiveness should be comparable with other projects, i.e. if the cost of achieving sufficient statistical power is much more than for monitoring similar species or habitats, the method should be revised to require less investment (e.g. to measuring a less expensive surrogate)
- spatial sampling should be representative of management sites, avoiding sampling bias (e.g. roads or specific tenures) wherever possible – explicitly reporting any unavoidable biases
- there are pre-treatment or baseline data for comparison, control sites, or a clear conceptual model against which to evaluate outcomes
- there are clearly articulated triggers for management to respond to monitoring results
- if some of, or all, the above cannot be met, this is offset by significant community engagement or citizen science benefits.

The role of the STG will be to review proposed monitoring methods against the above principles to ensure that they are appropriate (particularly for species receiving significant investment), that they are equivalent for similar species and ecological communities, and that all investment in monitoring activities is cost-effective (i.e. sufficient but not in excess of what is required to meet the objectives).

Seeking consistency between monitoring methods across the program, if and where appropriate, will ensure that data on the outcomes and effectiveness of managing particular threats can be aggregated to answer broader questions in a meaningful way (e.g. is fox control via ground baiting effective for reducing predation in a particular habitat type?).

When statewide surveillance monitoring is justified

Evaluating outcomes across a large area is challenging due to the:

- effort involved in monitoring
- variability in habitat features and tenure (i.e. land that is privately or publicly-owned)
- high uncertainty in species occurrence and distribution
- uncertainty regarding severity and presence of threats.

Therefore, it is generally not cost-effective to monitor and evaluate the status of species, TECs or threats everywhere they occur. Instead, monitoring should be targeted to where it is likely to return the most useful data for the least investment.

In practice, this means that most monitoring should focus on assessing the effectiveness of management and the status of local populations at specific sites.

Monitoring a landscape-managed species' population or a widespread TEC across its entire NSW geographic range may be justified where:

- complementarity with existing monitoring frameworks makes it cost-effective
- loss of extent is a known, ongoing critical threat
- a species' NSW range is known to represent a single, connected population.

This work will strongly tie to broader OEH environmental monitoring, assessment and reporting (e.g. BBA). The most cost-effective method for assessing the status of species, population sizes or habitat extent and condition across NSW may be to use large existing databases such as those held by Birdlife Australia or WildCount, or use modelling approaches with remotely-sensed data, as long as these approaches are sufficiently tested, and interpreted with proper consideration of their limitations.

Evaluation

Using predicted response to management curves

As stated in the introduction, the key evaluation question for all SoS conservation projects is: ‘is the target species, ecological community, habitat or threat responding to conservation management as expected at focal sites?’

The first part of the question refers to outcomes on the ground, i.e. population, ecosystem and threat responses to management, which is what a monitoring program should be designed to measure. While it is important to understand the status of and change over time in populations and threats, the only way to properly evaluate effectiveness is by comparison with a reference or target state (i.e. the ‘as expected’ part of the question above) (Burgman *et al.* 2012). Such targets – to inform evaluation of outcomes – can be derived from ‘predicted response to management curves’ which can themselves be derived from a process model (see Figure 3).

Predicted response to management curves is another type of conceptual model, which represent our understanding of how specific populations, ecosystems or threats are expected to change over time in response to management (see Figure 4). As these curves predict continuous change in an indicator (e.g. population size) from the present to some future point, indicator values predicted for any given time step (e.g. 1 year, 5 years, 20 years) can be used as targets.

These targets can then be compared to observed values (i.e. monitoring data) to evaluate progress. This provides a more relevant evaluation than simply assessing whether the indicator is stable or improving – it allows for an assessment of whether the indicator is ‘on track’ to meet longer-term targets (according to current predictions).

Setting targets

Under SoS, annual and long-term targets are required to be set for species populations and ecosystem viability indicators (see below) as well as for each threat under management, at every management site. Long-term targets for populations and ecosystems should be based on what is considered ‘viable’ at a site; i.e. for populations (see below for TECs):

- the size of the population is sufficient to avoid demographic problems
- the population is stable or growing
- there is sufficient available habitat for the population to persist.

This allows for aggregation of site-level outcomes to determine the number of projects that are ‘on track’ to be secure in New South Wales (i.e. all management sites meeting annual targets), which can be further aggregated to evaluate progress towards the high-level program objective – maximising the number of species on track to be secure in New South Wales.

The predicted response to management curve should allow for the derivation of annual targets each year as outcomes progress towards the long-term target. Given the likely uncertainty associated with such predictions, targets should generally be expressed as a range of values that represent tolerances around the predicted values, rather than a single point.

The more highly variable the system (e.g. boom-bust habitats), the larger these tolerances should be. Then for any given year, if observed indicator values are within this target range, the population/TEC can be considered ‘on track’ to meet its long-term target (see Figure 4).

Long-term targets for each threat under management should be based on their respective impacts on the species' population or ecosystem viability – i.e. to what extent or by what level of severity must each threat be reduced so that its impacts on the species/TEC do not prevent it from reaching its long-term target (i.e. viability) at the site. The development of such targets and response curves relies on a relatively good understanding of the ecology of species and their threats, which in many cases is absent.

For those systems where relevant data and knowledge are limited, quantitative indicators and targets may not be appropriate. Instead, more qualitative, precursor targets (e.g. ‘develop an understanding of species’ population growth rate and site carrying capacity’ or ‘quantify maximum browsing intensity required for recruitment and persistence’). Or, if the system or site is very data poor, multiple years of baseline data collection without target-setting or reporting outcomes may be required to build an evidence base for proper evaluation.

Under SoS project outcomes are evaluated annually (not all indicators are necessary to monitor annually, however). If any indicator is assessed as being outside of the target range (i.e. not on track), this should trigger a project review.

If the reason for the project’s ineffectiveness is clear (e.g. inadequate resources or effort, or unfavourable environmental conditions), the project should be changed accordingly, following the SoS governance framework.

If the reason is unclear, an adaptive management approach should be taken in consultation with the relevant species experts.

Evaluation for Threatened Ecological Communities

As with species projects, evaluation of management outcomes for TECs is based on indicator-specific targets, which are derived from a process model and response to management curves (see Figures 3 and 4). For each of the viability indicators and threats identified in the process model, it should be possible to quantify: current values of the monitoring metrics, as well as short- and long-term targets based on the concept of a viable patch of the TEC.

The conventional approach to setting such targets, recommended by the *National standards for the practice of ecological restoration in Australia* (McDonald *et al* 2016) and employed by *Biodiversity Assessment Method* (OEH 2017) is to use a reference or benchmark ecosystem (i.e. an example of the ecological community that has not been subject to degradation and is not impacted by any threatening processes; e.g. pre-1750 condition) (Noting that benchmarks under the BAM are based on Keith vegetation classes (Keith 2004), not Plant Community Type (PCT) and neither system has a one-to-one relationship with TECs. Appropriate benchmarks may be sourced or generated from the BioNet Vegetation Information System (VIS) if appropriate data are available).

Once a suitable local indigenous reference ecosystem has been identified, current values for particular indicators (particularly structural and functional) can be adopted as long-term targets for those indicators in the TEC under management.

Targets related to ecosystem extent should generally be developed with reference to IUCN Red List thresholds associated with acceptable levels of risk and/or other appropriate scientific literature (e.g. Bender *et al* 1998; Keith *et al* 2013). See McDonald *et al* (2016), Appendix 4 for a list of example indicators and associated targets (objectives).

Once long-term targets have been developed for all threat indicators and indicators relating to each of the four essential ecosystem elements, the final step is to estimate the shape of the expected response to management curve (simplest being linear) and the tolerances within which the indicator can be considered ‘on track’ to meet the long-term target (see Figure 4).

It is important that these tolerances are designed to accommodate expected inter-annual variation in environmental conditions (particularly in ‘boom-bust’ systems). At each evaluation step (generally annual), any indicator observed to be outside of set tolerances provides a trigger to diagnose the cause, then review and update management as appropriate.

The response may be to take a more experimental (active adaptive management) approach to management and monitoring if the cause is unclear or there is more uncertainty in the conceptual model than previously thought.

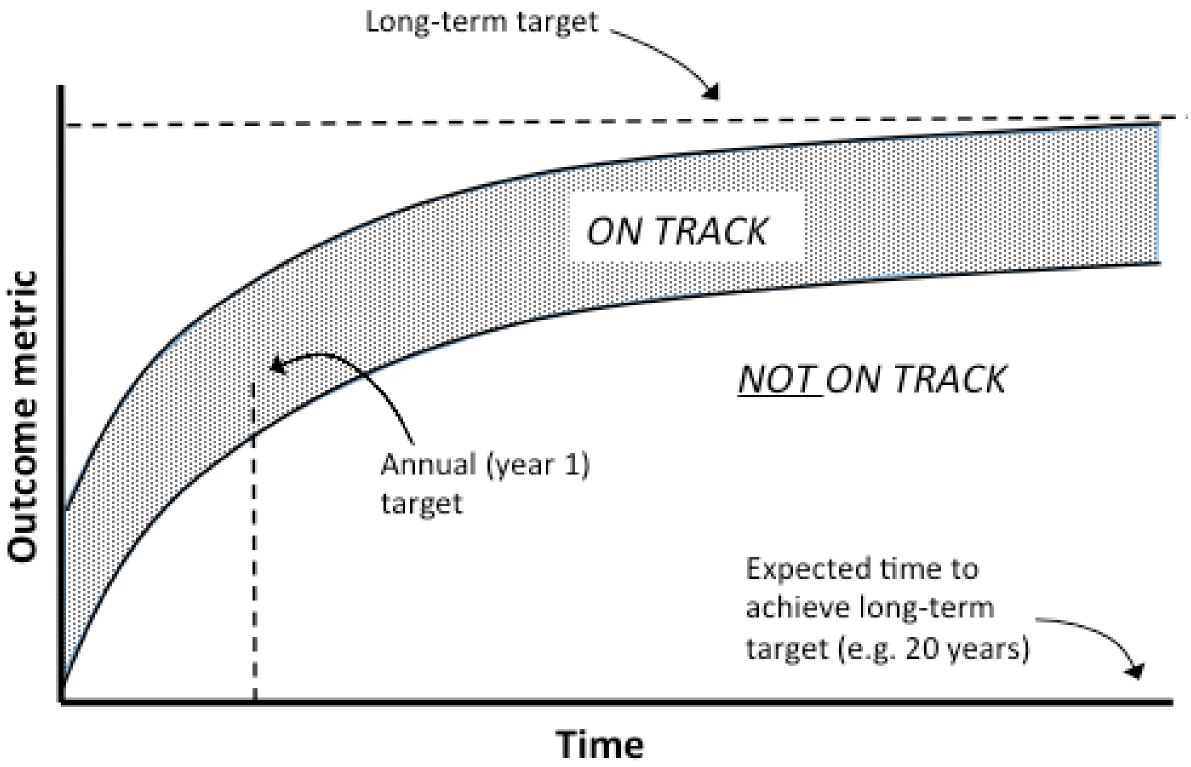

Figure 4 Generic predicted response to management curve, showing scenarios where the project is on track and not on track to meet its annual and long-term objectives

Benefit, success and cost in project prioritisation

An important function of evaluation in SoS conservation projects is to improve the reliability of the cost-effective prioritisation of projects over time. All site-managed projects are prioritised based on a score calculated from their benefit to the species, their likelihood of success and their cost (see the *Saving our Species Technical Report* for more detail).

These three factors are estimated by experts with a significant level of uncertainty. By monitoring project outcomes, each factor, informed by these data, can be more reliably calculated, producing a more accurate project priority score. This is particularly the case for likelihood of success and cost, in the short-term.

It is more difficult to incorporate how well a project is responding to management into the prioritisation of projects for investment. There is likely to be variation between projects assessed as being on track (e.g. a project responding quickly or strongly to management should be favoured over one responding slowly or weakly to management, all else being equal). This is particularly important when making decisions about when to cease investment in an action or project. Any such decision should consider:

- whether appropriate time has been allowed to evaluate the response to management (Ng *et al.* 2014)
- whether the monitoring is sufficient to detect a response (Gerber et al*.* 2005)
- how much is being invested?

Having a technically focused group with broad oversight of the program (STG) helps to meet this challenge.

Reporting

Saving our Species traffic light system

A primary purpose of monitoring and evaluating project outcomes under SoS is to report those outcomes to Government and the community in a transparent, objective and meaningful way. Outcomes of individual projects are reported annually to the wider community through species annual report cards. Annual report cards outline, for each project:

- What was the total investment in the project and who were the investors and other partners?
- Which threats are under control or on track to be under control at management sites?
- Which management sites have populations that are secure or on track to be secure?
- Is the project on track to secure the species in NSW for 100 years?

Table 3 Summary of the SoS traffic light reporting framework. A separate traffic light is applied to each threat at each management site as well as the population or TEC viability indicator(s)

Reported status	Interpretation
Outcomes	
Dark green light	Annual target has been met – i.e. the outcome metric(s) has been measured and is within the acceptable range to be on track to meet the long-term target.
Light green light	No monitoring data are available this year, but intermediate (e.g. threat) indicators have met annual targets – i.e. are within acceptable ranges or on track to meet their long-term objectives.
Amber light	No monitoring data are available this year, but intermediate (e.g. threat) indicators have not met annual targets – i.e. are outside acceptable ranges or are not on track for meeting their long-term objectives.
Red light	Annual target has not been met – i.e. the outcome metric has been measured and is outside the acceptable range or is not on track for meeting the long-term objective.
Confidence	
High	The monitoring method is scientifically rigorous and includes a direct, quantitative measure of the outcome metric using a statistically powerful design.
Moderate	The monitoring method is relatively robust but may use a qualitative measure or surrogate. The species or threat may be highly variable or cryptic, leading to inconsistent results.
Low	The monitoring method is ad-hoc or highly subjective (e.g. simple estimate).

The reporting methodology uses outcome monitoring data in a way that allows for reporting on every active project annually, irrespective of the response timeframes associated with the particular species or TEC (see Table 3 and Appendix A).

The method allocates a traffic light for the species population or ecosystem annually, as well as each threat under management at every management site. For any given year at any given site, if outcomes for population or ecosystem viability have been reported, the site will be allocated either a ‘dark green’ (on track) or ‘red’ (not on track) status based on assessment against the relevant target(s).

If monitoring results are not available/reported (e.g. population monitoring is not annual, poor conditions have prevented monitoring), then either a ‘light green’ (inferred on track) or amber (inferred not on track) status will be applied, based on assessment of threat outcomes against respective threat targets (see Appendix A). This reasoning is based on the assumptions articulated in Figure 1; i.e. that if all threats at a site are being controlled, the species' population is likely to be responding positively, but the positive status is reported with slightly lower confidence without a direct measure (i.e. ‘light green’ versus ‘dark green’).

There are various justifiable reasons why monitoring data may not be available (or reportable) for a particular indicator in any given year, e.g. planned monitoring frequency is less frequent than annual because the species responds over a longer timeframe (e.g. long-lived trees); species detection relies on favourable environmental conditions (e.g. rainfall); or preliminary data collection to establish a baseline to inform target-setting is required in the initial few years of a project.

For site-managed and iconic species and range-restricted TECs, site-level traffic lights are aggregated to report a project level traffic light. For a project to be allocated a ‘dark green’ traffic light (i.e. the project is on track to be secure in New South Wales for 100 years), all management sites must have a ‘dark green’ status (based on the assumption that the identified set of management sites represents the minimum required to meet the project objective).

If there is at least one site with a ‘red’ status, the project will be allocated a ‘red’ traffic light, with intermediate statuses – ‘light green’ or ‘amber’ – applied based on the poorest status of any site in the project (see Appendix A).

For landscape species and widespread TECs traffic lights are not aggregated above the site-level because the number of sites under management is not determined via a strategic process to meet a standard objective. Rather, it is determined by stakeholder capacity and available knowledge of important investment locations. Consequently, there is variability in the number of sites/extent of active management for each project and the extent to which total investment is ‘adequate’ to meet an objective equivalent to site-managed species. This prohibits meaningful reporting of status at the NSW scale.

Ensuring that these data are communicated transparently also requires a methodology for reporting on the **confidence** associated with evaluating outcomes. For example, consider a comparison of two projects; one with a statistically powerful monitoring program allowing for detection of a significant response to management through quantitative data analysis, the other with a monitoring program based on qualitative estimates of habitat condition and the manager’s subjective assessment that values have improved over time. Both projects could be reported as being on track to meet their respective objectives, although a significantly higher level of confidence would be attributed to the former scenario.

Table 3 outlines how confidence is assessed, based on the rigour of the monitoring method (see Appendix A for more detail).

Reporting on Threatened Ecological Communities

Reporting on the outcomes of TEC management will be via the traffic light system outlined above, the only difference being the method for aggregating the assessment of indicators at a management site to report on a single site-level status. Where species will generally have a single indicator informing the status (traffic light) at each site (e.g. population abundance), TECs will have at least four outcome measures (one for each of the four essential elements) contributing to the status assessment for each site.

The IUCN Red List of Ecosystems applies a conservative (precautionary) approach to aggregating risk assessment across multiple criteria, by applying a threat status to the ecosystem equivalent to the highest risk status attributed for any single criterion.

Adopting a similar logic, SoS TEC projects will evaluate and report status at the site-level based on the poorest outcome for any single 'site-level' indicator – i.e. to evaluate and report a TEC site as 'dark green' (on track to being secure in the long-term), **all** (minimum 4) site-level indicators must have met their respective annual targets.

If one or more indicators have not met their annual target, the site status will be reported as 'red'.

As with species project reporting, the traffic light system allows for annual reporting on-site status in the absence of data for particular indicators in a given year. For example, if one or more site-level indicators have not been measured, but all threat indicators have been measured and met annual targets, then the site status is reported as 'light green' (i.e. based on the measured severity and extent of threatening processes, the ecosystem at the site is inferred to be on track to viability, with somewhat less certainty).

Note that the inference of the TEC being on track to be viable in the long-term in New South Wales, based on measured outcomes at a number of management sites, rests on the assumption that the SoS TEC conservation project (i.e. number, size and distribution of sites) has been designed explicitly to meet this objective.

Any critical uncertainty about this assumption, or changes (e.g. emerging threats, climate change) that affect this assumption, should be addressed through reviewing and updating the project design on a regular (annual) basis.

Using the Saving our Species database

The SoS database (SoSDB) is the repository of all information and data relating to SoS conservation projects, e.g. management actions, site maps, prioritisation data, demographic data, species expert information and associated documents.

The SoSDB is web-enabled and designed to allow any stakeholder to access and edit data as appropriate for their level of engagement in the program.

The structure of SoSDB and its permissions is hierarchical, with many different user roles:

- the project coordinator can read, write and edit all data for a particular project
- the site manager can read, write and edit all data for a particular management site
- the action implementer can read, write and edit all data for a particular management action
- the species expert can only read data on a particular project or species
- the interested party can only read data on a particular management site.

The SoSDB contains details of priority management sites and actions for every site-managed, iconic species and TEC conservation project, and landscape-managed, partnership and KTP projects where relevant.

The outcomes of implementing these projects are reported annually through an action plan, in which project coordinators have identified the actions planned for implementation in any given financial year.

This action plan also includes annual targets for populations, ecosystem indicators and threats at each site. Proposed implementation activities/effort and targets are (ideally) identified during an annual planning phase at the beginning of each financial year.

Data corresponding to the monitoring questions in Table 2 must be entered into the SoSDB for each action in an action plan at the end of each financial year.

These data are relatively simple for management actions (i.e. relate to expenditure and implementation), while for population, TEC viability and threat monitoring, more quantitative data on outcomes and evaluation against annual targets is required (see Table 4).

The data are then summarised and interpreted using the traffic light system for reporting to government and the wider community via the annual species report cards.

Table 4 Summary of Saving our Species database monitoring results and outcome reporting fields (applicable to all population, threatened ecological communities and threat outcomes)

SoSDB reporting field	Explanation
What is the monitoring method?	Detailed description of the activities required to monitor the species, population or threat.
What monitoring metric is being used?	The specific variable being measured to assess each indicator relating to species populations, ecosystem viability or threat response to management.
What is the long-term target for the site?	The ultimate target for the population, ecosystem or threat, expressed as a value of the monitoring metric to be achieved within a stated timeframe, e.g. 300 breeding pairs in 5 years.
What is the target for this site for the financial year?	The annual target (acceptable range) derived from the response to management curve.
Was the monitoring conducted as planned for the financial year?	Yes/no; was the method and effort fully implemented this year?
Where is the data and analysis stored?	Location of monitoring data, e.g. data sheets, field notes, trend analyses, site reports (ideally saved in the SoSDB project documentation area)
What are the results of monitoring in quantitative terms?	The actual (or calculated based on sampling) value of the metric measured during the current year.
What are the results of the monitoring in qualitative terms?	Additional descriptive information about the data (e.g. number of sampling units)
How confident are you about the accuracy of the data?	Relates to the rigour with which the outcome was measured; e.g. direct quantitative measure with statistically powerful sampling design (high) versus simple estimate (low) – see Table 3
Has the target for the financial year been met?	Yes/no; was the actual measured value of the monitoring metric within the target range specified?
Should the monitoring continue to be implemented as stated for the current action?	Yes/no; identifies any issues with the proposed monitoring method; does it need to be updated or amended to ensure the data are accurate and meaningful?
Do data and/or an analysis exist to determine a trend?	Yes/no; the demonstration of a statistically significant population trend is highly dependent on the rigour of data collection and analysis. This provides context for the interpretation of reported population trends.
What is the trend?	Increasing, stable or declining. Only relevant in the context of the answer above.
Has a significant trend or issue been identified to trigger a review of the project?	Yes/no; provides an opportunity for adaptive improvement of projects (e.g. in response to emerging/changed threats or ineffective management).
Do you have any additional comments about this year's monitoring action?	Provides for additional interpretation of project outcome data.

Standardising reporting

Meaningful interpretation and evaluation of the success of SoS in delivering return on investment require the ability to aggregate project outcomes across the program. This is achieved by focusing evaluation of progress towards project-specific targets. Whether a project is monitoring the abundance of a frog, the reproductive success of a bird or individual condition of a shrub, the data are identical in terms of whether or not the project has met its respective annual targets.

These data can be aggregated to report on what proportion of projects, management sites or individual threats or actions are on track to meet their long-term targets.

This reporting method is designed to align with the broader program evaluation framework and answer high-level evaluation questions related to the program logic – i.e. how many species and ecological communities are on track to be secure in New South Wales for 100 years?

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Appendix A: Guidelines for applying the SoS project evaluation and reporting framework

Indicator level	Monitoring		Interpreting & evaluating outcomes: Indicator status				Guidelines for assessing confidence		
	Specific Questions	Explanation	Dark green	Light green	Amber	Red	High	Moderate	Low
Investment	How much was invested?	Total investment, including cash and in-kind resources (e.g. funding, OEH staff time, volunteer effort).	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Who invested?	Includes all sources (e.g. OEH divisions, NRM agencies, project partners, Environmental Trust, Commonwealth funding etc.							
Implementation	What actions were planned for the financial year?	May be a subset of actions proposed in the project (i.e. not all actions require annual implementation).	Action was fully implemented as planned for the financial year (or was not required)	n/a	Action was partially implemented as planned for the financial year	Action was not implemented as planned for the financial year	n/a	n/a	n/a
	Was the action implemented as planned?	Was activity implemented according to planned scale and intensity?							
	If not (or not completely), why not?	E.g. lack of resources, adverse conditions (e.g. drought) etc.							
Threat	What is being measured to assess threat severity/extent (monitoring index)?	Cost-effectively measurable snapshot metric or surrogate (e.g. weed density, predation rate, stream turbidity) of threat extent / severity of impact.	Threat has been monitored and results indicate that the extent, severity or impacts are within the target range (responding to management as predicted).	Threat has not been monitored directly this year; relevant management action(s) = 'Dark green' or 'Light green'	Threat has not been monitored directly this year; relevant management actions = 'Amber' or 'Red'	Threat has been monitored and results indicate that the extent, severity or impacts are outside of the target range (not responding to management or not responding as predicted).	Threat metric measured using statistically robust technique with high precision and accuracy	Response index measured using recognised technique (quantitative or qualitative data); moderate precision and/or accuracy	No formal data collection or low precision method (e.g. estimate only) or highly variable/subjective threat
	What method is being used?	What is the protocol for measuring stated metric (monitoring index), designed to answer key evaluation questions (below).							
	What is the long-term (ultimate) objective of management with respect to the threat (in terms of target value and timeframe)?	What is the target value (in terms of the stated metric) for the threat; at which point the managed threatened species could successfully survive and reproduce?							
	What is the annual objective - target range of threat metric values for the current financial year?	Based on a conceptual model of the threat response to management, what range of values of the stated metric (monitoring index) would be considered acceptable, given the implementation of proposed management over 12 months.							
	What is the threat outcome - is it within the target range?	Based on monitoring, what is the actual (measured) value of the stated metric this year, can management of the threat be considered 'on track' to meet the long-term (ultimate objective)?							
Site (species population) or TEC viability	What is being measured to assess species population or TEC viability outcomes?	Cost-effectively measurable snapshot metric or surrogate (e.g. abundance, area of occupancy, reproductive rate) of population; metrics for four indicators of viability (one per essential ecosystem element), that can be used to detect trend over multiple years.	Species population or 4 x TEC viability indicators (or validated surrogates) has been monitored and observed value of the metrics(s) is/are within target range(s) (responding to management as predicted)	Population/TEC viability indicators have not been measured directly; *all* relevant threats = 'Dark green' or 'Light green'	Population/TEC viability indicators have not been measured directly; at least one relevant threats = 'Amber' or 'Red'	Species population or 4 x TEC viability indicators (or validated surrogates) has been monitored and observed value of the metrics(s) is/are outside target range(s) (not responding to management as predicted))	Direct quantitative measure of abundance, distribution or condition; statistically valid inference from sample (e.g. mark-recapture / quadrat counts)	Indirect measure (e.g. surrogate) or abundance, distribution or condition measured with moderate accuracy and/or precision	No formal data collection or low precision method (e.g. estimate only); high population variability
	What method is being used?	What is the protocol for measuring stated monitoring metric, designed to answer key evaluation questions (below), including evidence base for using a surrogate.							
	What is the long-term target of management with respect to the species' (sub)population or TEC viability indicators at the site (metric value and timeframe)?	The target should relate to population/ecosystem viability; what (abundance/distribution/condition) is adequate to ensure that the population/TEC can sustain itself without management in the long-term?							
	What is the annual target - acceptable range of monitoring metric(s) for the current financial year?	Based on a predicted response to management curve, what range of values of the monitoring metric would be considered acceptable, given the implementation of proposed management over 12 months.							
	What is the measured outcome - is it within the target range?	From monitoring, what is the actual (measured) value of the stated metric this year, can management of the site be considered 'on track' to meet the long-term target(s)?							
Project	How many management sites can be considered 'on track' to be viable?	How many sites have a 'dark green' status at the sites level (i.e. population indicator or *all* TEC viability indicators)?	All sites' population/TEC viability outcomes = 'Dark green'	All sites' population/TEC viability outcomes = 'Dark green' or 'Light green'	All sites' population/TEC viability outcomes = 'Dark green', 'Light green' or 'Amber'	Any sites' population/TEC viability indicators outcome = 'Red'	n/a	n/a	n/a
Species in NSW*	What is the trend of the species' population or distribution or TEC viability across the full range in NSW? **Only if relevant data are available.*	Given sufficient demographic data and appropriate quantitative analyses, can a statistically significant trend in population or TEC viability indicators (e.g. extent of occurence) be demonstrated over a meaningful period of time (i.e. increasing, stable, declining)?	n/a	n/a	n/a	n/a	Statistically rigourous analysis of quantitative data for representative sample of NSW population	Statistically rigourous analysis of quantitative data for management sites only	Trend is estimated

Appendix B: Saving our Species Monitoring Plan Guidelines and Template for species and ecological community conservation projects

The SoS MER framework incorporates governance and quality assurance of monitoring methods across the program. It is expected that every active (i.e. being delivered via SoS funding or resourced externally) SoS conservation project has a detailed and comprehensive monitoring plan. This plan should be developed by the Project Coordinator in close consultation with Site Managers, species experts, land managers and statistical experts, as appropriate.

Peer review

It is expected that all monitoring plans will be peer reviewed, by either a relevant colleague or another person internal or external to OEH with relevant species and scientific expertise. In addition, SoS conservation projects that are receiving >$50,000 (on average) in SoS funding and include the management and monitoring of relatively complex systems (e.g. vertebrate pests, multiple drivers with significant uncertainty) will undergo a centralised review, coordinated by the SoS MER working group.

It is also expected that all monitoring plans be reviewed annually by project coordinators, to ensure that they are updated to reflect new information and in response to monitoring outcomes. This is particularly important for those projects reporting an ‘amber’ or ‘red’ status in their annual report card.

Developing a SoS conservation project monitoring plan

Included below is a template to guide the development of a monitoring plan for any conservation project under SoS. It includes all the elements recommended to ensure that the monitoring program is repeatable, easily reviewed, follows best practice, scientifically rigorous and based on the best available evidence.

Given the diversity of species, threats and habitats being monitored through SoS projects, the complexity and particular requirements of monitoring plans will vary significantly. Therefore, the content of structure of these plans is flexible, and these guidelines and the associated template are not intended to be prescriptive.

Project Coordinators should change or remove elements of the template as they see fit, or not use the template at all. However, all monitoring plans under SoS must include or address the following:

- A clear statement outlining the guiding objective of the monitoring program – i.e. simply monitoring outcomes to report on status and management effectiveness and track progress against targets, versus adopting an adaptive management approach to learn about the system and resolve critical uncertainties inhibiting effective management.
- A clear description (either graphic or words) of a process model or best understanding of the system drivers, that underpins and justifies the type of management and monitoring being undertaken (see template for an example). This should include, as a minimum, a description of the threatening processes impacting the target species population, the way in which the population is likely to respond to those threats, and the way in which the threats and the population are expected to respond to management.

- Long-term and annual targets that are measurable and are derived from the understanding of the system outlined above, for the species population (or appropriate surrogate) and all threats under management, at each management. Ideally, these would be derived directly from response curves (see template) that are described either graphically or in words.
- An outline of the general type of monitoring design being employed (e.g. surveillance, before-after-control-impact (BACI)) and a justification of why this is the most appropriate/cost-effective design (e.g. simple count without control or replication because there are insufficient sites/individuals to use a more complex design).
- Sufficient detail on the monitoring method to ensure that another person without background knowledge of the project could implement the monitoring regime effectively (e.g. detailed information on the location of sampling sites, measurement specific (e.g. ‘DBH measured at 130cm’), frequency, seasonality, examples/scales for scored indices (e.g. ‘browsing damage’), environmental pre-conditions (e.g. only monitor following rain/fire)).
- Clear documentation of the location where the raw data are stored – preferably the ‘Documentation’ section of the SoS database.

Saving our Species conservation project monitoring plan template

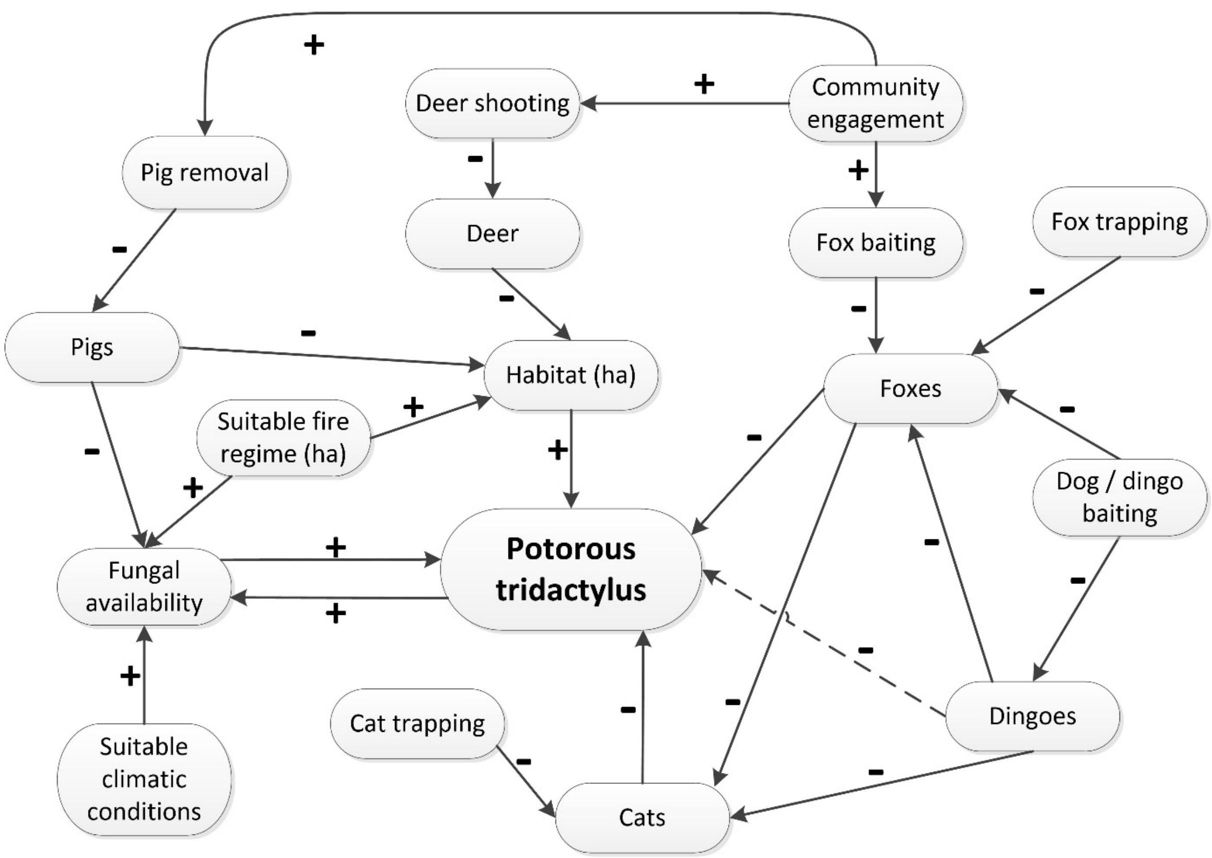
Species/TEC name: **Species profile ID:** **BC Act threat status:** **Funding status:** **Monitoring data stored:**	**Accountable Division/Region:** **Project Coordinator:** **Site Manager(s):** **Review date:**

Brief project outline: 2-3 paragraphs on species' requirements, primary threats under management, distribution of management sites, general monitoring methods used etc. Include a brief statement outlining the guiding objective of the monitoring program – i.e. simple tracking of progress against targets or adaptive management designed to resolve uncertainty.

Sites Summary

Site name	Site manager	Population/TEC viability indicator(s)	Threats monitored	Timing & frequency	Approximate cost (per session)
Site 1					
Site 2					
Site 3					

Process model



Include a graphical (e.g. as above) and/or a written description of how the species population or TEC indicators are predicted to interact with various drivers (e.g. threatening processes, environmental variables). Include reference to drivers that can't be managed/controlled as well as those that can.

Species population monitoring design

Detailed method: Describe the purpose (e.g. to assess change in abundance over time or better understand the relative impacts of various drivers) and logic of the monitoring design. If it has a standard name (e.g. multiple BACI designs) then state this but describe the treatments (e.g. control vs. management), the layout of sampling units (i.e. plots, transects, traplines) and how treatments are allocated to experimental units (if relevant). Include reference to monitoring metric(s), frequency, timing, number, size, shape and location of monitoring points, effort required, description of any surrogates used, variation in methods used between different management sites, condition dependencies (e.g. should follow rainfall or fire). Provide enough information to allow someone else to develop a consistent monitoring regime for a new site.

Justification: Why is the above method the most appropriate (i.e. in terms of rigour, detectability, cost-effectiveness, spatial and temporal variation in the species etc.)? How did you select the number, size, shape and location of monitoring points? If data are available from preliminary monitoring or other studies, then do a statistical power analysis to determine the minimum numbers of replicates necessary to detect change (see Green & MacLeod 2016). Alternatively, you may be able to refer to another monitoring study that was able to detect change. If using a surrogate, describe the evidence/reasoning to support the choice. Monitoring frequency should be justified based on species' life-history and cost-effectiveness. Approximately what proportion of the population/TEC range will be sampled by this monitoring plan (or how representative will this monitoring be of the TEC/population's NSW extent)?

Adaptive management: If any drivers of system change (or the most effective management actions to alter drivers) are uncertain, outline any adaptive management or experimental techniques being employed to reduce or resolve uncertainty (e.g. trial application of different interventions in different areas, or different interventions in different years, use of replicates, control sites). Alternatively, outline why an experimental approach is not appropriate, feasible or cost-effective.

Site 1: Site name (repeat for all sites in the project)

Site description: Outline the location of the site as well as the location and distribution of any known and/or potential locations of the species, any sampling points, transects etc. Include a map if/where relevant.

Site map

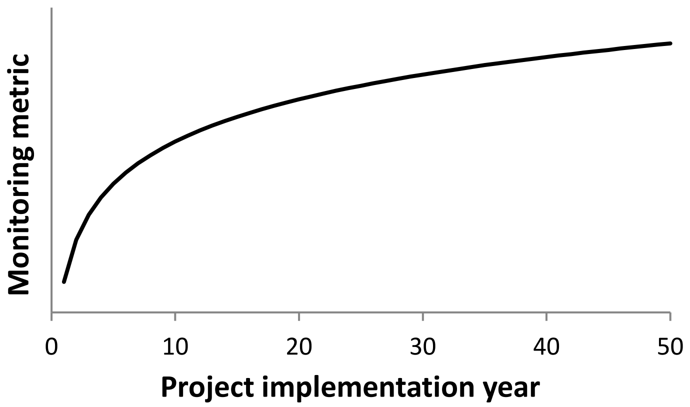
Site-specific monitoring method: Outline, highlighting any aspects of the monitoring or sampling regime that are different or specific to this site (e.g. numbers of sampling points, non-random sampling due to access difficulties). Which indicators and specific metrics will be used to assess the each of the four essential ecosystem elements to determine TEC viability at the site?

Long-term target: Identify the ultimate target value (or a range of plausible/acceptable values, determined by expert opinion or quantitative analysis) of the monitoring metric(s), assuming full and successful management, and over what timeframe it is predicted to be met. E.g. '500 breeding pairs within 20 years'.

Conceptual model and annual targets: Describe the predicted population (or surrogate) response to successful management over time using either a table or graph (predicted response to management curve). Identify annual target values of the monitoring metric (or range of values within a confidence interval) for each of the first three years, with reference to this curve. Separate curves and targets should be developed for each TEC viability indicator.

Model justification: Outline how the process model and related management response curves were developed and why particular targets were chosen. E.g. based on published data, extrapolated from previous monitoring data, manually derived based on discussion with experts. The justification can include a description of annual, seasonal or conditional fluctuations in the population. Inclusion of these sources of variability are important for understanding why annual targets may not be met. Describe any assumptions about how the population drivers will change over time (e.g. 'assumed all the drivers of the population that are not affected by management will remain unchanged' or 'the confidence interval considers variable rainfall but assumes a fire will not occur') or conditions/events that may substantially alter the predictions.

Year	Annual target (No. breeding pairs)
2017/18	80
2018/19	90
2019/20	95



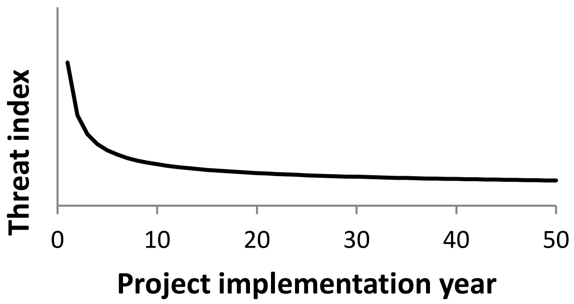
Threat 1 (repeat for all threats identified at the site)

Detailed method: Include reference to monitoring metric(s), frequency, timing, number, size, shape and location of monitoring points, effort required, description of any surrogates used, variation in methods used between different management sites, condition dependencies (e.g. should follow rainfall or fire). Provide enough information to allow someone else to develop a consistent monitoring regime for a new site.

Justification: Why is the above method the most appropriate (i.e. in terms of rigour, detectability, cost-effectiveness etc.)? How did you select the number, size, shape and location of monitoring points? If using a surrogate, describe the evidence/reasoning to support the choice. If monitoring frequency is less than annual, provide justification based on the nature of the threat or cost-effectiveness. How representative will this monitoring be of the threat?

Long-term target: Identify the ultimate target value (or range of values within a confidence interval) of the monitoring metric, assuming full and successful management, and over what timeframe it is predicted to be met. E.g. '<5% weed cover within 10 years'. This target should equate to the threshold extent/severity of the threat for causing significant impact on the target species' population or TEC viability indicators.

Conceptual model and annual targets: Describe the predicted threat response to successful management over time using either a table or graph (response to management curve). Identify annual target values of the monitoring metric (or range of values within a confidence interval) for each of the first three years, with reference to this curve.



Year	Annual target (weed cover)
2017/18	30%
2018/19	20%
2019/20	15%

Supplementary information

Data storage and management: Identify where the raw monitoring data are stored (e.g. Documentation section of SoS database, Biontet, CM9, local drive).

Statistical analysis: Describe the type of statistical analyses planned to be used to analyse and interpret the monitoring data (consultation with a statistician is recommended).

Species experts: Provide list of species experts (and contact details) that were consulted on the development of this monitoring plan.

References: Provide list of references for scientific papers, reports etc that provide support for the chosen monitoring methods.

Appendix C: Published resources available to guide the development of monitoring programs

Ecological monitoring and sampling methods

- Elzinga CL, Salzer DW and Willoughby JW 1998, *Measuring and Monitoring Plant Populations*. BLM Technical Reference 1730-1. U.S. Department of the Interior, Bureau of Land Management: Denver, Colorado (https://www.blm.gov/nstc/library/pdf/MeasAndMon.pdf).
- Gitzen RA, Millspaugh JJ, Cooper AB and Licht DS (Eds) 2012, *Design and Analysis of Long-term Ecological Monitoring Studies*. Cambridge University Press: Cambridge.
- Lindenmayer DB and Likens GE (2010). *Effective Ecological Monitoring*. CSIRO Publishing: Melbourne.
- Hughes NK, Burley AL, King SA and Downey PO 2009, *Monitoring manual for bitou bush control and native plant recovery*. Office of Environment and Heritage, NSW (http://www.environment.nsw.gov.au/bitouTAP/monitoring.htm).
- Magurran AE (2004). *Measuring Biological Diversity.* Blackwell Publishing, Carlton, Victoria.
- Buckland ST, Rexstad EA, Marques TA, & Oedekoven CS 2015, Distance Sampling: Methods and Applications.Springer: Heidelberg.
- Department of the Environment, Water, Heritage and the Arts 2010, Survey guidelines for Australia's threatened birds: Guidelines for detecting birds listed as threatened under the EPBC Act. Department of the Environment, Water, Heritage and the Arts: Canberra. http://www.environment.gov.au/resource/survey-guidelines-australias-threatened-birds-guidelines-detecting-birds-listed-threatened
- Department of the Environment, Water, Heritage and the Arts 2010, Survey guidelines for Australia’s threatened frogs Guidelines for detecting frogs listed as threatened under the Environment Protection and Biodiversity Conservation Act 1999. Department of the Environment, Water, Heritage and the Arts: Canberra. http://www.environment.gov.au/system/files/resources/ff3eb752-482d-417f-8971-f93a84211518/files/survey-guidelines-frogs.pdf
- Department of the Environment, Water, Heritage and the Arts 2010, Survey guidelines for Australia’s threatened bats Guidelines for detecting bats listed as threatened under the Environment Protection and Biodiversity Conservation Act 1999. Department of the Environment, Water, Heritage and the Arts: Canberra. http://www.environment.gov.au/system/files/resources/2f420bf1-d9e4-44ec-a69c-07316cb81086/files/survey-guidelines-bats.pdf
- Department of the Environment, Water, Heritage and the Arts 2011, Survey guidelines for Australia’s threatened reptiles. Guidelines for detecting reptiles listed as threatened under the Environment Protection and Biodiversity Conservation Act 1999. Department of the Environment, Water, Heritage and the Arts: Canberra. http://www.environment.gov.au/system/files/resources/eba674a5-b220-4ef1-9f3a-b9ff3f08a959/files/survey-guidelines-reptiles.pdf
- Elzinga CL, Salzer DW, & Willoughby JW 1998, Measuring and Monitoring Plant Populations. BLM Technical Reference 1730-1. U.S. Department of the Interior, Bureau of Land Management: Denver, Colorado. https://www.blm.gov/nstc/library/pdf/MeasAndMon.pdf
- Elzinga CL, Salzer DW, Willoughby JW, & Gibbs JP 2001, Monitoring Plant and Animal Populations: A Handbook for Field Biologists: Wiley-Blackwell.

- Gibbs JP 2000, Monitoring Populations. In L. Boitani & T. K. Fuller (Eds.), Research Techniques in Animal Ecology: Controversies and Consequences (pp. 213-252). Columbia University Press: New York. (Chapter 7 in http://www.ecolab.bas.bg/main/Members/snikolov/Boitani_Fuller_2000_Research_Techniques_in_Animal_Ecology.pdf)
- Gibbs JP, Droege S, & Eagle P 1998, Monitoring Populations of Plants and Animals. Bioscience, 48(11): 935-940. doi: 10.2307/1313297
- Gitzen RA, Millspaugh JJ, Cooper AB, & Licht DS (Eds.) 2012, Design and Analysis of Long-term Ecological Monitoring Studies. Cambridge University Press: Cambridge.
- Gregory RD, Gibbons DW, & Donald PF 2004, Bird census and survey techniques. In W. J. Sutherland, I. Newton & R. E. Green (Eds.), Bird Ecology and Conservation. A Handbook of Techniques (pp. 17-56). Oxford: Oxford University Press. http://www.wallaceresourcelibrary.com/assets/m02d03/5.%20Associated%20Resources/Key%20papers/Gregory%20et%20al%20(2004)%20Bird%20census%20and%20survey%20techniques.pdf
- Larsen TH (ed.) 2016, Core Standardized Methods for Rapid Biological Field Assessment. Conservation International, Arlington, VA.
- Meek P, Fleming P, Ballard G, Banks P, Claridge A, Sanderson J & Swann D 2014, Camera Trapping. Wildlife Management and Research. CSIRO Publishing: Melbourne. ISBN: 9781486300396/9781486300402 (ePDF)/ 9781486300419 (ePUB) http://publish.csiro.au/book/7150#sthash.o6DbiWgk.dpuf
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- Thompson WL (ed.) 2004, Sampling Rare or Elusive Species: Concepts, Designs, and Techniques for Estimating Population Parameters. Island Press: Washington.
- Vos P, Meelis E, & Ter Keurs WJ 2000, A framework for the design of ecological monitoring programs as a tool for environmental and nature management. Environmental Monitoring and Assessment, 61: 317–344.
- Wintle BA, Kavanagh RP, McCarthy MA, & Burgman MA 2005, Estimating and dealing with detectability in occupancy surveys for forest owls and arboreal marsupials. The Journal of Wildlife Management, 69(3): 905-917. doi: 10.2193/0022-541X(2005)069(0905:EADWDI)2.0.CO;2
- Wintle BA, Walshe TV, Parris KM, & McCarthy MA 2012, Designing occupancy surveys and interpreting nondetection when observations are imperfect. Diversity and Distributions, 18(4): 417-424. doi: 10.1111/j.1472-4642.2011.00874.x

Online resources

- ‘Designing and implementing fauna surveys’ https://qaeco.com/2013/02/15/designing-and-implementing-fauna-surveys/
- ‘The detection of species and their abundance’ https://qaeco.com/2013/02/19/the-detection-of-species-and-their-abundance/

Australian Government ’Threatened species and ecological communities’ publications:

- Bats http://www.environment.gov.au/system/files/resources/2f420bf1-d9e4-44ec-a69c-07316cb81086/files/survey-guidelines-bats.pdf

- Frogs https://www.environment.gov.au/resource/survey-guidelines-australias-threatened-frogs-guidelines-detecting-frogs-listed-threatened
- Reptiles http://www.environment.gov.au/system/files/resources/eba674a5-b220-4ef1-9f3a-b9ff3f08a959/files/survey-guidelines-reptiles.pdf