



In partnership with



SAVING OUR SPECIES

Guidelines for estimating and evaluating species' response to management



Contents

Introduction	1
Step 1: Define scope	4
Step 2: Develop process model	5
Construct narrative	6
Select measure used for the target species	7
Include any dependencies	8
Identify the threats	8
Identify the interventions	16
Check for feedback cycles	17
Note any additional considerations	17
Simplify the process model	18
Check the process model	18
Step 3: Select potential indicators	19
Step 4: Estimate response to management curves	22
Setting short-term and long-term targets	31
Glossary	32
References	33
Case studies	34
1. <i>Potorous tridactylus</i> (Long-nosed potoroo)	35
2. <i>Petroica boodang</i> (Scarlet robin)	44
3. <i>Miniopterus schreibersii oceanensis</i> (Eastern bentwing-bat)	52
4. <i>Anthochaera phrygia</i> (Regent honeyeater)	59
5. <i>Uperoleia mahonyi</i> (Mahony's toadlet)	66
6. <i>Pterostylis chaetophora</i> (Tall rustyhood)	75
7. <i>Acacia curranii</i> (Curly-bark wattle)	82
8. <i>Bossiaea fragrans</i>	89
9. <i>Dasyornis brachypterus</i> (Eastern bristlebird)	95
10. <i>Grevillea caleyi</i> (Caley's grevillea)	105
11. <i>Petalura gigantea</i> (Giant dragonfly)	114
12. <i>Hoplocephalus bungaroides</i> (Broad-headed snake)	119

Acknowledgements

Authors: Mayfield H, Rhodes J, Evans M and Maron M

Steering committee: Brazill-Boast J, Auld T, Burley A, Cox M, Gorrod E, McSorley A, Tozer M

Case study participants: Deborah Ashworth, Tony Auld, David Bain, Ian Baird, Lynn Baker, Sarah Bell, Joss Bentley, Rebecca Bradley, Andrew Claridge, Simon Clulow, Lachlan Copeland, Huw Evans, Luke Foster, Garry Germon, David Geering, Nick Hanlon, Paul Hillier, Meagan Hinds, Amanda Jowett, Krystyna Jordan, Erica Mahon, Doug Mills, Melinda Norton, Damon Oliver, Michael Pennay, Dean Portelli, Mick Roderick, Darren Shelly, Zoe Stone and Jonathan Webb.

The development of these guidelines was led by the University of Queensland and received funding from the Australian Government's National Environmental Science Program through the Threatened Species Recovery Hub.

Introduction

The *Saving our Species* (SoS) program is an initiative of the NSW Office of Environment and Heritage (OEH), aimed at ensuring the viability of as many threatened species in the wild as possible for the next 100 years (OEH 2013). The practical side of the SoS program is the development and implementation of conservation projects and interventions for a wide range of threatened species. To facilitate the evaluation of these projects, OEH has developed a monitoring, evaluation and reporting (MER) framework for managed species (OEH 2016). The framework states the key evaluation question for all SoS conservation projects as: 'Is the species, habitat or threat responding to management as expected, regarding a particular site or population?'

For site-managed species, each site is evaluated using a traffic light system (OEH 2016). Sites are allocated a dark green light if annual targets have been met, a red light if not. If data for annual targets are not yet available, two intermediate classifications are also possible. A light green light is allocated if other lower level indicators are within acceptable limits and an amber light if not. In many cases, targets can be based on data from prior monitoring efforts; however, it is also common for sites or species to be lacking substantial amounts of data. Amongst other reasons, data deficiency can be a result of either a lack of resources or difficulties in monitoring, such as for 'boom and bust' or cryptic species. In these instances, expert knowledge can be a valuable source of information for defining system behaviour and estimating species' response to management interventions (Kuhnert et al. 2010, Martin et al. 2012). Even in cases where detailed monitoring and empirical data exist, experts are still needed to interpret and give context.

These guidelines expand on the MER framework by providing SoS project coordinators with a step by step approach to using conceptual models for selecting relevant indicators and estimating a species' expected response to management for these indicators. Conceptual modelling is a useful technique that can help experts test and formalise their knowledge about a species and the threats it faces (Margoluis et al. 2009, Mata et al. 2017). It can also be used to assist in the selection of indicators for species monitoring (Lindenmayer et al. 2015). Conceptual models take various forms ranging from a simple text narrative to tables, or diagrams using boxes and arrows (Fischenich 2008). There are several advantages to creating a formal conceptual model. Firstly, the model may highlight uncertainties or gaps in how the ecosystem components interact (Bland 2017). Secondly, documenting the model used to select indicators allows for transparency when justifying why decisions were made, and can be updated as new information becomes available (Rumpff et al. 2011). Conceptual models are a particularly attractive tool for the SoS program as they are able to combine monitoring data with expert knowledge to create an overall description of the processes occurring at each site (and are a requisite component of project monitoring plans).

These guidelines utilise two types of conceptual models: process models (or influence diagrams), and response to management curves. Process models (for example Figure 1) represent the assumed relationships between a species and key components of its ecosystem. They can be used to identify potential indicators, which are nodes (such as species or environmental factors) that can be measured to evaluate or infer whether a species is responding as expected to management interventions.

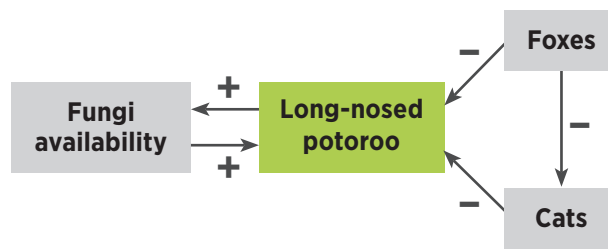


Figure 1 An example process model showing that an increase in fungal availability leads to an increase in the potoroo population (and vice versa), an increase in foxes leads to a decrease in potoroos and cats, and an increase in cats leads to an expected decrease in potoroos

Response to management curves (Figure 2) can be generated for each indicator by estimating the expected values for the indicator at specific points in time, and under specific management scenarios.

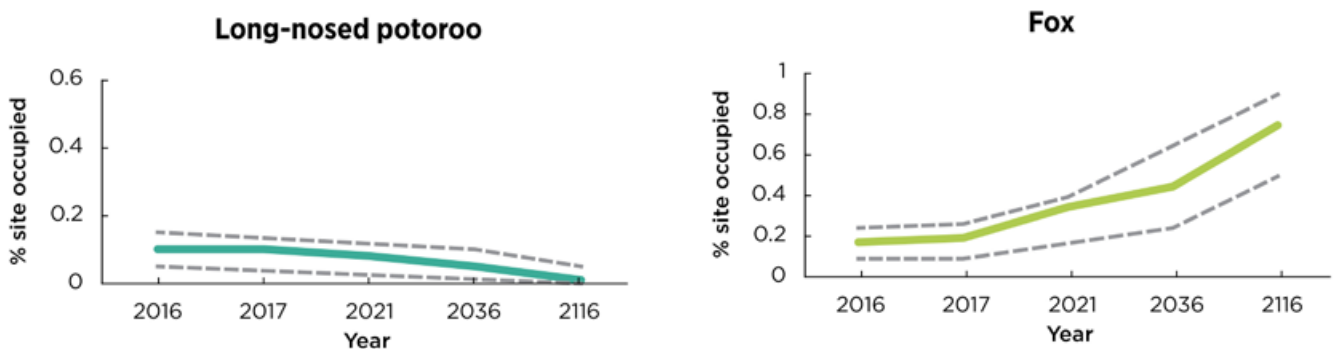


Figure 2 Example response to management curves for potoroo occupancy and fox occupancy on a site with no management for five time points.

Occupancy refers to the percentage of site occupied. Dashed lines represent the minimum and maximum expected values at each year.

The estimated response to management curves can then be used for identifying benchmarks and setting targets for an SoS project. An overview of the process is outlined in Figure 3.

These guidelines are designed for use either by individuals working independently, or in a facilitated workshop setting. They do not cover the selection of a suitable monitoring method or regime and should be referred to alongside existing OEH MER guidelines. Where the process is undertaken by more than one expert, they should ideally work collaboratively to design the process model and select indicators (steps 2 and 3). By using this shared model to individually estimate the response to management curves (step 4), variation in the estimated value between experts can be used as an additional measure of uncertainty. After generating individual estimates for the final indicators, experts should confer to discuss and decide on the agreed values. The application of the guidelines is illustrated through a series of 12 case studies that were generated in workshops with SoS project coordinators, site managers and external species experts.

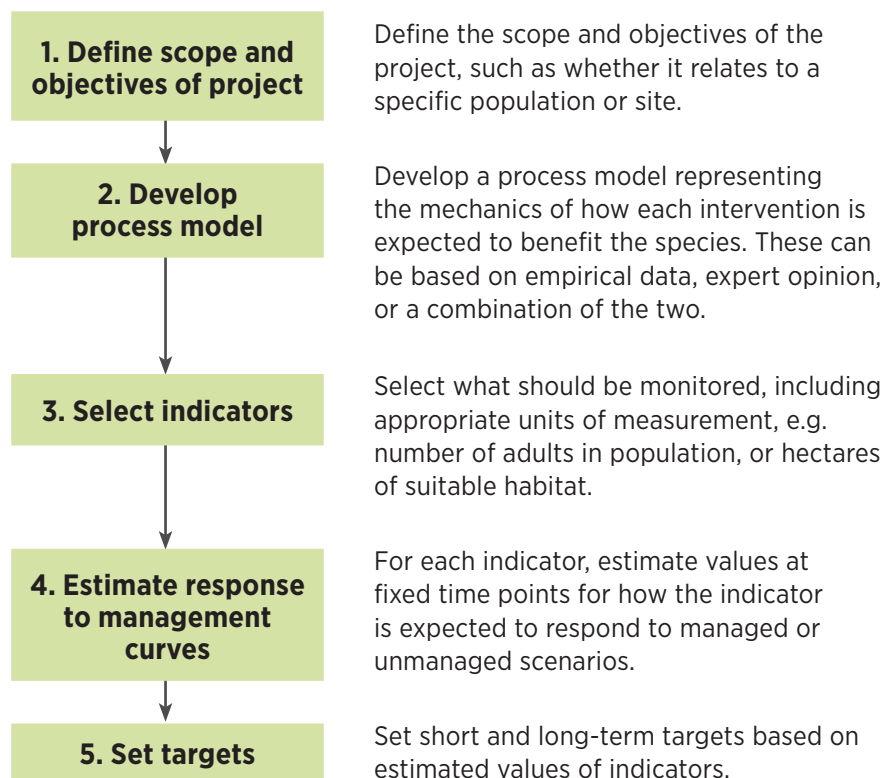


Figure 3 Five steps for identifying indicators and setting targets for an SoS project

Step 1: Define scope

Prior to constructing the process model in the next step, project coordinators should write a brief statement describing the scope of what is being considered. This could be a population at a single site or over a range of sites. It may include one or more management interventions, but exclude others that are carried out outside of the SoS program and are not expected to change the species' response to the SoS management. While the SoS traffic light system requires each site to be evaluated separately, the same process model may be used for multiple sites if the threats and dynamics are similar at each one. If the threats facing a species vary significantly from site to site, or where the species is expected to respond differently to these threats, such as for the eastern bristlebird (*Dasyornis brachypterus*), two separate process models should be constructed (see case study 9). In cases where the threats are only slightly different, a single process model is appropriate. For example, in the curly-bark wattle (*Acacia curranii*), while not all sites have rabbit proof fences, a single process model with a caveat regarding fences is sufficient (see case study 7).

The scope should cover:

- the target (focal) species
- the sites considered when designing the process models
- when the intervention started/will start and how long it will run for
- the interventions being implemented
- any previous management that was in place prior to SoS and whether this will continue
- what each intervention specifically targets and where, e.g. foxes in a given protected area, habitat in a certain area, behaviour of the general public, such as keeping people to the path
- anything that is specifically considered out of scope, e.g. populations in a different region or management activities that are expected to cease in the near future. For example, wildfire is not included in the scarlet robin (*Petroica boodang*) case study (case study 2. as it generally occurs away from the breeding sites and is managed outside of the SoS program.

Any threats that could potentially affect the species' response to management, but are not being managed due to feasibility or cost, should also be listed here.

This statement forms part of the supporting documentation for the resulting process model. Refer to the case studies provided for examples.

Step 2: Develop process model

Process models represent the relationships between an SoS species, its environment, and the planned management interventions. This can be based on scientific data from research or monitoring efforts, expert knowledge or a combination of the two. For the purpose of evaluating SoS projects, the objective of the process model is to describe the expected consequences of management interventions and provide a basis for identifying possible indicators for evaluating whether the species, habitat or threat is responding to management as expected. They are not designed to be comprehensive ecological models.

In a process model, a node represents a component of the system, such as species population, a measure of a species' threat, or a measure of some management intervention. A relationship between two nodes is represented with an arrow with either a + or - symbol, indicating the nature of the relationship. A negative (-) relationship indicates that a change in one node leads to a change to the other node, in the opposite direction, e.g. a decrease in one node leads to an increase in the other. A positive (+) relationship means both nodes change in the same direction, i.e. an increase in one causes an increase in the other; a decrease in one causes a decrease in the other. The notation for constructing a process model is summarised in Figure 4.









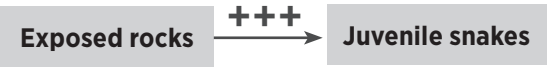
Notation	Meaning	Example
<p>Negative relationship</p> 	<p>↑ in A gives ↓ in B ↓ in A gives ↑ in B</p>	 <p>An increase in foxes decreases potoroos</p>
<p>Positive relationship</p> 	<p>↑ in A gives ↑ in B ↓ in A gives ↓ in B</p>	 <p>An increase in fungal availability increases potoroos and an increase in potoroos increases fungal availability</p>
<p>Uncertainty</p> 	<p>↑ in A possibly gives ↑ in B ↓ in A possibly gives ↓ in B</p>	 <p>Nest predation is possibly a factor in decreased number of nestlings</p>
<p>Magnitude</p>  	<p>A is a major influence on B</p>	 <p>Exposed rocks are a major influence on juvenile snakes</p>

Figure 4 Notation for constructing a process model

Most nodes will be definable by an objective, quantifiable unit, such as habitat in hectares, occupancy, population size, average density, etc. Where a threat cannot be measured objectively or with specific units, a subjective scale can be specified, e.g. ranging from 1 (unsuitable) to 10 (ideal). Two examples of this approach are given in Figure 5.

Water quality (Mahony's toadlet)

10 – Perfect: No chemical contamination and very little sediment. Breeding is unhindered and tadpoles can thrive.

7 – Suitable: Minor contamination but not affecting breeding or survival of tadpoles.

5 – Acceptable: Some contamination, likely having some detrimental effect, but breeding and tadpole survival still possible.

3 – Unacceptable: Major contamination and sediment issues cause difficulties with breeding and tadpole survival.

1 – Not suitable: Neither frogs nor tadpoles can survive.

Habitat structural complexity (scarlet robin)

7-10 – Optimal habitat: 50% chance of habitat selection.

3-6 – Moderate habitat condition: 10–50% chance of habitat selection.

0-2 – Low habitat condition: <10% chance of habitat selection.

Figure 5 Example definitions of scales for subjectively measuring water quality for Mahony's toadlet and habitat structural complexity for the scarlet robin

The following steps are a guide to constructing a process model for an SoS site. Any assumptions, extra considerations or disagreements in the diagram structure should be recorded separately and noted in supporting documentation.

Construct narrative

Prior to designing the diagram, write a short narrative describing how the species interacts with the system, and the mechanisms behind the expected response to management. Make sure to include:

- any specific habitat requirements that could change, e.g. microclimate in an eastern bentwing-bat (*Miniopterus schreibersii oceanensis*) roost
- other species that the focal species is dependent upon, such as pollinators or hosts

- any threats facing the species which might include:
 - introduced predators, e.g. foxes, cats
 - important natural predators
 - weeds
 - competition from over abundant species
 - inappropriate fire regime
 - urban or industrial developments
 - habitat fragmentation, loss or degradation
 - disease
 - poor water quality
- why the interventions listed in the scope are expected to help, e.g. fencing will reduce grazing.

Example narratives are included in the accompanying case studies.

Select measure used for the target species

Decide on a measure for the target species; for example, it might be:

- total number of individuals
- area/probability of occupancy
- density of individuals.

Life stages should be modelled separately if the threats are different at each, with a reinforcing loop between the stages. For example, fish will eat tadpoles but not frogs, however frogs are possibly susceptible to chytrid fungus.

An increase in tadpoles leads to an increase in frogs, which will result in more tadpoles. Conversely, fewer breeding adults would lead to fewer tadpoles, leading to a decline in population (Figure 6).

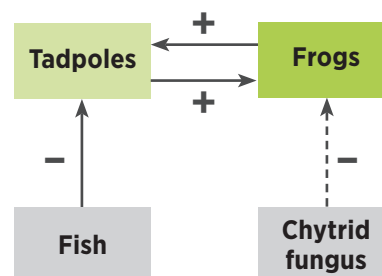


Figure 6 Process model representing the different threats at different life stages for Mahony's toadlet

Include a definition for each node. Definitions should be specific, explain the node in a measurable way and include the unit, e.g. number of individuals, shrubs per square metre, or occupancy. Including these definitions does not imply that resources are available to obtain values for each (see Step 3 – selecting indicators). For example, it may not be possible to estimate the number of tadpoles for a species, or the number of birds likely to occur at a site. Record any assumptions or qualifications.

Include any dependencies

Include any key dependencies for the target (focal) species that are relevant to management, for example:

- a particular food source, such as fungi for potoroos, which may be reduced by inappropriate fire management
- many plants require a pollinator to be present; if the availability of this pollinator might change, this should be included
- certain species may rely on fire for germination.

Identify the threats

Identify significant threats to the population, which might include:

- predation
- herbivory
- trampling
- poaching
- habitat loss
- habitat degradation
- inappropriate fire regimes.

Include any interactions among the threats. Threats which are not being managed, either through SoS or other organisations, should be included if they will change how the species responds to SoS management interventions. For example, if habitat degradation is not being managed, but is likely to reduce a species' response to predator control (i.e. species population will not increase if habitat degradation remains unchecked, regardless of whether predators are managed), then it should be included in the process model. In cases where lack of knowledge is considered a problem, this should be included in the model assumptions, but not included in the model itself. Likewise, research or monitoring being conducted should be described in the narrative, but not included in the process models.

Some examples of threats are given in Figure 7 (full definitions of nodes are given in the relevant case studies). Further guidance on common threats and modelling challenges are given in the remainder of this section.

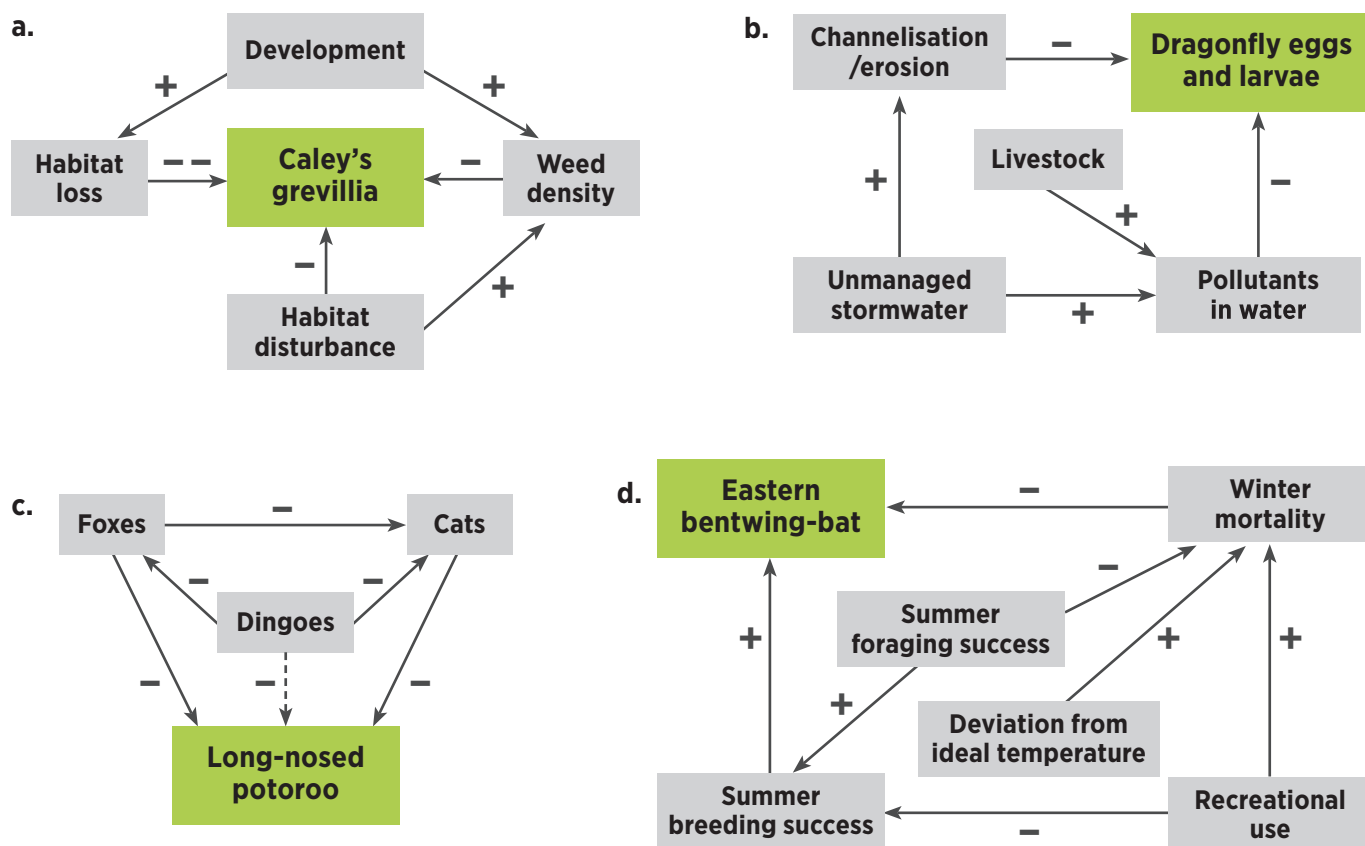


Figure 7 Process model representing selected threats faced by: a. Caley's grevilleia (*Grevillea caleyi*), b. giant dragonfly (*Petalura gigantea*), c. long-nosed potoroo (*Potorous tridactylus*), and d. eastern bentwing-bat

Interactions between threats

Where the severity of threat is in part determined by some other factor, this can be modelled by expanding the model to specifically include the mechanisms. For example, if fire will reduce dragonfly numbers more when groundwater levels are low, a 'fire severity' node can be added (Figure 8), which is influenced by both fire intensity and groundwater levels.

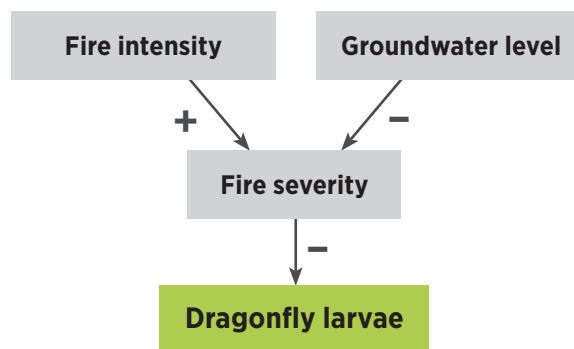


Figure 8 Inclusion of a 'fire severity' node to model the interaction between fire intensity and groundwater levels on the impact of fire on dragonfly larvae for the giant dragonfly

Another example is when the severity of drought in terms of a species' mortality is a function of the length of the drought and the size of the population's geographical distribution (Figure 9).

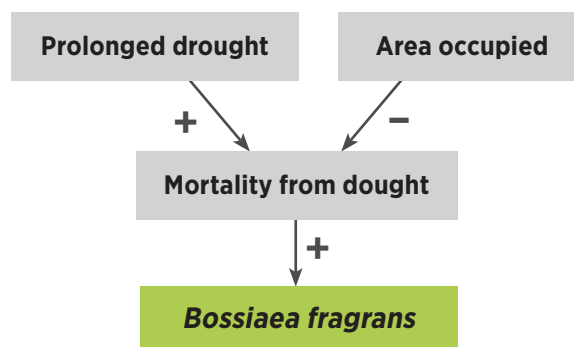


Figure 9 Inclusion of a 'Mortality from drought' node to model the interaction between prolonged drought and geographic distribution on the impact of drought on *Bossiæa fragrans*

Non-linear responses

If the species' response to a threat or action is expected to be non-linear, such as an initial drop in a population after a fire followed by a rapid increase, this can be represented in several ways. One option is to include the response curve in the model, with further details given in the description (Figure 10a). Another option is to categorise the threat, e.g. occasional soil disturbance (which may encourage seedling recruitment) compared to frequent soil disturbance, which can decrease the number of plants (Figure 10b).

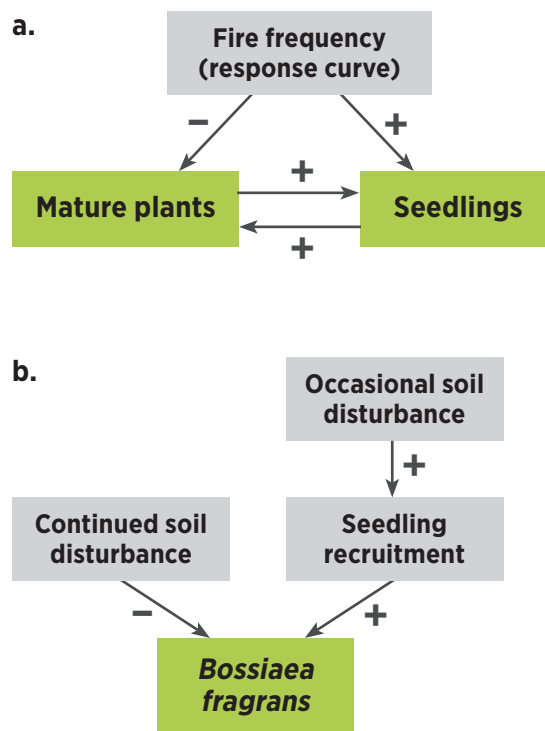


Figure 10 Modelling non-linear responses: a. Including a response curve for curly-bark wattle response to fire. Details of the response curve should be specified in the model description, e.g. seedlings will initially decrease after a fire, but there will be an overall increase after germination (assuming not more than one fire every three years); b. Continued soil disturbance will decrease *Bossiaea fragrans* numbers, while occasional disturbance will increase seedling recruitment

Fire

Several characteristics of fire, such as intensity, frequency and patch size (area burnt) can influence its effect on threatened species. In many cases the ideal fire regime isn't known, however there will be some information on the species' approximate response, or a known relationship between some aspects (such as germination immediately after fire or increased predation in burnt areas). Several examples for representing a species' relationship with fire are shown in Figure 11. The choice of which to use depends on how much is known about a species' response and the preferences of the experts constructing the model.

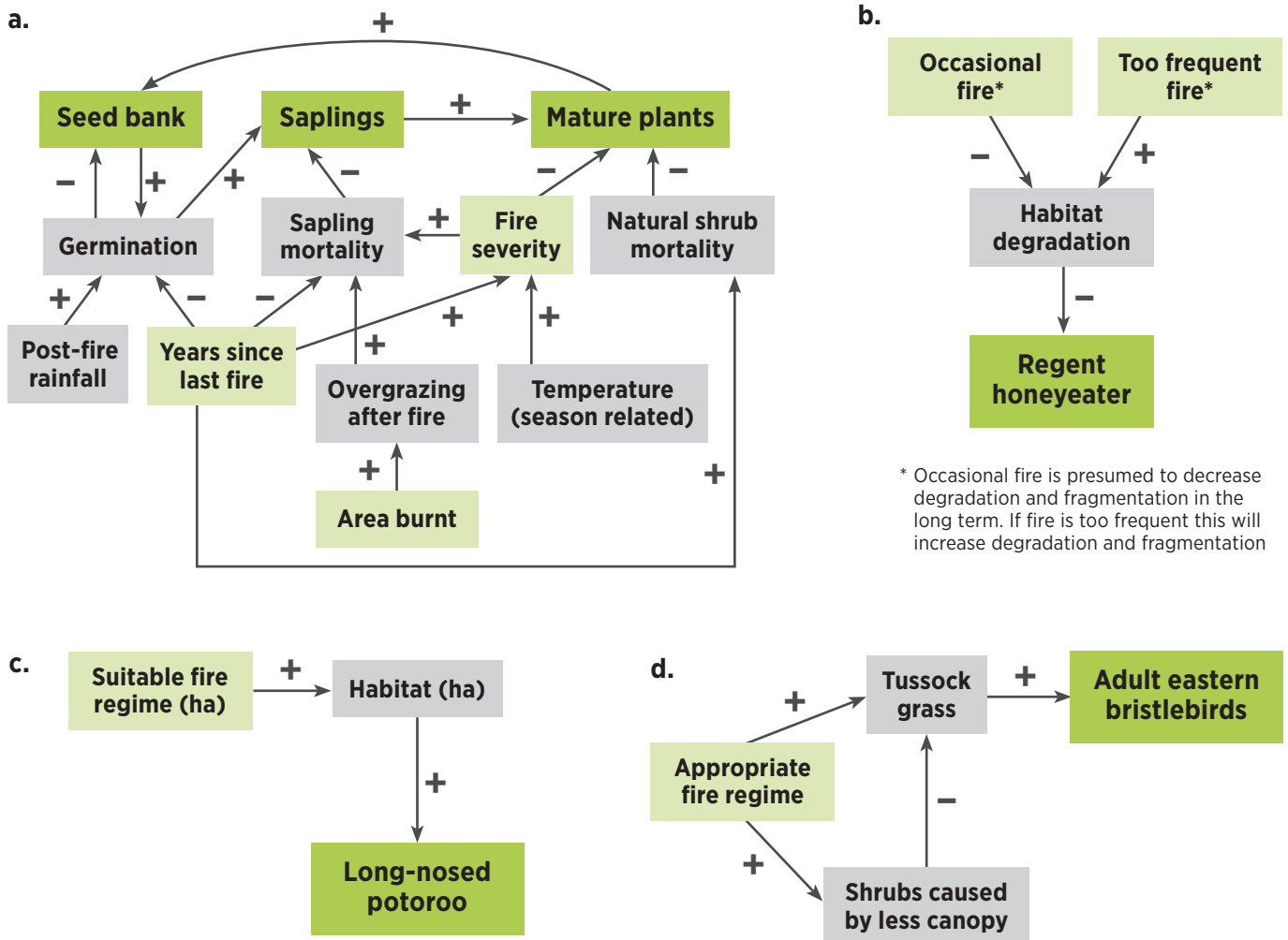


Figure 11 Different options for modelling the effects of fire for a. Caley's grevillea, b. regent honeyeater (*Anthochaera phrygia*), c. long-nosed potoroo, and d. northern population of the eastern bristlebird

Habitat

Threats may be represented by some component of the habitat such as weeds or water, or by availability of some resource, such as exposed rocks used by the broad-headed snake (*Hoplocephalus bungaroides*). In these instances the specific threat can be included (Figure 12).

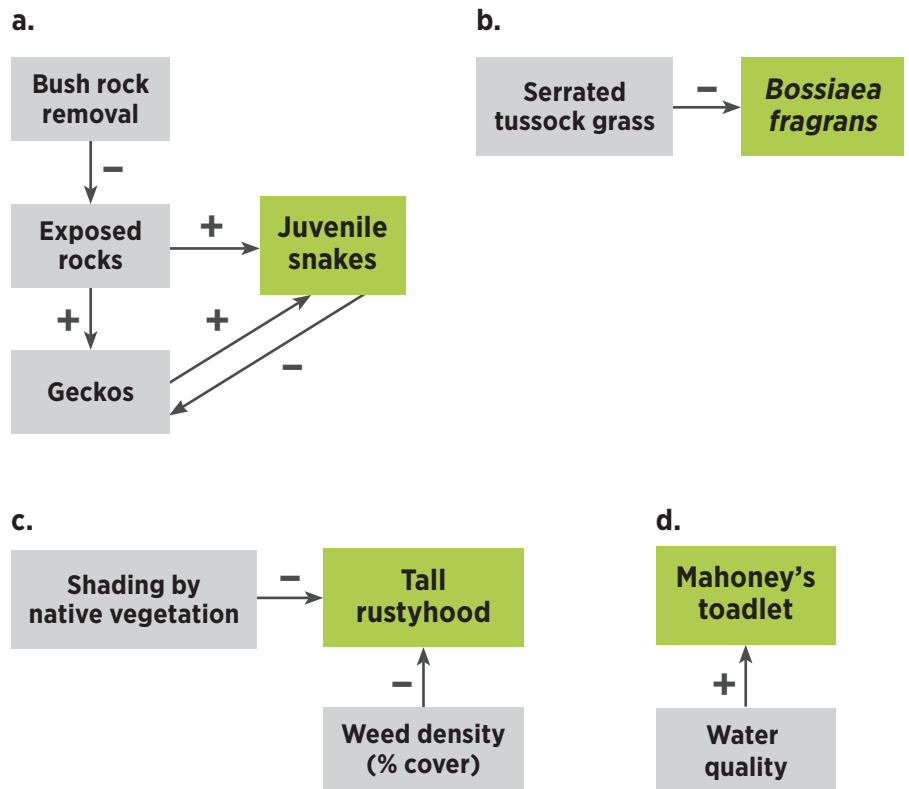


Figure 12 Modelling specific habitat components for a. broad-headed snake, b. *Bossiaea fragrans*, c. tall rustyhood (*Pterostylis chaetophora*), and d. Mahony's toadlet

Where the amount of habitat is the main threat, this can be specified in several ways (Figure 13).

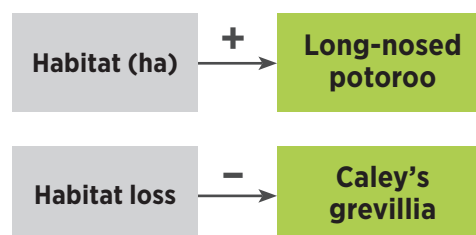


Figure 13 Two options for modelling the effects of habitat loss, where the amount of habitat is the primary driver

The threat may also be a combination of habitat quality and quantity, which can be modelled separately, or combined to indicate the carrying capacity of the site (Figure 14).

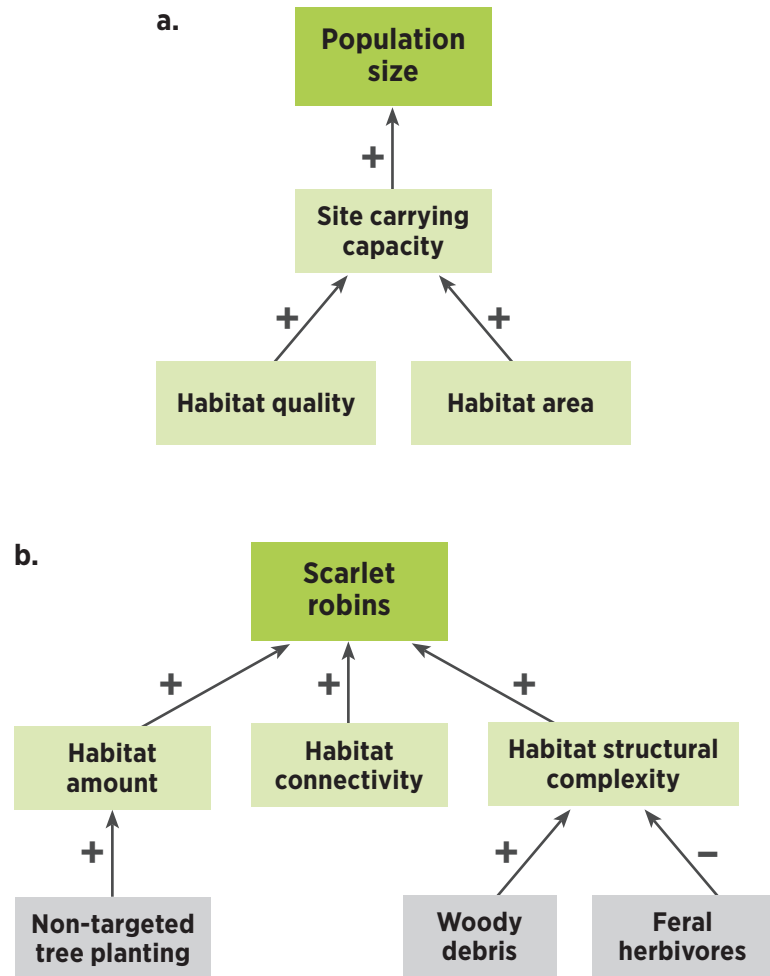


Figure 14 Modelling the combined effects of habitat loss and degradation: a. combining quality and area to calculate carrying capacity of the site, and b. three aspects of habitat related to the decline of the scarlet robin

Climate change

If the species is expected to be at risk from climate change, this should be operationalised as a specific threat rather than listed generally. For example, the models in Figure 15 show various ways that climate change is likely to affect threatened species, such as increased drought, increased fire, and changes to temperature and rainfall.

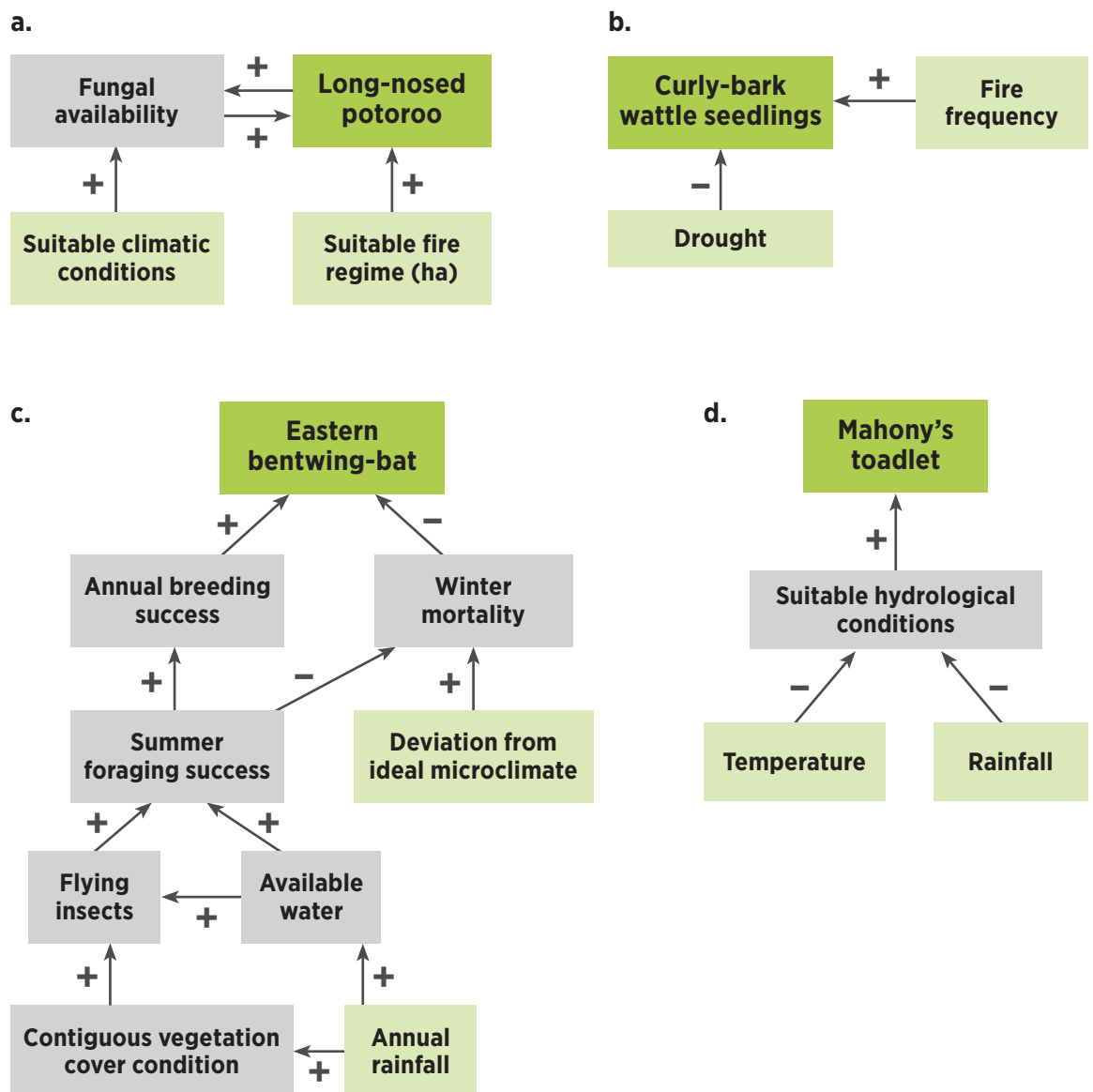


Figure 15 Operationalising the effects of climate change for: a. long-nosed potoroo, b. curly-bark wattle, c. eastern bentwing-bat, and d. Mahony's toadlet

Identify the interventions

Add the management actions that are being implemented. Any pre-SoS interventions that will continue during the SoS period should be marked with an asterisk (*). This allows them to be easily distinguished when estimating response to management curves during later steps. Any surrogates or indices used in current monitoring programs should also be included at this point.

For each intervention, identify the factors or threats that it targets (either directly or indirectly), and include the relationships, i.e. the mechanism through which the intervention is expected to help the species. Examples are given in Figure 16.

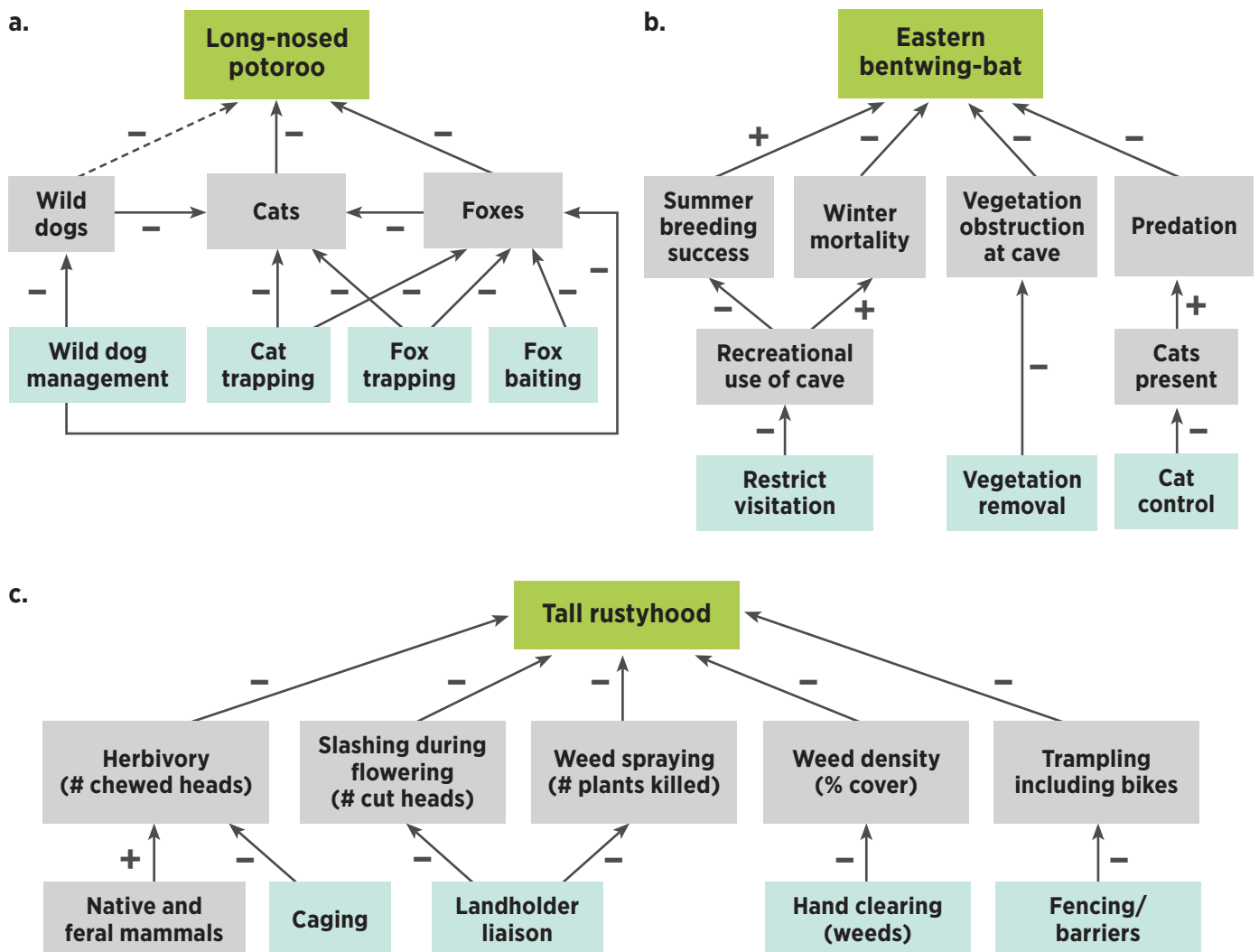


Figure 16 Management interventions (shaded blue) for: a. long-nosed potoroo, b. eastern bentwing-bat, and c. tall rustyhood

Check for feedback cycles

Feedback cycles are a common occurrence in ecology. Relevant feedback cycles should be included in the process model. Examples are given in Figure 17.

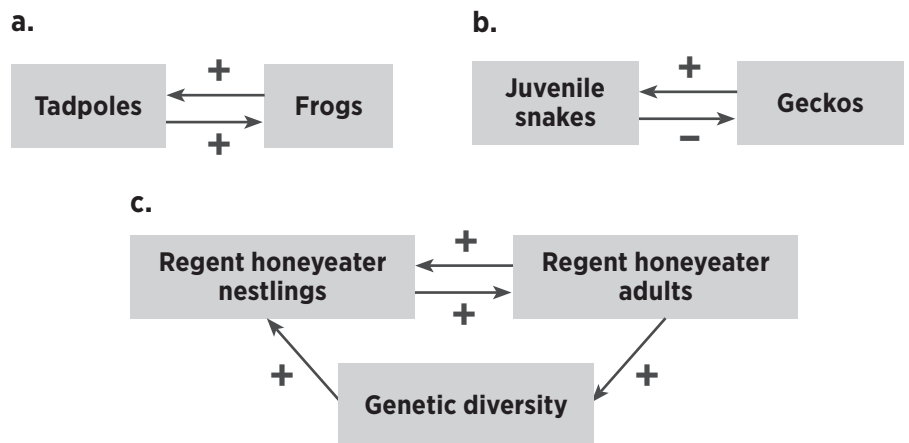


Figure 17 Examples of feedback cycles in the process model for: a. Mahony's toadlet, b. broad-headed snake, and c. regent honeyeater

Note any additional considerations

Consider the effects that the interventions may have on other species in the area that interact either directly or indirectly with the target species. For example, as well as decreasing the number of foxes, fox trapping might also reduce the number of cats, which may be caught in fox traps. Similarly, wild dog management may also reduce fox numbers, for the same reason (Figure 18).

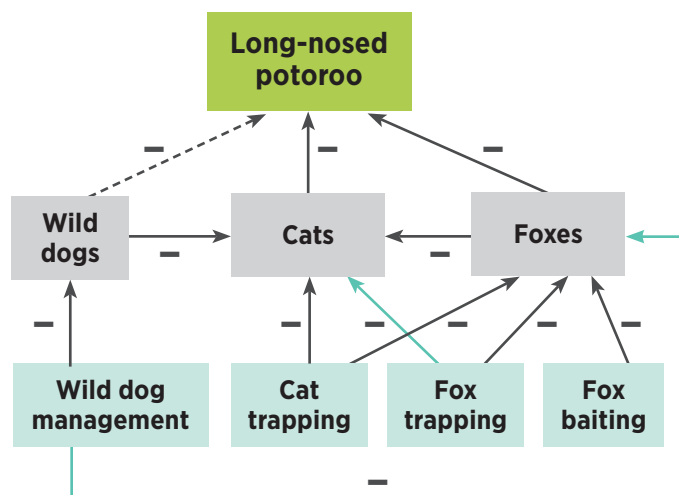


Figure 18 Modelling the additional effects of interventions; fox trapping could also reduce cat numbers and wild dog management could affect foxes as well as wild dogs

Simplify the process model

In many cases, process models can be simplified. For each node, consider whether it is in scope by revisiting what was defined in step one. Check if any nodes can be merged together to form functional groups. Any nodes removed or merged should be listed in the supporting documents. For example:

- Noisy miners and yellow-throated miners, both of which pose a similar threat to small birds, could be merged into a single node if their effect and response to management are the same.
- If a pollinator for a plant is assumed to be constantly present and is not affected by any of the management actions, this can be removed from the model and instead listed as an assumption.

Check the process model

Run through the following steps to help spot any changes required to the process model:

- For each intervention, follow the model through to check that the effect on the target species is correctly indicated. Make any changes needed. New nodes can be added if required to account for non-linear effects or interactions.
- Re-read the narrative and check whether anything has been left out.
- Seek an external opinion from someone who was not part of the modelling process (but is knowledgeable about the system), either by talking them through the model, or having them describe it in a written paragraph. This is particularly important when the model has been constructed individually rather than in discussion with other experts.
- Ensure that every node in the process model has been defined with a metric or score (for example, from 1 -10) alongside the diagram. See the case studies for examples.
- Check that all the relevant assumptions have been listed alongside the model.

Step 3: Select potential indicators

An indicator is a measurable entity related to a specific information requirement (Foundations of Success 2012). In this context an indicator refers to something that is being measured to evaluate if the species, habitat or threat is responding to management as expected (OEH 2016). Not all of the nodes in the process model will represent indicators that are to be measured. The targets (i.e. indicator values) selected for evaluating response to management should be specific, measurable, relevant, achievable, time-bound and cost-effective (OEH 2016). It is therefore important to choose indicators that facilitate this by selecting those that are specific (e.g. number of adults in population, square kilometres of quality habitat), measurable with the resources available, closely linked with the response of the target species, and cost-effective in terms of the monitoring requirements for measuring.

Many species can be measured directly, such as by abundance or occupancy, and this should always be the preferred option where feasible. In instances where data on the species population is either absent or unreliable, such as when the species is rare or absent (e.g. reintroduction schemes or disturbance responders), surrogate metrics are sometimes measured to supplement this missing information (Pierson et al. 2015). In these cases, the selection of surrogate indicators is often not straightforward, as the relationships between a species and the corresponding environmental surrogates may not be consistent across time and space (Pierson et al. 2015). Whenever a surrogate indicator is selected, there will necessarily be trade-offs in accuracy vs. generality, cost-effectiveness vs. certainty, stability vs. responsiveness, and communicability vs. robustness (Lindenmayer et al. 2015). If a surrogate has been identified previously that was not included in the process diagram, it should be added to the process model to confirm it is expected to respond in a similar fashion to the target species.

The SoS MER framework and database requires you to select an indicator for the target species (number of adults, density per metre, etc.), and some measure of each threat being managed. Where monitoring of the target species is known to be problematic, a surrogate measure should be selected.

In some cases, such as for long lived species, it may be appropriate to generate response curves for both juveniles (or saplings) and adults. When selecting indicators, consider:

- whether or not the indicator is expected to respond within a reasonable time, such as with long lived or slow growing species like some trees. In this case measuring mature trees may not be a good indicator of response to management, as no change would be expected to the number of mature trees for several decades. Therefore, the number of juvenile trees or recruits would be a better indicator in the short term
- whether the species takes a long time to reach reproductive age. In these instances, measuring a reduction in threat may be more appropriate initially than measuring the number of reproducing adults.

It may be reasonable to select different indicators for different time periods; for example, by setting initial benchmark values for an indicator which is expected to show an earlier response (such as saplings), with the intention of adjusting the benchmark to mature trees as these individuals develop.

For the example in Figure 19, the indicators selected were fox occupancy, cat occupancy, potoroo occupancy and hectares under suitable fire regime.

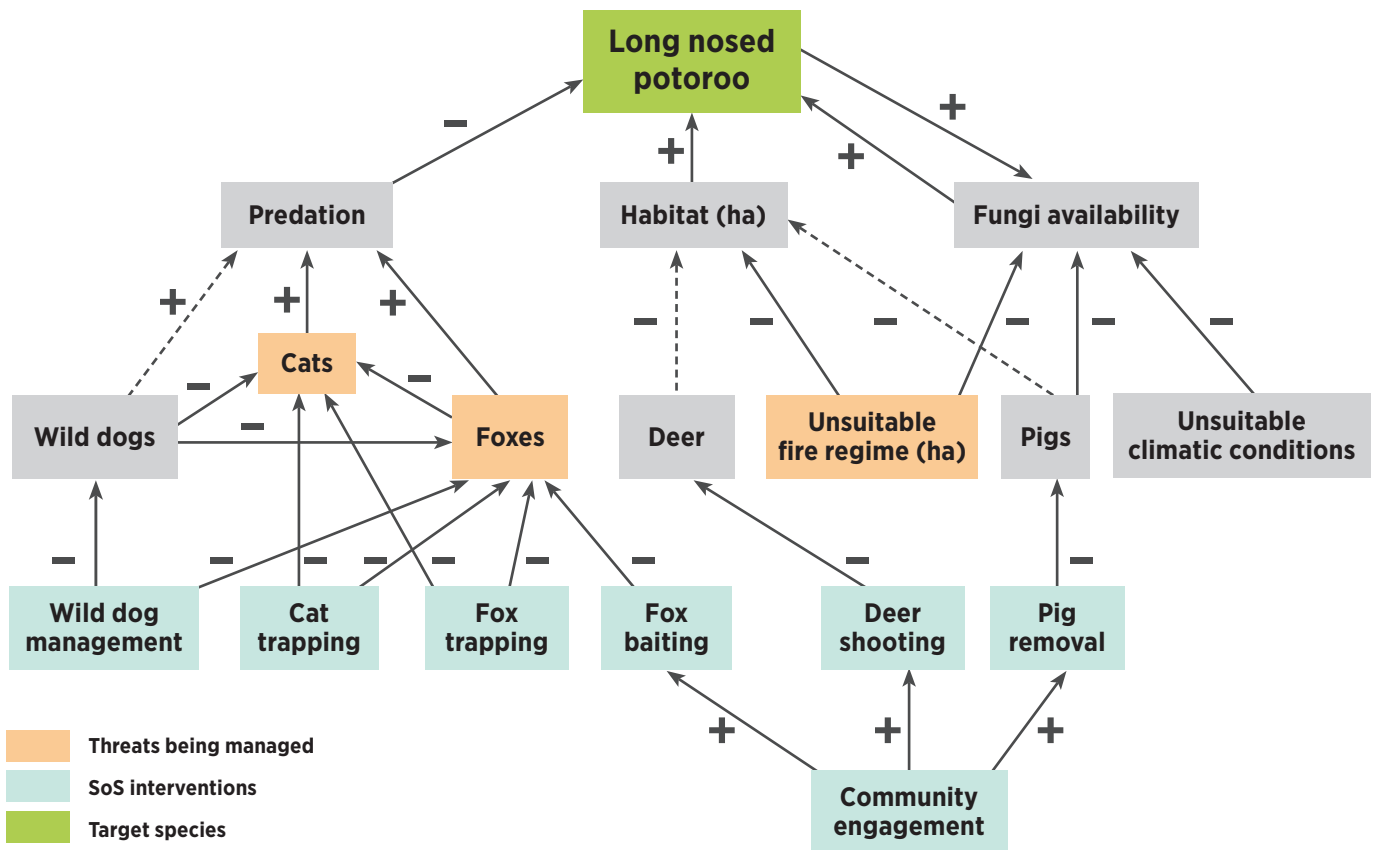


Figure 19 Process model for the long-nosed potoroo used to select indicators. Indicators selected were occupancy for potoroos, cats and foxes, as well as the number of hectares managed under a suitable fire regime

Potential indicators should be selected based on the relationships identified in the process model, and in consideration of proposed sampling techniques. Ongoing or long-term monitoring schemes already in place should also be taken into account and utilised where possible. The process model should be used to determine what should be measured as an indicator; for example, is it more meaningful to monitor the number of adults, the total number of individuals (either measured directly or extrapolated) or the density per hectare. When selecting potential indicators for estimating response to management curves, it is recommended you select indicators that are closely linked with the response of the SoS target species (i.e. more directly connected in the process model), and are cost-effective in terms of the monitoring requirements.

It is recommended you select between three and five initial indicators (including the target species) and generate response to management curves for each (detailed in the following section).

Guidelines for indicator selection

- Select between three and five potential indicators (including the SoS target species) for which response to management curves will be estimated.
- At least one measure of each threat being managed must be included.
- Indicators and target species should be closely linked in the process model.
- Indicators should be specific, measurable, relevant, and cost-effective to measure.

Step 4: Estimate response to management curves

Response curves (or response to management curves) are estimates of how indicators are expected to respond over time for defined management scenarios. By making estimates for one step at a time for a range of indicators, it is possible to consider how they influence each other at each step. All estimates are relative to the start of the SoS intervention being implemented.

To derive estimated responses to management, use a four-step elicitation question format (Speirs-Bridge et al. 2010), by estimating upper and lower plausible bounds, a best guess and a confidence value (i.e. how sure you are) (Hemming et al. 2018). Your specified confidence (x%), means that you believe the true value would be expected to fall within your upper and lower bound estimates in approximately x out of 100 cases. Confidence values should be between 50% and 100% (i.e. you should be at least 50% sure that the values of this indicator will fall between these boundaries). A spreadsheet template is available for this step.

To allow for comparison, estimates are required for four different scenarios:

- **Scenario 1** assumes that no management action occurs on the site. In Figure 19, this would equate to no fire management regime, no fox baiting and no fences.
- **Scenario 2** assumes management continues as it was pre-SoS. In Figure 19, this would equate to the implementation of a fire management plan, but no fencing or fox baiting.
- **Scenario 3** assumes all previous interventions continue alongside SoS interventions, which are funded indefinitely. In Figure 19 this equates to fire management, fencing and fox baiting.
- **Scenario 4** assumes all previous interventions continue alongside SoS interventions, which are funded only until the end of the current funding period.

All four scenarios assume that current land use continues (with the exception of species intervention changes) and excludes any impact from climate change that is not specifically operationalised in the process model. If the species is a boom and bust (disturbance response) species, assume the year being measured relates to a good year, or the peak of the cycle. While it is preferable to complete all four scenarios, in cases where many indicators have been selected, or when time is not available to properly complete every scenario, at a minimum, scenarios for 'no management' and 'continued management' should be attempted.

A series of elicitation questions is provided below to assist with deriving estimated responses to management. Table 1 indicates the question numbers that apply to each of the four scenarios.

When answering the elicitation question for a given indicator and time-step, it is useful to consider the following:

1. What was the value of the indicator at the previous time-step? According to the process model, should it have gone up or down in the current scenario?
2. What are the expected values of the other indicators at this time point? If a threat has been significantly reduced, how will this affect other indicators?
3. How long should the species take to respond?

Table 1 Scenarios for estimating response to management curves

Question numbers	Scenario
1	Current value of the indicators
2 – 5	Estimates for the next 1, 5, 20 and 100 years assuming no management occurred
6 – 9	Estimates for the next 1, 5, 20 and 100 years assuming no SoS intervention, but maintaining current management practices
10 – 13	Estimates for the next 1, 5, 20 and 100 years assuming full SoS intervention is implemented for all threats and continues for 100 years
14 – 17	Estimates for the next 1, 5, 20 and 100 years assuming SoS intervention is implemented as planned for all threats and additional SoS actions cease at the current end date of the program

It should be noted that values estimated for the indicators are designed to show only whether the species is responding as expected on the site (or sites) in question. They should not be interpreted as indicators of population viability, which should be calculated as part of a population viability analysis.

If your SoS funded intervention does not run for five years, please adjust this number accordingly.

Before answering the questions, make a note of when the SoS intervention began, or will begin, e.g. January 2019.

Question 1:**Value of indicators at the start of the SoS project**

For each indicator identified in step 3, and referring to the process model from step 2, answer the following questions:

- a. Realistically, what do you think the highest plausible value of <indicator> is at the start of the SoS intervention?
- b. Realistically, what do you think the lowest plausible value of <indicator> is at the start of the SoS intervention?
- c. Realistically, what is your best guess for the value of <indicator> at the start of the SoS intervention?
- d. How confident are you that your interval, from lowest to highest, includes the value of the <indicator> at this date?

Questions 2–5 refer to Scenario 1, which assumes **no management interventions** were to take place.

Question 2:**No management (SoS or otherwise), 1 year after start date of SoS intervention**

Assuming no management was implemented, for each indicator identified in step 3, and referring to the process model from step 2, answer the following questions:

- a. Realistically, what do you think the highest plausible value of <indicator> is 1 year after the start date of the SoS intervention?
- b. Realistically, what do you think the lowest plausible value of <indicator> is 1 year after the start date of the SoS intervention?
- c. Realistically, what is your best guess for the value of <indicator> 1 year after the start date of the SoS intervention?
- d. How confident are you that your interval, from lowest to highest, includes the value of the <indicator> at this date?

Question 3:**No management (SoS or otherwise), 5 years after start date of SoS intervention**

Assuming no management is implemented, for each indicator identified in step 3, and referring to the process model from step 2, answer the following questions:

- a. Realistically, what do you think the highest plausible value of <indicator> is 5 years after the start date of the SoS intervention?

- b. Realistically, what do you think the lowest plausible value of <indicator> is 5 years after the start date of the SoS intervention?
- c. Realistically, what is your best guess for the value of <indicator> 5 years after the start date of the SoS intervention?
- d. How confident are you that your interval, from lowest to highest, includes the value of the <indicator> at this date?

Question 4:

No management (SoS or otherwise), 20 years after start date of SoS intervention

Assuming no management is implemented, for each indicator identified in step 3, and referring to the process model from step 2, answer the following questions:

- a. Realistically, what do you think the highest plausible value of <indicator> is 20 years after the start date of the SoS intervention?
- b. Realistically, what do you think the lowest plausible value of <indicator> is 20 years after the start date of the SoS intervention?
- c. Realistically, what is your best guess for the value of <indicator> 20 years after the start date of the SoS intervention?
- d. How confident are you that your interval, from lowest to highest, includes the value of the <indicator> at this date?

Question 5:

No management (SoS or otherwise), 100 years after start date of SoS intervention

Assuming no management is implemented, for each indicator identified in step 3, and referring to the process model from step 2, answer the following questions:

- a. Realistically, what do you think the highest plausible value of <indicator> is 100 years after the start date of the SoS intervention?
- b. Realistically, what do you think the lowest plausible value of <indicator> is 100 years after the start date of the SoS intervention?
- c. Realistically, what is your best guess for the value of <indicator> 100 years after the start date of the SoS intervention?
- d. How confident are you that your interval, from lowest to highest, includes the value of the <indicator> at this date?

Questions 6–9 refer to a scenario that assumes that **management continues as it was prior to the SoS intervention**. If this is the same as scenario 1 (i.e. there was no management prior to the SoS project), please skip to Question 10.

**Question 6:
Continuation of pre-SoS management, 1 year after start date of
SoS intervention**

Assuming continuation of pre-SoS management, for each indicator identified in step 3, and referring to the process model from step 2, answer the following questions:

- a. Realistically, what do you think the highest plausible value of <indicator> is 1 year after the start of the SoS intervention?
- b. Realistically, what do you think the lowest plausible value of <indicator> is 1 year after the start of the SoS intervention?
- c. Realistically, what is your best guess for the value of <indicator> 1 year after the start of the SoS intervention?
- d. How confident are you that your interval, from lowest to highest, includes the value of the <indicator> at this date?

**Question 7:
Continuation of pre-SoS management, 5 years after start date of
SoS intervention**

Assuming continuation of pre-SoS management, for each indicator identified in step 3, and referring to the process model from step 2, answer the following questions:

- a. Realistically, what do you think the highest plausible value of <indicator> is 5 years after the start of the SoS intervention?
- b. Realistically, what do you think the lowest plausible value of <indicator> is 5 years after the start of the SoS intervention?
- c. Realistically, what is your best guess for the value of <indicator> 5 years after the start of the SoS intervention?
- d. How confident are you that your interval, from lowest to highest, includes the value of the <indicator> at this date?

**Question 8:
Continuation of pre-SoS management, 20 years after start date of
SoS intervention**

Assuming continuation of pre-SoS management, for each indicator identified in step 3, and referring to the process model from step 2, answer the following questions:

- a. Realistically, what do you think the highest plausible value of <indicator> is 20 years after the start of the SoS intervention?

- b. Realistically, what do you think the lowest plausible value of <indicator> is 20 years after the start of the SoS intervention?
- c. Realistically, what is your best guess for the value of <indicator> 20 years after the start of the SoS intervention?
- d. How confident are you that your interval, from lowest to highest, includes the value of the <indicator> at this date?

**Question 9:
Continuation of pre-SoS management, 100 years after start date of SoS intervention**

Assuming continuation of pre-SoS management, for each indicator identified in step 3, and referring to the process model from step 2, answer the following questions:

- a. Realistically, what do you think the highest plausible value of <indicator> is 100 years after the start of the SoS intervention?
- b. Realistically, what do you think the lowest plausible value of <indicator> is 100 years after the start of the SoS intervention?
- c. Realistically, what is your best guess for the value of <indicator> 100 years after the start of the SoS intervention?
- d. How confident are you that your interval, from lowest to highest, includes the value of the <indicator> at this date?

Questions 10–13 refer to a scenario that assumes the **SoS management intervention is implemented as planned and SoS actions continue for the next 100 years.**

**Question 10:
SoS management is implemented indefinitely, 1 year after start date of SoS intervention**

Assuming SoS management is implemented as planned and SoS actions continue for the next 100 years, for each indicator identified in step 3, and referring to the process model from step 2, answer the following questions:

- a. Realistically, what do you think the highest plausible value of <indicator> is 1 year after the start of the SoS intervention?
- b. Realistically, what do you think the lowest plausible value of <indicator> is 1 year after the start of the SoS intervention?
- c. Realistically, what is your best guess for the value of <indicator> 1 year after the start of the SoS intervention?
- d. How confident are you that your interval, from lowest to highest, includes the value of the <indicator> at this date?

Question 11:**SoS management is implemented indefinitely, 5 years after start date of SoS intervention**

Assuming SoS management is implemented as planned and SoS actions continue for the next 100 years, for each indicator identified in step 3, and referring to the process model from step 2, answer the following questions:

- a. Realistically, what do you think the highest plausible value of <indicator> is 5 years after the start of the SoS intervention?
- b. Realistically, what do you think the lowest plausible value of <indicator> is 5 years after the start of the SoS intervention?
- c. Realistically, what is your best guess for the value of <indicator> 5 years after the start of the SoS intervention?
- d. How confident are you that your interval, from lowest to highest, includes the value of the <indicator> at this date?

Question 12:**SoS management is implemented indefinitely, 20 years after start date of SoS intervention**

Assuming SoS management is implemented as planned and SoS actions continue for the next 100 years, for each indicator identified in step 3, and referring to the process model from step 2, answer the following questions:

- a. Realistically, what do you think the highest plausible value of <indicator> is 20 years after the start of the SoS intervention?
- b. Realistically, what do you think the lowest plausible value of <indicator> is 20 years after the start of the SoS intervention?
- c. Realistically, what is your best guess for the value of <indicator> 20 years after the start of the SoS intervention?
- d. How confident are you that your interval, from lowest to highest, includes the value of the <indicator> at this date?

Question 13:**SoS management is implemented indefinitely, and SoS actions continue for the next 100 years**

Assuming SoS management is implemented as planned and SoS actions continue for the next 100 years, for each indicator identified in step 3, and referring to the process model from step 2, answer the following questions:

- a. Realistically, what do you think the highest plausible value of <indicator> is 100 years after the start of the SoS intervention?
- b. Realistically, what do you think the lowest plausible value of <indicator> is 100 years after the start of the SoS intervention?
- c. Realistically, what is your best guess for the value of <indicator> 100 years after the start of the SoS intervention?
- d. How confident are you that your interval, from lowest to highest, includes the value of the <indicator> at this date?

Questions 14–17 refer to a scenario that assumes the **SoS management intervention is implemented as planned and ceases at the current project end (i.e. management returns to the pre-SoS scenario).**

Question 14:

SoS management is implemented as planned and ceases at the end of the project, 1 year after start date of SoS intervention

Assuming SoS management is implemented as planned and ceases at the end of the project, for each indicator identified in step 3, and referring to the process model from step 2, answer the following questions:

- a. Realistically, what do you think the highest plausible value of <indicator> is 1 year after the start of the SoS intervention?
- b. Realistically, what do you think the lowest plausible value of <indicator> is 1 year after the start of the SoS intervention?
- c. Realistically, what is your best guess for the value of <indicator> 1 year after the start of the SoS intervention?
- d. How confident are you that your interval, from lowest to highest, includes the value of the <indicator> at this date?

Question 15:

SoS management is implemented as planned and ceases at the end of the project, 5 years after start date of SoS intervention

Assuming SoS management is implemented as planned and ceases at the end of the project, for each indicator identified in step 3, and referring to the process model from step 2, answer the following questions:

- a. Realistically, what do you think the highest plausible value of <indicator> is 5 years after the start of the SoS intervention?
- b. Realistically, what do you think the lowest plausible value of <indicator> is 5 years after the start of the SoS intervention?
- c. Realistically, what is your best guess for the value of <indicator> 5 years after the start of the SoS intervention?
- d. How confident are you that your interval, from lowest to highest, includes the value of the <indicator> at this date?

Question 16:

SoS management is implemented as planned and ceases at the end of the project, 20 years after start date of SoS intervention

Assuming SoS management is implemented as planned and ceases at the end of the project, for each indicator identified in step 3, and referring to the process model from step 2, answer the following questions:

- a. Realistically, what do you think the highest plausible value of <indicator> is 20 years after the start of the SoS intervention?
- b. Realistically, what do you think the lowest plausible value of <indicator> is 20 years after the start of the SoS intervention?
- c. Realistically, what is your best guess for the value of <indicator> 20 years after the start of the SoS intervention?
- d. How confident are you that your interval, from lowest to highest, includes the value of the <indicator> at this date?

Question 17:

SoS management is implemented as planned and ceases at the end of the project, 100 years after start date of SoS intervention

Assuming SoS management is implemented as planned and ceases at the end of the project, for each indicator identified in step 3, and referring to the process model from step 2, answer the following questions:

- a. Realistically, what do you think the highest plausible value of <indicator> is 100 years after the start of the SoS intervention?
- b. Realistically, what do you think the lowest plausible value of <indicator> is 100 years after the start of the SoS intervention?
- c. Realistically, what is your best guess for the value of <indicator> 100 years after the start of the SoS intervention?
- d. How confident are you that your interval, from lowest to highest, includes the value of the <indicator> at this date?

Setting short-term and long-term targets

The SoS MER framework requires that for every site/population and every threat under management, there is a measurable indicator with an annual and long-term (i.e. ultimate) target value (OEH 2016). These target values – particularly the annual target – are critical to informing the annual project evaluation and reporting process (see SoS Monitoring, Evaluation and Reporting guidelines for more details). Generally, it is recommended that these targets be derived from response to management curves developed using the method outlined above. Once a response to management curve has been developed for all relevant indicators, predicted values for each indicator at one year and 100 (or 20, as appropriate) years can be applied as annual and long-term targets, respectively.

An important caveat to this process is the consideration of uncertainty. The process models produced for any species/system will always include some (variable) level of uncertainty. Response to management curves will also be (probably more) uncertain, given they involve predictions about the future. The cumulative impact of both these sources of uncertainty should influence the interpretation of model predictions, and therefore, the derivation of targets.

In practice, this means that targets should generally be defined as an acceptable range of values, i.e. control limits, such as in Burgman et. al (2012), with the range size proportionate to the level of uncertainty and confidence in the models. Ideally, as monitoring data accumulate through time as projects are implemented, this should reduce uncertainty in the models, improving accuracy and precision of model predictions, and improving confidence in the validity of targets.

Glossary

Conceptual model: A representation of a mental model. In these guidelines this is done through the use of process models and response to management curves

Indicator: A measurable entity related to a specific information requirement, for example 'total adults on site'

Intervention: The management action being carried out

MER: Monitoring, evaluation and reporting

OEH: NSW Office of Environment and Heritage

Process model: Representations of reality that can be used to formalise knowledge about a species and its relationship with the ecosystem

Response curves: Estimates of how indicators are expected to respond over time to defined management scenarios (or response to management curves)

SoS: *Saving our Species*, an initiative of OEH aimed at ensuring the viability of as many threatened species in the wild as possible for the next 100 years

References

- Bland LM, Keith DA, Miller RM, Murray RJ and Rodríguez JP 2017, *Guidelines for the application of IUCN Red List of Ecosystems Categories and Criteria Version 1.1*, International Union for Conservation of Nature, Gland, Switzerland.
- 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 D Lindenmayer and P Gibbons, *Biodiversity Monitoring in Australia*, CSIRO Publishing, Collingwood, Victoria.
- Fischenich C 2008, *The application of conceptual models to ecosystem restoration*, EBA Technical Notes Collection, ERDC/EBA TN-08-1, US Army Engineer Research and Development Center, Vicksburg, MS, USA, www.wes.army.mil/el/emrrp.
- Foundations of Success 2012, *Step 1D Conceptual Models*, Foundations of Success, Bethesda Maryland, USA.
- Hemming V, Burgman MA, Hanea AM, McBride MF and Wintle BC 2018, A practical guide to structured expert elicitation using the IDEA protocol, *Methods in Ecology and Evolution* vol.9, no.1, pp.169–180.
- Kuhnert PM, Martin TG and Griffiths SP 2010, A guide to eliciting and using expert knowledge in Bayesian ecological models, *Ecology Letters* vol.13, no.7, pp.900–914.
- Lindenmayer D, Pierson J, Barton P, Beger M, Branquinho C, Calhoun A, Caro T, Greig H, Gross J, Heino J, Hunter M, Lane P, Longo C, Martin K, McDowell WH, Mellin C, Salo H, Tulloch A and Westgate M 2015, A new framework for selecting environmental surrogates, *Science of The Total Environment* vol.538 (Supplement c.), pp.1029–1038.
- Margoluis R, Stem C, Salafsky N and Brown M 2009, Using conceptual models as a planning and evaluation tool in conservation, *Evaluation and Program Planning* vol.32, no.2, pp.138–147.
- Martin TG, Burgman MA, Fidler F, Kuhnert PM, Low-Choy S, McBride M and Mengersen K 2012, Eliciting Expert Knowledge in Conservation Science, *Conservation Biology* vol.26, no.1, pp.29–38.
- Mata L, Garrard GE, Kutt AS, Wintle BC, Chee YE, Backstrom A, Bainbridge B, Urlus J, Brown GW, Tolsma AD, Yen AL, New TR and Bekessy SA 2017, Eliciting and integrating expert knowledge to assess the viability of the critically endangered golden sun-moth *Synemon plana*, *Austral Ecology* vol.42, no.3, pp.297–308.
- OEH 2013, *Introducing Saving our Species*, NSW Office of Environment and Heritage, Sydney, www.environment.nsw.gov.au/-/media/OEH/Corporate-Site/Documents/Animals-and-plants/Threatened-species/introducing-saving-our-species-130344.pdf.
- OEH 2016, *Saving our Species Monitoring, Evaluation and Reporting: Guidelines for conservation projects*, NSW Office of Environment and Heritage, Sydney, www.environment.nsw.gov.au/research-and-publications/publications-search/saving-our-species-monitoring-evaluation-and-reporting-guidelines-for-conservation-projects.
- Pierson JC, Barton PS, Lane PW and Lindenmayer DB 2015, Can habitat surrogates predict the response of target species to landscape change? *Biological Conservation* vol.184, (Supplement c.), pp.1–10.
- Rumpff L, Duncan DH, Vesik PA, Keith DA and Wintle BA 2011, State-and-transition modelling for Adaptive Management of native woodlands, *Biological Conservation* vol.144, no.4, pp.1224–1236.
- Speirs-Bridge A, Fidler F, McBride M, Flander L, Cumming G and Burgman M 2010, Reducing overconfidence in the interval judgments of experts, *Risk Anal* vol.30, no.3, pp.512–523.

Case studies

Twelve case studies have been provided to demonstrate the application of the guidelines (Table 2). The selected species cover a range of taxa and represent both data rich and data poor situations. Each case study was completed by species and site experts including SoS project coordinators, site managers and external experts. Most case studies were designed in a facilitated single-day workshop and have been reviewed by a species expert not present at the initial workshop.

Refer to **Figure 4** for the notation used for the process models in the case studies.

Table 2 Details of species included in the case studies

	Scientific name	Common name	Listing in NSW
1	<i>Potorous tridactylus</i>	Long-nosed potoroo	Vulnerable
2	<i>Petroica boodang</i>	Scarlet robin	Vulnerable
3	<i>Miniopterus schreibersii oceanensis</i>	Eastern bentwing-bat	Vulnerable
4	<i>Anthochaera phrygia</i>	Regent honeyeater	Critically endangered
5	<i>Uperoleia mahonyi</i>	Mahony's toadlet	Endangered
6	<i>Pterostylis chaetophora</i>	Tall rustyhood	Vulnerable
7	<i>Acacia curranii</i>	Curly-bark wattle	Vulnerable
8	<i>Bossiaea fragrans</i>	<i>Bossiaea fragrans</i>	Critically endangered
9	<i>Dasyornis brachypterus</i> (central population)	Eastern bristlebird	Endangered
	<i>Dasyornis brachypterus</i> (northern population)	Eastern bristlebird	Endangered
10	<i>Grevillea caleyi</i>	Caley's grevillea	Critically endangered
11	<i>Petalura gigantea</i>	Giant dragonfly	Endangered
12	<i>Hoplocephalus bungaroides</i>	Broad-headed snake	Endangered

1. *Potorous tridactylus* (Long-nosed potoroo)



Long-nosed potoroo.
(Sharon Wormleaton)

Joss Bentley and Melinda Norton

Potorous tridactylus is listed as vulnerable in New South Wales and is assigned to the site-managed stream of the SoS program. Its range includes patches along the south-eastern coast of Australia, including Tasmania. Individuals can weigh up to 1.6 kilograms and live on average 4–5 years in the wild, reaching reproductive maturity at about one year of age. The species is largely nocturnal and feeds mostly on fungi supplemented by plant materials and, to a lesser extent, invertebrates.

Scope

The long-nosed potoroo project consists of four sites, during the period of SoS intervention (2015–2020):

- Budderoo/Barren Grounds/Kangaroo Valley
- South East
- Mt Royal/Barrington Tops, and
- Richmond Range.

The fourth SoS potoroo site (Richmond Range) is out of scope as site experts were not available to provide input. Prior to SoS, fox and cat control programs were in place in some sites, but varied in frequency and intensity, and therefore effectiveness. Wild dogs are present across all sites and are variously controlled to reduce predation on domestic stock and maintain neighbour relations, rather than to reduce predatory pressure on potoroos. To date fox and cat control, and fire management have not been undertaken in one section of the South East site (Nadgee Nature Reserve), as it serves a critical role as a non-treatment area from which to judge the success of fox control works elsewhere. Under current policy and SoS program settings this will continue, although there is provision for fox and cat control to be undertaken in the event of wildfire, to assist recovery of species like the potoroo. Other than in Nadgee, fox and cat control programs are ongoing as required (or to be initiated in some areas), and will therefore remain in-scope. SoS will also review fire management plans and prescriptions across all sites in the long term. Specific details of the four sites are as follows.

Budderoo/Barren Grounds/Kangaroo Valley

- Fox baiting – initiated 2004, consistently increased in intensity since then, especially with SoS intervention; unlikely to increase further.
- Fox and cat trapping – initial but occasional from roughly 2000; biannual from 2016 (SoS intervention).
- Fire (managing prescriptions) – 2015.

All actions occur across entire reserves. Some off-park fox baiting also included.

South East

- Fox baiting – low intensity across two sections (Bournda and Mimosa Rocks) part of park management for at least a decade. Intensive and high frequency baiting in Ben Boyd for over a decade. No baiting in Nadgee (wilderness area). Based on two seasons' monitoring in Bournda and Mimosa Rocks baiting will need to increase there (to be SoS funded). Long-term monitoring in Ben Boyd continues to indicate baiting is effective.
- Cats – nothing in Bournda and Mimosa Rocks. Based on monitoring results will need to be implemented. Potential to trial grooming traps. Cat control has been instigated in Ben Boyd since start of the SoS program, under the auspices of protecting the endangered southern brown bandicoot. No cat management is proposed for Nadgee, until the reserve is wildfire affected.
- Fire – input into prescriptions for future years, no input in past for Bournda and Mimosa Rocks. Input for areas of identified potoroo habitat in Ben Boyd and Nadgee, which should be extended to the other reserves.

With the exception of Nadgee, existing actions occur across entire reserves. Future actions may be more targeted.

Mt Royal/Barrington Tops

- Fox and wild dog control – low intensity and irregular as part of park management since at least 2010. Only one season's monitoring data, unclear whether increased baiting required.
- Cats – no management, further monitoring required to determine whether management required.
- Fire – input into prescriptions in future, no input until now. Input will be in areas of identified potoroo habitat. All management actions across all SoS sites will need to be ongoing.

Narrative

Long-nosed potoroos are threatened by predation by foxes and cats. A number of control techniques are available for foxes (baiting and trapping), which are capable of reducing fox densities to levels where the predation pressure exerted on potoroos is low enough to allow potoroo numbers to increase. Cat control is highly problematic, with few cost-effective techniques available. Fox and cat control is expected to reduce predation pressure, resulting in an increase in the potoroo population, provided habitat condition is also maintained.

Wild dogs also prey on potoroos, but they are unlikely to have population-level impacts on the species as they are mostly focused on other, larger, prey types. Currently, wild dog control is undertaken to reduce predation on domestic stock and maintain neighbour relations. It would only be undertaken for potoroos if new evidence becomes available that suggests that wild dog predation is resulting in a decline in the potoroo population, or is limiting its growth. Wild dog presence/absence may however influence fox and cat behaviour, and foxes will take some baits that are deployed for wild dog control purposes.

Fire frequency influences food supply (predominantly fungi with the addition of vascular plants and arthropods) and habitat suitability (high structural complexity particularly in the understory) for long-nosed potoroos. Potoroos are particularly vulnerable to predation post-fire, and foxes and cats are known to move large distances to hunt in recently burnt areas. Ongoing management of fire regimes will be required across all sites.

Pigs are likely to compete directly with potoroos for food resources as well as changing habitat structure, reducing its suitability for potoroos. We expect that pig control may be needed in some sites in the near future. Deer (multiple species) are increasing rapidly in south-east and central New South Wales and are expected to change habitat structure to make it less suitable for potoroos. Deer also create tracks through otherwise dense habitat which may facilitate predator access. While currently not a pressing management issue for potoroos in any of the nominated priority sites, a watching brief needs to be maintained for deer to ensure they are not problematic.

The interactions modelled in the following section are:

- threats to *Potorous tridactylus* include habitat loss, and predation by cats, foxes and possibly wild dogs
- wild dogs may reduce the number of foxes and cats through interspecific killing, as well as changing the behaviour of these introduce predators
- foxes reduce the number of cats both through interspecific killing and a general deterrent effect
- assuming best practice is followed, baiting for wild dogs reduces the number of wild dogs and also the number of foxes
- fox baiting reduces the number of foxes. It may also occasionally remove cats, but this effect is not significant
- trapping for cats or trapping for foxes reduces the number of cats and the number of foxes
- habitat can be highly modified and/or destroyed by pigs or deer
- pig numbers can be reduced with pig removal (e.g. live-trapping and shooting) and deer numbers may be locally reduced with targeted ground-based shooting
- *Potorous tridactylus* rely heavily on fungi availability for food. They also increase fungi availability by dispersing the spores of the fungi they eat
- fungi availability is decreased by pigs through over-consumption, and decreased through unsuitable climactic conditions and the amount of area under unsuitable fire regimes
- the amount of area under an unsuitable fire regime will decrease the amount of habitat
- community engagement can assist with landscape-scale management of foxes, deer and pigs, including on adjacent tenures.

Process model

Cats: Area (in ha) with cats present

Cat trapping: Area (in ha) with adequate cat trapping

Community engagement: Hours spent on community engagement

Deer: Area (in ha) with deer present

Deer shooting: Area (in ha) with adequate deer removal (shooting)

Foxes: Area (in ha) with foxes present

Fox baiting: Area (in ha) with adequate fox baiting

Fox trapping: Area (in ha) with adequate fox trapping

Fungi availability: Approximate biomass of fungi accessible by *Potorous tridactylus*

Habitat: Area (in ha) of suitable habitat

Pigs: Area (in ha) with pigs present

Pig removal: Area (in ha) with adequate pig removal (shooting or trapping)

***Potorous tridactylus*:** Occupancy of long-nosed potoroos

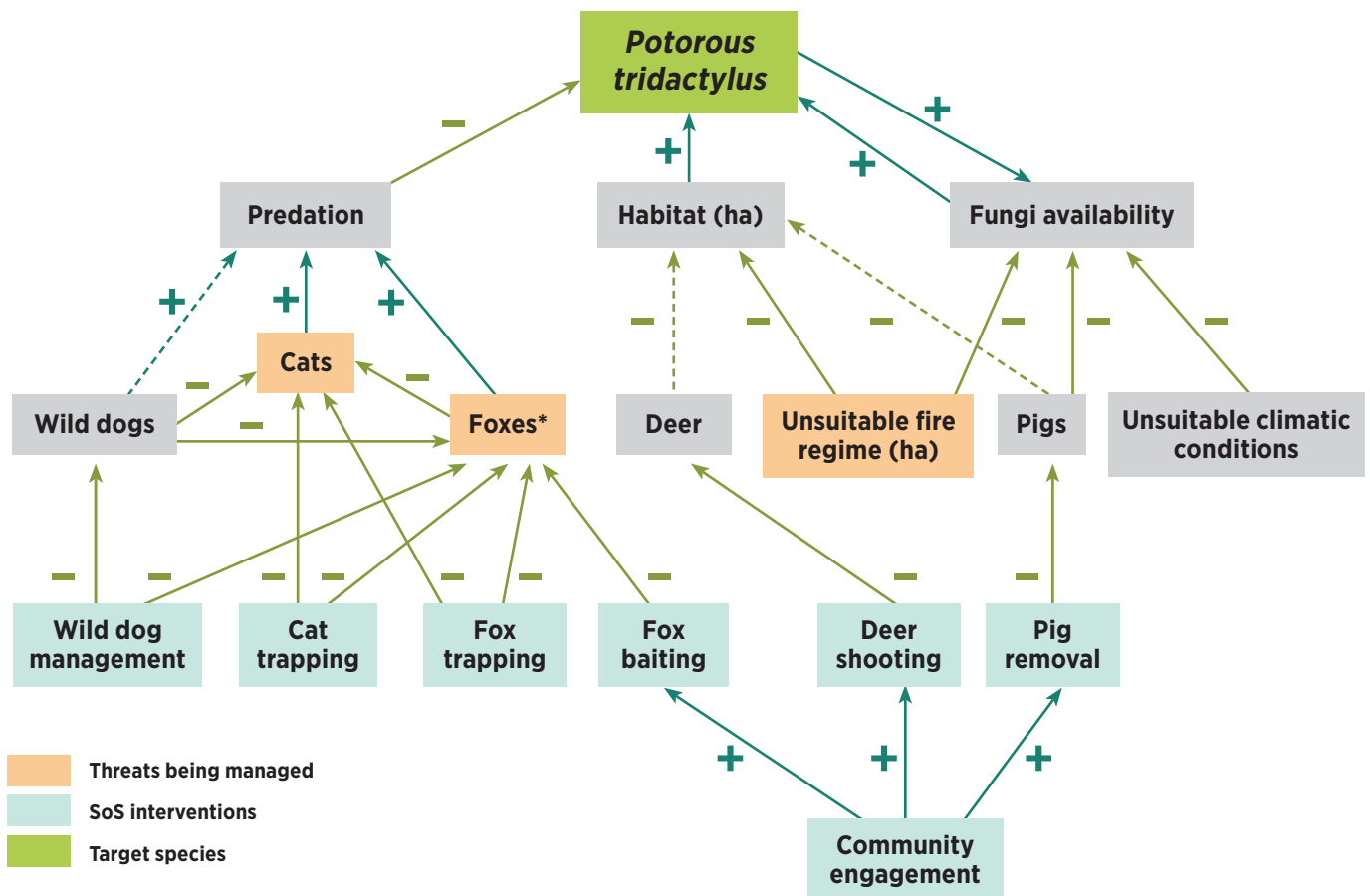
Predation: Number of *Potorous tridactylus* predated each year

Unsuitable fire regime: Area (in ha) not managed under a suitable fire regime

Unsuitable climatic conditions: Months per year with unsuitable climatic conditions for fungus

Wild dogs: Area (in ha) with wild dogs present

Wild dog management: Area (in ha) with adequate baiting and trapping



* Some fox management occurs outside of SoS.



Potoroo trapping, Barren Grounds, measuring the head.

(Michael Van Ewijk/OEH)

Modelling decisions and assumptions

- The effect of climate change on this species is unknown; however, it is represented in the inclusion of suitable climatic conditions and possibly suitable fire regime.
- Fox baiting may occasionally kill cats, but not in sufficient numbers to warrant inclusion in the model.
- A suitable fire regime can be disrupted at any time by wildfire; however, it was still included in the model as the wildfires are infrequent enough to consider implementing deliberate fire in-between wildfires.
- Suitable habitat structure includes both dense refugia and more open foraging patterns. It is unclear whether 'suitable habitat structure' limits predator access, so this direct effect has not been represented in the model.
- Suitable fire regime will increase the amount of suitable habitat up to the size of the site. The amount of suitable habitat will decline immediately after a fire, but generally increases from about 10 years post-fire for at least several decades, until understorey vegetation cover declines.

Indicators

The indicators selected for monitoring *Potorous tridactylus* are:

- Potoroo occupancy (% of site with potoroos present)
- Fox occupancy (% of site with foxes present)
- Cat occupancy (% of site with cats present)
- Hectares under suitable fire regime (a measure of unsuitable fire regime).

It is acknowledged that additional metrics other than site occupancy may be required for long-nosed potoroos as they are not likely to display a dispersal response that sees them filling in large amounts of the landscape, even under optimal fox and/or cat control – this has been proven elsewhere in south-eastern mainland Australia.

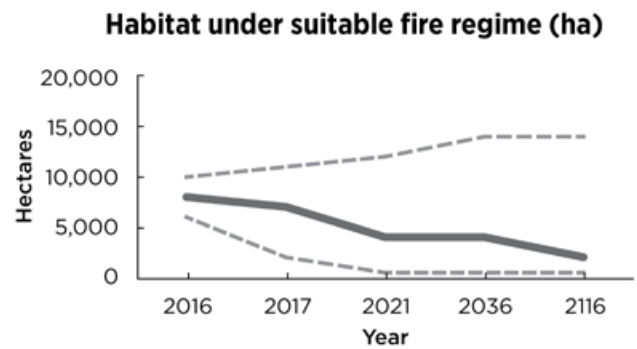
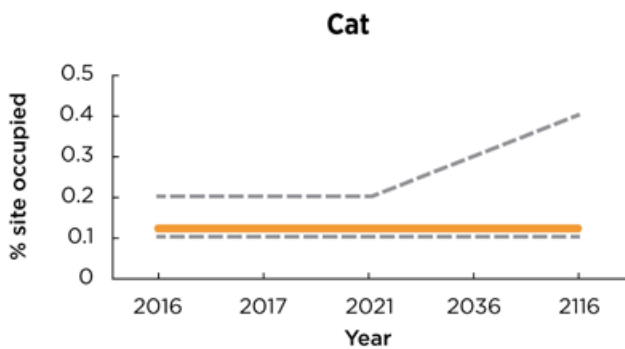
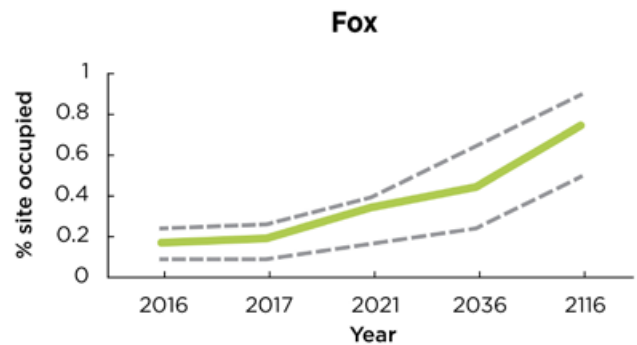
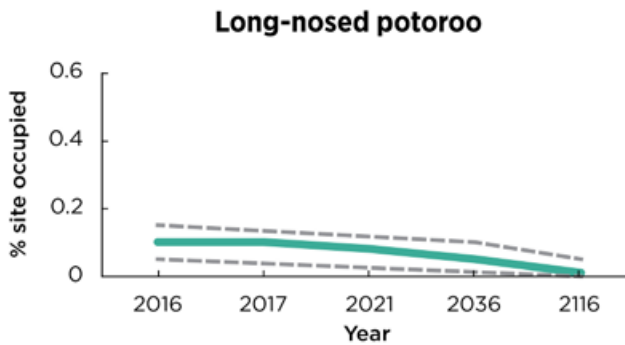
Instead, potoroos are more likely to increase density around known localities, with large gaps in the landscape between those localities. Monitoring arrays set up on evenly spaced or grid-like bases will fail to pick up these trends.

Response to management estimates

The following response to management curves were estimated during the workshops by species experts. Plots show the experts' best guess for how each indicator would respond under different scenarios, as well as the highest and lowest expected values (shown with dashed lines). The confidence that the value for each indicator will fall inside this range is given underneath each plot.

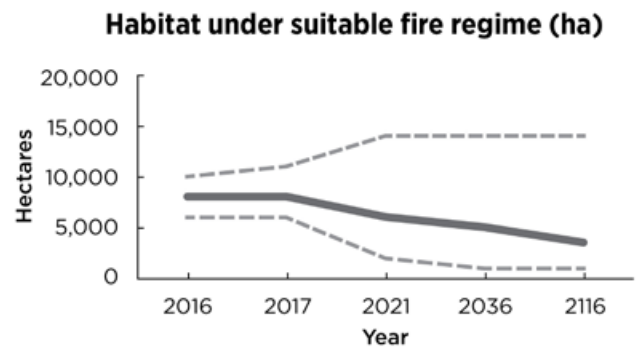
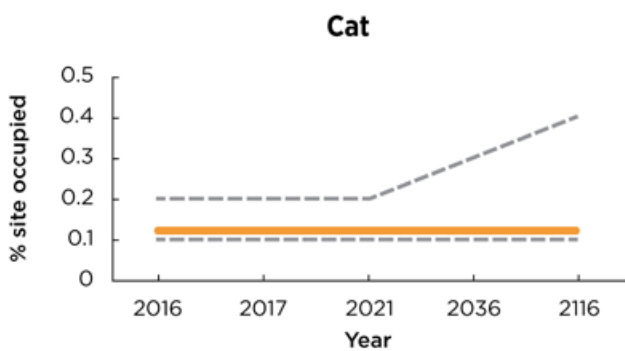
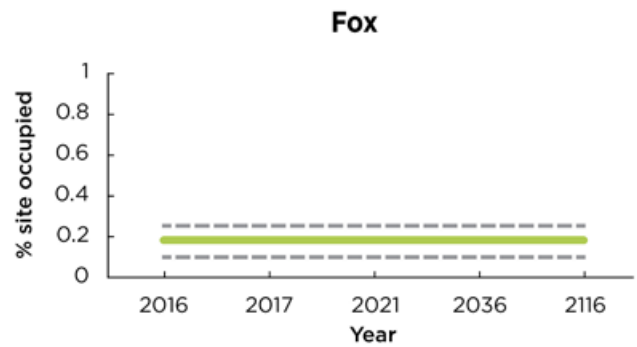
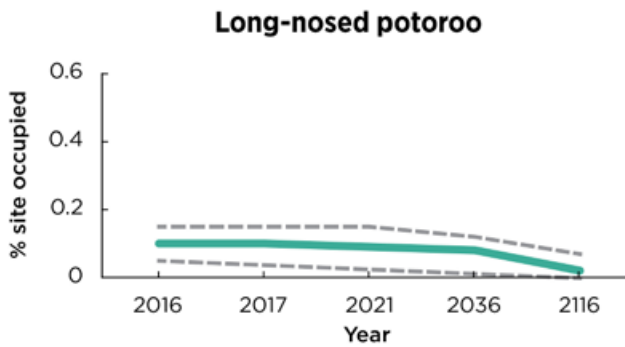
Scenario 1: No management

Estimated values for each indicator's response to management under a no management scenario. Plots show highest, lowest and most likely plausible values as estimated by experts. Confidence values for each indicator are given below each plot.



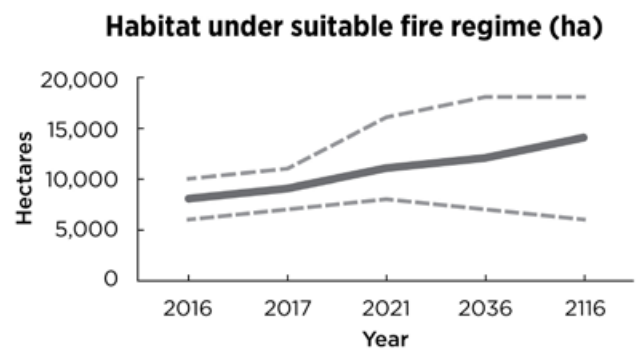
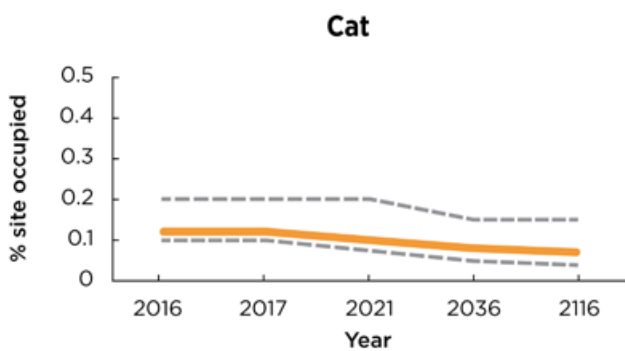
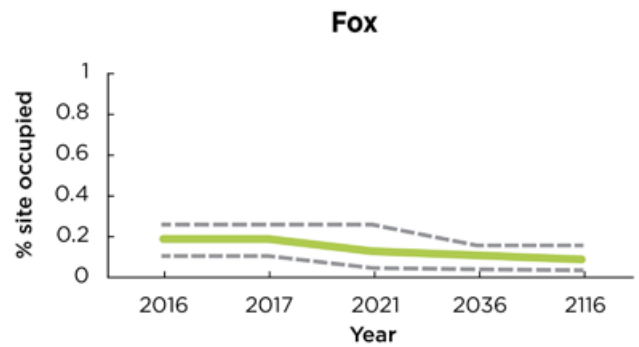
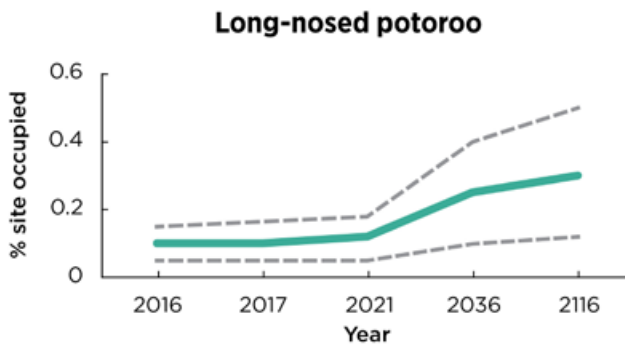
Scenario 2: Continuation of pre-SoS management

Estimated values for each indicator's response to management under a pre-SoS management scenario. Plots show highest, lowest and most likely plausible values as estimated by experts. Confidence values for each indicator are given below each plot.



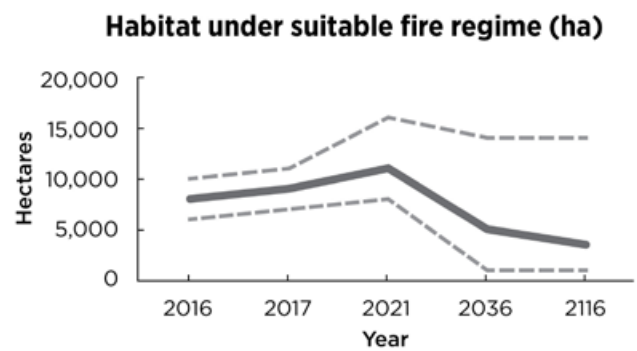
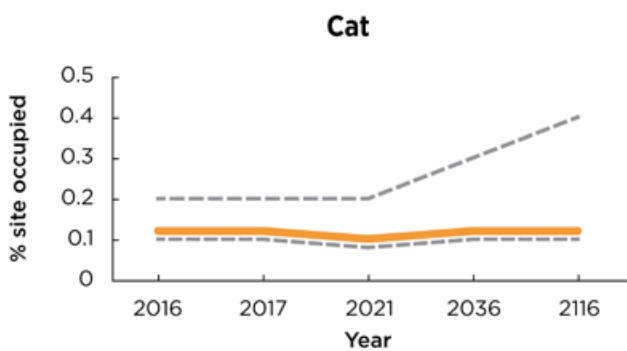
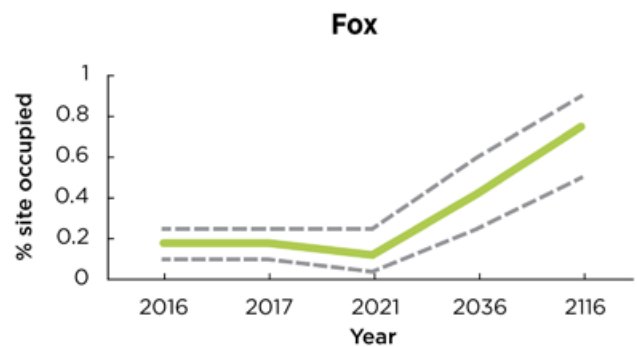
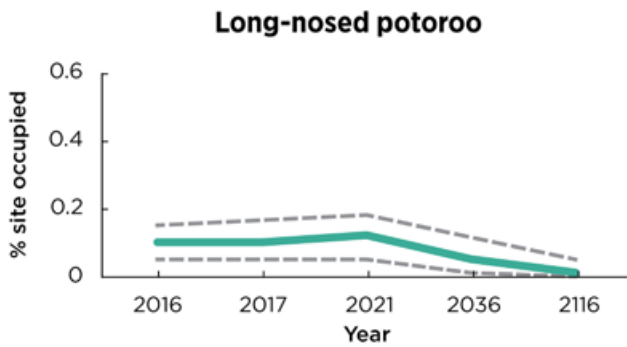
Scenario 3: Continued SoS intervention

Estimated values for each indicator's response to management under a continued SoS management scenario. Plots show highest, lowest and most likely plausible values as estimated by experts. Confidence values for each indicator are given below each plot.



Scenario 4: Current SoS intervention only

Estimated values for each indicator's response to management under the current SoS management scenario. Plots show highest, lowest and most likely plausible values as estimated by experts. Confidence values for each indicator are given below each plot.



2. *Petroica boodang* (Scarlet robin)



Scarlet robin (*Petroica boodang*).
(Dean Ingwersen/Environ Imagery)

Damon Oliver and Rebecca Bradley

Petroica boodang is a small, colourful, woodland bird that has wide, yet patchy, geographical distribution across Australia, being found in Western Australia, South Australia, Victoria, Tasmania, New South Wales and Queensland. Birds breed between July and January, and may utilise more open, grassy habitats outside of the breeding season.

In New South Wales, the species is considered to be a seasonal 'altitudinal migrant', where birds typically breed at higher elevations in spring and summer, then retreat to lower altitudes including tablelands, slopes and coastal areas, in autumn and winter. The species is insectivorous and therefore depends on fallen woody debris, good leaf litter cover and diversity in ground and shrub strata within its habitat for foraging. *Petroica boodang* is listed as vulnerable in New South Wales and has been allocated to the landscape-managed stream of the SoS program.

Scope

1. Target species – Scarlet robin *Petroica boodang* – project commenced in 2016–17
2. Sites – Delegate and Queanbeyan-Palerang
3. Interventions – tree and shrub planting, grassy and woody weed control, stock grazing management in non-breeding habitat, retention of large, fallen, woody debris, community education and engagement.
4. Previous management – some habitat augmentation and increase from general vegetation restoration programs, but not targeted specifically at scarlet robins. There have been previous community engagement activities about the conservation and management of threatened woodland birds, but not specifically scarlet robins.
5. Threats targeted by interventions – habitat loss and reduction in structural complexity (degradation), weed invasion, loss of connectivity (increased isolation), lack of landholder/land manager knowledge of management requirements of the scarlet robin.
6. Out of scope:
 - Wildfire is a key threat in breeding habitat in spring and summer away from the two SoS sites – this is not being dealt with through SoS – fire management and planning is carried out by the NSW National Parks and Wildlife Service (NPWS).
 - Climate change is likely to affect breeding habitat in higher altitude areas over the next few decades to 100 years, which is not addressed in this project.
 - Habitat degradation by feral herbivores – rabbits, goats, pigs and deer – is not being managed within the two investment sites, though landholders are encouraged to manage these threats through different programs and funding sources.



Male scarlet robin. (Jackie Miles/OEH)

- Loss of fallen woody debris is not being managed in this project, except through community engagement actions and landholder agreements.
- Predation by currawongs is also not being measured – threat is addressed through woody weed removal.

Narrative

Scarlet robins in the Queanbeyan-Palerang and Delegate sites are at risk of loss of habitat, reduced habitat structural diversity and reduced ability to move through the landscape due to fragmentation of remnants. A number of activities will improve foraging habitat and movement of these species within the landscape. Fencing existing remnants from grazing animals will allow for regeneration of understorey species, providing improved shelter. Establishment of revegetation areas including corridors and stepping stones adjacent to remnants will assist scarlet robin movement across the landscape. Reduction in weeds including grassy weeds and berry bearing shrubs will improve available habitat/food sources and is anticipated to reduce predation. Increasing land manager awareness of scarlet robins and their habitat requirements will assist in improving land management decisions for the benefit of scarlet robin including retention of large, fallen, woody debris, management of weeds and exotic animals.

This has been modelled as follows:

- The number of scarlet robins is directly affected by the amount of habitat, the habitat structural complexity and the habitat connectivity.
- Habitat structural complexity is negatively affected by the amount of grassy weeds, damage caused by exotic/introduced herbivores and the removal of woody debris.
- Fencing managed remnants and community engagement with landholders can reduce the number of feral herbivores.
- Fencing managed remnants can also increase habitat connectivity by increasing extent and complexity.
- Woody debris is directly reduced through firewood collection and other human activities.
- Community engagement can reduce firewood collection, improve grazing management and increase weed control.
- Scarlet robins are predated by currawongs, which are encouraged by an increase in berry bearing shrubs or a decrease in habitat structural complexity.
- Grazing management and weed control reduce grassy weeds, which increases the amount of habitat. Grazing management also increases habitat structural complexity.
- Weed control will also reduce berry bearing shrubs.
- Non-targeted tree planting (e.g. by landholders) will increase the amount of habitat, but not habitat connectivity.
- Augmented (targeted) tree planting and targeted restoration will increase the amount of habitat, and also habitat connectivity.

Process model

Amount of habitat: Amount of suitable habitat (ha)

Augmented/targeted tree planting: Hectares planted

Berry bearing shrubs: Average density of berry bearing shrubs on site

Community engagement: Number of landholders engaged with

Currawong predation: Number of scarlet robins predated by currawong

Exotic herbivores: Density of feral herbivores on site

Fencing managed remnants: Hectares fenced

Firewood collection: Total biomass removed from a site each year

Grassy weeds: Average weed density of a site

Grazing management: Amount of a site where suitable grazing management takes place

Habitat connectivity: Average distance between patches

Habitat structural complexity: Suitability of habitat on a scale of 0 – 10:

7–10: optimal habitat with >50% chance of habitat selection

3–6: moderate habitat condition with 10–50% chance of habitat selection

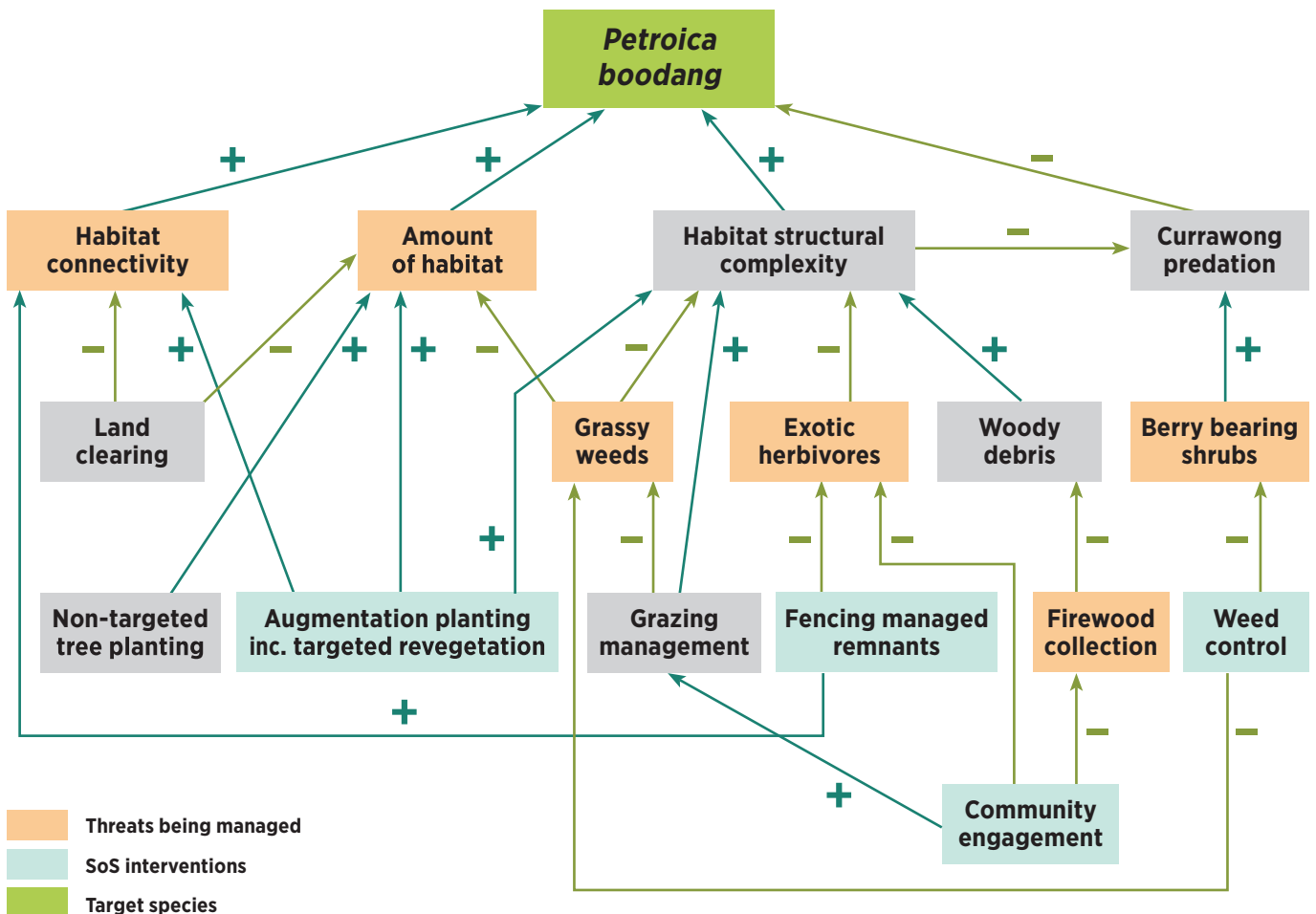
0–2: low habitat condition with <10% chance of habitat selection

Non-targeted tree planting: Hectares of trees planted by landowners

Scarlet robins: Population size

Weed control: Hectares managed

Woody debris: Average biomass of woody debris per hectare





Female scarlet robin. (Jackie Miles)

Modelling decisions and assumptions

- The level of fox predation and the effect of foxes on scarlet robin habitat is not known, and has therefore been excluded from the model.

Indicators

- Abundance/occupancy levels of scarlet robins (birds per ha)
- Amount (ha) of new habitat
- Amount (ha) of augmented habitat
- Habitat structural complexity (1-10)

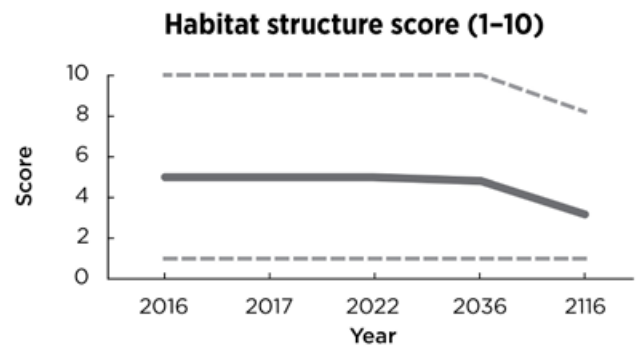
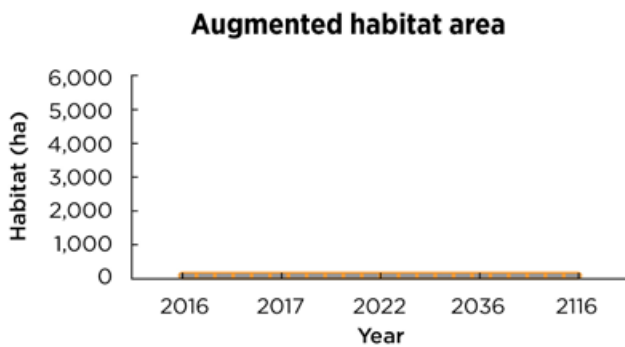
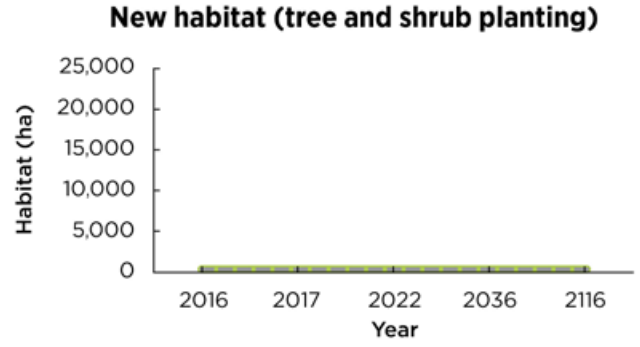
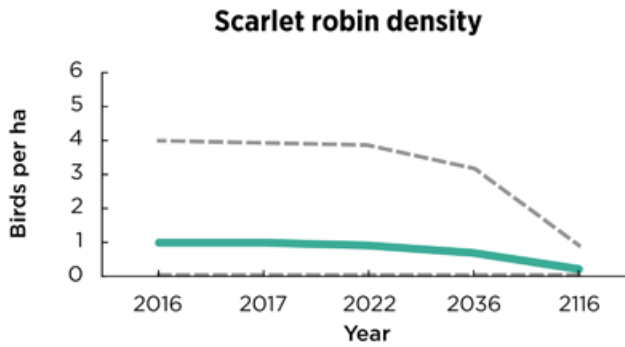
It is acknowledged that an additional indicator for total population may also be required as the use of an abundance metric will not reflect changes in populations in relation to new or removed habitat (e.g. the density may stay the same, but an increase in habitat will carry a larger population at this density).

Response to management estimates

The following response to management curves were estimated during the workshops by species experts. Plots show the experts' best guess for how each indicator would respond under different scenarios, as well as the highest and lowest expected values (shown with dashed lines). The confidence that the value for each indicator will fall inside this range is given underneath each plot. Augmented habitat represents supplementary planting and grazing/fencing agreement in remnant vegetation (ha).

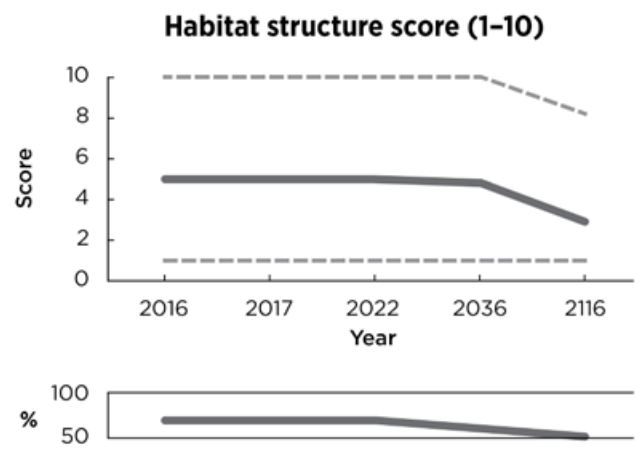
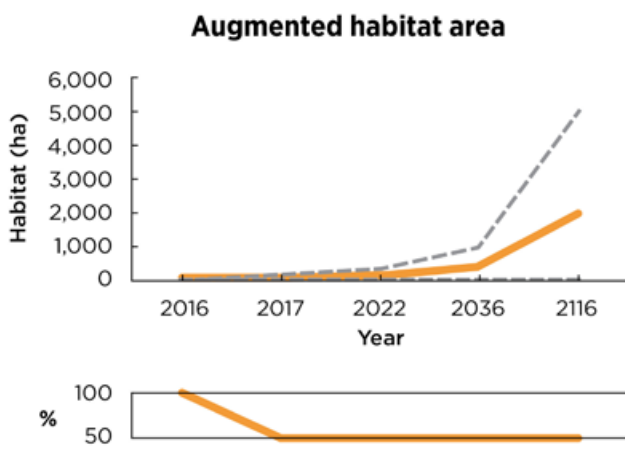
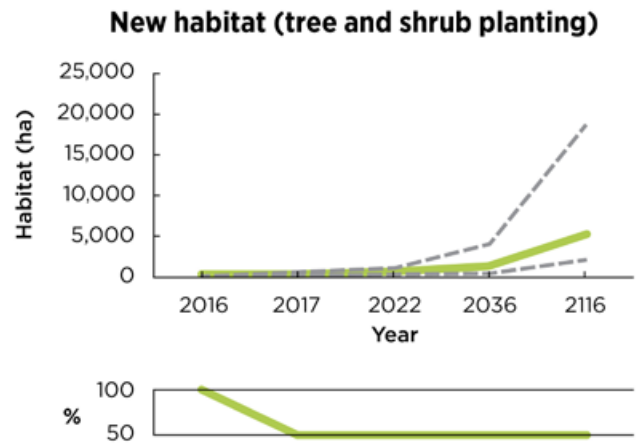
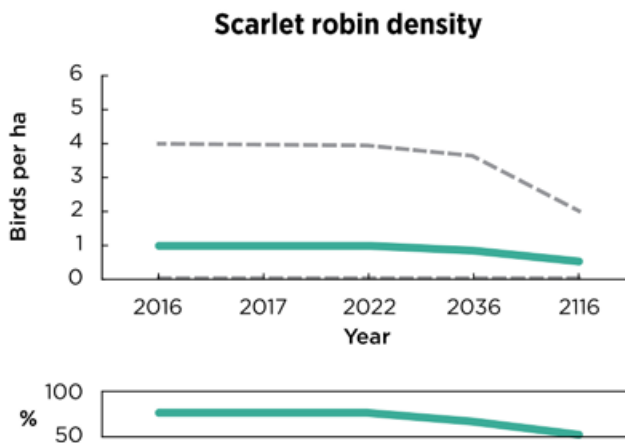
Scenario 1: No management

Estimated values for each indicator's response to management under a no management scenario. Plots show highest, lowest and most likely plausible values as estimated by experts. Confidence values for each indicator are given below each plot.



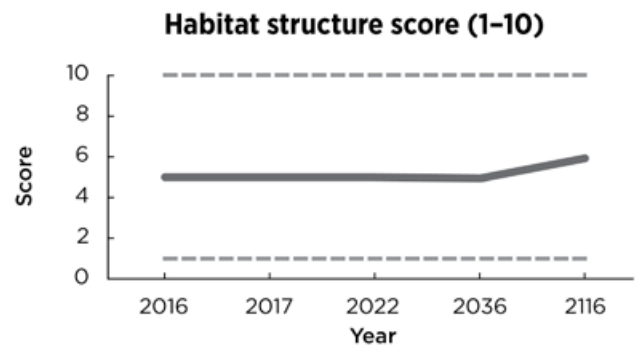
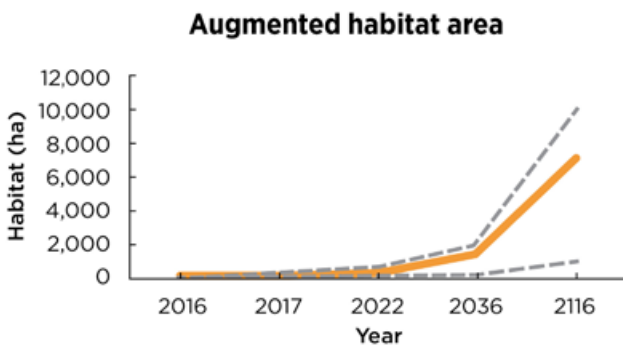
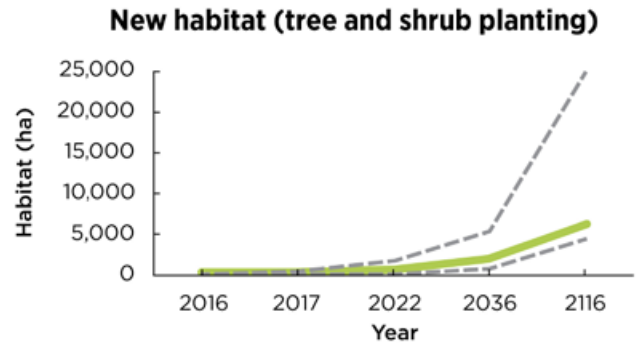
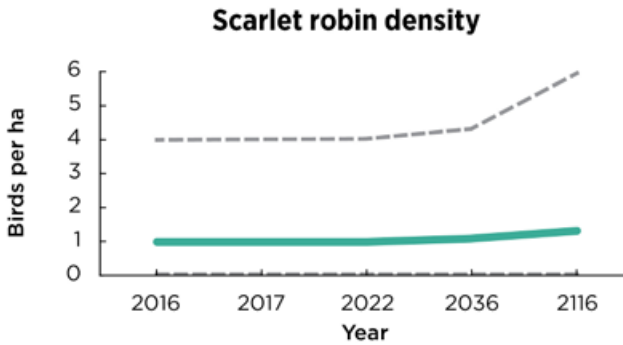
Scenario 2: Continuation of pre-SoS management

Estimated values for each indicator's response to management under a pre-SoS management scenario. Plots show highest, lowest and most likely plausible values as estimated by experts. Confidence values for each indicator are given below each plot.



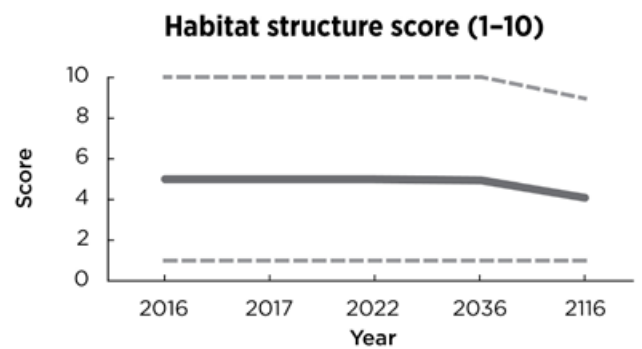
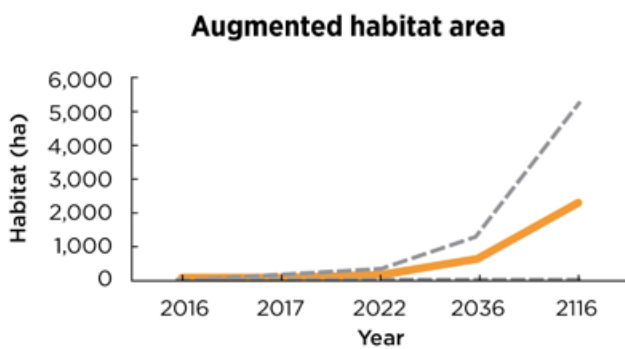
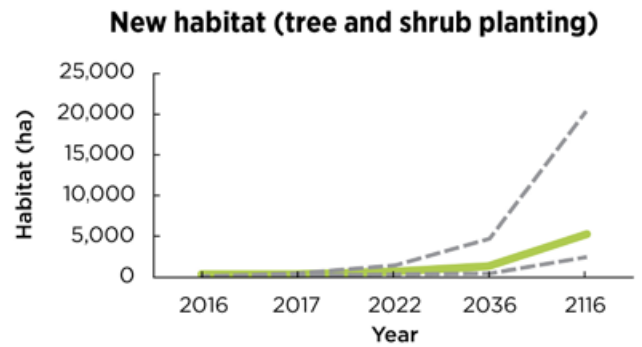
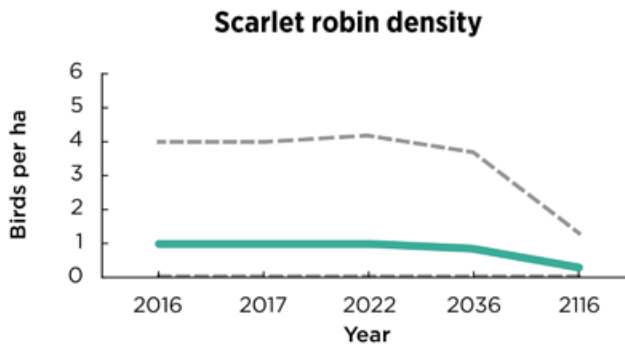
Scenario 3: Continued SoS intervention

Estimated values for each indicator's response to management under a continued SoS management scenario. Plots show highest, lowest and most likely plausible values as estimated by experts. Confidence values for each indicator are given below each plot.



Scenario 4: Current SoS intervention only

Estimated values for each indicator's response to management under the current SoS management scenario. Plots show highest, lowest and most likely plausible values as estimated by experts. Confidence values for each indicator are given below each plot.



3. *Miniopterus schreibersii oceanensis* (Eastern bentwing-bat)



Bentwing-bat (*Miniopterus schreibersii*) also known as vesper bat.
(K Stepnell/OEH)

Doug Mills and Michael Pennay

Miniopterus schreibersii oceanensis is an insectivorous microbat with a wingspan up to 35 centimetres. The species is found along the east coast of mainland Australia, and primarily roosts in caves. Females form maternity roosts in summer, where they typically raise a single pup each year. During the colder months, the species usually hibernates in separate winter roosts. The species is listed as vulnerable in New South Wales and is included in the site-managed stream of the SoS program due to its dependence on subterranean roost sites.

Scope

The distribution of the eastern bentwing-bat covers a large section of eastern New South Wales. Some of the threats are therefore widespread, such as habitat fragmentation and degradation. Although this species has an extensive foraging range, the model developed here specifically focuses on SoS actions surrounding the maternity roosting sites, which are located within national parks. Relevant threats that could affect a species' response to management, such as an unsuccessful foraging season, have also been included in the model.

SoS interventions for this species include vegetation clearing to maintain a clear passage for bats entering and leaving the roost, limiting the use of pesticides, and controlling any cats located near the caves. Limiting visitor access to the sites during breeding (or hibernation for winter roosts) is also important as the disturbance will have an impact on survival rates.

There is good monitoring data for this species and the main threats are well understood. The major unknowns are the species' response to climate change and how it will respond if white-nose fungus appears in the colony.

Narrative

- The population size of eastern bentwing-bats is increased by the annual breeding success (proportion of pups weaned and dispersing) and decreased by winter mortality rates.
- Factors increasing winter mortality are disturbance to the roost from feral animals and recreational use by cavers or other people, and deviation from ideal microclimate (for both temperature and humidity). Winter mortality is reduced by a successful foraging season.
- A key potential threat to increasing winter mortality (not yet active but assessed as almost certain within 10 years)¹ is fungal infection with the invasive pathogen *Pseudogymnoascus destructans*.
- Recreational use of caves by unauthorised people is also a potential threat to the annual breeding success.
- Restricting visitation through signs or gates reduces recreational use and the associated roost disturbance.
- The annual foraging success is a key factor to the annual breeding success, as it allows females to successfully raise pups.
- The annual foraging success will also affect winter mortality as bats need to reach a sufficient body weight to survive hibernation.
- Annual foraging success is increased by the abundance of flying insects and the amount of readily available water for lactating females to drink.
- The abundance of flying insects is likely to increase when there is more available water and there is good quality contiguous vegetation in the foraging area.
- The available water is affected by the annual rainfall as well as the river/dam levels.
- Annual rainfall directly affects the river/dam levels and vegetation condition.
- Cat predation on bats emerging from the cave is probably sporadic but, if left unmanaged without cat control, is likely to seriously affect population numbers.
- Predation from sources other than cats may also be an issue.
- Vegetation obstructions at the cave entrance may reduce the number of eastern bentwing-bats by causing injuries and restricting exit and entry to the cave.
- Obstruction at the cave is reduced by obstruction removal (primarily vegetation removal).
- Wind farms may potentially reduce numbers of eastern bentwing-bats through mortalities from turbine strike; however, the magnitude is not known.

¹ www.wildlifehealthaustralia.com.au/Portals/0/Documents/ProgramProjects/WNS_Disease_Risk_Analysis_Australia.pdf

Process model

Annual rainfall: Seasonal rainfall in millimetres or soil moisture

Annual breeding success: Proportion of pups weaned and dispersing

Annual foraging success: Proportion of bats reaching the minimum weight for a feasible hibernation

Available water: Area of surface water accessible by bats within a 10 kilometre radius of the roost

Cats present: Number of nights a year where cats are present

Cat control: Number of cats removed from site

Contiguous vegetation cover condition: Condition (poor, fair, good, very good) of the vegetation within 30 kilometres of the roost

Deviation from ideal microclimate: Deviation from ideal conditions in terms of degrees temperature and percent humidity

Eastern bentwing-bat: Population size in January (pre pups)

Feral animal disturbance: Number of days during winter where hibernating bats are disturbed by feral animals, e.g. cats or goats

Flying insects: Average insect density in foraging area

Fungal pathogens: Number of bats showing signs of pathogens (*Pseudogymnoascus destructans*); currently none, but has been flagged as a potential yet serious threat

Recreation use at caves: Number of people each season accessing roost sites

Restrict visitation: Whether or not access to the site is restricted

River/dam levels: Dam level in metres

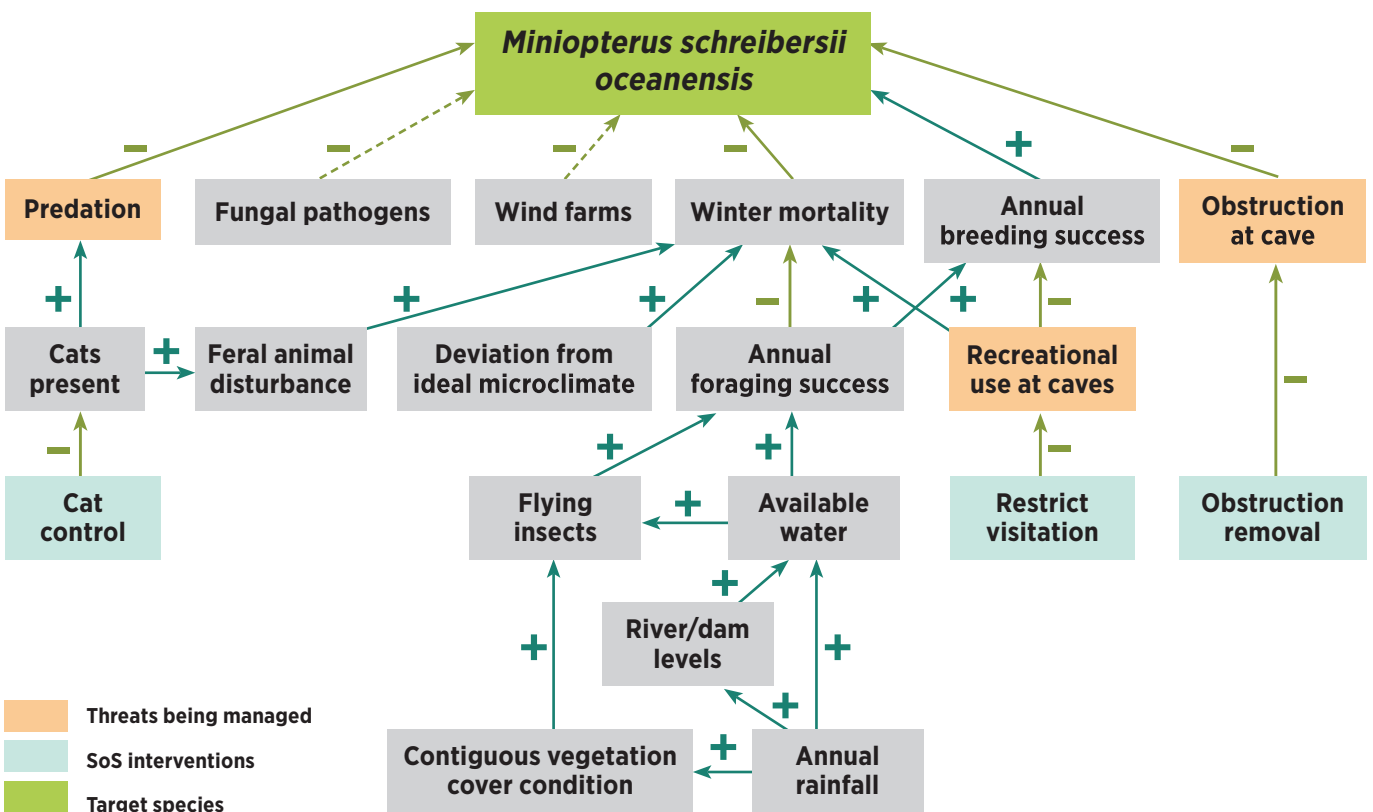
Obstruction at cave: Proportion of cave entrance obstructed (most commonly by vegetation)

Obstruction removal: Percentage of cave entrance cleared of obstructions

Predation: Number of bats predated by cats or other predators

Wind farms: Number of wind turbines within 30 kilometres of roost site

Winter mortality: Proportion of bats not surviving winter





Ashford Caves in Kwiambal National Park. (Simone Cottrell/OEH)

The large arch-shaped opening was made to access the phosphate (guano) resources for use as fertiliser. A colony of eastern bentwing-bats inhabits the cave system and breeds from November through to March.

Modelling decisions and assumptions

- Bat numbers will be reduced by natural deaths outside of winter hibernation through factors not listed here; however, this has not been explicitly represented as it is ultimately linked to the breeding success of the species.
- It is assumed that the carrying capacity of specific roost sites is not exceeded. If this occurs it should be added to the model as a restriction on population size.
- The potential effects of climate change on this species are represented by including nodes for rainfall and temperature.

Indicators

Indicators selected reflect the threats that are being managed under the SoS interventions currently in place. The selected indicators are:

- Eastern bentwing-bat population during breeding season (pre pups)
- Proportion of roost entrance covered
- Number of nights that cats have been detected on site.

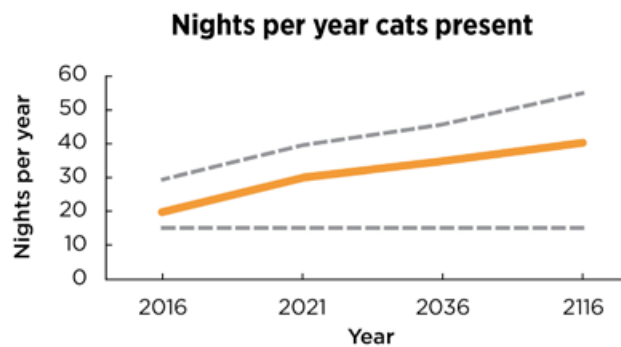
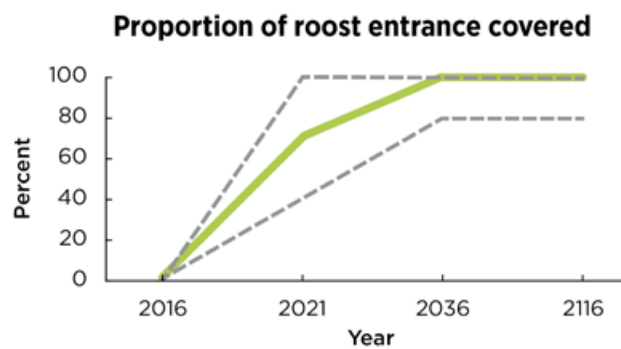
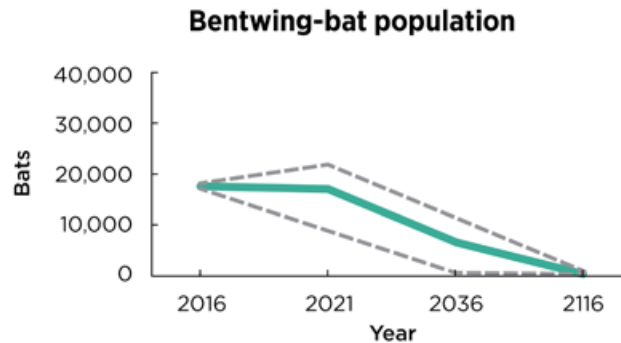
Response to management estimates

The following response to management curves were estimated during the workshops by species experts. Plots show the experts' best guess for how each indicator would respond under different scenarios, as well as the highest and lowest expected values (shown with dashed lines). The confidence that the value for each indicator will fall inside this range is given underneath each plot.

The eastern bentwing-bat case study followed a previous version of the guidelines where only three scenarios and four time-steps were considered. If SoS was implemented as planned over the five years, the long-term indicator response would most likely be the same as the estimates for Scenario 2: Continuation of pre-SoS management.

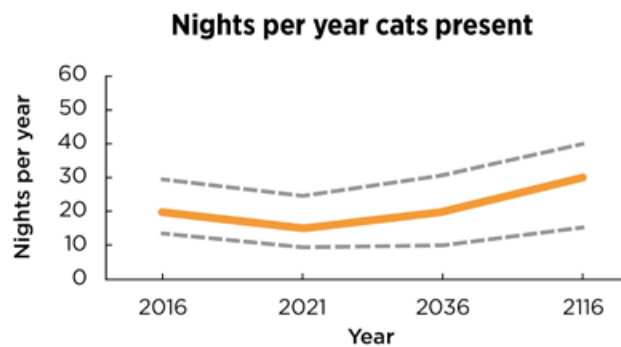
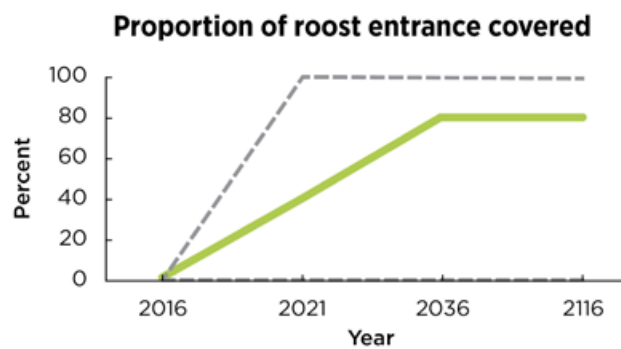
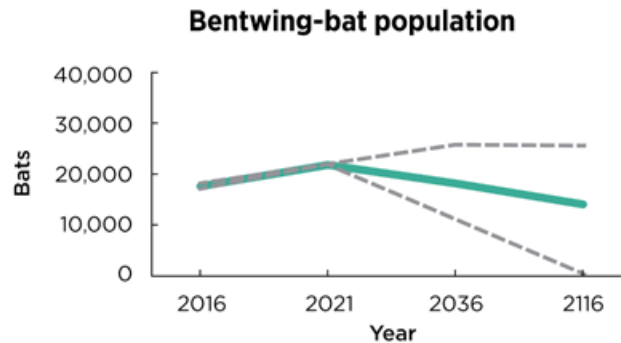
Scenario 1: No management

Estimated values for each indicator's response to management under a no management scenario. Plots show highest, lowest and most likely plausible values as estimated by experts. Confidence values for each indicator are given below each plot.



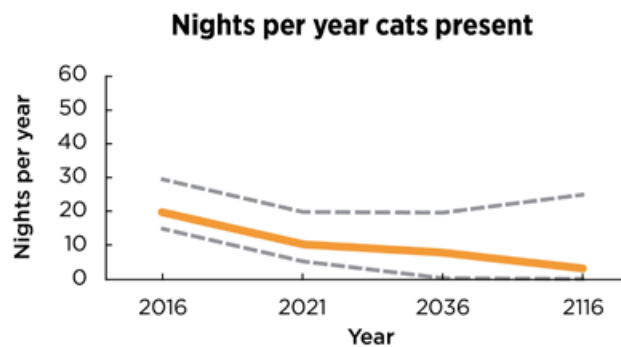
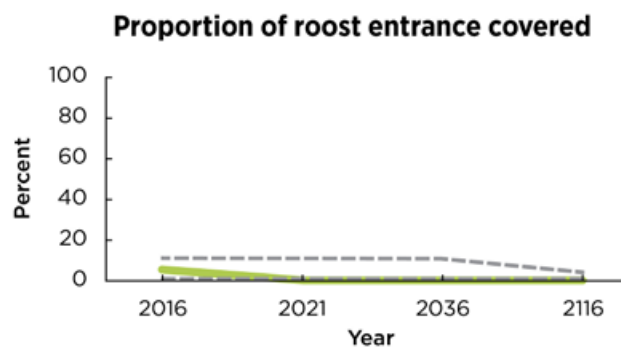
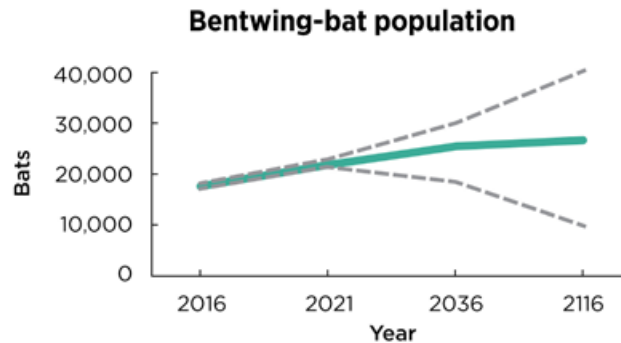
Scenario 2: Continuation of pre-SoS management

Estimated values for each indicator's response to management under a pre-SoS management scenario. Plots show highest, lowest and most likely plausible values as estimated by experts. Confidence values for each indicator are given below each plot.



Scenario 3: Continued SoS intervention

Estimated values for each indicator's response to management under a continued SoS management scenario. Plots show highest, lowest and most likely plausible values as estimated by experts. Confidence values for each indicator are given below each plot.



4. *Anthochaera phrygia* (Regent honeyeater)



Regent honeyeater (*Anthochaera phrygia*). (Mick Roderick)

Sarah Bell, Garry Germon, David Geering, Mick Roderick and Huw Evans

Anthochaera phrygia is listed as critically endangered and is included in the site-managed stream of the SoS program. The species is a nectarivore, utilising key species of eucalypts for nectar, but its diet also includes insects, honeydew and fruit from mistletoe. It has a restricted range across south-eastern Australia with three of the four known key breeding sites in New South Wales. Breeding occurs between July and January, and chicks fledge after 16 days. The birds' movements outside the breeding season are not well understood, but *Anthochaera phrygia* is known to be semi-nomadic, travelling hundreds of kilometres.

Scope

There are a wide range of threats affecting the population, which is widely dispersed across eastern New South Wales. Management of this species occurs on both private and protected land. As there is currently extremely limited knowledge of the species' movements outside the breeding season, the process model covers only the known threats during the breeding season. It is presumed that many of these, such as fragmentation and degradation of habitat and access to nectar resources, are also relevant during the winter period.

Narrative

- Accessible nectar resources are a key requirement for adult regent honeyeaters.
- Accessible nectar resources are reduced by ongoing drought, competition with bees, mistletoe die off and interspecific competition with other nectarivores.
- Land clearing reduces accessible nectar resources by reducing the number of trees, as well as increasing habitat fragmentation and degradation, making it more difficult for birds to move from one resource to another.
- Habitat fragmentation and degradation directly affects the number of regent honeyeaters by reducing nest sites and other key resources.
- Habitat fragmentation and degradation increases interspecific competition by creating favourable conditions for more aggressive birds, including noisy miners and other nectarivores.
- Effective control of noisy miners can reduce interspecific competition.
- Mistletoe research may reduce mistletoe die off through increasing our understanding and helping to inform actions. Reducing mistletoe die off will reduce habitat fragmentation and degradation.

- Occasional fire is presumed to decrease degradation and fragmentation in the long term; however, if fire is too frequent this will increase degradation and fragmentation as well as decreasing accessible nectar resources.
- The amount of habitat fragmentation and degradation can be reduced by tree planting, habitat protection such as covenants, and by weed and pest management.
- Tree planting also directly increases access to nectar resources.
- Key threats to nestlings are nest predation and nest disturbance.
- Nest predation increases with increased interspecific competition, as well as habitat fragmentation and degradation, and can be reduced through predator control and other nest protection, such as collars.
- Promoting responsible bird watching strategies can reduce nest disturbance.
- Nest disturbance increases with increased habitat fragmentation and degradation.
- Cooperative defence by adult regent honeyeaters reduces nest disturbance and interspecific competition.
- The small size of the remaining regent honeyeater population means that genetic diversity may cause reduced breeding fitness and affect the number of nestlings that are successfully hatched. Increasing the number of adults by supplementing the population from captive birds can increase the genetic diversity.
- Unknown movements in winter may reduce the number of regent honeyeaters as the threats during this time cannot be effectively managed.
- The impact of access to a constant and relatively close water source on breeding/nesting success is uncertain.

Process model

Accessible nectar resources: Amount of nectar that is accessible to regent honeyeaters

Bees: Number of bees or other nectar eating insects

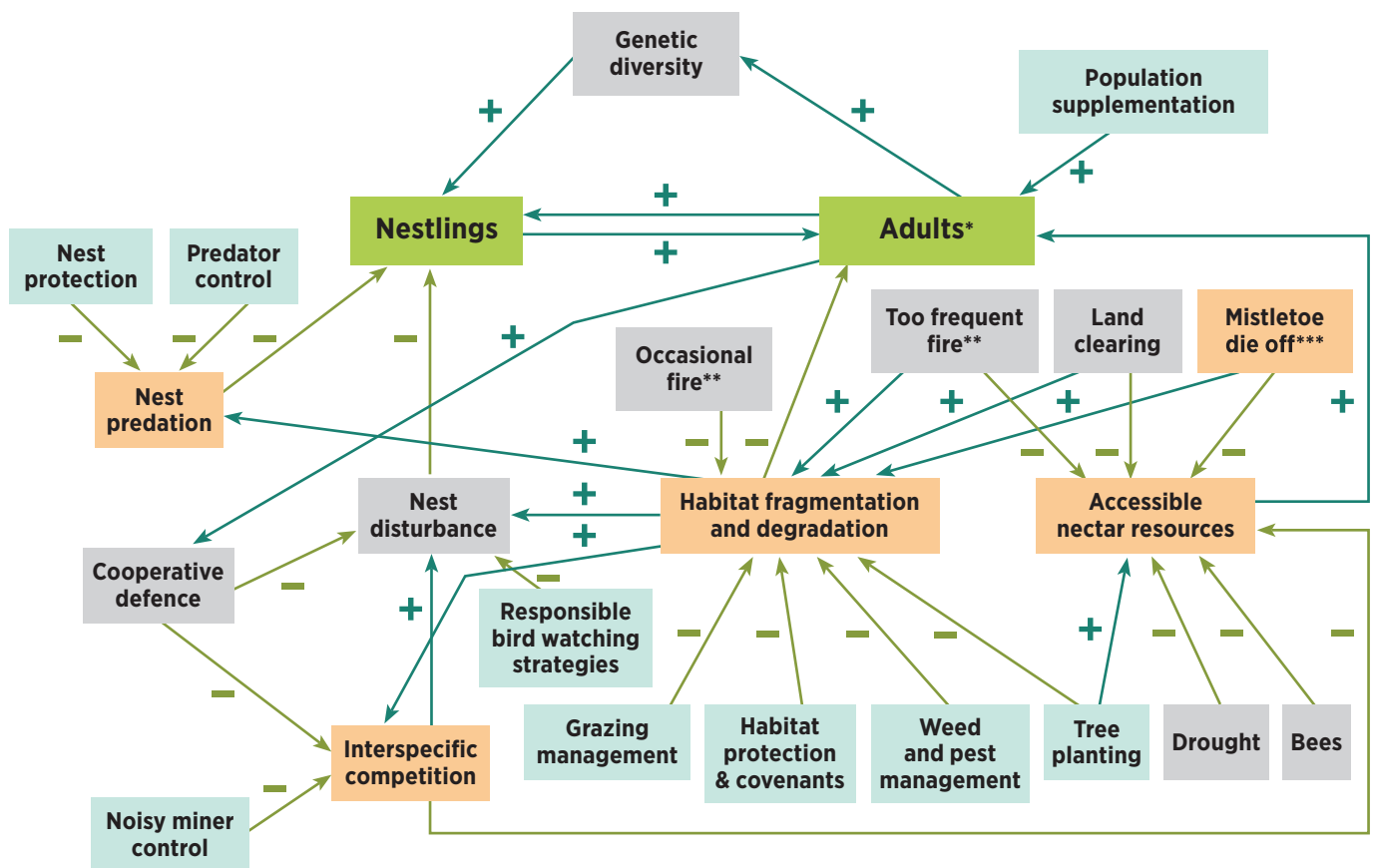
Cooperative defence: Effectiveness of the cooperative defence of a regent honeyeater flock

Drought: Months per year under drought conditions

Genetic diversity: Degree of genetic diversity in the wild population

Interspecific competition: Number of competing birds in the breeding area

Habitat fragmentation and degradation: Edge density of the patches of non-degraded habitat/average distance between patches/rating of habitat quality (including number of spring flowering eucalypts)



* The movements of adults in winter are not known, so a full model of the threats is not possible. Satellite tracking may provide more information in the future.

** Occasional fire is presumed to decrease degradation and fragmentation in the long term. If fire is too frequent this will increase degradation and fragmentation.

*** Research into mistletoe die off may inform future management actions.

Habitat protection and covenant: Number of hectares protected

Land clearing: Number of hectares cleared per year

Mistletoe die off: Proportion of mistletoe plants affected

Nest disturbance: Proportion of nestlings not successfully fledged due to disturbance

Nest predation: Number of nests predated

Noisy miner control: Net reduction in noisy miners accounting for control measures and any re-infestation

Occasional fire: Whether or not occasional fires occur in the area

Nest protection: Number of nests protected

Population supplementation: Number of birds released

Predator control: Number of predators removed or restricted from accessing nests

Regent honeyeater adults: Size of adult regent honeyeater population in the wild

Regent honeyeater nestlings: Number of nestlings that successfully fledge each year

Responsible bird watching strategies: Proportion of birders acting responsibly

Satellite tracking: Number of bird hours tracked

Tree planting: Number of hectares strategically planted

Too frequent fire: Whether or not the average time between fires is too frequent

Weed and pest management: Number of hectares managed



Regent honeyeater habitat, *Anthochaera phrygia*, endemic to eastern Australia. Capertree Valley.
(Michael Todd)

Modelling decisions and assumptions

- Catastrophic fire is a possible risk, but was excluded as it is unlikely on the site being modelled.
- Lack of nesting sites is not currently included as a specific threat as this is considered to be part of the threat of habitat fragmentation and degradation.

Indicators

The following indicators were selected during the workshop:

- Nest success – proportion of nests that successfully fledge
- Diversity of bird species – selected as a surrogate for the number of adult regent honeyeaters, which are impossible to survey except from random sightings
- Long-term use by small honeyeaters (birds per hectare) – alternative surrogate for number of regent honeyeaters
- Noisy miner control (birds removed) – a measure of nest disturbance
- Area protected – a measure of whether habitat fragmentation is being reduced.

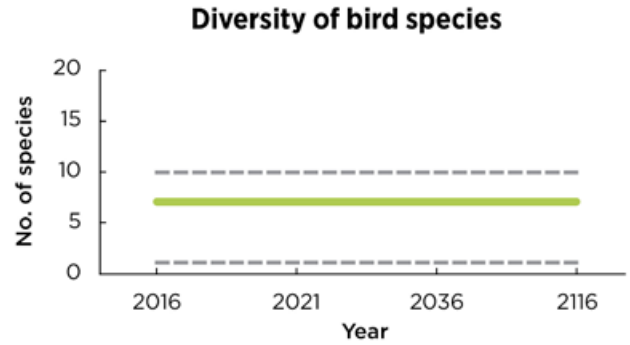
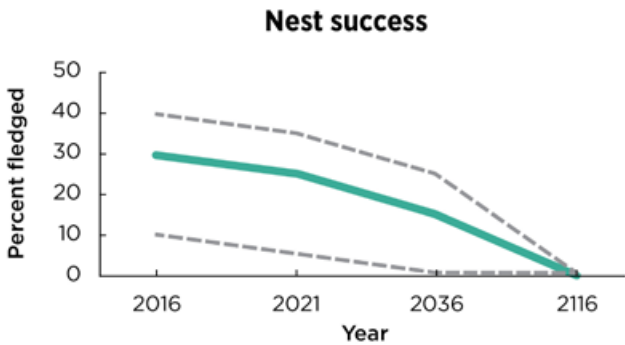
Response to management estimates

The following response to management curves were estimated during the workshops by species experts. Plots show the experts' best guess for how each indicator would respond under different scenarios, as well as the highest and lowest expected values (shown with dashed lines). The confidence that the value for each indicator will fall inside this range is given underneath each plot.

The *Anthochaera phrygia* case study followed a previous version of the guidelines where only three scenarios and four time-steps were considered. Due to time restrictions in a workshop setting, estimates are given for the first two indicators only.

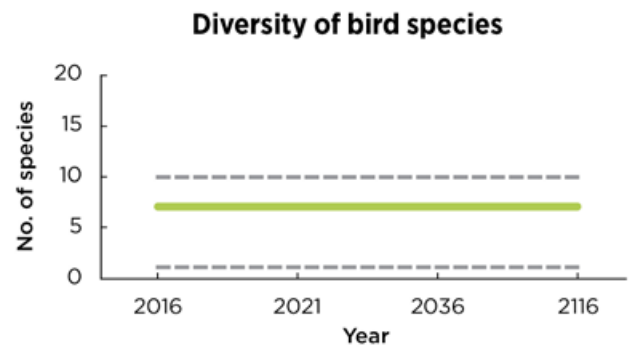
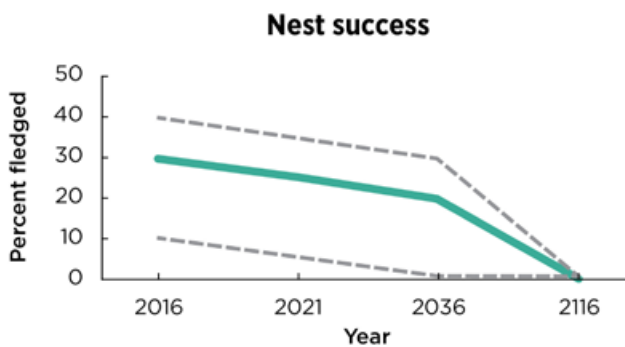
Scenario 1: No management

Estimated values for each indicator's response to management under a no management scenario. Plots show highest, lowest and most likely plausible values as estimated by experts. Confidence values for each indicator are given below each plot.



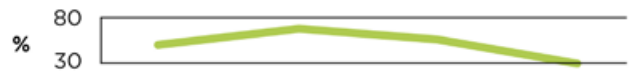
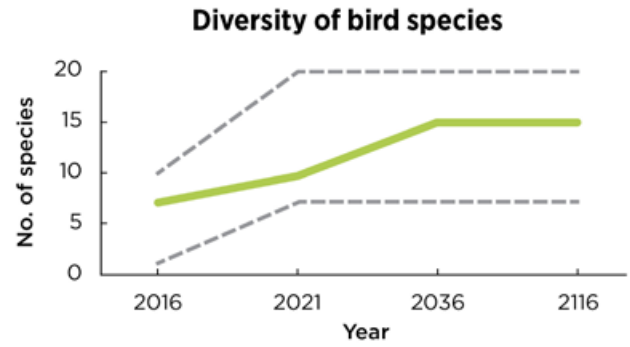
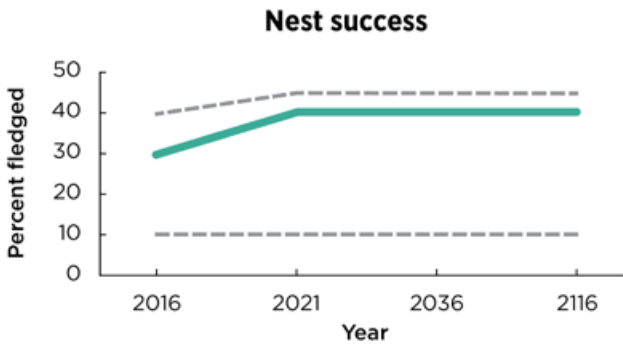
Scenario 2: Continuation of pre-SoS management

Estimated values for each indicator's response to management under a pre-SoS management scenario. Plots show highest, lowest and most likely plausible values as estimated by experts. Confidence values for each indicator are given below each plot.



Scenario 3: Continued SoS intervention

Estimated values for each indicator's response to management under a continued SoS management scenario. Plots show highest, lowest and most likely plausible values as estimated by experts. Confidence values for each indicator are given below each plot.



5. *Uperoleia mahonyi* (Mahony's toadlet)



Mahony's toadlet. (Simon Clulow)

Luke Foster and Simon Clulow

Uperoleia mahonyi was first described in 2016. This species is currently assigned to the data deficient stream of the SoS program and is classified as endangered in New South Wales. Individuals reach around 32 millimetres long. Shallow ephemeral/semi-permanent bodies of water are important for breeding, although adults are known to use a variety of habitats up to 500 metres from the water. Habitat requirements are still not well understood, but records to date have been in heath habitats with leached white sand, and frequently in acid paperbark swamps and wallum habitats.

Scope

- Mahony's toadlet is currently in the data deficient management stream.
- As this species is in the data deficient SoS management stream, there are no specific SoS sites for this species; however, known habitat is coastal heath or wallum almost exclusively associated with leached white sand. Known sites for this species are associated with shallow ephemeral/semi-permanent water bodies with limited flow of water.
- To date, the species has been recorded from eight 'locations' between Seal Rocks at the top of the Myall Lakes sand bed system to the north, and Kangy Angy to the south, which would likely be separated from one another by a great enough distance to also meet the definition of separate 'populations'.
- Currently no SoS interventions are being undertaken.
- Initial SoS interventions will start in April 2018 and run for two years. Further SoS interventions will run for the life of the SoS program.
- No previous management has been in place for this species (newly listed – 2016).
- Initial SoS actions include studying:
 - lack of distributional knowledge – will initially look at suitable habitat between Sydney and the mid north coast
 - lack of population dynamics knowledge – across known sites and newly discovered sites.
- Out of scope – these actions have been designed to move this species out of the data deficient SoS management stream and into another (possibly site-managed or landscape-managed). As such, these actions will cease and new actions will be designed and implemented.
- There are currently major development threats to this species, particularly on the Central Coast and in Tomago, Port Stephens.



Mahony's toadlet. (Simon Clulow)

- The most plausible threat to the species is likely to be habitat loss or degradation due to activities such as coastal development or sand mining. Such prior activities in the region where the frog occurs have involved the removal of large areas of habitat, usually larger than the scale of an individual water body and surrounding occupied terrestrial habitat.
- Sand mining poses a greater risk than coastal development, because sand mining targets the sand specifically used by this species. Mahony's toadlet is found exclusively in sandy swamps and often on the kind of sand substrate (leached sand) that is targeted by sand mining.

Narrative

- No management actions are currently underway and there has been no history of any active management to date. Targeted surveys and an assessment of potential threats will be undertaken in mid-2018 from which a better understanding of the threats will be obtained.
- One major threat is a reduction in the amount of habitat due to coastal development and sand mining.
- Coastal development and sand mining also negatively impact local hydrology; however, this impact can be reduced by maintaining or increasing vegetation buffers around swamps (which also increases/maintains habitat).
- Expected changes to local hydrology from habitat degradation, coastal development and more broadly, climate change – through rainfall and temperature – will likely have a negative effect on both tadpole and adult survival rates and the ability of the species to reproduce.
- Reduction in both water quality and terrestrial habitat quality is a current threat to both tadpoles and adults.
- Runoff will impact both water quality and terrestrial habitat quality.
- Feral pigs likely decrease terrestrial habitat quality and this threat can be reduced through management such as fencing or physical control.
- Hypothetically, by restricting access to key areas of habitat, through fencing and community education, it is expected water quality and terrestrial habitat quality will increase.
- Habitat rehabilitation, including planting of suitable native species (which provide cover) and weed control, is also expected to increase necessary terrestrial habitat.
- The impact of chytrid fungus on this species is not known, but is presumed to be a possible threat.
- *Gambusia* will eat tadpoles, but if there are no tadpoles, they will eat something else (i.e. the number of tadpoles does not affect fish numbers).

Suitable hydrological conditions: Water level maintained at acceptable levels during breeding season

Tadpoles: Approximate number of tadpoles surviving to froglets in a breeding season

Temperature: Deviation in degrees from optimal range (optimal range not yet known)

Terrestrial habitat quality: Scale of 1 – 10 defined as:

- 10: Perfect conditions – sufficient sand and vegetation for adults to thrive
- 7: Suitable – minor degradation, but not severely impacting frog survival
- 5: Acceptable – some degradation, likely having some detrimental effect, but adults can survive
- 3: Unacceptable – major degradation having significant impact on mortality
- 1: Not suitable – no longer suitable for species

Vegetation buffer around swamps: Total area with suitable vegetation within 500 metres of swamp

Weeds: Average weed density on site

Water quality: Scale of 1 – 10 defined as:

- 10: Perfect conditions – no chemical contamination and very little sediment; breeding is unhindered and tadpoles can thrive
- 7: Suitable – minor contamination but not affecting breeding or survival of tadpoles
- 5: Acceptable – some contamination, likely having some detrimental effect, but breeding and tadpole survival still possible
- 3: Unacceptable – major contamination and sediment issues cause difficulties with breeding and tadpole survival
- 1: Not suitable – neither frogs nor tadpoles can survive

Modelling decisions and assumptions

- Rainfall and temperature have been included as measures of climate change, as changes to local hydrology potentially pose a serious threat.
- Tadpoles and adults are modelled separately as the threats facing each are different. It is acknowledged that monitoring or counting tadpoles at this stage is difficult as they are visually indistinguishable from those of similar species; however, similar species (i.e. other species of *Uperoleia*) very rarely co-occur at the same sites.
- *Gambusia* might be a threat, but the nature of the usually ephemeral or semi-permanent water bodies that the species occupies means that they dry up every so often and probably kill any *Gambusia* populations, at least from time to time. So, they are a possible threat, but probably not a massive one in this instance. They have therefore been included as a dashed line.
- While coastal development will naturally affect water quality and runoff, the major impact is habitat loss. Links to water quality and runoff have been left out as these relationships are outweighed substantially by habitat loss.

Potential indicators

As this species is classified as data deficient, no specific threats are currently being targeted. The selected indicators therefore include a measure for each relevant life stage as well as two of the major assumed threats that are candidates for SoS intervention:

- Number of adults
- Number of tadpoles
- Water quality – score 1 – 10 (10 being highest quality)
- Presence of pigs/damage – score 1 – 10 (10 being highest level of damage).

Notes on indicator estimates

- For the current SoS funding estimates, it is assumed ongoing funding of \$30,000 a year (which is what is currently available to undertake targeted surveys only). Assumes the ongoing \$30,000 will be used for management actions.
- As no pre-SoS management has occurred, the current SoS funding estimates are assumed to be the same as the continued SoS funding estimates.

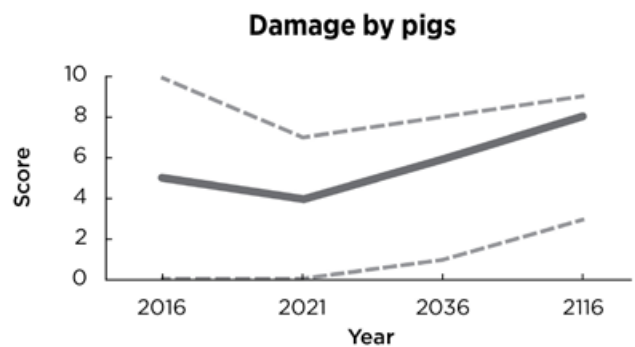
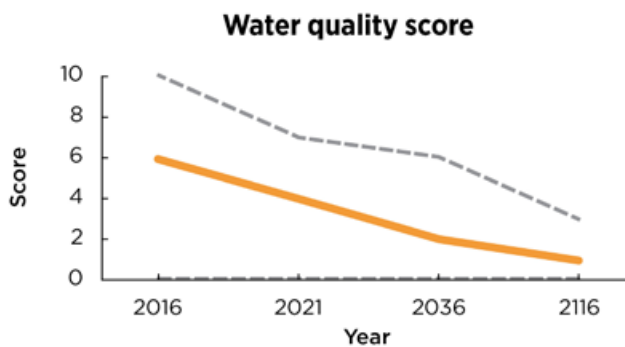
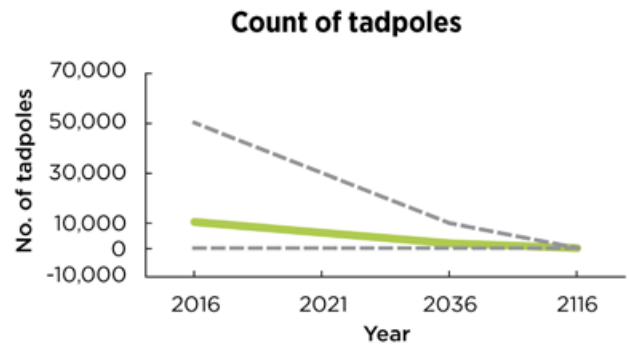
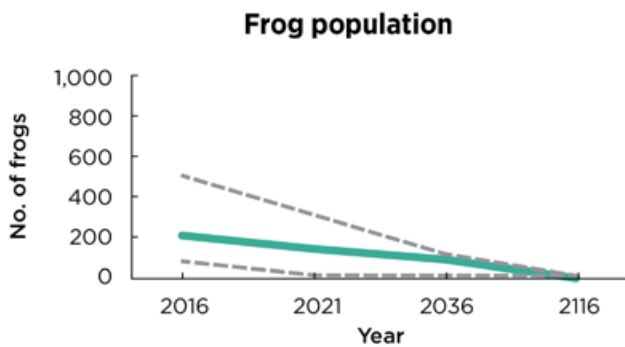
Response to management estimates

The following response to management curves were estimated during the workshops by species experts. Plots show the experts' best guess for how each indicator would respond under different scenarios, as well as the highest and lowest expected values (shown with dashed lines). The confidence that the value for each indicator will fall inside this range is given underneath each plot.

The *Uperoleia mahonyi* study followed a previous version of the guidelines where only four time-steps were considered.

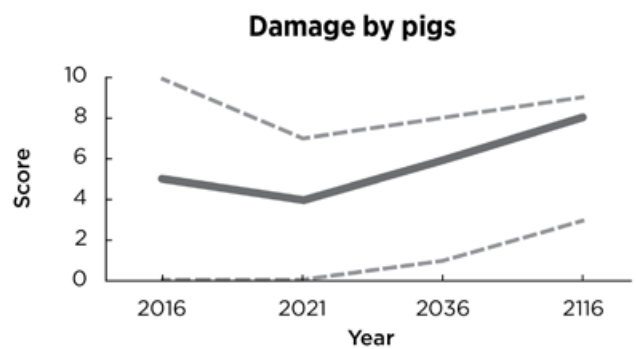
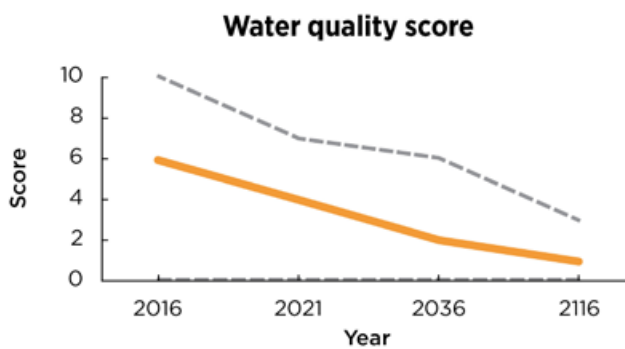
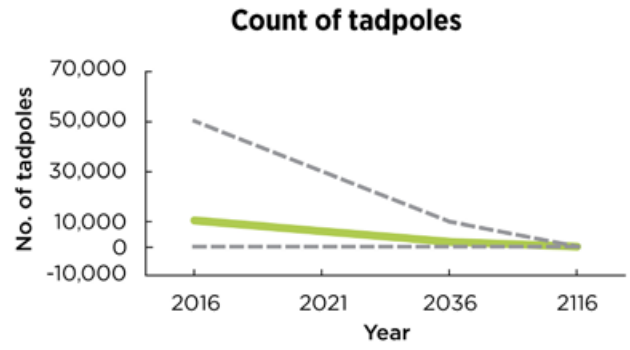
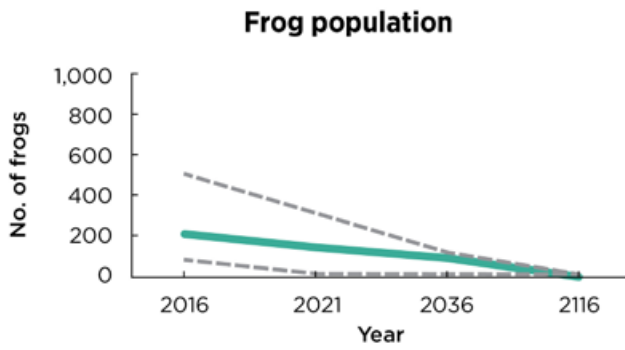
Scenario 1: No management

Estimated values for each indicator's response to management under a no management scenario. Plots show highest, lowest and most likely plausible values as estimated by experts. Confidence values for each indicator are given below each plot.



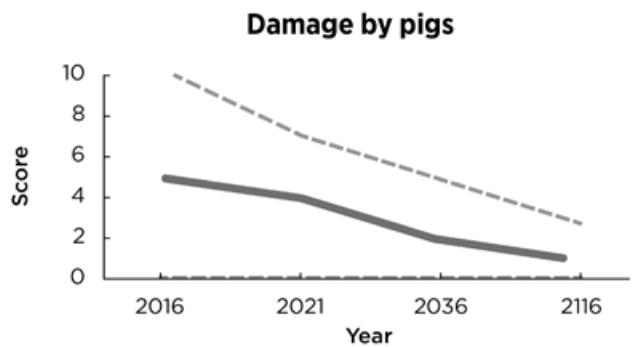
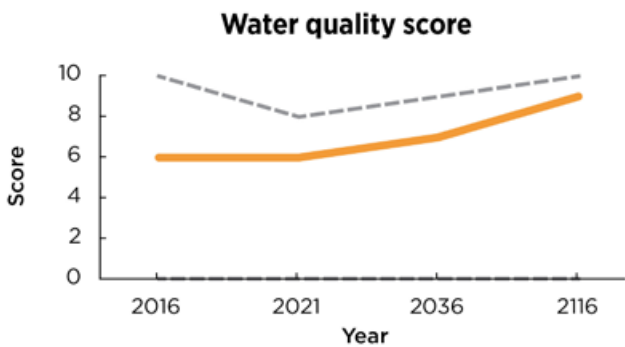
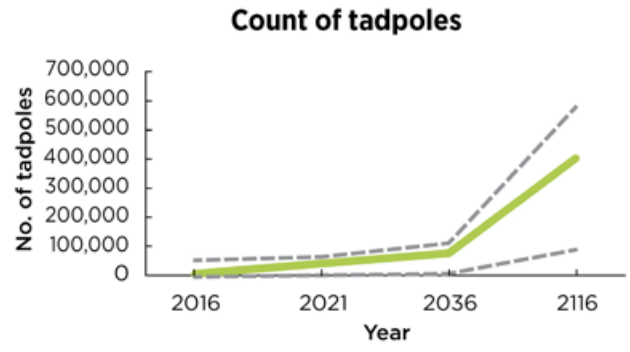
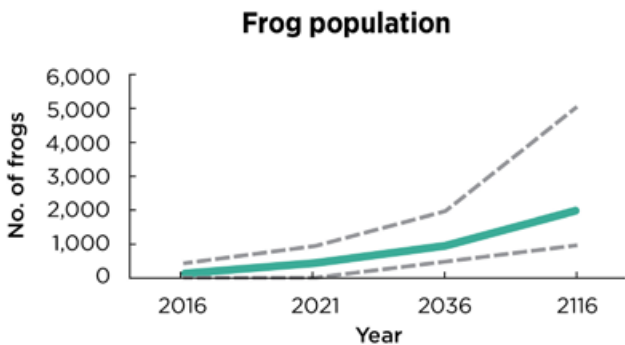
Scenario 2: Continuation of pre-SoS management

Estimated values for each indicator's response to management under a pre-SoS management scenario. Plots show highest, lowest and most likely plausible values as estimated by experts. Confidence values for each indicator are given below each plot.



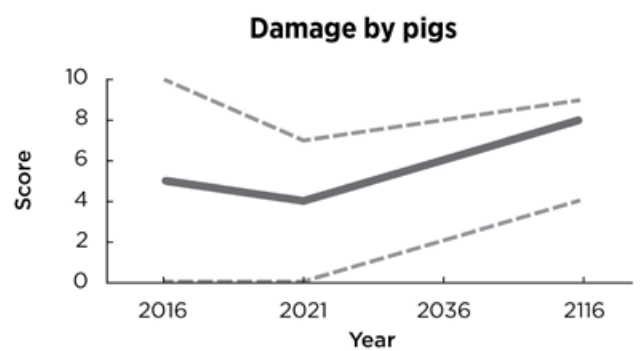
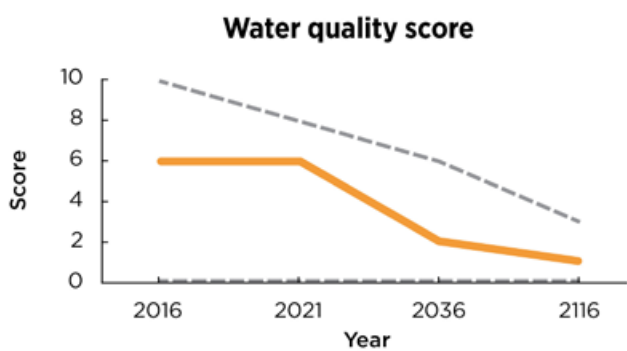
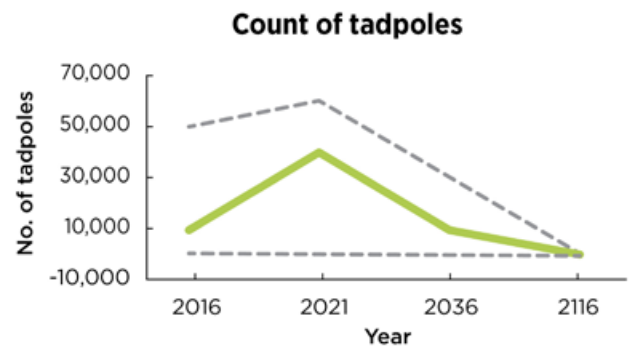
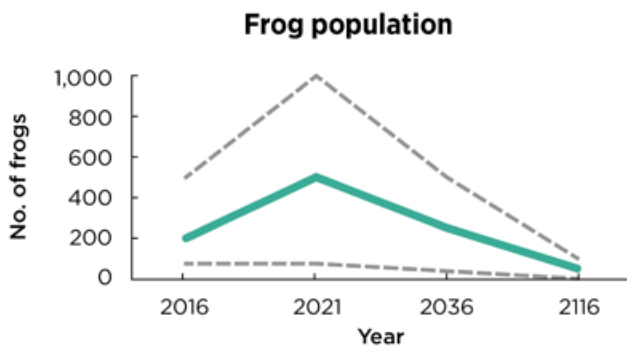
Scenario 3: Continued SoS intervention

Estimated values for each indicator's response to management under a continued SoS management scenario. Plots show highest, lowest and most likely plausible values as estimated by experts. Confidence values for each indicator are given below each plot.



Scenario 4: Current SoS intervention only

Estimated values for each indicator's response to management under the current SoS management scenario. Plots show highest, lowest and most likely plausible values as estimated by experts. Confidence values for each indicator are given below each plot.



6. *Pterostylis chaetophora* (Tall rustyhood)



Pterostylis chaetophora. (P Hillier)

Paul Hillier and Lachlan Copeland

Pterostylis chaetophora is a terrestrial orchid which is included in the site-managed stream of the SoS project, and is listed as vulnerable in New South Wales. The species is deciduous, flowering from September to November (providing sufficient rainfall occurs) before dying back to underground tubers. While the species is known to occur in less than a dozen sites in New South Wales, knowledge of its distribution outside of these areas is lacking. Ideal habitat requirements are not fully known; however, the species occurs mainly in forested areas with a grass and shrub under storey. The *Pterostylis chaetophora* case study followed a previous version of the guidelines where only four time-steps were considered.

Scope

Pterostylis chaetophora is being managed at six sites occurring within the MidCoast, Dungog, Port Stephens and Cessnock local government areas. SoS interventions are landholder liaison, weed control, fencing and caging plants. These actions are proposed to commence in the 2018–19 financial year and continue until the end of the 2020–21 financial year. Monitoring occurred in the 2017–18 financial year to collect baseline data; however, no targeted management actions have yet occurred. While each site has its own threats and challenges, a general process model that covers all six sites has been designed. The response to management estimates are specific to the Black Creek SoS site.

Narrative

The **predominant threats** to *Pterostylis chaetophora* are:

- herbivory (either by insects or mammals, uncertain which)
- trampling by bikes, vehicles and foot traffic
- weed competition, and overgrowing by native shrubs and small eucalypts
- disturbance from road or track maintenance activities (including spraying for weeds)
- slashing during flowering.

A management program will aim to manage these threats. Landholders and land managers will be engaged to encourage management practices that are compatible with this species' survival, such as slashing outside of the flowering season and avoiding plants during road and track maintenance activities. Hand control of weeds and native woody plants will reduce competition to enable survival and population expansion. Fencing and other appropriate barriers will be used to prevent disturbance to plants by vehicles, foot traffic and rubbish dumping. Caged plants will be protected from herbivory during flowering to increase reproductive success. Cages will be removed outside of flowering to enable grazing to reduce competitive groundcover.



Pterostylis chaetophora.
(Ashley Deveridge)



Pterostylis chaetophora. (P Hillier)

An additional possible threat is collection by orchid enthusiasts. This threat is managed outside of the SoS program by adhering to OEH's Sensitive Species Data Policy.

Fire may also be a threat to this species; however, not enough is known about the most appropriate fire regime to develop an action. Some of the SoS sites have fire management protocols that would manage this potential threat outside of the scope of the SoS program.

Modelling decisions and assumptions

- The effects of inappropriate fire, or what even constitutes appropriate fire, are poorly understood. This uncertainty has been represented with a dashed line.
- Threats marked with an asterisk (*) are not being managed under SoS.

Indicators for Black Creek SoS site

The threats being managed at this site are herbivory and weed density. The selected indicators are:

- Number of individuals within site (indicator of target species)
- Proportion of chewed flower stems (indicator of herbivory)
- Percent cover of weeds.

Response to management estimates

The response to management curves were estimated during the workshops by species experts. Plots show the experts' best guess for how each indicator would respond under different scenarios, as well as the highest and lowest expected values (shown with dashed lines). The confidence that the value for each indicator will fall inside this range is given underneath each plot. It is assumed that some weed control would take place outside of the SoS program.

Process model

Caging: Number of flowering plants caged

Fencing/barriers: Amount of site protected by fences

Hand control (native woody plants): Number of flower stems within immediate area cleared

Hand control (weeds): Number of flowering plants within immediate area cleared

Herbivory: Number of chewed flower stems

Inappropriate fire: Amount of site not managed appropriately for this species. Appropriate fire regimes for this species are not well understood

Insects: Density of orchid eating insects on site

Landholder liaison: Number of landholders made aware

Mycorrhizal fungi: Presence of mycorrhizal fungi

Native and feral mammals: Number of individuals (includes herbivores only)

Overgrowing native vegetation: Percent canopy cover of non-compatible species

Poaching: Number of plants collected by orchid collectors

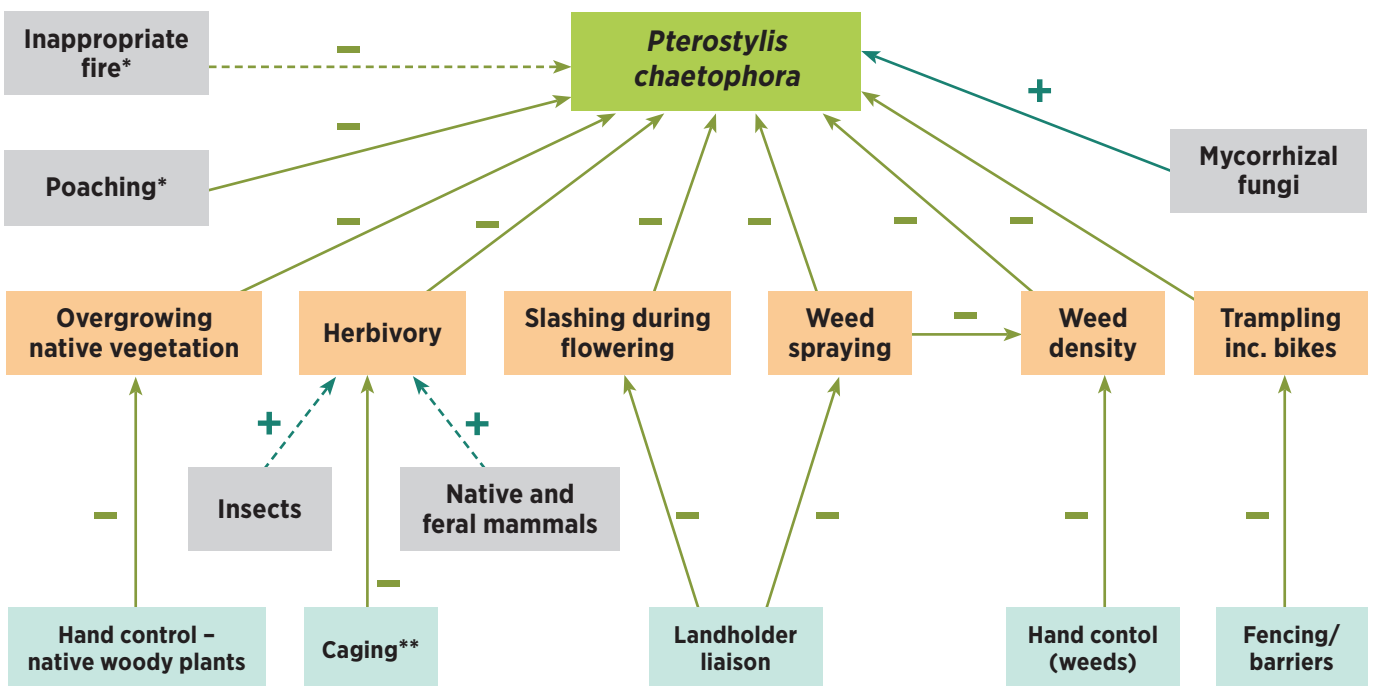
***Pterostylis chaetophora*:** Number of plants

Slashing during flowering: Number of flower stems cut

Trampling: Percentage of area of site showing signs of trampling

Weed density: Average weed density per metre on site

Weed spraying: Area of site sprayed



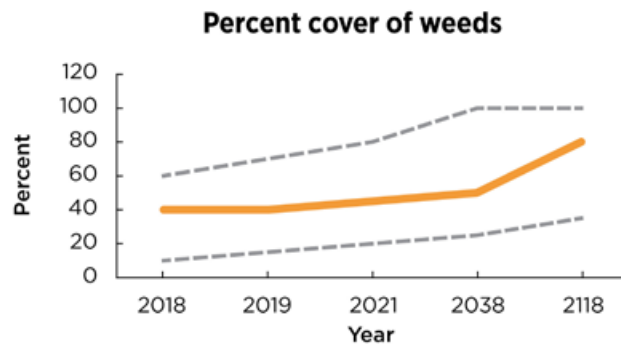
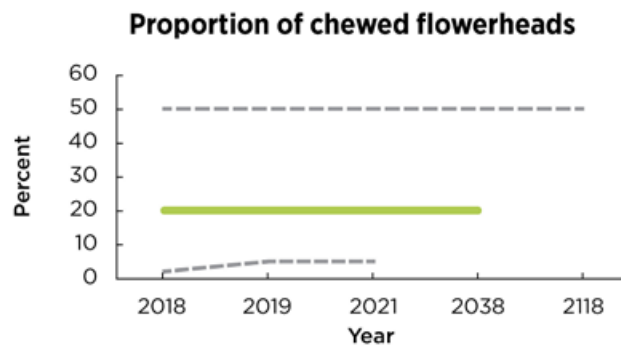
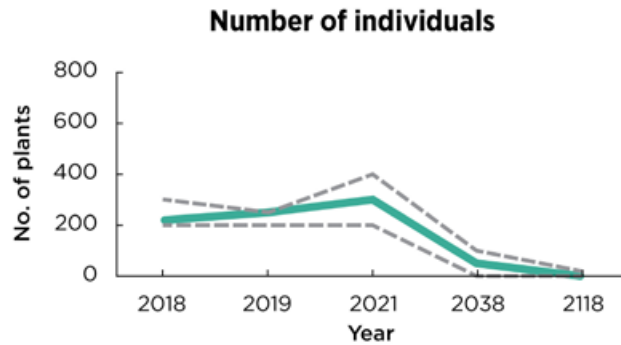
Threats being managed
 SoS interventions
 Target species

* not managed within SoS

** will not reduce herbivory from insects

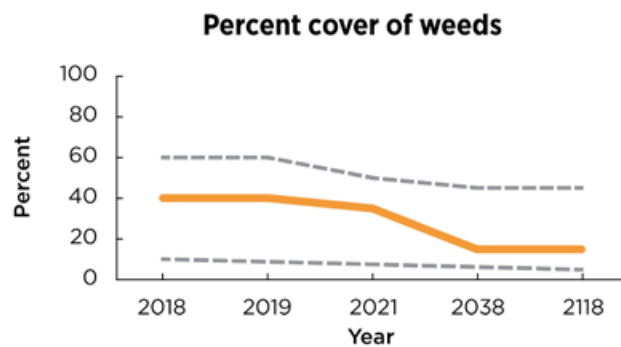
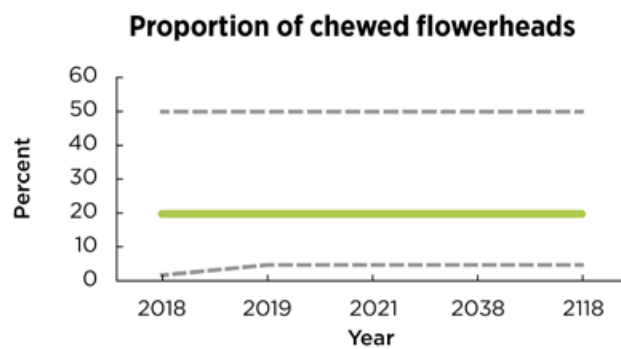
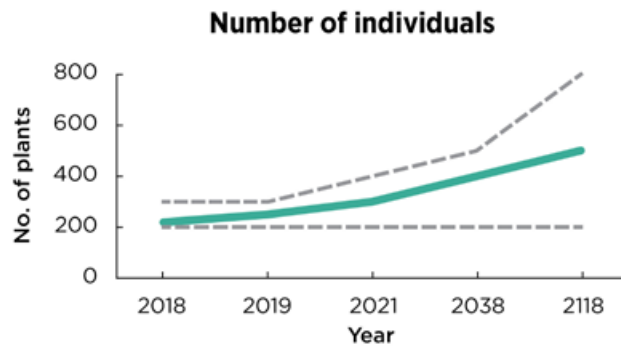
Scenario 1: No management

Estimated values for each indicator's response to management under a no management scenario. Plots show highest, lowest and most likely plausible values as estimated by experts. Confidence values for each indicator are given below each plot.



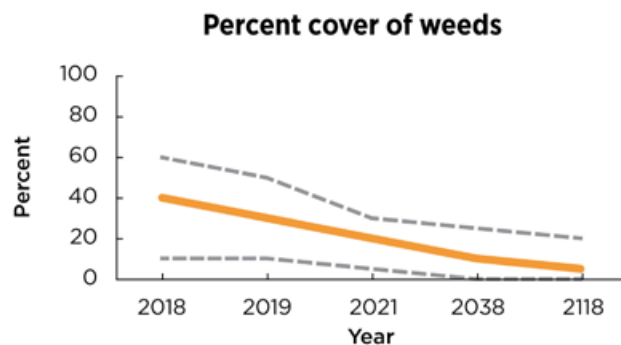
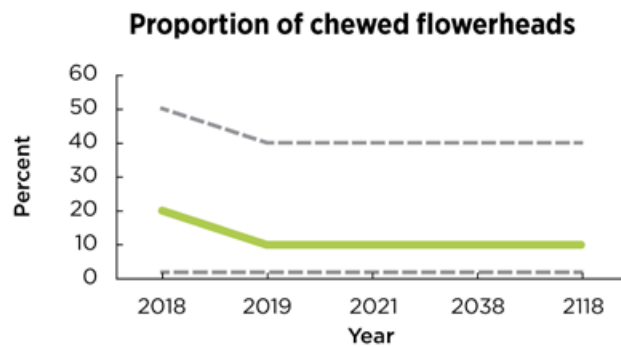
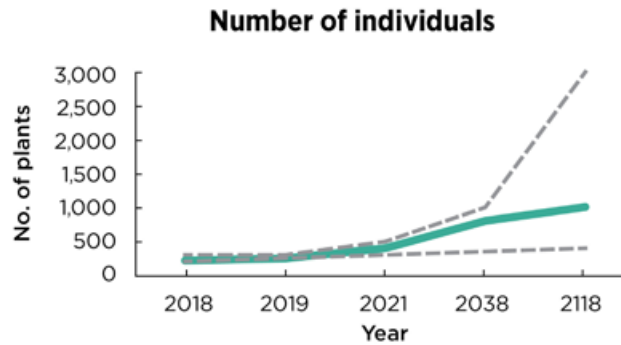
Scenario 2: Continuation of pre-SoS management

Estimated values for each indicator's response to management under a pre-SoS management scenario. Plots show highest, lowest and most likely plausible values as estimated by experts. Confidence values for each indicator are given below each plot.



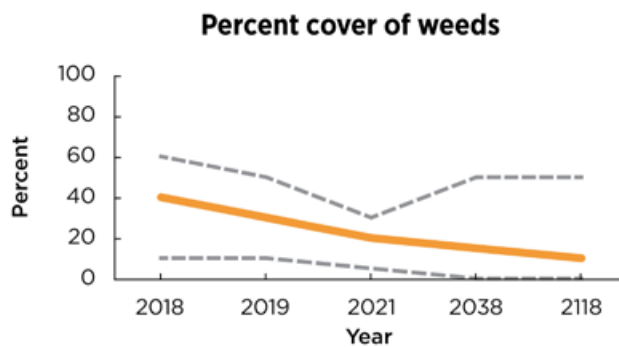
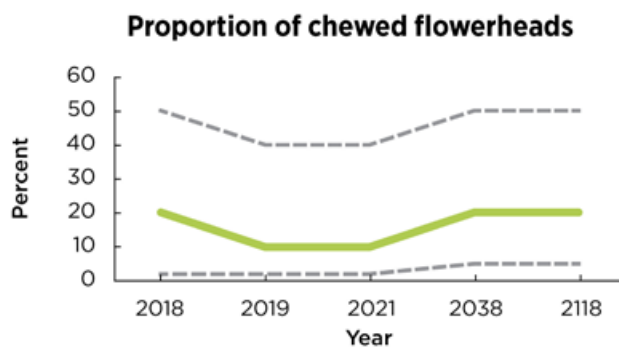
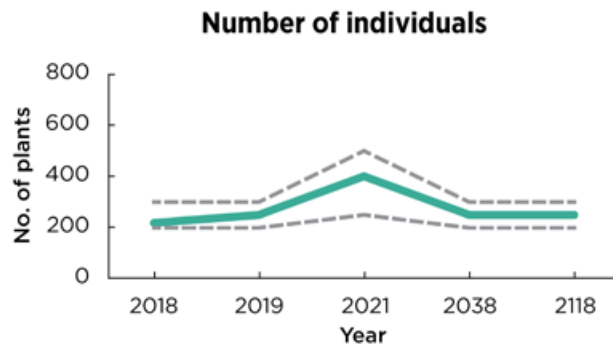
Scenario 3: Continued SoS intervention

Estimated values for each indicator's response to management under a continued SoS management scenario. Plots show highest, lowest and most likely plausible values as estimated by experts. Confidence values for each indicator are given below each plot.



Scenario 4: Current SoS intervention only

Estimated values for each indicator's response to management under the current SoS management scenario. Plots show highest, lowest and most likely plausible values as estimated by experts. Confidence values for each indicator are given below each plot.



7. *Acacia curranii* (Curly-bark wattle)



Curly-bark wattle bush.
(Lachlan Copeland/OEH)

Darren Shelly and Nick Hanlon

Acacia curranii is allocated to the site-managed stream of the SoS program. There are approximately 20 known populations, the majority situated in New South Wales with several in Queensland. Plants grow to around four metres high and distribution is limited to specialised habitats comprising rocky ridges. Mature plants flower between August and September. Based on knowledge of similar species, it is assumed that seedling establishment is likely to be fire dependant, and root suckers probably regenerate after fire. It is possible that seasonal conditions may be major triggers for seedling establishment.

Scope

Curly-bark wattle is currently managed on four sites. Two of these, Gundabooka National Park and Yathong Nature Reserve, are government owned. Monia Gap is on private land. The fourth site, Shepherd's Hill, is on Australian Rail Track Corporation managed land and borders Round Hill Nature Reserve. It is managed by the National Parks and Wildlife Service, but is excluded from the scope of this model as the threat is site-specific. The process model also excludes other smaller sites where the species is known to occur. It is acknowledged that a reduction in pollinators may result in a species decline; however, for the purpose of this model, pollinators are assumed to be present. It is assumed that the species relies on a suitable fire regime for germination, with an initial population decline immediately following a fire, followed by an increase caused by germination. The ideal range of fire frequency is not known.

Habitat requirements are not fully understood, with the majority of the populations being located on well drained ridge tops. SoS interventions for this species include managing feral goats and pigs. Outside of the SoS program, the NPWS manages fire regimes in the area. Prior to the SoS program, three small grazing animal exclosures were established around the Gundabooka National Park population.



Curly-bark wattle blossoms. (Lachlan Copeland/OEH)

Narrative

The threats facing *Acacia curranii*, as well as its expected response to management are poorly understood. The likely relationships have been included in the narrative.

- Goats and pigs are the main threats to mature plants and a threat to seedlings. Both these threats can be reduced through fencing. Goat numbers can be reduced through goat control.
- Fragmentation is a risk to the number of mature plants.
- Fire increases the number of seedlings (by triggering germination) and reduces the number of mature trees (through incineration). Fire management can increase the frequency of fires over those that would occur naturally.
- Soil disturbance increases the number of seedlings by triggering germination.
- Goats and rabbits decrease seedlings through grazing.
- Seed predation reduces the number of potential seedlings.
- Intraspecific competition and drought reduce seedlings. More seedlings will increase intraspecific competition.
- Fencing will reduce rabbits as some sites, but not all.

Indicators

The following indicators were selected for monitoring:

- Mature trees (number of mature plants across the three sites)
- Seedlings (number of seedlings across the three sites)
- Goats (size of goat population across the three sites).

Response to management estimates

The response to management curves were estimated during the workshops by species experts. Plots show the experts' best guess for how each indicator would respond under different scenarios, as well as the highest and lowest expected values (shown with dashed lines). Estimated response to management is for a three-year SoS plan starting in 2018.

Process model

Drought: Months per year that are in drought conditions

Fire frequency: Average number of fires per decade

Fire management: Number of controlled burns across the sites.

Fencing: Amount of habitat that is fenced off.

Fragmentation: Edge density of *Acacia curranii* patches at each site

Goats: Number of goats across the three sites

Goat control: Number of goats removed from site

Intraspecific competition: Number of seedlings that don't survive due to competition

Mature plants: Number of mature plants across the three sites

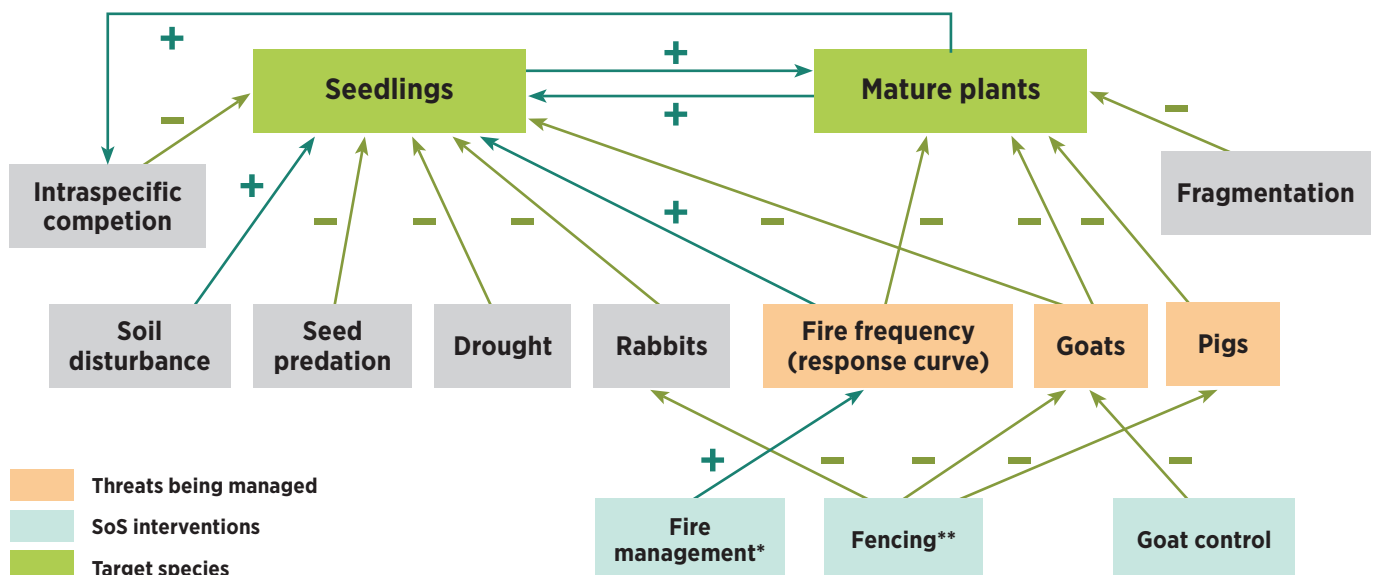
Pigs: Number of pigs on site

Rabbits: Average density of rabbits across three sites

Seed predation: Proportion of seeds that are taken

Seedlings: Number of seedlings across the three sites

Soil disturbance: Area in square metres where soil disturbance has occurred

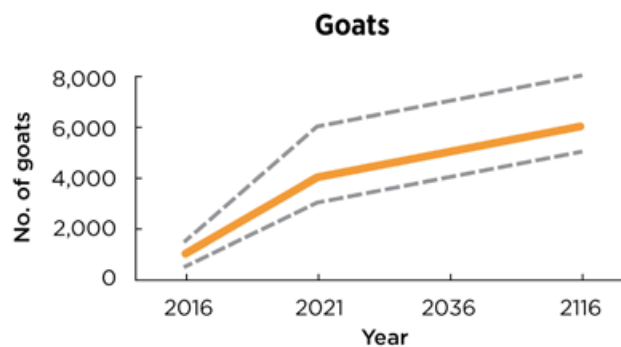
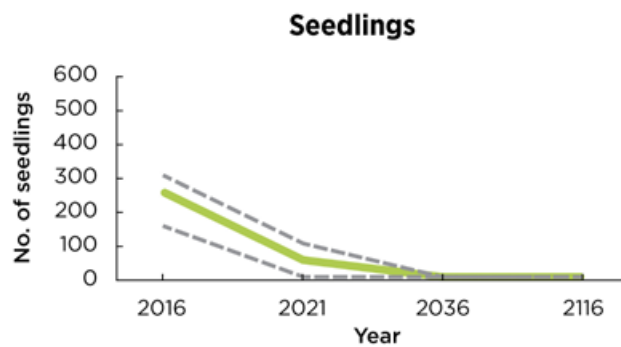
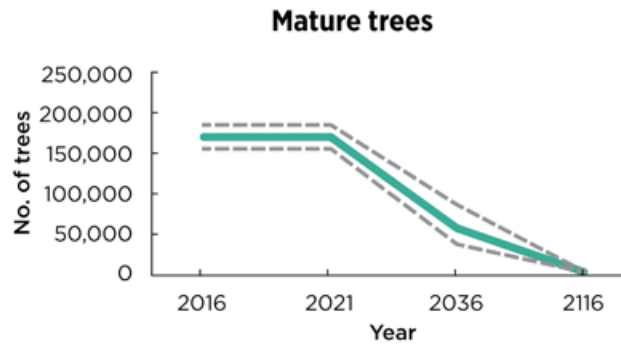


* Fire management (number of controlled burns across the site) will only increase seedlings while there is sufficient time between fires for existing seedlings to mature and produce seeds. Increase past this will result in a decline. Fire management is managed outside of SoS.

** Fencing will not reduce rabbits at all sites.

Scenario 1: No management

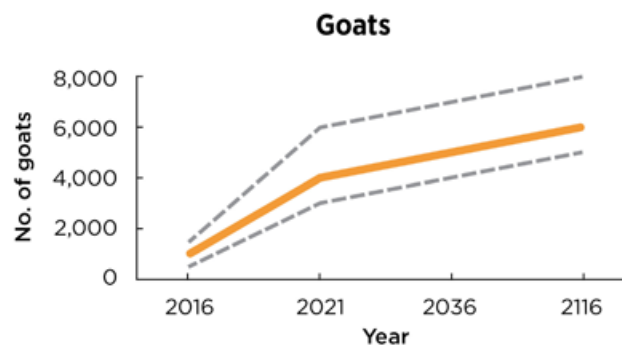
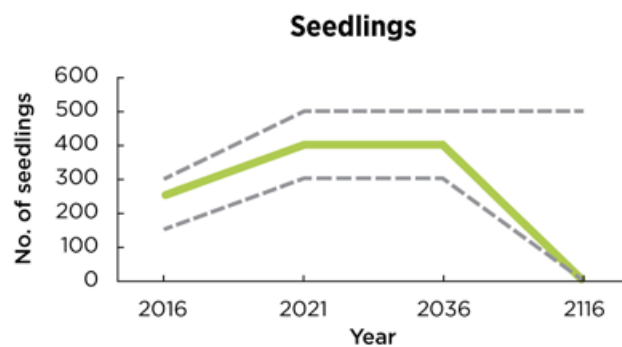
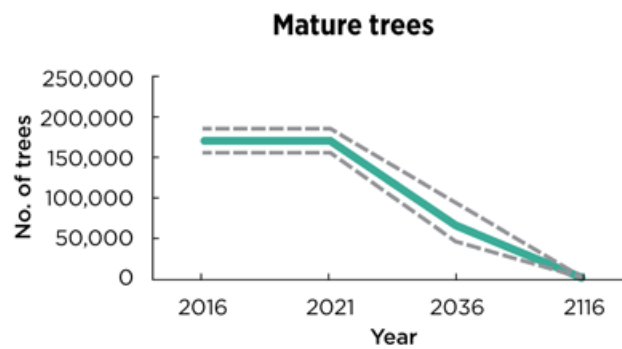
Estimated values for each indicator's response to management under a no management scenario. Plots show highest, lowest and most likely plausible values as estimated by experts. Confidence values for each indicator are not included in this example.



Scenario 2: Continuation of pre-SoS management

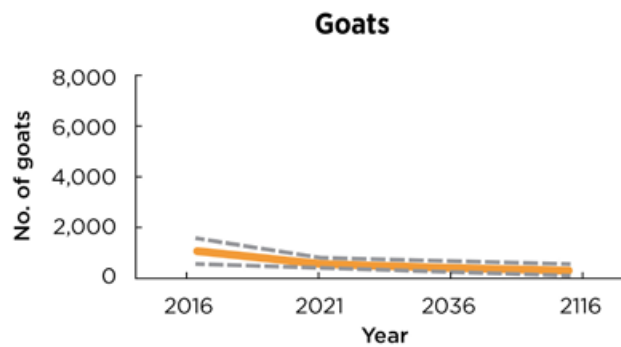
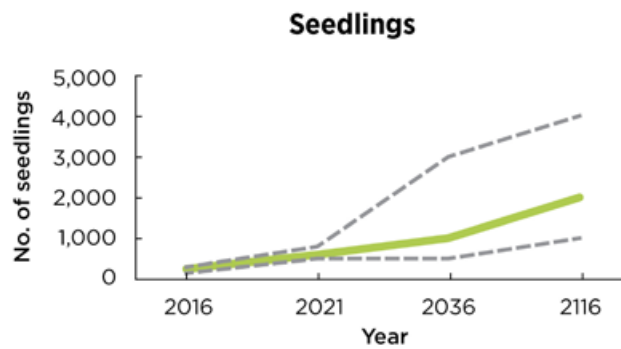
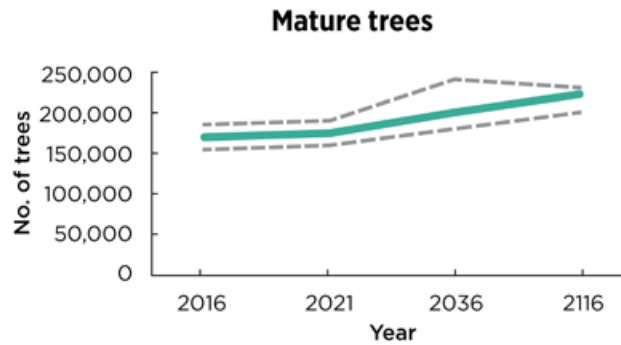
Pre-SoS scenario assumes existing fences keep out feral grazers for a few years, then deteriorate.

Estimated values for each indicator's response to management under a pre-SoS management scenario. Plots show highest, lowest and most likely plausible values as estimated by experts. Confidence values for each indicator are not included in this example.



Scenario 3: Continued SoS intervention

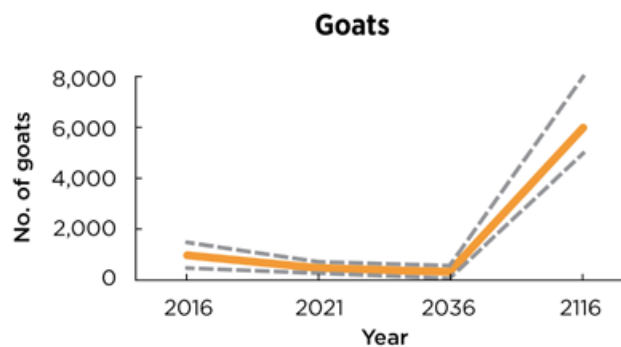
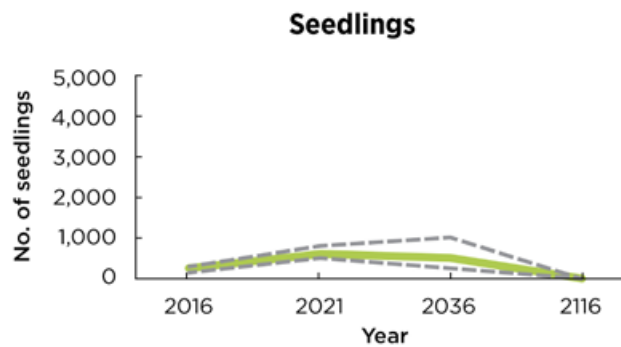
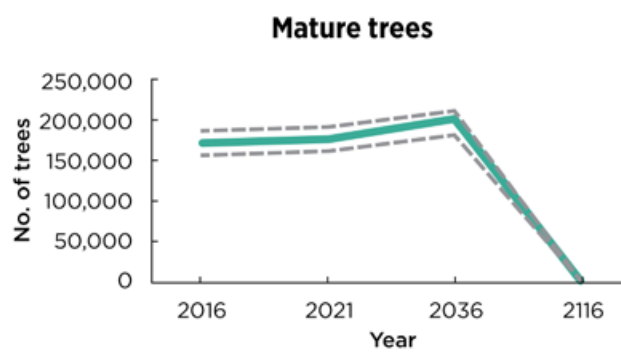
Estimated values for each indicator's response to management under a continued SoS management scenario. Plots show highest, lowest and most likely plausible values as estimated by experts. Confidence values for each indicator are not included in this example.



Scenario 4: Current SoS intervention only

Current SoS intervention scenario assumes actions stop in 2021. Estimated response to management graphs represent the gradual breakdown of fenced exclosures by 2036 that allows feral grazers to eat plants.

Estimated values for each indicator's response to management under the current SoS management scenario. Plots show highest, lowest and most likely plausible values as estimated by experts. Confidence values for each indicator are not included in this example.



8. *Bossiaea fragrans*



***Bossiaea fragrans* resprouting.**
(Amanda Jowett/OEH)

Amanda Jowett and Krystyna Jordan

Bossiaea fragrans is a critically endangered shrub species that has been allocated to the site-management stream in the SoS program. Mature plants can reach 2.5 metres high. The species' range is extremely restricted and the ideal environmental conditions are not fully understood. Seedling recruitment is likely fire dependant.

Scope

The site being considered is the Abercrombie Karst Conservation Reserve. Prior to SoS only targeted searches had been conducted. The species was previously only known at three locations (20 plants) within the reserve, all within close proximity of one another. After surveys in 2011, more plants were found, bringing the population to around 400 mature plants. Monitoring of seedling recruitment and grazing impacts commenced in 2014.

Goats are the main target for annual culls, though pigs are also targeted. Culls cover the entire reserve as well as neighbouring properties. Weed management only covers areas in which *Bossiaea* plants occur and involves the manual removal of serrated tussock grass. Translocation has not been considered previously; however, this is being investigated, with the main issue being finding suitable habitat given the plants grow on unique geology.

The interventions being implemented are:

- goat control (annual cull starting in 2014)
- fencing/caging of plants at two of the seven monitoring sites. Monitoring site 7 occurred in July 2015, monitoring site 4 occurred in May 2017. The monitoring action only involves fencing/caging part of the population to provide more information regarding the grazing pressure, as while it is considered a threat, we don't know if this is influencing the decline in the population. This allows us to make comparisons between grazed and ungrazed (fenced/caged) plants and thus determine if and how much grazing is threatening the population
- monitoring of seedling recruitment and grazing impacts (volume in cubic metres of tagged plants). The tagged plants are also rated on severity of grazing (e.g. none, light, moderate, severe, etc.)
- seed collection – storage and ex-situ population. Collected in 2012 but more seed collection is required for 2018. This is particularly important if translocation is to be considered as a new action
- pig control (annual – during winter period) – not yet started
- weed control as of 2017 – spraying of serrated tussock grass and other potential weeds.



Close up of *Bossiaea fragrans* flowers.
(Amanda Jowett/OEH)

Narrative

- *Bossiaea fragrans* population is reduced through herbivory by goats and trampling by goats and pigs. Reductions in numbers are caused either by directly killing the plant, or damaging plants, which may limit their ability to produce flowers and fruit. Fencing and animal control reduce both of these threats.
- Seed predation is a suspected threat, but the extent is not known.
- The presence of serrated tussock grass potentially decreases the population of *Bossiaea fragrans* through increased competition. Serrated tussock grass is reduced with weed management.
- There is an increased risk of decline in the *Bossiaea fragrans* population from disease due to lack of genetic diversity. Less seedling recruitment reduces the genetic diversity of the remaining population.
- Having the entire population in a small area increases the population's susceptibility to disease and increases the mortality from droughts when they occur, as well as increasing the mortality caused by frequent fires.
- Prolonged drought decreases the number of *Bossiaea fragrans*.
- Seed collection increases the total number of *Bossiaea fragrans* by increasing the offsite seed bank.
- Translocation could potentially increase the number of *Bossiaea fragrans* and decrease the effects of a small distribution range (area occupied).
- The relationship between *Bossiaea fragrans* and the frequency of fire is not well understood, but it is thought that occasional fire is required to prompt germination for seedling recruitment.
- An increase in continued soil disturbance will result in a decrease in the *Bossiaea fragrans* population.
- Occasional soil disturbance increases seedling recruitment.

Process model

Animal control: Number of animals removed from the reserve and participating neighbouring properties. This is an indicator that is being measured by the National Parks and Wildlife Service during annual culls

Area occupied: Amount of land where *Bossiaea fragrans* is present

Bossiaea fragrans: Number of individuals including seedlings, mature plants and seeds in the offsite seed bank

Continued soil disturbance: Size of the area affected by continued soil disturbance

Disease risk: Proportion of plants showing signs of disease

Fencing: Number of plants fenced/caged

Genetic diversity: Genetic diversity of the population

Herbivory: Severity of herbivory (volume of plants)

Mortality from drought: Proportion of population that die due to drought

Mortality from fire: Proportion of population that die due to fire

Occasional fire: Whether or not there is occasional fire on the site

Occasional soil disturbance: Whether or not there is occasional soil disturbance

Prolonged drought: Months per year under drought conditions

Seed collection: Number of seeds collected and held in offsite storage

Seed predation: Proportion of seeds that are eaten

Seedling recruitment: Number of new seedlings per year

Serrated tussock grass (STG): Presence/absence of STG within 50 metres of *Bossiaea* population

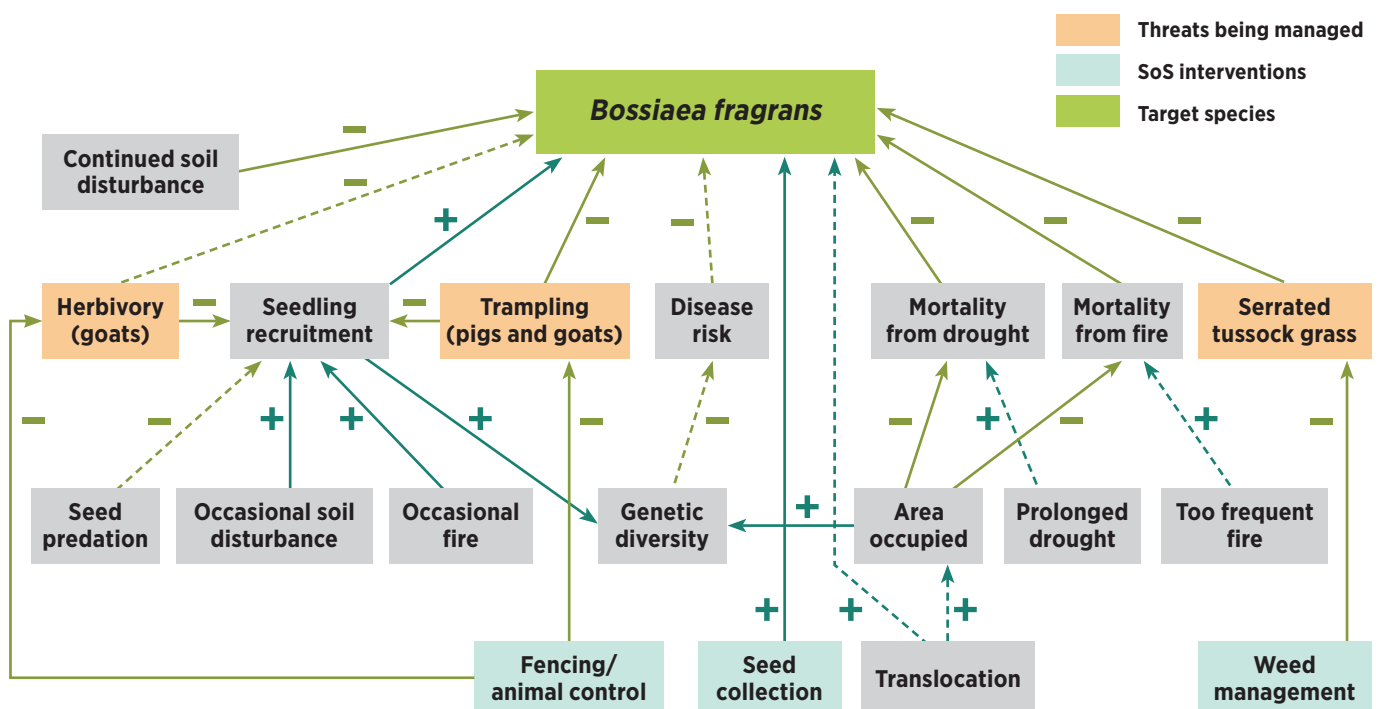
Too frequent fire: Whether or not frequent fires occur. The ideal frequency is not known

Trampling (pigs and goats): Number of plants that are trampled

Translocation: Number of plants relocated

Weed management: Number of hectares treated

Note on fire: Occasional fire frequency is expected to generally increase seedling recruitment by increasing germination; however, too frequent fire (e.g. two fires in seven years) will decrease the population through increased mortality, which is exacerbated by the small geographic distribution of the species.



Modelling decisions and assumptions

- Seed overproduction has not been included in the model at this stage as it is not being measured and is unlikely to be. The overproduction of seed pods was a one off observation made by a seed collector from the Botanic Gardens Trust. This measurement is unlikely to provide us with any useful data.
- It is assumed that seed collection is at levels below that which would affect seedling recruitment.
- Translocation is likely to be difficult as the species has specific habitat requirements; however, it has been included in the model as a possible future action.

Indicators

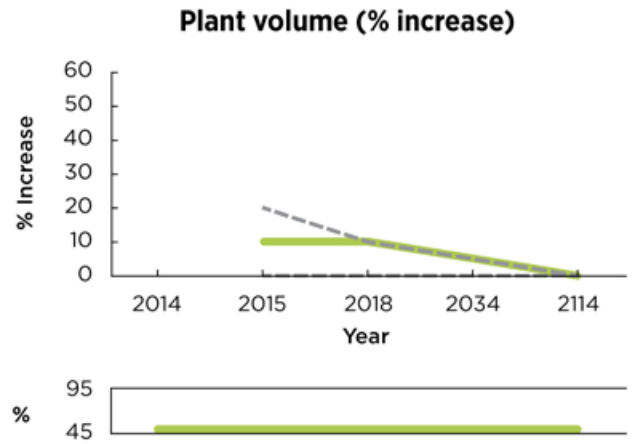
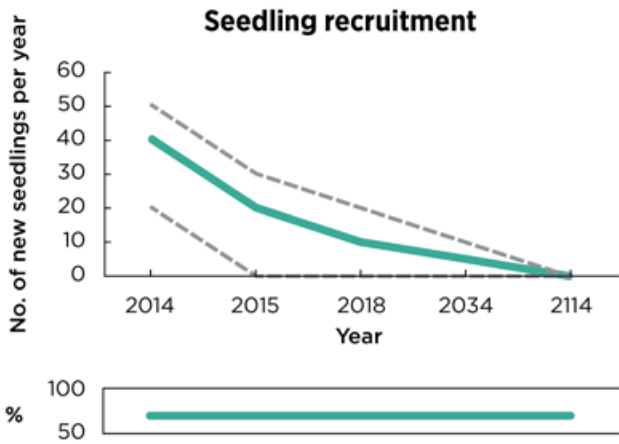
- Seedling recruitment – selected from the process model as a measure to determine whether the grazing/trampling threats were impacting on the *Bossiaea*'s ability to reproduce
- Plant volume (% increase from 2014) – selected to determine the extent to which grazing/trampling was impacting growth of the plants

Response to management estimates

The following response to management curves were estimated during the workshops by species experts. Plots show the experts' best guess for how each indicator would respond under different scenarios, as well as the highest and lowest expected values (shown with dashed lines). The confidence that the value for each indicator will fall inside this range is given underneath each plot.

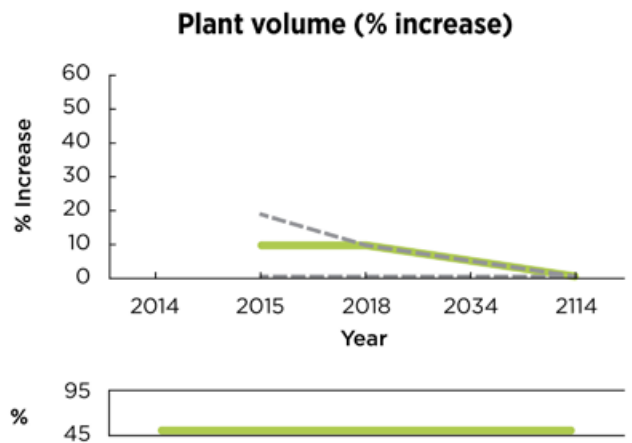
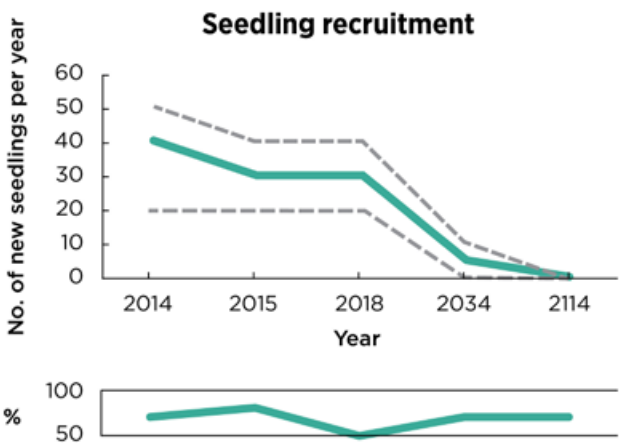
Scenario 1: No management

Estimated values for each indicator's response to management under a no management scenario. Plots show highest, lowest and most likely plausible values as estimated by experts. Confidence values for each indicator are given below each plot.



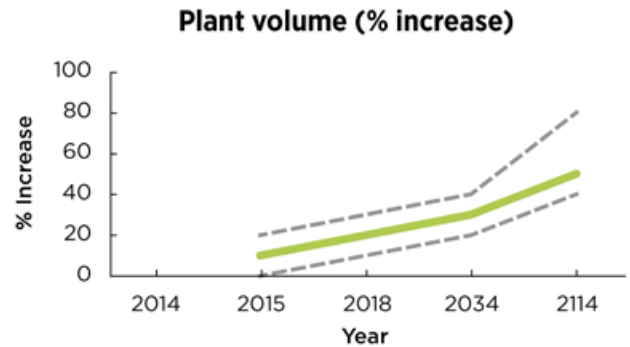
Scenario 2: Continuation of pre-SoS management

Estimated values for each indicator's response to management under a pre-SoS management scenario. Plots show highest, lowest and most likely plausible values as estimated by experts. Confidence values for each indicator are given below each plot.



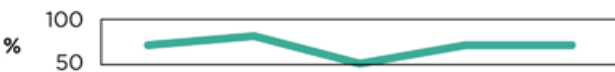
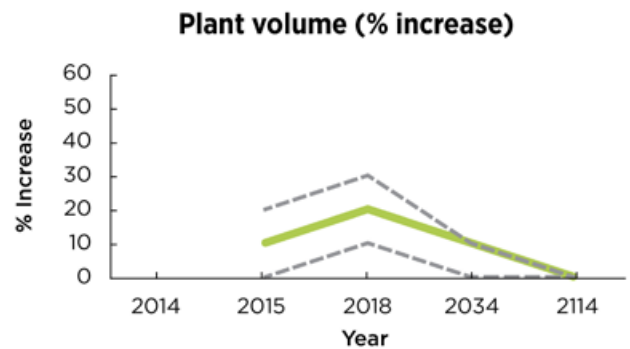
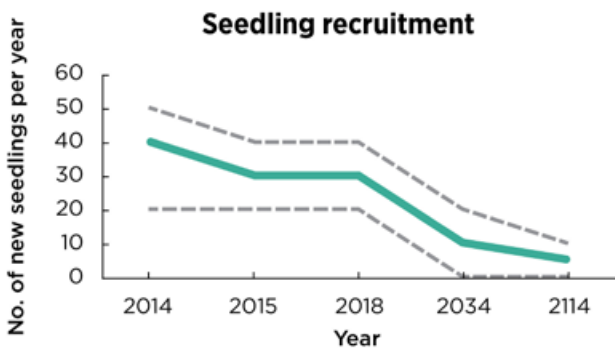
Scenario 3: Continued SoS intervention

Estimated values for each indicator's response to management under a continued SoS management scenario. Plots show highest, lowest and most likely plausible values as estimated by experts. Confidence values for each indicator are given below each plot.



Scenario 4: Current SoS intervention only

Estimated values for each indicator's response to management under the current SoS management scenario. Plots show highest, lowest and most likely plausible values as estimated by experts. Confidence values for each indicator are given below each plot.



9. *Dasyornis brachypterus* (Eastern bristlebird – central population)



Eastern bristlebird (*Dasyornis brachypterus*).

(Matthew Jones Photography)

Zoe Stone, David Bain, Lynn Baker and Damon Oliver

The eastern bristlebird is an omnivorous passerine of south-eastern Australia. Adults weigh approximately 42 grams and reach 18–20 centimetres body length. It is a semi-flightless, ground-dwelling species that relies on dense understorey habitat types for cover. It is currently confined to three main disjunct populations, a southern population in Victoria and the far south coast of New South Wales, a central population in New South Wales and a northern population 800 kilometres away along the Queensland – New South Wales border. Both southern and central populations have similar ecology and occupy a range of heath vegetation types. In comparison, the northern population occupies high elevation grassy sclerophyll forest along the rainforest margin. There is some evidence that northern birds are slightly larger and have brighter plumage. *Dasyornis brachypterus* is listed as endangered in New South Wales and is allocated to the site-managed stream of SoS.

Due to the differences in response to management for the northern and central/southern populations, two separate process models were designed.

Scope

The model covers the Barren Grounds population which is part of the two central populations (approximately 1250 adults). Habitat is generally all connected and located within reserves (Barren Grounds Nature Reserve and Budderoo National Park), with approximately 4500 hectares within the reserve boundaries. The small nearby translocated population at Cataract Dam has not been included in this scope.

The other component to the central population is at Jervis Bay (central), approximately 1200 adults. Habitat is found as two separate areas of largely connected habitat on Bherwerre Peninsula in the west, through Jervis Bay National Park and Booderee National Park (approximately 4500 ha) and on defence land at Beecroft Peninsula in the east (approximately 2000 ha). This population is not considered in this narrative, but varies in relation to Barren Grounds primarily as a result of its proximity to urban development (fire, ferals, roads, urban interface management).

The southern population is found at Nadgee Nature Reserve, approximately 400 adults. Habitat is found as a series of large heathlands that are tenuously connected by dense creek lines and other coastal vegetation. Habitat is all found within Nadgee Nature Reserve and Croajingolong National Park (approximately 3000 ha). This population is not considered in this narrative, but varies in relation to Barren Grounds primarily because it occurs in a wilderness area with few management access trails (especially for fire) and no feral predator control.

Narrative

Barren Grounds (central)

- The major threats to the central population of eastern bristlebirds are inappropriate fire and feral predators.
- Large intense fires kill bristlebirds, leaving habitat temporarily unsuitable (period of time varies depending on circumstances/context) and leaving habitat more porous to feral predators.
- Large intense fires are increased by droughts, which may increase with climate change.
- Adjacent unburnt habitat or refuges within the burnt area are critical for bristlebird survival and recolonisation.
- Bristlebirds are known to remain for over 60 years in unburnt habitat.
- Bristlebirds have also recolonised within two years small burnt areas (sub 200 ha) that have adjacent unburnt habitat. This response is also significantly impacted by the level of feral predator abundance in the burnt areas.
- Foxes and cats are considered predators of bristlebirds, with high intensity control being linked to population increases.
- Bristlebirds are found in a range of dense low vegetation, from heathland, swamp, heathy woodland, shrubby forest and wet sclerophyll forest (although this last is more likely to represent marginal habitat on the edge of 'full' habitat).
- Weeds are generally not an issue due to the shallow, low nutrient, sandstone soils.
- Natural predation of nestlings by goannas, currawongs, snakes and quoll is assumed, but is unlikely to be a major threat to the species.
- *Phytophthora* (a type of root rot fungus) will reduce the amount of heathy vegetation.

Process model

Drought: Months under drought conditions

***Dasyornis brachypterus*:** Total size of population

Fire intensity and areas burnt: Combined measure of how intense (hot) the fire is and how much of the habitat is burned

Feral predator control: Number of foxes and cats removed from site

Fire management: Whether or not fire prevention strategies are in place

Foxes and cats: Number of foxes/cats on site

Heathy vegetation: Total area of high quality heathy vegetation

Human disturbance: Number of people entering habitat per month

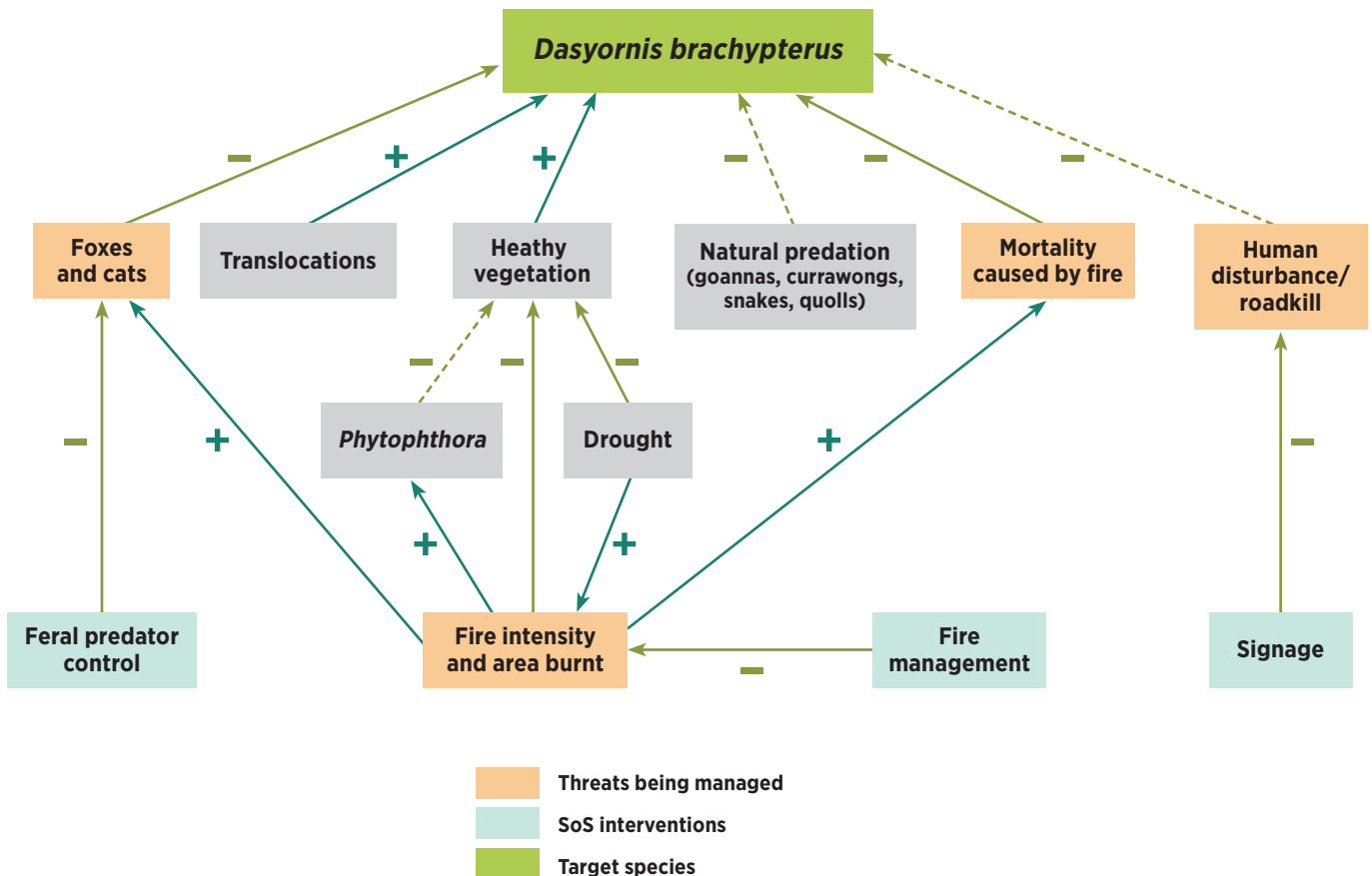
Mortality caused by fire: Percentage of population killed by fire

Natural predation: Predation by natural predators

***Phytophthora*:** Area of habitat (in hectares) affected by *Phytophthora*

Signage: Number of signs

Translocations: Number of birds translocated to alternative sites





Eastern bristlebird nest.
(Stephen King/OEH)

Indicators

These responses relate only to Barren Grounds population (part of central population). Jervis Bay population (central) and Nadgee population (southern) will have slightly different indicators and responses due to site specifics and management.

- Birds detected on survey transects (EBBs/500 m)
- Percentage of cameras with feral predators, either fox or cat (cameras out for four weeks twice a year and averaged)
- Area of habitat burnt (ha)

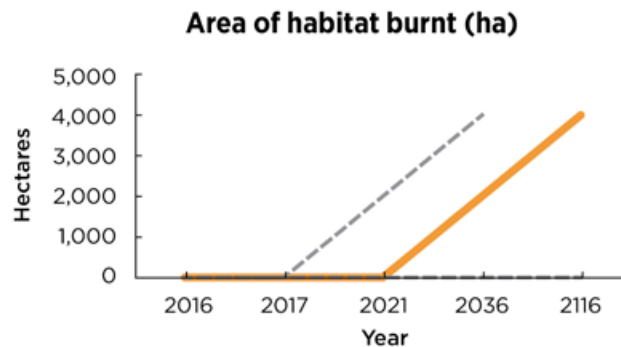
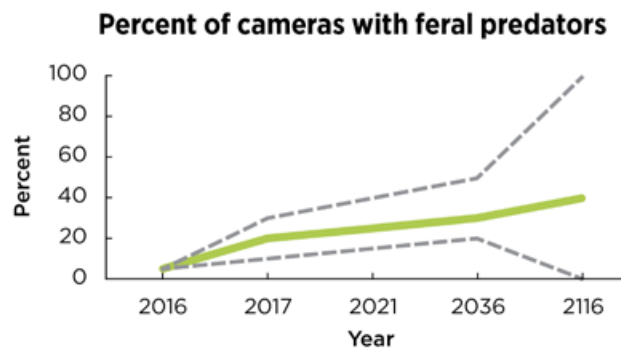
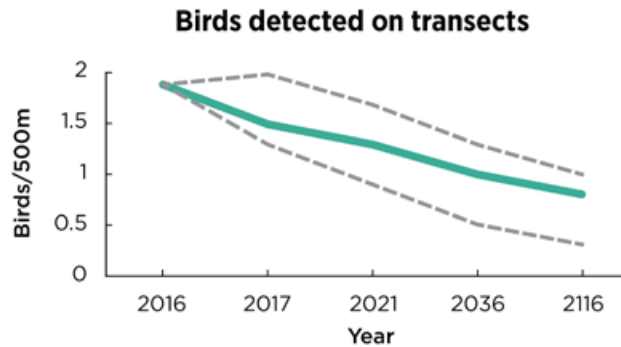
Response to management estimates

The following response to management curves were estimated during the workshops by species experts. Plots show the experts' best guess for how each indicator would respond under different scenarios, as well as the highest and lowest expected values (shown with dashed lines). The confidence that the value for each indicator will fall inside this range is given underneath each plot.

These responses relate only to the Barren Grounds population (part of central population). FoxTAP (another program) funds the control of foxes. SoS only funds the control of cats and rides on the back of FoxTAP. No management = none; Continuation of pre = just FoxTAP; Continued SoS = both FoxTAP and SoS; Current SoS = FoxTAP continues & SoS for five years. Most management was already being undertaken before SoS (fox control and appropriate fire management).

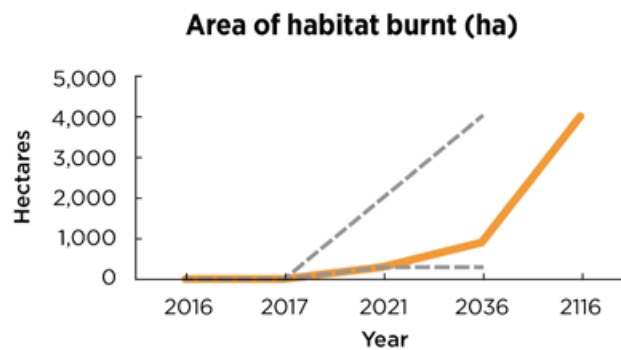
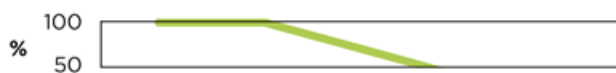
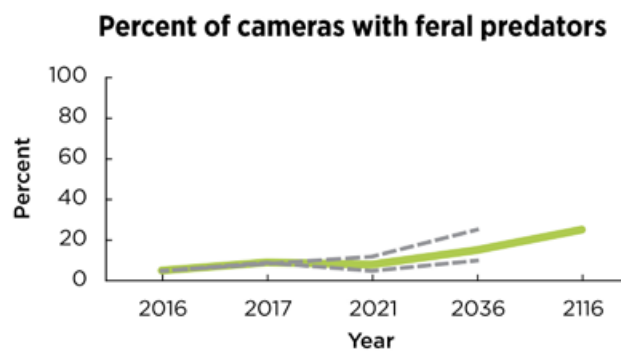
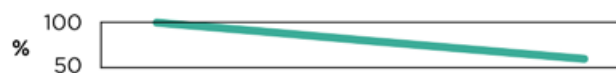
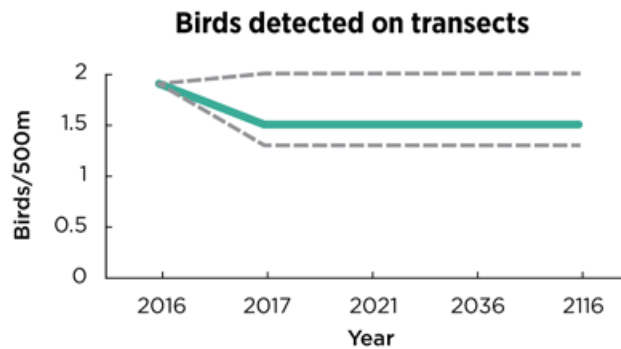
Scenario 1: No management

Estimated values for each indicator's response to management under a no management scenario. Plots show highest, lowest and most likely plausible values as estimated by experts. Confidence values for each indicator are given below each plot.



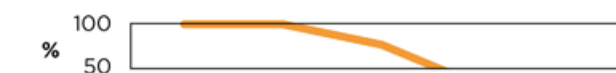
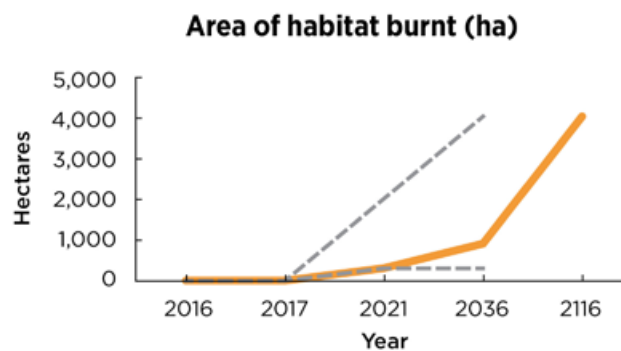
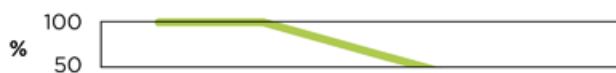
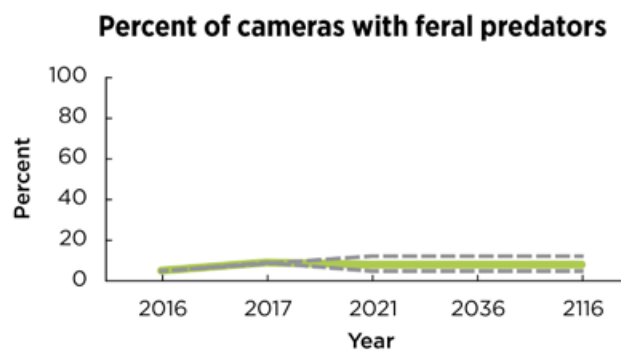
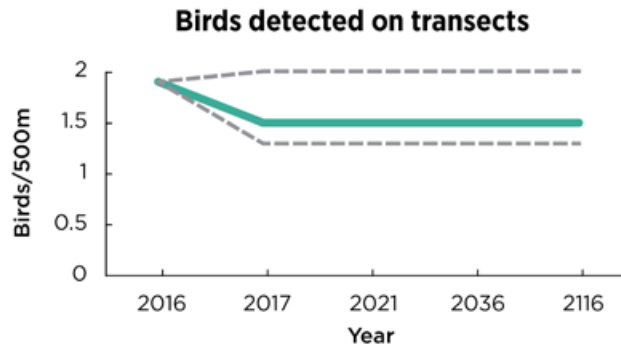
Scenario 2: Continuation of pre-SoS management

Estimated values for each indicator's response to management under a pre-SoS management scenario. Plots show highest, lowest and most likely plausible values as estimated by experts. Confidence values for each indicator are given below each plot.



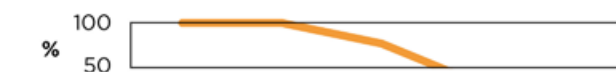
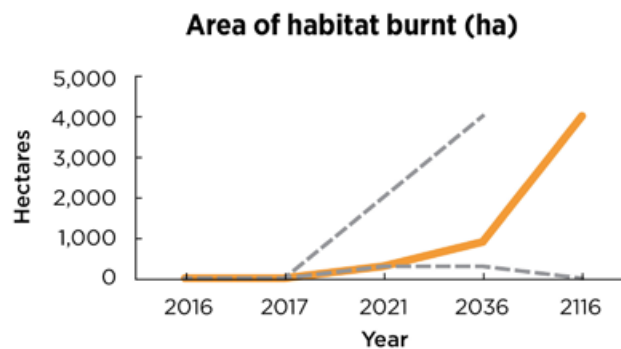
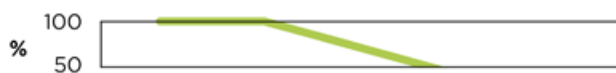
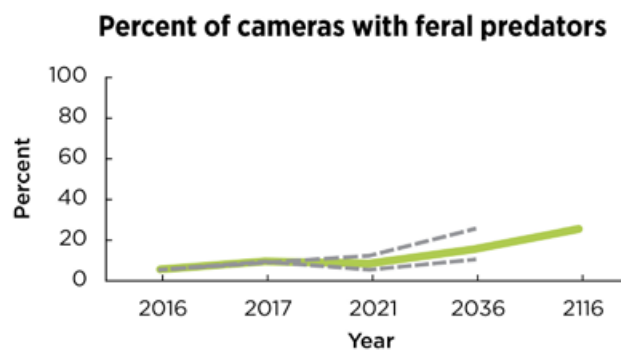
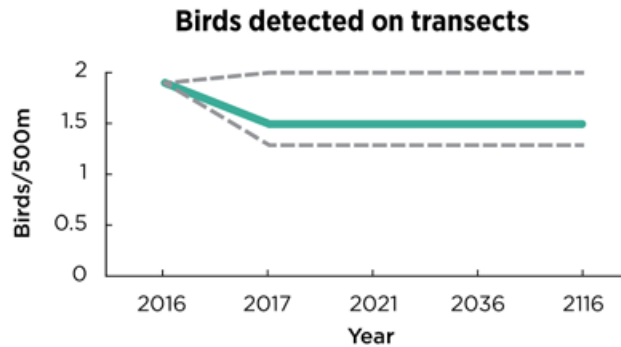
Scenario 3: Continued SoS intervention

Estimated values for each indicator's response to management under a continued SoS management scenario. Plots show highest, lowest and most likely plausible values as estimated by experts. Confidence values for each indicator are given below each plot.



Scenario 4: Current SoS intervention only

Estimated values for each indicator's response to management under the current SoS management scenario. Plots show highest, lowest and most likely plausible values as estimated by experts. Confidence values for each indicator are given below each plot.



Dasyornis brachypterus (Eastern bristlebird – northern population)



Eastern bristlebird (northern population). (Zoe Stone)

Scope

The model covers the northern population of eastern bristlebirds (approximately 40 adults) across one site. Habitat patches are small on average, most under 100 hectares. There are two large patches remaining (900 ha and 400 ha). In total the average is 150 hectares, but without those two larger sites it is down to 65 hectares. Breeding territories can be 2–5 hectares, so smaller patches are unlikely to support a large number of birds. Indicators and estimated response to management have not been provided as this population is outside New South Wales.

Narrative

The major threat to the northern population of eastern bristlebirds is habitat loss.

- Adults have a preference for foraging in tussock grass, with this habitat also being essential for nesting sites, and hence this affects the number of nestlings.
- An increase in shrubs reduces the amount of tussock grass.
- An increase in shrubs and other weeds causes an increase in bell miners, leading to an increase in psyllid/sap sucking insect infection, which reduces the tree canopy, resulting in more shrubs.
- A catastrophic fire will kill adults (presumably nestlings as well, but this has been simplified). The chance and impact of a catastrophic fire are both increased by drought, but decreased by more shrubs (which hold moisture).
- An increase in adults increases genetic diversity, which increases nestlings (through breeding success).
- Genetic diversity can increase the success of captive breeding programs, meaning more captive reintroductions are possible, which increase the number of adults. Captive reintroductions also directly increase the genetic diversity of the wild population, increasing the breeding success (nestlings).
- Natural predation of nestlings by goannas, currawongs, snakes and quoll is assumed, but is unlikely to be a major threat to the species.
- Weed control reduces the number of shrubs and weeds.
- An appropriate fire regime will increase tussock grass by increasing soil nutrients and eliminating compressed grass to allow for new grass.
- An appropriate fire regime will reduce the number of shrubs.
- Cats are not included, but in similar situations are known to predate small birds at recently burnt sites (fire scars).
- Cattle grazing reduces tussock grass by converting the habitat to other grasses and also increases nest abandonment via cattle and other farming activities. The majority of landholders keep stock away from the birds, and birds are generally located on steeper slopes, which minimises the risk of habitat or nest disturbance. Further landholder liaison has therefore not been included as an action in the model.

10. *Grevillea caleyi* (Caley's grevillea)



***Grevillea caleyi*.**

(Greg Steenbeeke/OEH)

Tony Auld and Erica Mahon

Grevillea caleyi (Proteaceae) is a critically endangered shrub endemic to New South Wales. Mature plants can grow up to four metres. Persistence of the species is dependent on fire. While fire will trigger germination of new seedlings from the seed bank in the soil, it also kills mature plants. The population size therefore changes in cycles related to fire, rather than remaining constant.

Scope

Grevillea caleyi occurs on approximately 70 hectares of habitat made up of 23 sites. The model and estimates given here refer to the entire population, as the threats facing each site are similar. The main threats to the species are clearing and fragmentation, habitat disturbance, inappropriate fire regimes and weed impacts. The ideal time between fires is thought to be between 10 and 30 years. Good historical monitoring data are available for several sites and management plans have been in place since 1996, with an updated recovery plan being developed in a collaboration between New South Wales and the Commonwealth of Australia.

Numerous interventions are in place including:

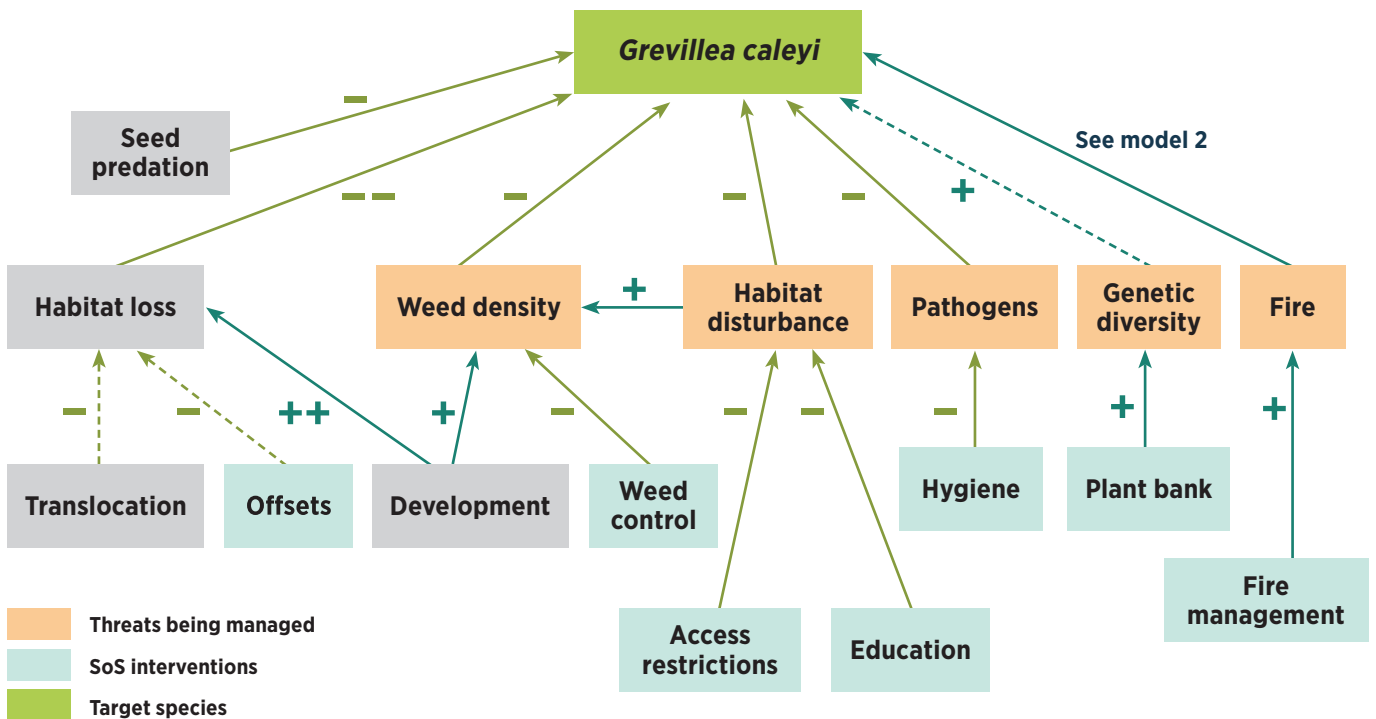
- weed control – targeting ongoing control, and any new incursions
- advice on fire management to limit impacts of frequent fire, fire severity and fire patch size. This targets fire planning, but also incorporates the impacts of grazers on juvenile plants post-fire, where a fire burns only a small area of habitat
- minimising habitat disturbance (e.g. closing bike tracks, fencing to reduce rubbish dumping)
- seed collection for seed banking as a backup.

Offsetting of clearing has not been proven to be effective.

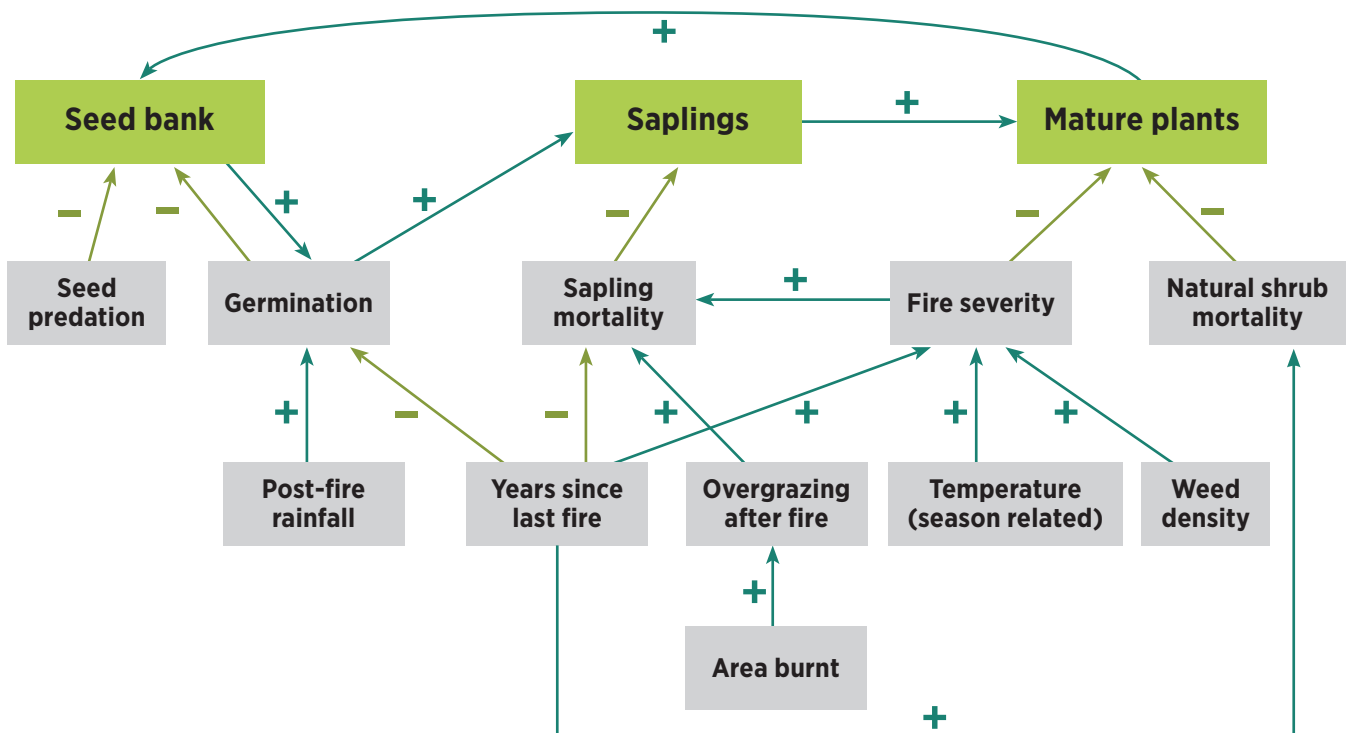
Narrative

- Habitat loss, caused by development, is the major ongoing threat to *Grevillea caleyi*.
- Translocation and offsets are possible mitigating strategies to habitat loss, but these are unproven. Habitat loss is ongoing and has not been effectively offset.
- Weed density, which is increased by development and habitat disturbance, reduces the number of *Grevillea caleyi* plants.
- Weed density is decreased by weed control. High weed density decreases fire severity.
- *Grevillea caleyi* numbers are decreased through habitat disturbance, which itself can be reduced through access restrictions and education.
- Pathogens can decrease *Grevillea caleyi* through plant mortality. Proper hygiene when working on site can reduce this risk.
- The low numbers of *Grevillea caleyi* mean that lack of genetic diversity may become a threat. Maintaining an ex-situ soil seed bank can reduce this risk.
- Seed predation decreases the number of seeds stored in the soil seed bank.
- An increase in mature plants increases the number of seeds stored in the soil seed bank.
- Recruitment of new plants (seedlings) is triggered by fire, which kills existing mature plants and seedlings.
- An increase in seedling recruitment levels is expected to lead to an increase in mature plants.
- Germination decreases the seeds in the seed bank, but increases the number of seedlings.
- The level of post-fire germination is increased by increases in the seed bank, and in long unburnt habitat (>30 years since last fire) is decreased by the years since last fire.
- An increase in the years since last fire up to around 10–15 years causes an increase in fire severity and an increase in the chance of a fire.
- An increase in seedling mortality, through fire or high levels of grazing after a fire, results in a decrease in seedlings.
- An increase in the area burnt reduces the chance of adverse grazing after a fire.
- An increase in fire severity increases germination and the number of seedlings post-fire.
- Temperature will affect the fire severity.
- Post-fire rainfall will increase germination and reduce seedling mortality.

Process model



Model 2 - Response to fire



While representing the impact of fire on *Grevillea caleyi* requires the different life stages to be modelled separately, there are also several major threats that impact the species at all stages. For simplicity, two separate, complementary, models were created.

Access restrictions: Amount of habitat in hectares where access restrictions are in place

Area burnt: Size of the area burnt in each fire that burns one of the 26 'sites'

Habitat disturbance: Proportion of remaining habitat disturbed by recreational use, tracks, maintenance, etc.

Habitat loss: Percentage of original habitat lost per year

Development: Amount in area of developments (urban or industrial)

Education: Funding spent on community education

Fire event: Occurrence of a fire on the site

Fire severity: Degree of heat produced by a fire, incorporating soil heating

Genetic diversity: Amount of genetic diversity remaining in the wild population

Germination: Number of seeds germinating after a fire event

***Grevillea caleyi*:** Total population size (includes seed bank, sapling and mature plants)

Hygiene: Whether or not hygiene measures are in place and followed correctly

Mature plants: Number of mature plants

Offsets: Hectares of habitat offset at other locations that may partially mitigate against original losses

Over grazing after fire: Number of saplings eaten

Pathogens: Proportion of *Grevillea caleyi* affected by pathogens

Plant bank: Plants or seeds kept offsite

Post-fire rainfall: Millimetres of rain within one month of fire event

Seedlings: Number of seedlings present

Seedling mortality: Proportion of a sapling generation that perishes

Seed predation: Proportion of seeds removed from the seed bank via predation or disturbance

Seed bank: Seeds remaining dormant in soil on site

Temperature: Temperature at the time of the fire event

Translocations: Number of plants successfully translocated and reproducing at translocated site

Weed control: Proportion of remaining habitat where weed management is in place

Weed density: Average weed coverage per metre across the site

Years since last fire: Number of years since the last fire, either up to 15 years after which time there is no further effect on fire severity, or after 30 years, after which the seed bank will decline



Grevillea caleyi.
(Stephen Douglas/OEH)

Indicators

The following indicators were selected for monitoring the response to management for *Grevillea caleyi*:

- Habitat area (ha) – permanent loss of habitat and the fragmentation of the remaining habitat is one of the key threats to the long-term viability of the species in the wild. It is expected that further loss of habitat will occur and factors that minimise and offset habitat loss are predominately outside of the scope of the SoS project.
- Weed density (average % of plots with >5% canopy cover) – assumption of 100 plots. The condition of the habitat to maximise the survival over the life-cycle of the plant, including building a sufficient seed bank, is an area of major investment of the SoS project.
- Relative disturbance from illegal tracks – 0 = no disturbance. Recreational disturbance leads to the loss of habitat, encroachment of weeds and fragmentation of habitat. Community education and illegal track closures are an area of investment by the SoS project.
- Post-fire seedling abundance relative comparison (1=population stable across fires). Mass recruitment occurs after a fire event with limited recruitment between fire events. Appropriate fire regimes are essential to the seedling abundance post-fire, which is linked to the population viability at each remnant.

Response to management estimates

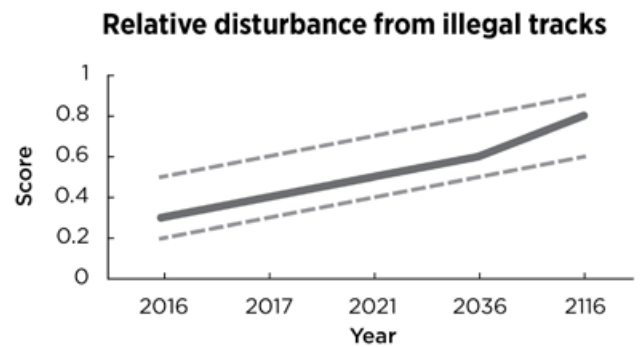
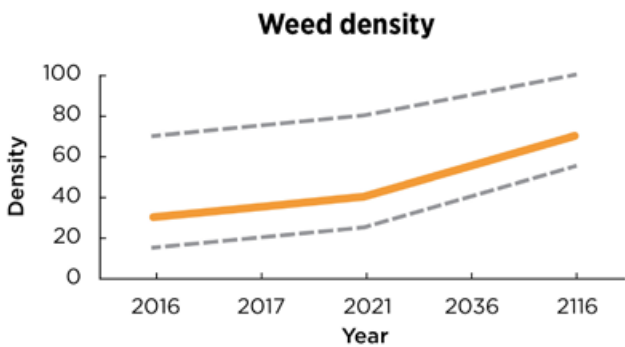
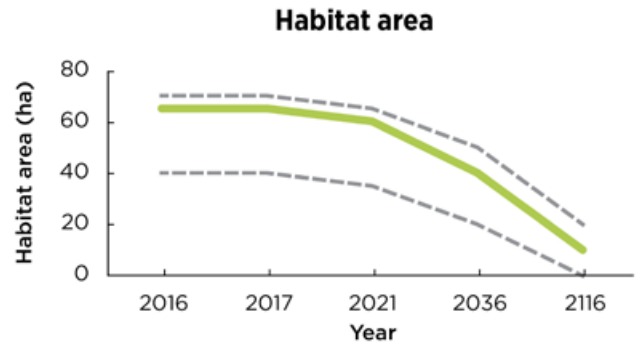
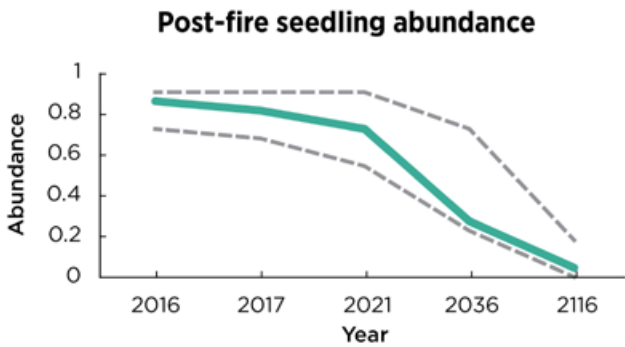
The following response to management curves were estimated during the workshops by species experts. Plots show the experts' best guess for how each indicator would respond under different scenarios, as well as the highest and lowest expected values (shown with dashed lines). The confidence that the value for each indicator will fall inside this range is given underneath each plot.

Assumptions

- No management – assume statutory processes still occur, e.g. offset for development loss.
- SoS has had no positive influence on illegal track disturbance to date.
- Weed densities assumes access to all sites to undertake plots.

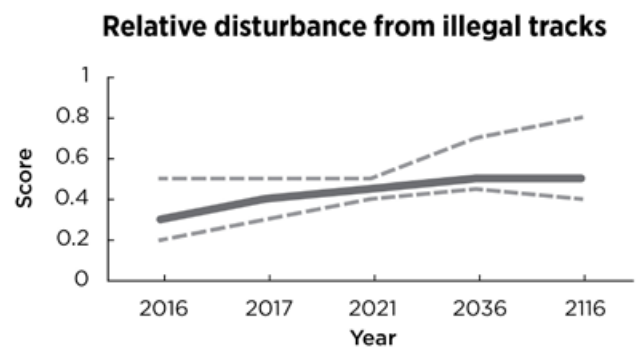
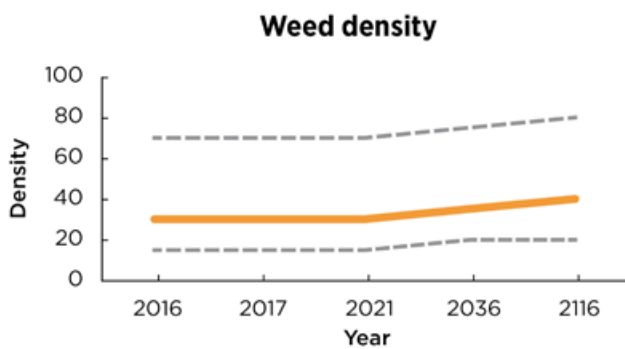
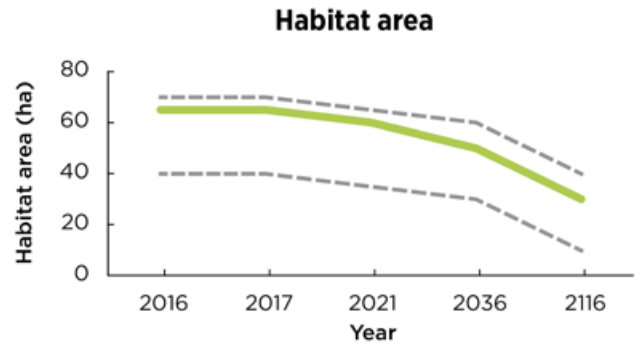
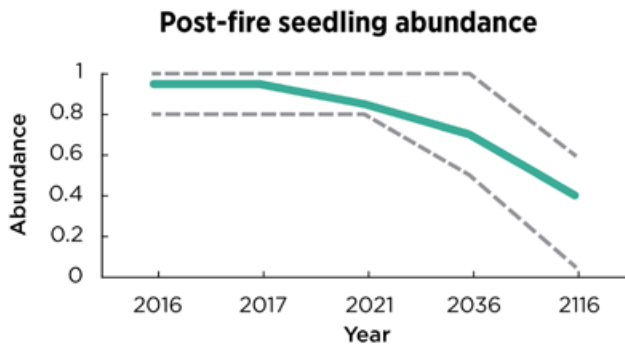
Scenario 1: No management

Estimated values for each indicator's response to management under a no management scenario. Plots show highest, lowest and most likely plausible values as estimated by experts. Confidence values for each indicator are given below each plot.



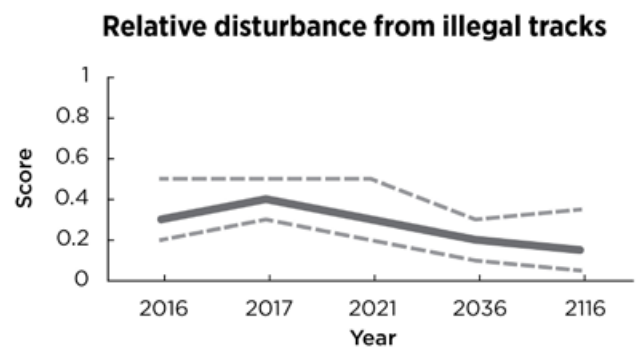
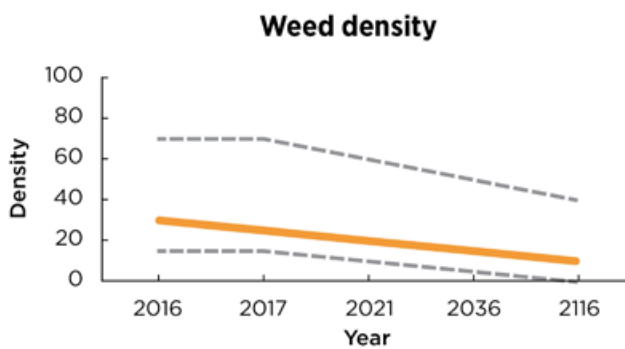
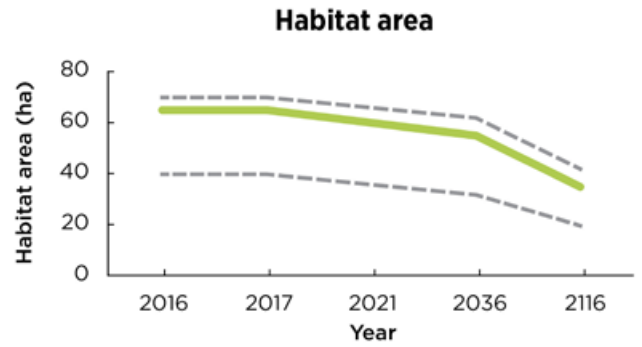
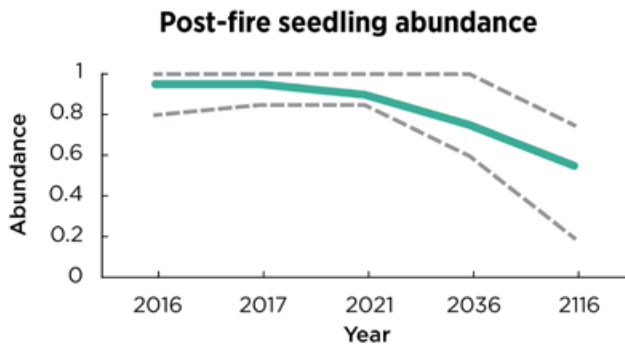
Scenario 2: Continuation of pre-SoS management

Estimated values for each indicator's response to management under a pre-SoS management scenario. Plots show highest, lowest and most likely plausible values as estimated by experts. Confidence values for each indicator are given below each plot.



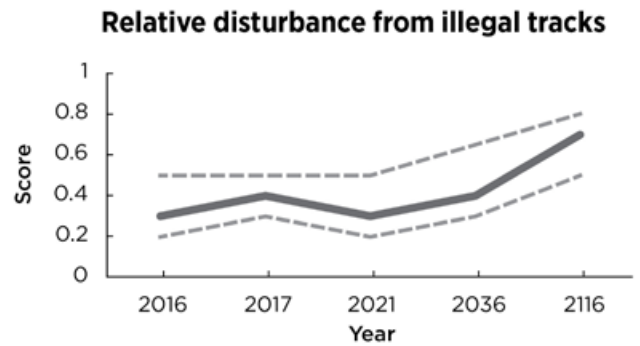
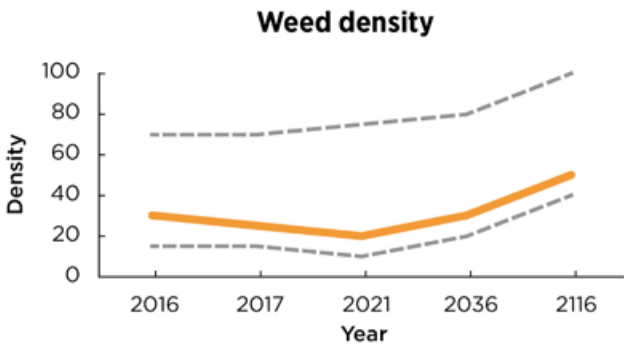
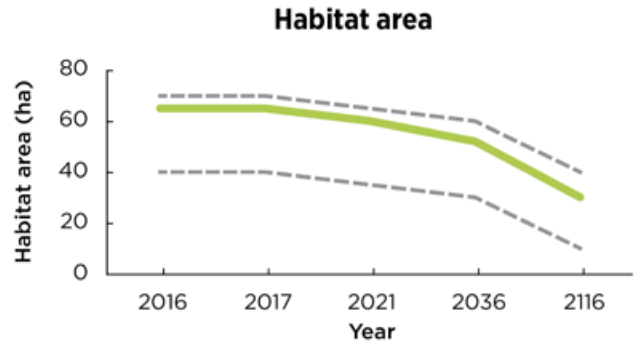
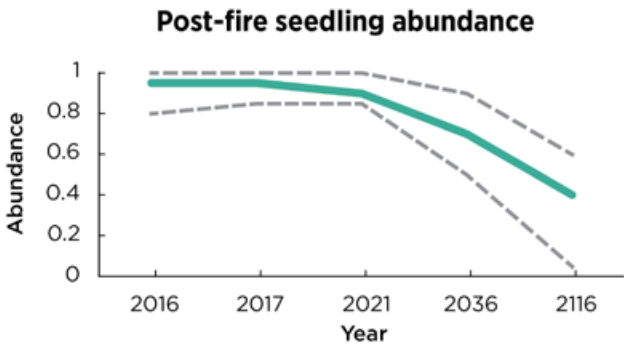
Scenario 3: Continued SoS intervention

Estimated values for each indicator's response to management under a continued SoS management scenario. Plots show highest, lowest and most likely plausible values as estimated by experts. Confidence values for each indicator are given below each plot.



Scenario 4: Current SoS intervention only

Estimated values for each indicator's response to management under the current SoS management scenario. Plots show highest, lowest and most likely plausible values as estimated by experts. Confidence values for each indicator are given below each plot.



11. *Petalura gigantea* (Giant dragonfly)



Female *Petalura gigantea*.
(Dr Ian Baird)

Ian Baird, Huw Evans and Deborah Ashworth

Petalura gigantea is a large dragonfly with adults having a wingspan up to 12.5 centimetres. The species is distributed along the coast, ranges and adjacent tablelands of eastern New South Wales, and immediately across the border in south-eastern Queensland. The species is generally described as being semi-terrestrial and is restricted to groundwater-dependent peat swamps (mires). After mating, adult females insert their ovipositor and lay eggs into some form of moist or saturated, organic-rich soil substrate, into fissures in the substrate, or among or under live or decomposing plant material overlying the substrate, including graminoids, sphagnum, roots and litter.

Larvae excavate permanent burrows (up to 75 centimetres deep, but generally much less) which they maintain and occupy throughout their long larval stage, which is probably at least six years, and potentially more than 10 years, in some situations. All burrows contain groundwater, usually throughout most of their depth. The species is an obligate groundwater-dependent species. From late October through into January larvae leave their burrows at the end of their long larval stage and undergo emergence to the adult stage. The adult flying season extends potentially from late October into March, although it is generally restricted to a period between mid-November and mid-February.

Males are mostly territorial within swamp breeding habitat although they may wander after emergence before returning to swamp habitat. Females, however, typically depart their larval swamp habitats after emergence and only return to a swamp to find a mate and lay eggs. Adults live for only one late spring–summer flying season.

Due to time constraints in a workshop setting, indicators and response to management curves were not completed for this case study.

Scope

Petalura gigantea is listed as an endangered species in New South Wales, and has been allocated to the landscape-managed stream of the SoS program. Around 32% of the species' distribution occurs on protected land. The major threats to the species include habitat loss and degradation, climate change, intense fire regimes, increased runoff from stormwater and reduction in groundwater levels. Because of the long larval stage of the species (at least six years), many of the major threats relate to larvae rather than the adults. The species is specifically managed at one site in the Blue Mountains.

SoS actions include liaising with local fire authorities, habitat restoration, groundwater management and access restrictions where possible.



Male *Petalura gigantea*. (Dr Ian Baird)

Narrative for the Blue Mountains site

- Swamp habitat quality and swamp habitat area are two major factors in the number of adults.
- Swamp habitat area is reduced by channelisation and erosion by stormwater, as well as by clearing and filling.
- Swamp habitat quality is reduced by lowering water tables, pollutants in the water, trampling and pugging, and weed density.
- Cats and foxes possibly predate adults.
- Lack of ovipositing and larval establishment sites is a major factor limiting eggs and larvae.
- Reduction in swamp habitat area reduces the number of potential ovipositing and larval establishment sites.
- Sedimentation reduces the number of ovipositing and larval establishment sites, including filling in those that already contain eggs or larvae, which will probably perish.
- Lowering groundwater levels will reduce the number of eggs and larvae that survive to the adult stage.
- Trampling and pugging by livestock or public access destroys ovipositing and larval establishment sites, degrades swamp habitat quality and directly crushes eggs and larvae in the soil.
- Livestock and unmanaged stormwater increase the pollutants in the water.
- Unmanaged stormwater also carries sediment from surrounding urban areas/unsealed roads/development sites/highway construction, etc. as well as causing channelisation and erosion of swamps.
- Channelisation and erosion lowers groundwater levels, which reduces potential ovipositing and larval establishment sites. It also washes away eggs and larvae and increases weed density through seed dispersal.
- Weed density, which reduces swamp habitat quality and potentially ovipositing and larval establishment sites, is also increased by public access, livestock and increased sedimentation.
- When fire occurs, the fire severity will increase the impact of the fire on ovipositing and larval establishment sites, eggs and larvae, which can perish through combustion or heat effects, as well as possibly adults.
- Fire severity is affected by the groundwater levels, the fire intensity and whether or not the fire occurs in the breeding season. Fire during dry conditions, with lower soil moisture, will result in increased combustion of organic-rich peaty soils.
- More frequent fires will increase the number of eggs and larvae killed by fire and loss of organic-rich soils through combustion.

- Fire management can reduce the number of fires that occur during breeding season, reduces the intensity of fires, but will likely increase the frequency of fire over what would naturally occur.
- Access restrictions can reduce livestock numbers and public access.
- Stormwater management reduces the volume of unmanaged stormwater.
- Sambar deer are an emerging threat that roll in mud, degrading swamp habitat quality and increasing trampling and pugging.

Process model

Due to the complexity of the system, fire has been expanded in a separate model.

Access restrictions: Percentage of site where access is restricted to either livestock or public

Adults: Number of adult dragonflies

Cats/foxes: Number of animals on the site

Channelisation/erosion: Area (in square metres) of the site where stormwater channelisation or erosion has occurred

Clearing/filling: Area in square metres that is either cleared of all vegetation or where water bodies were filled in

Eggs and larvae: Estimated number of eggs and larvae per season

Fire severity: Measure of the actual impact of a fire in terms of egg and larval mortality and loss of ovipositing and larval establishment sites as a result of the fire

Fire intensity: Temperature of the fire

Fire frequency: Average fires per decade

Fire management: Whether or not appropriate fire management regimes are applied

Groundwater level: Level of the groundwater on the site

Livestock: Density of livestock on site

Occurs during breeding season: Whether or not the fire occurs during the breeding season

Ovipositing and larval establishment sites: Approximate number of sites

Pollutants in water: Concentration of pollutants (chemicals, etc.) in the water bodies on site

Public access: Number of times per year site is accessed. Includes access by 4WDs, trail bikes and pedestrians

Sambar deer: Density of deer on site

Sedimentation: Amount of sedimentation that reaches water bodies on site where dragonflies are known to breed

Stormwater management: Area of site that has effective stormwater management

Swamp habitat area: Amount of the site suitable for breeding and ovipositing and larval establishment sites

Swamp habitat quality; measured as:

- 1 – Unsuitable for breeding
- 2 – Major degradation, but limited breeding may occur
- 3 – Suitable, but not ideal; degradation sufficient to reduce breeding pairs and ovipositing
- 4 – Some degradation to habitat, possibly affecting the number of females mating and ovipositing
- 5 – Ideal habitat for breeding.

Trampling and pugging: Percentage of site affected by trampling and/or pugging

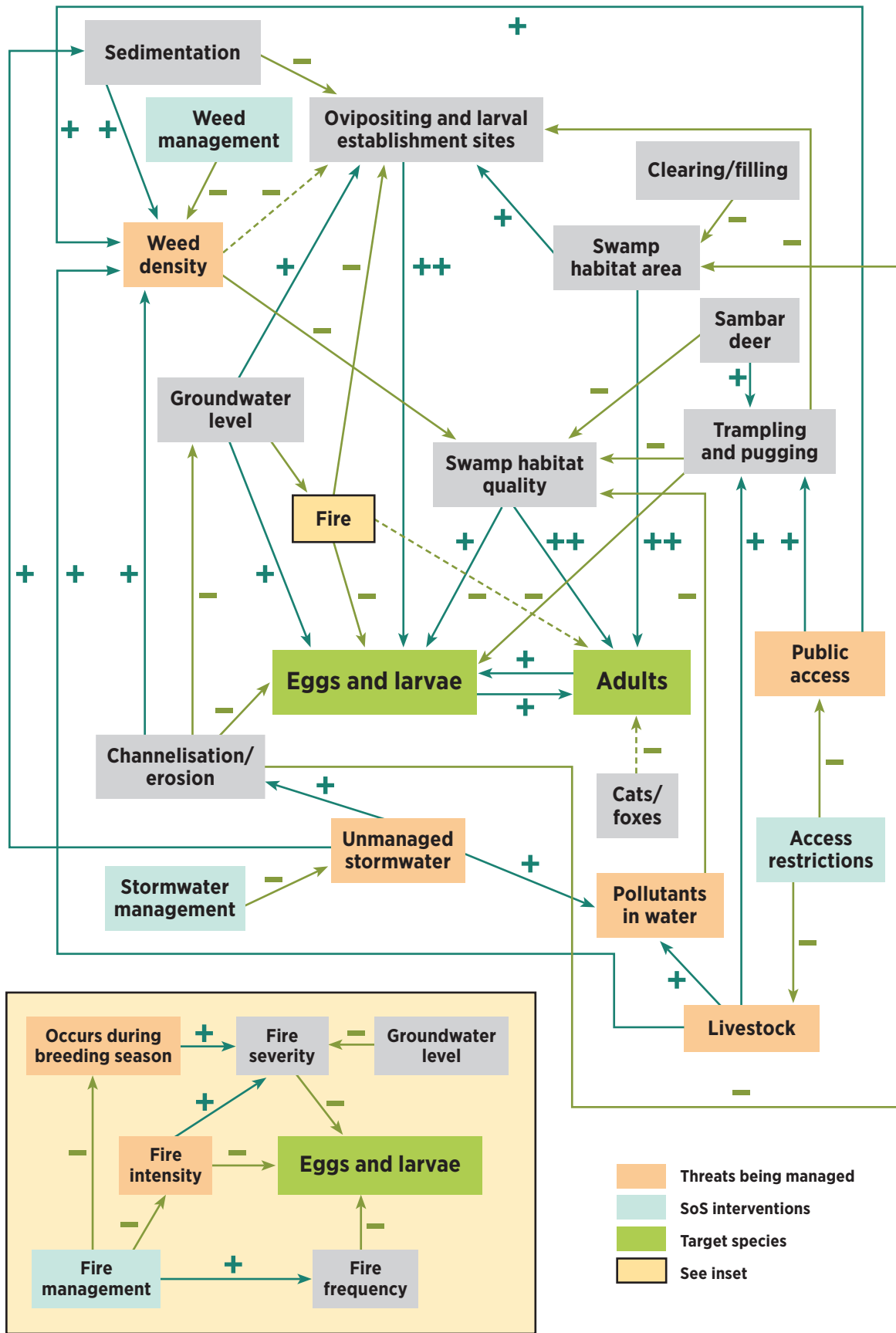
Unmanaged stormwater: Volume of stormwater that is not managed

Weed density: Average weed coverage per square metre on the site

Weed management: Amount of site in square metres where weeds are managed/removed

Modelling decisions and assumptions

- While sedimentation directly buries eggs and larvae as well as destroying existing ovipositing and larval establishment sites, it was considered sufficient to include the link only to sites, as the key mechanism through which the animals are killed is through the destruction of the site. This relationship is already included in the model through the link from ovipositing and larval establishment sites to eggs and larvae.



12. *Hoplocephalus bungaroides* (Broad-headed snake)



Broad-headed snake. (Jonathan Webb)

Meagan Hinds, Dean Portelli and Jonathan Webb

The broad-headed snake is a nocturnal species, with full grown adults averaging around 60 centimetres, with a maximum length of around 90 centimetres. Individuals take around five years to reach maturity. While adults feed on lizards, frogs and small mammals, the majority of the juvenile diet consists of small reptiles such as velvet geckos and skinks. Individuals shelter under flat, exposed sandstone rocks during autumn to late spring, and use tree hollows over summer. The entire range of the species is within New South Wales, where it is listed as endangered.

Scope

Target species: Broad-headed snake (*Hoplocephalus bungaroides*).

Sites being considered:

- Morton National Park and adjacent Crown lands
- Royal National Park
- Woronora Plateau.

The interventions being implemented at each site:

- **Morton – Morton National Park** – locked gates on fire trails to keep out bush rock collectors and snake collectors, signage to inform public about bush rock collection, maintenance of restricted access to Yarramunmun Tops, disturbance monitoring, gate and outcrop monitoring, artificial rock restoration, natural and artificial rock replacement, liaison with Crown Lands/Nowra Local Aboriginal Land Council (LALC) and advocacy for restricted access to their land and broad-headed snake habitat
- **Morton – Crown/Nowra LALC lands** – signage to inform public about bush rock collection, habitat restoration to increase rock numbers at sites damaged by bush rock collectors
- **Royal National Park** – signage to educate public about bush rock disturbance, habitat restoration using natural rock replacement, surveillance of outcrops, signage
- **Woronora Plateau** – no interventions in water catchment land, signage and access restrictions in Dharawal National Park.

Locked gates and signage were implemented in 2007. Locked gates target bush rock collectors and snake collectors and aim to reduce these threats. Signage targets the public and aims to reduce disturbance to rocks.

Monitoring is planned for Royal National Park this year which had 10 sites out of 26 burnt in 2017–18 summer fires, and will look at changes in canopy cover over time and trends in occupancy data. The tracking on the captive breeding program has been developed to try and mitigate the collection from the wild. Breeding has been successful in captivity but only a limited number of keepers are registered or have the appropriate licence to keep this species. Chipping and DNA



Broad-headed snake.
(John Turbill/OEH)

testing of all held individuals is intended to create a database of authorised individuals and improve opportunities to prosecute those in possession of any new individuals entering the program.

A bush rock protection campaign including developing a video on bush rock protection for plants and animals, which will be displayed at Royal NP and potentially other locations. This will also be paired with online and social media and further education and awareness around bush rock protection to discourage certain types of behaviour (e.g. building rock cairns, removing rocks, sensitive recreation, alternatives to bush rock in gardens).

Narrative

- Snake poaching is a threat to juvenile and adult snakes.
- An increase in the number of adult or juvenile snakes makes them easier to find and leads to an increase in the number of snakes taken by poaching.
- An increase in geckos would result in an increase in juvenile snakes due to increased prey abundance. An increase in juvenile snakes would result in a decrease in gecko numbers.
- Gecko numbers are reduced by gecko poaching by collectors.
- Juvenile snakes and geckos both rely heavily on suitable exposed rocks.
- Human disturbance, which is increased with snake poaching, gecko poaching and bush rock removal, disturbs the habitat and reduces the number of suitable rocks.
- The number of suitable rocks is reduced by bush rock removal. Public education can reduce this threat, as well as that of general human disturbance.
- The number of suitable rocks is also reduced by increases in canopy cover, which is reduced by prescribed fire.
- Habitat restoration also increases the number of suitable rocks.
- An increase in canopy cover can lead to an increase in the amount of the site affected by fire (if it occurs).
- Fire reduces the number of small eyed snakes, decreases the number of mature trees and promotes tree hollows in remaining trees.
- Tree hollows are used by adult snakes.
- Goats are a threat to both adult and juvenile snakes.
- Small eyed snakes reduce the number of juvenile snakes and adult snakes through competition for rocks and predation of juveniles.
- A combination of increase in legal trade and maintaining a registry of licensed keepers can reduce both gecko poaching and snake poaching provided all snakes in private collections are screened to ensure there is no wild harvest.
- Road mortality is a factor for both juveniles and adults.
- Access restrictions (including increased surveillance, notices and locked gates) will reduce bush rock removal, gecko poaching, snake poaching and other causes of human disturbance.

Process model

Access restrictions: Amount of habitat under access restrictions such as signs, cameras and locked gates

Adult snakes: Number of adult broad-headed snakes on site

Bush rock removal: Number of rocks being removed each year

Canopy cover: Area of the site that is shaded by plant canopy

Legal trade: Value in dollars of the legal trade market

Geckos: Number of velvet geckos on site

Gecko poaching: Number of velvet geckos taken by collectors

Goats: Number of goats on site

Habitat restoration: Number of rocks replaced/introduced

Human disturbance: Number of rocks disturbed

Juvenile snakes: Number of juvenile snakes on site

Public education: Hours spent on public education

Registry of licensed keepers: Whether or not a registry of licensed keepers is maintained

Road mortality: Number of broad-headed snakes killed by road vehicles

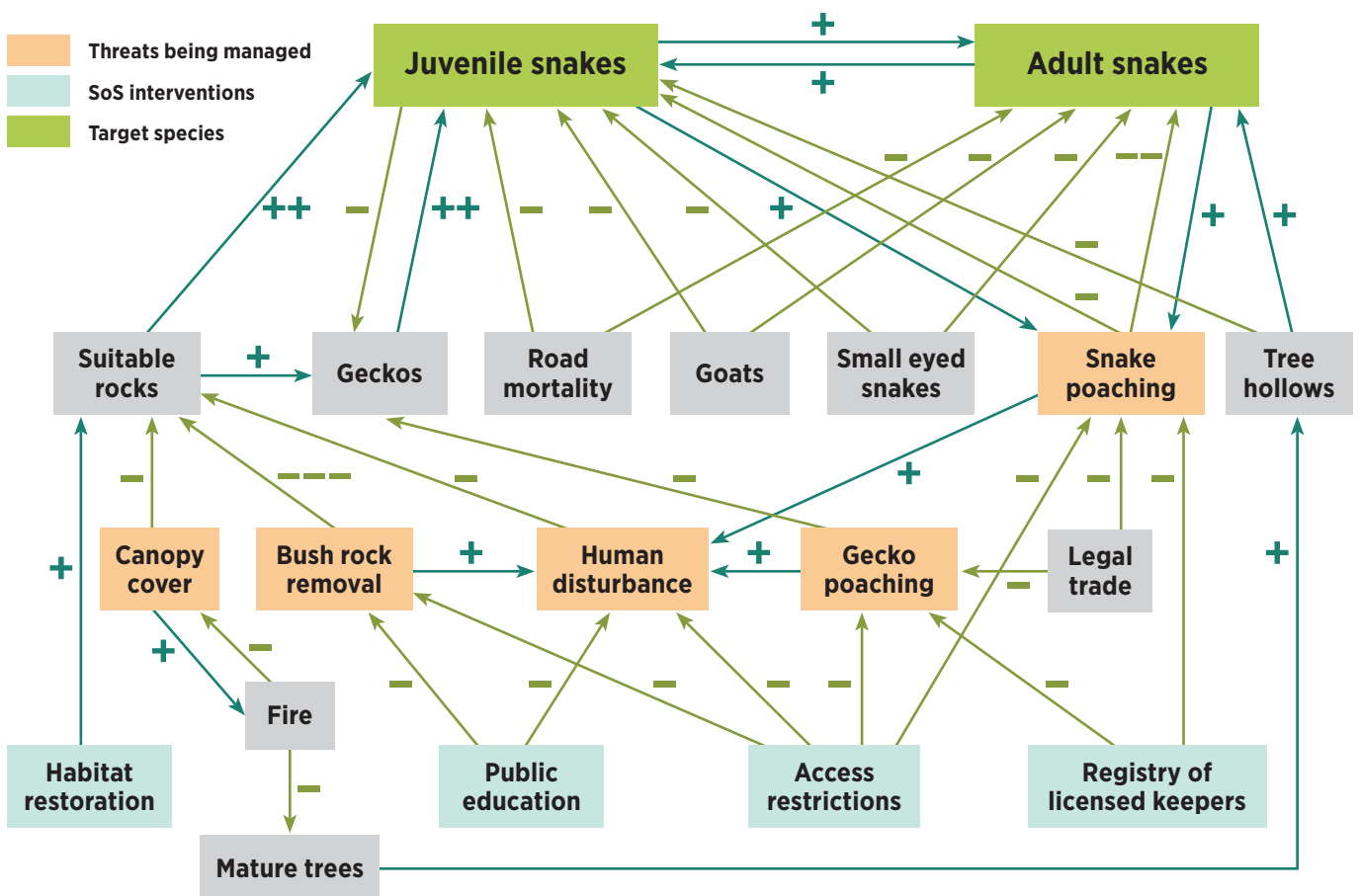
Suitable rocks: Number of small exposed rocks on site

Fire: Amount of site affected by fire in a given year

Small eyed snake: Number of small eyed snakes on site

Snake poaching: Number of broad-headed snakes taken by collectors

Tree hollows: Number of tree hollows suitable for adult snakes



Modelling decisions and assumptions

- Signage, locked gates and cameras target similar threats and have been combined into ‘access restrictions’.
- A simplified model for fire was included as this isn’t thought to be a major threat.
- Although they share some common threats, there is sufficient variation to justify splitting the adults and juveniles into different nodes.

Indicators

- Number of broad-headed snakes
- Percentage of rocks disturbed
- Percentage of rocks remaining
- Number of adult geckos

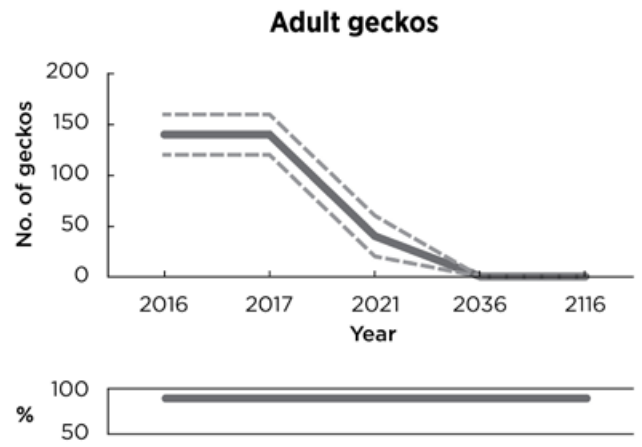
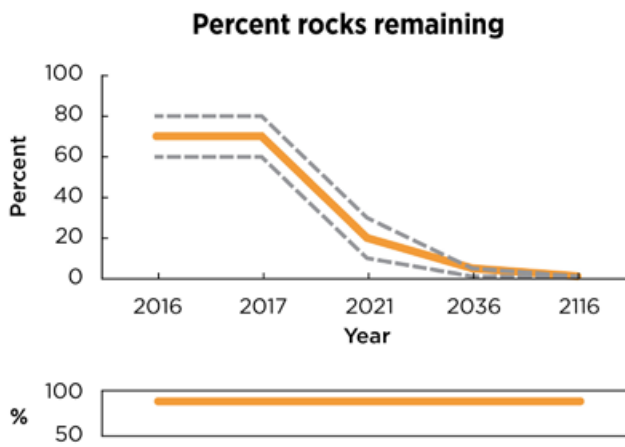
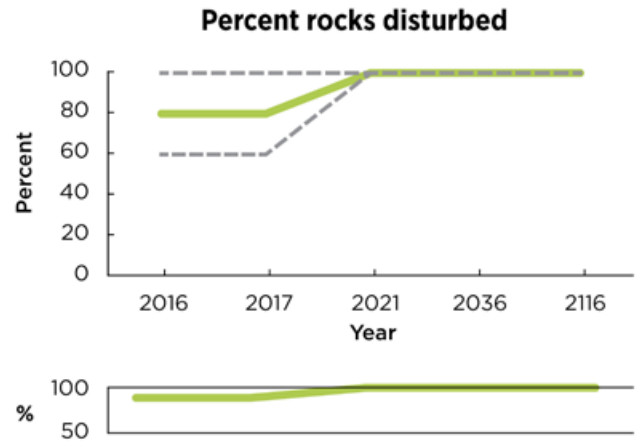
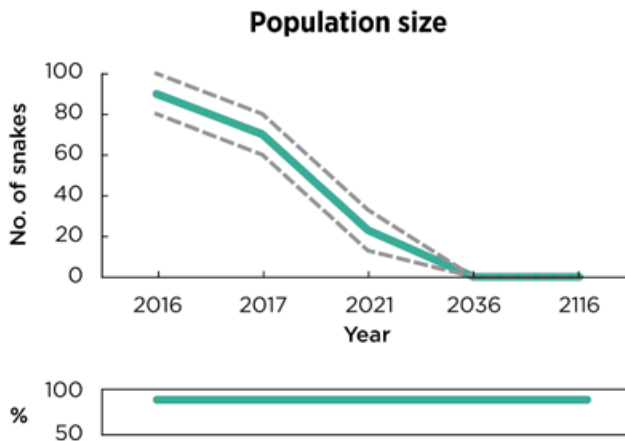
Response to management estimates

The following response to management curves were estimated during the workshops by species experts. Plots show the experts’ best guess for how each indicator would respond under different scenarios, as well as the highest and lowest expected values (shown with dashed lines). The confidence that the value for each indicator will fall inside this range is given underneath each plot.

Crown land sites, currently no management. Assumes that management includes: locked gates on all fire trails, signage, cameras, habitat restoration, and captive breeding and sale of broad-headed snakes to take pressure off wild populations. If captive breeding is not included as a management tool then continued habitat damage, harvesting of snakes and geckos will occur in future, and populations of snakes and geckos will likely go extinct. Alternative scenarios based on alternative management are needed. This would require population viability analysis (PVA) modelling (about a day’s work to do properly).

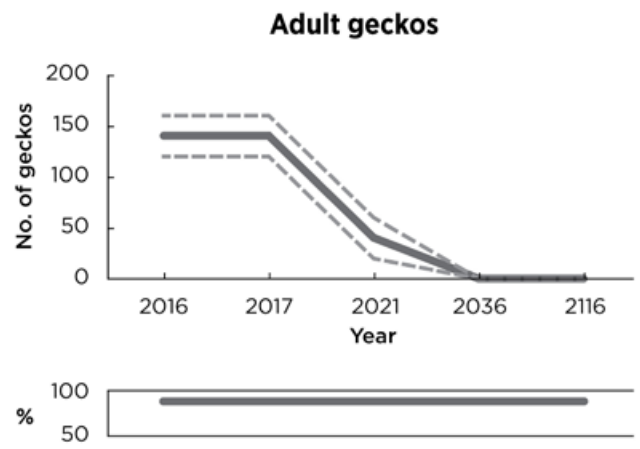
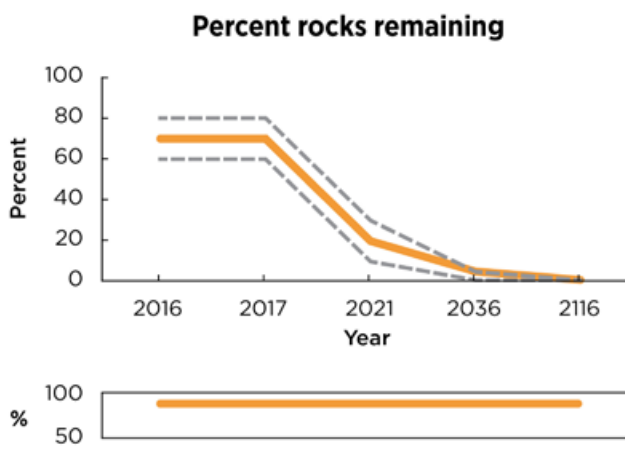
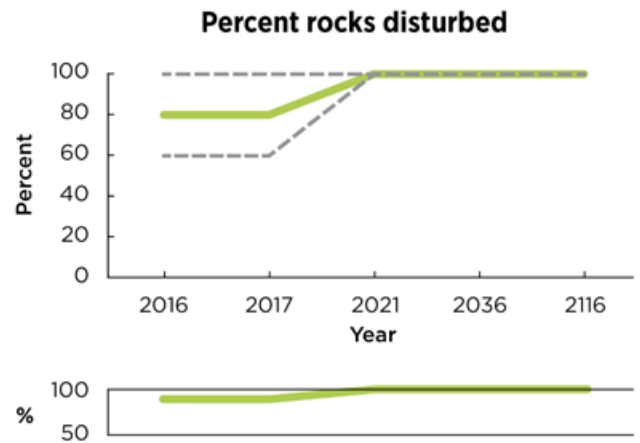
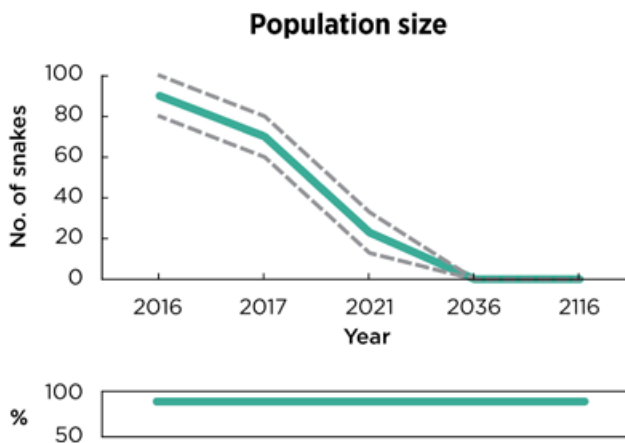
Scenario 1: No management

Estimated values for each indicator's response to management under a no management scenario. Plots show highest, lowest and most likely plausible values as estimated by experts. Confidence values for each indicator are given below each plot.



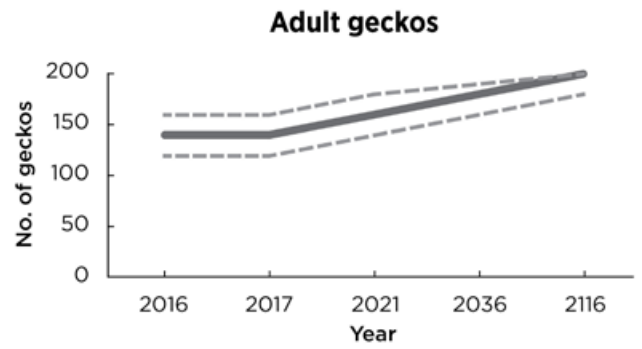
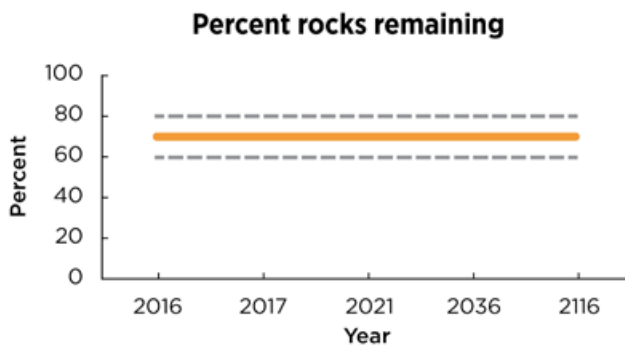
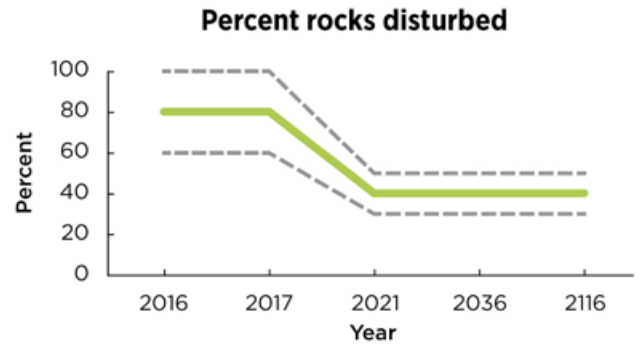
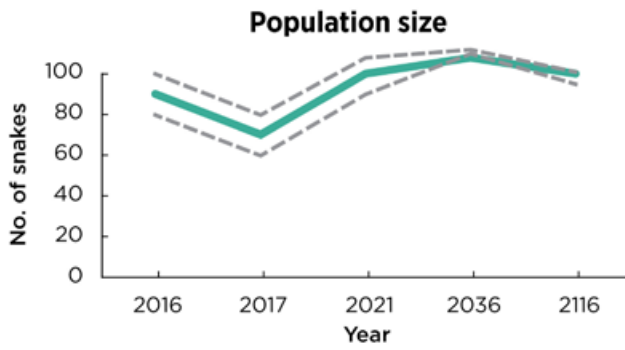
Scenario 2: Continuation of pre-SoS management

Estimated values for each indicator's response to management under a pre-SoS management scenario. Plots show highest, lowest and most likely plausible values as estimated by experts. Confidence values for each indicator are given below each plot.



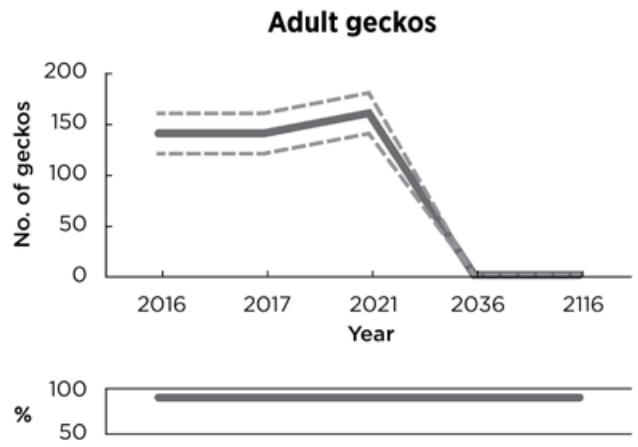
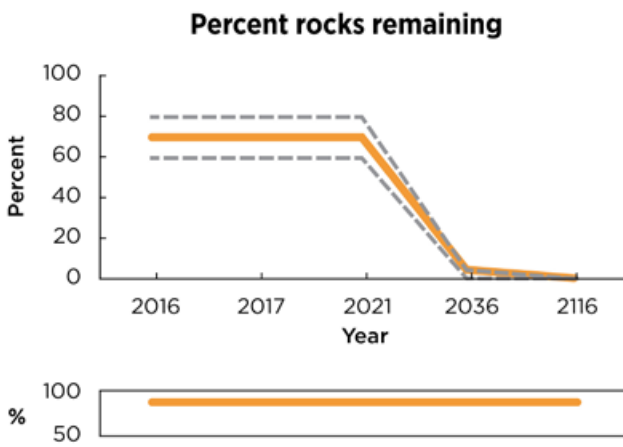
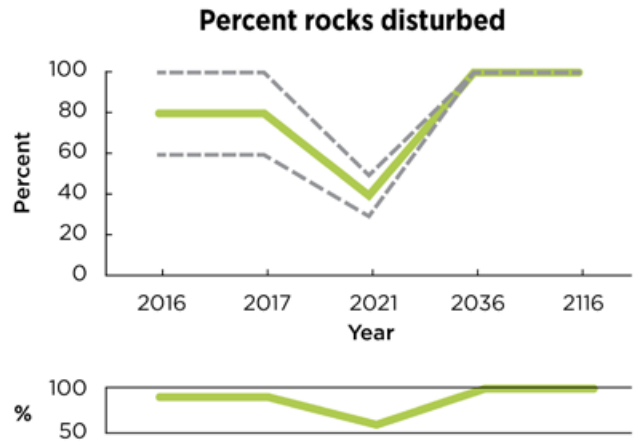
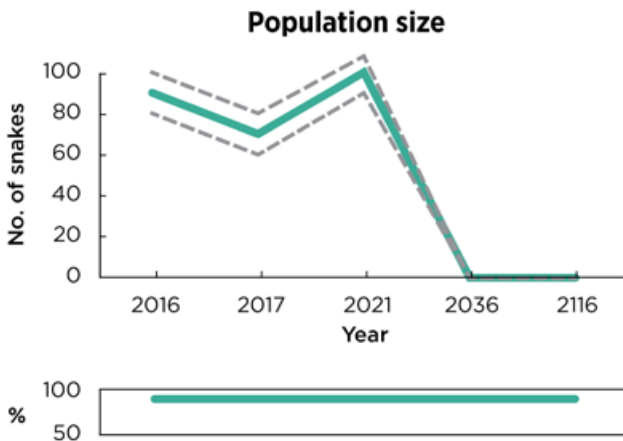
Scenario 3: Continued SoS intervention

Estimated values for each indicator's response to management under a continued SoS management scenario. Plots show highest, lowest and most likely plausible values as estimated by experts. Confidence values for each indicator are given below each plot.



Scenario 4: Current SoS intervention only

Estimated values for each indicator's response to management under the current SoS management scenario. Plots show highest, lowest and most likely plausible values as estimated by experts. Confidence values for each indicator are given below each plot.



Find out more about your environment at:

www.environment.nsw.gov.au

© 2019 State of NSW and Department of Planning, Industry and Environment

These guidelines were developed in a collaboration between the Department of Planning, Industry and Environment and the University of Queensland. The project was funded by the Threatened Species Recovery Hub of the Australian Government's National Environmental Science Program. With the exception of photographs, the State of NSW and Department of Planning, Industry and Environment are pleased to allow this material to be reproduced in whole or in part for educational and non-commercial use, provided the meaning is unchanged and its source, publisher and authorship are acknowledged. Specific permission is required for the reproduction of photographs.

The Department of Planning, Industry and Environment (DPIE) and the Threatened Species Recovery Hub have compiled this guide in good faith, exercising all due care and attention. No representation is made about the accuracy, completeness or suitability of the information in this publication for any particular purpose. DPIE and the Threatened Species Recovery Hub shall not be liable for any damage which may occur to any person or organisation taking action or not on the basis of this publication. Readers should seek appropriate advice when applying the information to their specific needs.

All content in this publication is owned by DPIE and the Threatened Species Recovery Hub and is protected by Crown Copyright, unless credited otherwise. It is licensed under the Creative Commons Attribution 4.0 International (CC BY 4.0), subject to the exemptions contained in the licence. The legal code for the licence is available at Creative Commons.

DPIE and the Threatened Species Recovery Hub assert the right to be attributed as author of the original material in the following manner: © State of New South Wales and Department of Planning, Industry and Environment and the Threatened Species Recovery Hub of the National Environmental Science Program 2019.

Cover photo: Broad-headed snake (*Hoplocephalus bungaroides*) (Jonathan Webb)

Published by:

Environment, Energy and Science
Department of Planning, Industry and Environment
59 Goulburn Street, Sydney NSW 2000
PO Box A290, Sydney South NSW 1232
Phone: +61 2 9995 5000 (switchboard)
Phone: 1300 361 967 (Environment, Energy and Science enquiries)
TTY users: phone 133 677, then ask for 1300 361 967
Speak and listen users: phone 1300 555 727,
then ask for 1300 361 967
Email: info@environment.nsw.gov.au
Website: www.environment.nsw.gov.au

Report pollution and environmental incidents
Environment Line: 131 555 (NSW only)
or info@environment.nsw.gov.au
See also www.environment.nsw.gov.au

ISBN 978-1-925974-75-1

EES 2019/0359

July 2019