Threatened Species Recovery Hub

National Environmental Science Programme

Guidance for estimating the benefits and costs of biodiversity offsets using expert elicitation

Martine Maron, Megan C. Evans, Tida Nou, Zoë L. Stone, Scott Spillias, Helen J. Mayfield, Jessica Walsh

July 2021

The University of Queensland Australia · Monash University · UNSW Australia · Massey University, Te Kunenga ki Pūrehuroa, University of New Zealand

Acknowledgements

This is an output from the Threatened Species Recovery Hub's Project 5.1 "Better offsets for threatened species", supported by funding from the Australian Government's National Environmental Science Program (NESP).

This project was approved by the UQ Human Research Ethics Committee (Protocol Number: 2017000674) under the National Health and Medical Research Council (NHMRC) Human Research Ethics Application (HREA) process.

We thank our key informants for their valuable support and assistance in developing the content for surveys: Tim Burnard, Joe Benshemesh, Nick Leseberg, Steve Murphy, Judy Dunlop, Billy Ross and the subject matter experts: Liz Kington, Melanie Bannerman, Kate McWhinney, Simon Nally, Darren Southwell, Robert Wheeler, Jennifer Jackson, Belinda Bastow, Allan Burbidge, Stephen Garnett, Julian Reid, Alex Kutt, Rod Kavanagh, Rob Davis, Alexander Watson, John Read, Mike Bamford, Stephen van Leeuwen, Kate Crossing, John Woinarski, Ian Radford, Harry Moore, Lorna Hernandez-Santin, Teigan Cremona, Tim Doherty, Chris Knuckey, Damien Cancilla, Katherine Tuft, who dedicated substantial time and expertise to participate in our surveys and project discussions. We also thank several anonymous subject matter experts who participated in the expert elicitation processes. We also thank Victoria Hemming for her advice and assistance in using the IDEA Protocol, and Hugh Possingham and Matthew Holden for their contributions to the approach for incorporating uncertainty into benefit estimates. Thanks to Nick Leseberg and Joe Benshemesh (BirdLife Australia) for preparing distribution maps. We also thank Naomi Indigo, Monique van Sluys, Kate Crossing, Australian Wildlife Conservancy, BirdLife Australia and Bush Heritage Australia for their valuable assistance providing specific costs data for this project.

We received invaluable feedback on earlier drafts of this document from Kahli Beissner and Rod Dann at the Commonwealth Department of Agriculture, Water and the Environment; Manda Page, Vanessa Coverdale, Carole Rayner, Craig Hempel and the offsets team at the Queensland Department of the Environment and Science; and Michelle Cox and Penelope Rogers in the New South Wales Department of Primary Industries and the Environment. We are very grateful to all.

We thank the NESP Northern Australia Environmental Resources Hub, Zoë L. Stone (Massey University), Kim Kraeer, Lucy Van Essen-Fishman and Tracey Saxby (Integration and Application Network Library) for creating and sharing the graphics used in this document. Thanks to Jane Thomas (NESP Northern Australia Environmental Resources Hub) for her assistance with NESP Northern Australia graphics.

Cite this publication as: Maron, M., Evans, M.C., Nou, T., Stone, Z.L., Spillias, S., Mayfield, H.J., Walsh, J. 2021. Guidance for estimating the benefits and costs of biodiversity offsets using expert elicitation. NESP Threatened Species Recovery Hub, Brisbane, Australia. Project 5.1 report.

Cover image: Northern Quoll. Image: Nicolas Rakatopare

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Executive summary

Biodiversity offsets aim to provide a measurable biodiversity benefit, or gain, to compensate for impacts, or losses, from development activities. Offset actions can include restoration activities to increase or maintain the quality of habitat for a species or to improve the condition of ecological communities, the abatement of a threat to a species or ecological community, or protecting a site through tenure change to prevent loss of its environmental values in the future.

Offsets require the benefit from the offset action to be at least as large as the loss caused by the impact. So, effective biodiversity offsetting requires information about the benefits of on-ground management actions to be readily available to decision makers. It also often requires information about the relative costs of different offset options. A key challenge of biodiversity offsetting is that this information is often difficult to obtain, or in many cases, may not exist.

An increasingly common technique for addressing conservation knowledge gaps, particularly with limited resources to collect empirical data and the short time frames associated with decision making, is the use of expert knowledge. Currently, there are no guidelines available on how to apply structured expert elicitation in a biodiversity offset context.

This document provides step-by-step guidance on how to use expert elicitation to estimate the benefits and costs of a range of biodiversity offset actions. Our approach combines elements of structured decision making, well-established expert elicitation techniques, and cost-effectiveness analysis.

This guidance is generic and can be used to ensure biodiversity offset decisions in a wide range of contexts are informed by expert knowledge and evidence in an unbiased and consistent way. It can be used on a one-off basis to identify an appropriate offset action for an individual case, or applied across a suite of matters that commonly trigger offset requirements to create a catalogue of offset requirements for a given unit of impact. It can be used to estimate benefits and costs of potential offset actions for species, groups of species, or ecosystems. We provide worked examples using case studies for two Australian threatened species.

Expert-elicited estimates of benefit using the approach described herein should not replace sound, empirically-derived data from trials of the effectiveness of actions. However, the approach presents a structured, repeatable way of accessing expert knowledge and converting it into actionable information in the absence of complete data. It can also help reveal where uncertainty about the benefits of offsets is genuinely unacceptably high. Ongoing field-based research is necessary to continually improve decisions about how to benefit species and ecosystems affected by residual impacts of development.

Section 1. Background

Biodiversity offsets are increasingly relied upon to address residual impacts of development projects on biodiversity. A successful biodiversity offset must generate enough benefit for impacted biodiversity – such as a species, or an ecosystem – to fully counterbalance the impact that triggered the offset requirement.

Often we don't know what types of offset actions are most appropriate to benefit a particular species or ecosystem, or we don't know how much benefit we will get from those offset actions. Expert knowledge can help to fill these gaps, but eliciting this knowledge must be done in a clear and structured way to reliably and credibly inform biodiversity offset decisions. Importantly, formal expert elicitation protocols are transparent and repeatable, so estimates can be updated in the future if new information emerges.

This document is aimed at those involved in designing or evaluating proposed offset approaches, either at the level of the individual action and associated offset, or at the level of an offset program, where knowledge is needed about the likely benefits from offset actions for a range of species or ecosystems. It is intended to provide guidance on eliciting expert knowledge, and quantifying uncertainty, about likely benefits of offset actions for components of biodiversity.

In **Section 1**, we introduce the basics of best-practice offsetting and outline the logic behind generating and estimating the benefit associated with an offset action at a site. It also sets out some of the challenges associated with such estimation, and describes how expert elicitation can help where knowledge gaps exist.

In **Section 2**, we set out how to generate credible and robust estimates of the likely benefits of alternative biodiversity offset strategies, using expert elicitation. The approach can be used to evaluate or check the plausibility of a specific proposed offset action at a particular site, to compare the relative benefits expected from alternative offset actions at a generic, hypothetical offset site, or to explore how the amount of offset benefit might change depending on hypothetical offset site characteristics. We also provide options for how to adjust the estimate of benefit based on how uncertain the estimate is.

Section 3 provides a framework for eliciting information about the costs associated with offset actions, and analysing the cost-effectiveness of different offset actions for threatened species. In many policy contexts, this information may not be required, such as when a proposed offset approach needs only to be evaluated for its ability to counterbalance an impact. However, it is likely to be useful in situations such as providing guidance when determining the appropriate size of monetary contributions to central funds, which in turn deliver the required offset benefits.

Finally, **Section 4** presents two case studies showing how the framework is used to derive offset benefits and costs for examples of Australian threatened species: the malleefowl, and the night parrot.

1.1 Introduction

Biodiversity offsets are a widespread policy tool used by both the public and private sectors to compensate for the adverse impacts of development projects (such as mineral extraction or infrastructure construction) on the environment (Sonter et al., 2018; ten Kate & Crowe, 2014).

Biodiversity offsets are generally implemented following adherence to the "mitigation hierarchy", the process by which environmental impacts from development are avoided, unavoidable impacts are then minimised, and residual impacts are then offset (Box 1.1).

Biodiversity offsets must, at a minimum, deliver a 'no net loss' outcome for the biodiversity values negatively impacted by development (Gardner, 2013; Maron et al., 2018)

Box 1.1: The mitigation hierarchy and offsets principles

Under the IUCN Policy on Biodiversity Offsets (2016), offsets must only occur after all previous steps in the mitigation hierarchy have been considered and no alternatives are available. Avoidance is the first and most important step in the mitigation hierarchy. International best-practice principles for the appropriate application of the mitigation hierarchy include that it should:

1. Be applied as early as possible in the project life cycle, to inform potential development decisions.
2. Explicitly consider the project within a broader landscape or seascape context.
3. Identify and respect nationally and internationally recognised 'no-go' areas.
4. Thoroughly examine lower impact alternatives in the project design, including not proceeding with the project at all, recognising that not all impacts can be offset to achieve No Net Loss.
5. Give priority to avoiding any damage to biodiversity.
6. Take full account of direct, indirect and cumulative impacts, geographically and over time.
7. Clearly distinguish impact avoidance, minimisation and on-site restoration measures from offsets.
8. Design offsets to achieve at least No Net Loss and preferably a Net Gain of biodiversity.
9. Ensure any biodiversity offsets used as part of the mitigation hierarchy secure additional conservation outcomes that would not have happened otherwise.
10. Use approaches that are science-based, transparent, participatory, and address the effects of the project and mitigation actions on livelihoods.
11. Follow a Rights-based Approach (as defined by the relevant IUCN resolution)
12. Identify and put in place the legal, institutional and financial measures needed to ensure long-term governance of all mitigation actions (including any biodiversity offsets).
13. Apply a rigorous monitoring, evaluation and enforcement system that includes independent verification of all mitigation actions.
14. Apply the precautionary principle throughout all stages of the mitigation hierarchy.
15. Apply the Ecosystem approach in all stages of the mitigation hierarchy (as defined by the IUCN).

Source: IUCN Policy on Biodiversity Offsets, 2016

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1.2 Generating benefits for biodiversity using offsets

Offsets typically aim to generate a biodiversity benefit or 'gain' that is sufficient to counterbalance biodiversity losses in two broad ways:

- by **averting the loss** of biodiversity (in terms of its area, its quality, or both), and/or
- by **restoring or creating** biodiversity values at a proposed offset site.

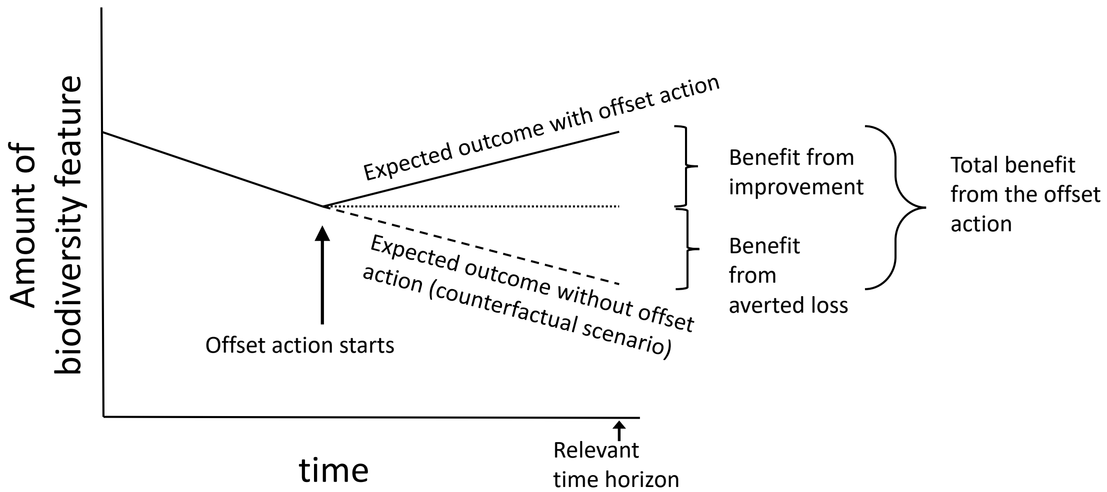
A commonly used approach to secure the biodiversity benefits delivered by an offset is to protect an area against future losses, such as by strengthening the legal tenure status of the offset site, and to manage that site to ensure its condition does not decline. This is an example of a protection and maintenance offset.

While protection and maintenance will sometimes generate a biodiversity benefit by averting future loss, it will not restore or create biodiversity beyond its existing state without additional actions. When considered together, a biodiversity loss at an impact site, and an offset that achieves just protection and maintenance result in less overall biodiversity after the impact than before. However, if the biodiversity at the offset site is at risk of being lost if not protected, this can be a valid approach.

Sometimes, actions that improve the state of biodiversity are also included to create offset benefits. A threatened plant species might be able to increase in numbers at a site if a threatening process, such as a weedy competitor, is managed. In this case, the weed management is the offset action, and the increase in the number of individuals of that threatened plant species is the biodiversity benefit.

In both cases, estimating *how much benefit* is expected from an offset action is essential, as the benefit must be at least as large as the loss at the impact site for the offset to achieve a no net loss outcome.

Box 1.2: estimation of benefit, from an offset action at a site



The benefit achieved by an offset action at a site is the difference it makes to the specific biodiversity feature that is the target of the offset with a specific time horizon. In a protection and maintenance offset, only averted loss is achieved; an offset involving active restoration may also improve the site over time. The total benefit can be estimated by first estimating the **counterfactual scenario** – what would have happened to the biodiversity value without the offset – and then estimating the offset scenario and taking the difference between the two. The counterfactual scenario is sometimes also called the 'baseline scenario', 'do nothing' or the 'business as usual scenario'.

1.3 Offsets may involve multiple actions

In many cases, site protection and maintenance alone may not create meaningful benefit for the targeted biodiversity feature. Threats to biodiversity values may remain low even in the absence of specific protection and management actions, resulting in little averted loss. For example, some sites might be well-protected under existing regulations, so adding further protection does not add any new benefit. In other cases, delivering an offset via protection may not be possible due to land tenure restrictions.

In these situations, an offset will need to involve other management actions (often in addition to permanent protection) to generate a sufficient benefit to compensate for biodiversity losses. These actions might include invasive species control, fencing, management of fire, or removal of livestock (Box 1.3).

Although biodiversity offsets are often characterised by their size – the area over which the actions are done - it is clear that area alone does not tell us how much benefit we have achieved for the target biodiversity, i.e. the species or ecosystem impacted. To estimate the size of the benefit (so that we can compare it with the loss) we need to focus on the target biodiversity itself, and how the offset actions change outcomes for that biodiversity.

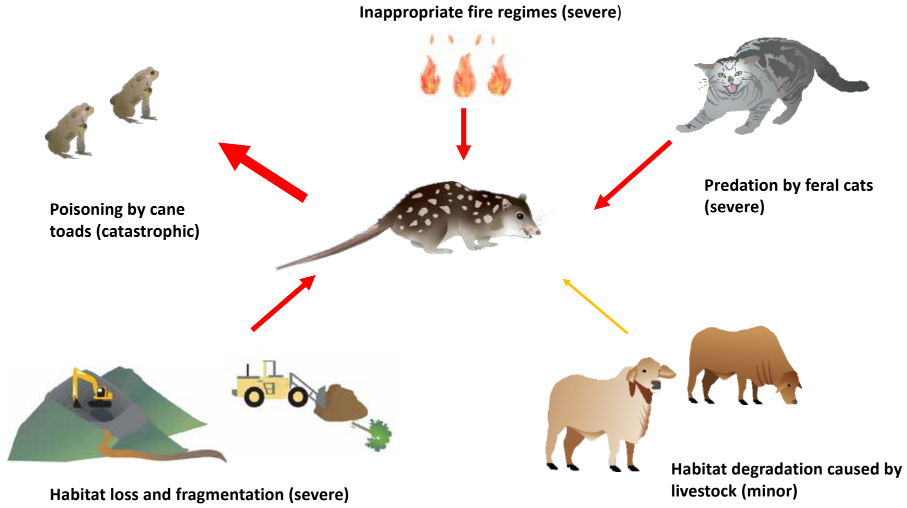
Further, each of these actions may have different financial costs associated with them, which has a major impact on the likely cost-effectiveness of a biodiversity offset strategy. The most effective action in terms of creating a benefit might not be the most cost-effective.

Box 1.3: Example of situation where protection actions are not beneficial or feasible

The northern quoll *Dasyurus hallucatus* is a medium sized carnivorous marsupial and the smallest of the four Australian quoll species. It has a broad diet comprising invertebrates, frogs, small mammals, reptiles, birds, carrion and fruit.

Northern quolls were formerly distributed across a wide swathe of northern Australia from Western Australia to south-east Queensland, but have declined dramatically. They are now found mainly in the Pilbara and Kimberley regions of Western Australia, parts of the Top End of the Northern Territory (including offshore islands), and parts of coastal Queensland.

Native frogs and toads form part of the diet of the northern quoll. Northern quoll declines are occurring in close association with the spread of the introduced cane toad, which is predated by the quolls but is highly poisonous to them. Predation by feral cats, inappropriate fire regimes and habitat loss and degradation are also contributing to northern quoll declines.



Some key threat factors and consequence ratings for northern quoll populations. Arrow sizes correspond to consequence rating. Source: (adapted from Woinarski et al., 2014)

A common approach to biodiversity offsetting, the legal protection of land, may not on its own be the most beneficial action for the northern quoll, given its main threats are posed by poisoning from consuming cane toads, inappropriate fire regimes, and predation by feral cats, in addition to habitat loss and fragmentation.

Therefore, additional conservation actions such as the management of feral cats, fire management and cane toad aversion training are likely to be required to generate a sufficient benefit for the species.

1.4 Challenges with estimating offset benefits and costs

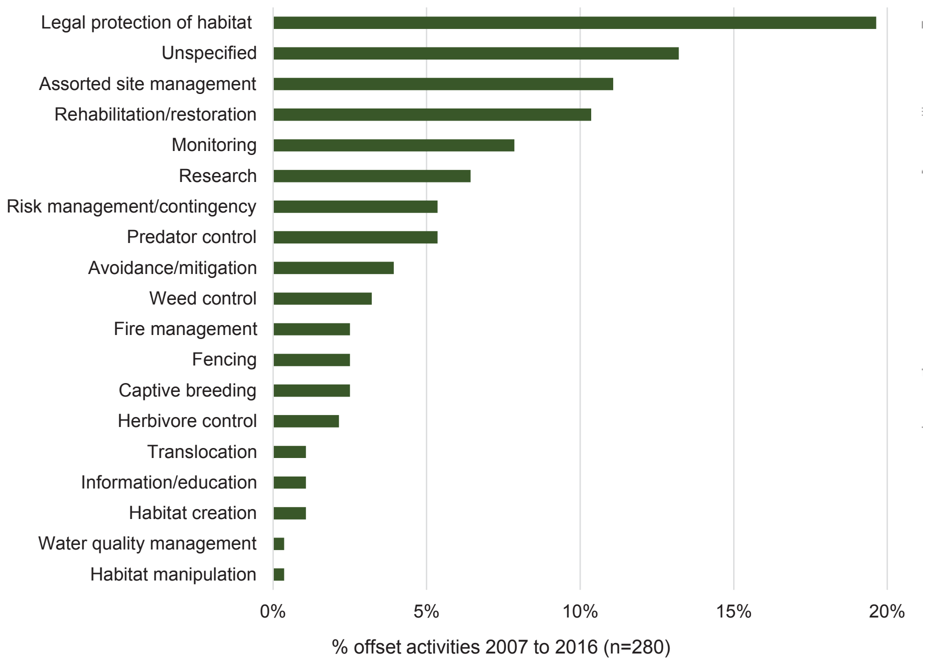
Data on the likely benefits and costs of on-ground conservation actions are often scarce, or cannot be obtained without a significant investment of time and resources.

A consequence of this data scarcity is that development projects (and their associated biodiversity offsets) may be approved with a limited understanding of how or whether offsets will provide adequate compensation for the impacted biodiversity (Australian National Audit Office, 2014, 2020)

In Australia, legal protection is the most common type of action undertaken as an offset (Box 1.4), but calculation of the 'benefit' to biodiversity from that action varies among states and individual cases. Sometimes this is in conjunction with some management actions, but offsets are often approved without specifying the management actions that are required to compensate for a given impact. Often these actions are not considered in the initial development planning or even specified in the conditions of approval (Evans et al., 2017). This is especially risky where there is not robust scientific understanding of how to generate a given amount of benefit for a species or ecological community.

This situation can lead to inconsistency, lack of transparency, and mistrust that offsets will achieve the goal of 'no net loss' for impacted biodiversity. There is a need for a standard approach to generate rapid, credible estimates of the benefits, and relative financial costs, of potential offset actions.

Box 1.4: Management actions used as offsets in Australia



In an analysis of 80 approved developments under the federal *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), we found that of the 280 activities which formed offset packages conditioned as part of environmental approvals for 30 threatened species and ecological communities, most specified legal protection of habitat as the action, while in 12% of cases the action was unspecified.

1.5 Expert knowledge in conservation and environmental management

Expert knowledge is increasingly used to inform environmental decision-making where data, time or resources are scarce (Martin et al., 2012; Mayfield et al., 2020).

Experts hold knowledge and on-ground expertise that allows them to provide valuable insight into the behaviour of environmental systems, including the benefits, costs, and likelihoods of certain events occurring (Raymond et al., 2010). Many environmental decisions require quantitative, empirically valid data, and formal elicitation protocols can capture expert knowledge in this format.

Gathering expert knowledge broadly involves asking a number of "experts" (Box 1.5) a series of questions relating to their judgments on a particular subject. In the case of biodiversity conservation and environmental management, experts have been asked to quantitatively estimate the extinction risk of threatened species (Geyle et al., 2020; Geyle et al., 2018; McBride et al., 2012) , population trajectory of threatened species (Geyle et al., 2019), priorities for management (Carwardine et al., 2019) , vegetation condition (Dorrough et al., 2019), the likely impacts of grazing as a threat on birds (Martin et al., 2005), and the probability of invasive species expansion (Kuhnert, 2011).

Box 1.5: Who is an expert?

"Expert knowledge" is what qualified individuals know as a result of their technical practices, training, and experience (Booker & McNamara, 2004).

Experts may be identified on the basis of qualifications, training, experience, professional memberships, and peer recognition (Ayyub, 2001) although broader definitions of expertise may include people who possess direct, practical experience (Burgman et al., 2011). For example, an expert in landscape ecology might be a practitioner who has formal training or years of deliberate practice, and whose ability to solve professional problems has led to their recognition as an "expert" by their peers.

Good expert performance is about:

- Having an holistic understanding of the subject matter
- Always seeking the truth and actively minimising bias
- Knowing the limitations of your knowledge
- Producing success when practicing your expertise.

However, experts are human, and so they can be influenced by a range of cognitive biases that can affect the quality of their judgements (Box 1.6). Experts can also be affected by competing interests that reduce their independence. This is why it is crucial that rigorous approaches are used at all stages of the expert elicitation process, from recruitment of individual experts, question structure and design, to the aggregation and analysis of data.

Box 1.6: Common cognitive biases that can affect expert judgements

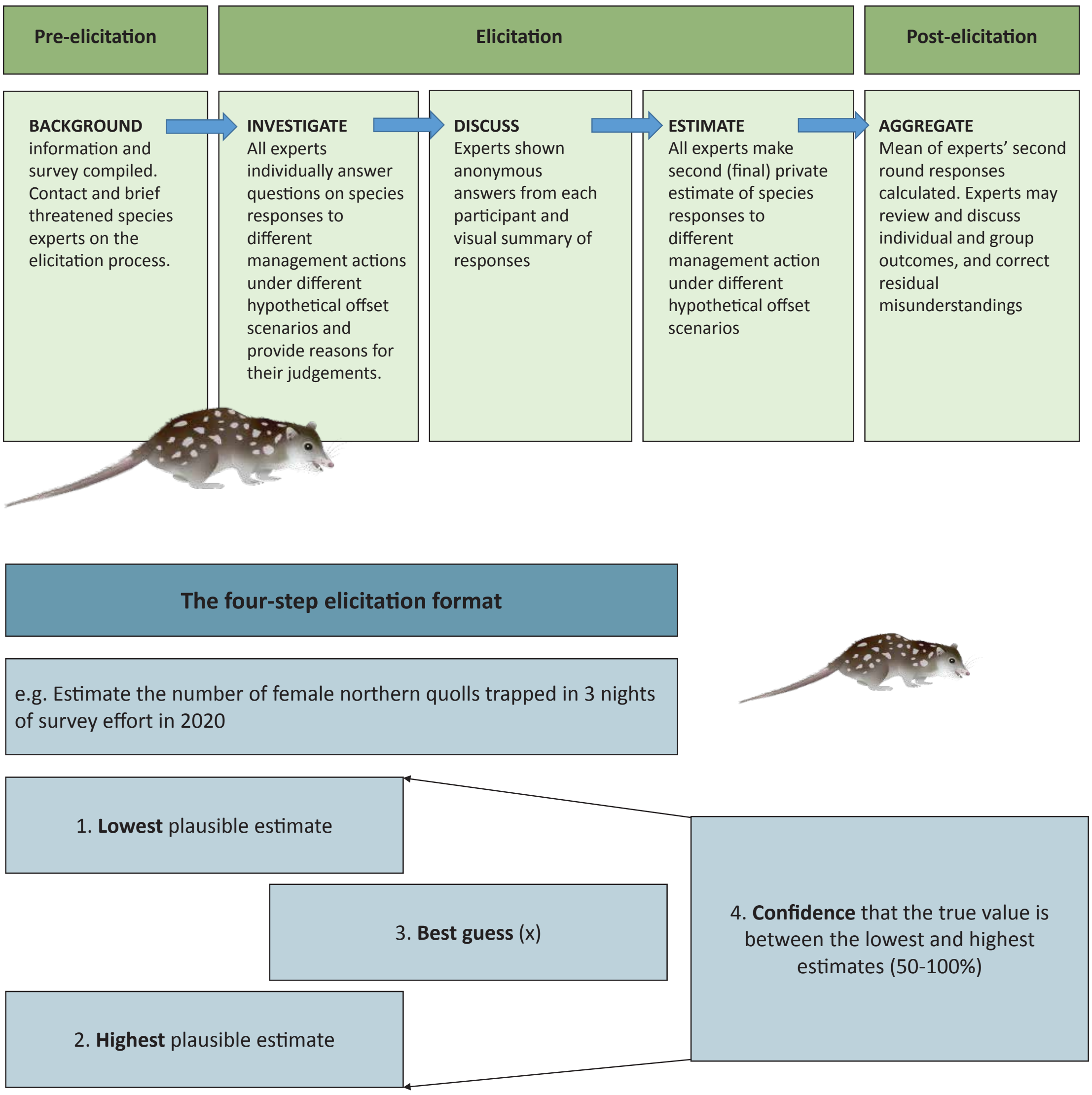
- Anchoring/availability heuristic, in which people give estimates that are heavily affected by the more recent or well-known events or evidence that comes most readily to mind (Kahneman & Tversky, 1973).
- Social expectation hypothesis, where more highly regarded and experienced experts are presumed to give better advice (Burgman et al., 2011).
- Groupthink, which is a mode of thinking that persons engage in when people focus on achieving concurrence or consensus to the detriment of appropriately considering different options (Janis, 1971).
- Overconfidence, in which people often overestimate their confidence when they provide subjective intervals for a quantitative estimate; for example suggesting they are 90% sure about a fact when this doesn't reflect reality (Soll & Klayman, 2004).
- Probability neglect, in which people focus on the desirability of the outcome in question and pay (too) little attention to the probability that a particular outcome will occur (Sunstein, 2002), for example describing the desired outcome rather than the most likely outcome when asked to give a best guess of a parameter.
- Loss aversion, in which people typically exhibit greater sensitivity to losses than equivalent benefits when making decisions (Tom et al., 2007), potentially leading to more negative estimates of outcomes under undesirable scenarios.
- Confirmation bias, the tendency for people to hang onto their favoured hypotheses with unwarranted tenacity and confidence (Klayman, 1995).

Structured elicitation protocols have been shown to minimise the impact of cognitive biases (Mukherjee et al., 2018; O'Hagan et al., 2006), and produce estimates of greater accuracy by carefully facilitating input from diverse experts (Carey & Burgman, 2008). They also provide a relatively cost-effective and repeatable way to improve the transparency and quality of expert judgements, including appropriately quantifying uncertainty.

In this guidance document, we will be following the steps outlined in the IDEA protocol ("Investigate," "Discuss," "Estimate" and "Aggregate") (Hemming et al., 2017). The IDEA protocol (Box 1.7) has been demonstrated to overcome many of the aforementioned challenges associated with expert elicitation, through use of a modified Delphi process. As such, it has been used successfully in many contexts, both within and beyond environmental science (Adams-Hosking et al., 2016; Arlidge et al., 2020; Geyle et al., 2020; McBride et al., 2012)

Here, we use the four-step question format (Speirs-Bridge et al., 2010) for the "Estimate" step and ask experts to provide whole-number estimates rather than probabilities, for the sake of simplicity and to minimise the effect of probability neglect bias (Sunstein, 2002). However, the IDEA protocol is flexible and a range of other estimation approaches (e.g, the Trial Roulette method, Dorrough, Sinclair, and Oliver 2019) can be used as part of the "Estimate" step if more appropriate for the problem at hand.

Box 1.7: The IDEA Protocol and 4-step elicitation format



The IDEA protocol and four-step question format (adapted from (Hemming et al., 2017). The four-step question format involves asking for: (i) lower and (ii) upper plausible estimates, (iii) a best guess and (iv) a 'degree of belief' (confidence that the true value is between the lowest and highest estimates (adapted from (Hemming et al., 2017).

While the IDEA protocol is described in detail elsewhere (Hemming et al., 2017), we will describe its application to the specific problem of estimating the benefits of biodiversity offsets – which requires some adaptations.

In particular, the complex nature of biodiversity offsetting means that careful attention is needed to appropriately design and frame survey questions.

1.6 Designing expert elicitation questions for biodiversity offsetting

Structured expert elicitation is a powerful tool, but its use in the design of biodiversity offsets has been relatively limited to date. Instead, most expert input to estimates of benefit from biodiversity offsets is relatively unstructured, increasing the risk of the biases described (Box 1.7). Although general guidance is readily available to help improve aspects of expert elicitation, less information is available on how to appropriately design the questions used to elicit expert judgement in an offset context.

Existing guidance recommends ensuring questions are free from linguistic ambiguity and are framed to minimise unwanted bias. It is also recommended that questions are in a format that aligns with the knowledge and experiences of the experts being questioned (Aspinall & Cooke, 2011). There are, however, a number of additional decision steps and complexities associated with calculating biodiversity losses and benefits which can influence our capacity to generate credible offset estimates.

For example, a common misconception is that the benefit derived from the protection of biodiversity as part of an offset is more certain, whereas the benefit achieved by restoration and active management is less certain. However, while the outcome at the site if it is protected as an offset might be reasonably certain (the site will not be cleared), the benefit depends equally *on what would have happened if the site was not protected* (the counterfactual scenario). This counterfactual scenario is often highly uncertain. If the predicted risk that a proposed offset will be cleared in future is lower than expected, this can lead to the benefits of the offset being overestimated (Maseyk et al., 2016). Because of this, we need to ask questions about the counterfactual scenario as well.

In short, it is important to ensure that the *questions* used to elicit expert judgements on the benefits of biodiversity offsets are *designed to be rigorous and logical*.

1.7 A structured approach for estimating offset benefits and costs

In this Section, we have described the principles of biodiversity offsetting, and how offsets may generate a biodiversity benefit by *averting loss* and/or *restoring or creating* biodiversity values.

We have described how offsets may deliver biodiversity benefits through a range of management actions. These might include, for example, protecting land, invasive species management, or installing next boxes. Unfortunately, there is often limited information that can inform how to quantify the benefit these actions provide for biodiversity. We cannot know whether offsets are likely to meet their 'no net loss' objective if we don't have an understanding of what benefit they are expected to provide.

We have outlined how expert knowledge is increasingly used to inform conservation and environmental decision-making in data-poor situations, and how structured elicitation protocols can collate this information in a way that is transparent, repeatable, and scientifically valid.

Finally, we have explained that while expert elicitation is a powerful tool, it needs to be used carefully in the context of biodiversity offsetting since there are several additional complexities which can lead to incorrect estimates of their benefits and costs.

In the next two Sections of this document, we will introduce a structured decision making approach as a step-by-step guide for how to estimate the benefits and costs of biodiversity offsets using expert elicitation.

Broadly, structured decision making helps us to better understand and creatively solve complex problems (Box 1.8). By breaking the problem down into small steps and prompting consideration of important factors (e.g. uncertainty, costs, trade-offs), the approach helps identify and evaluate possible solutions in a transparent and repeatable manner.

Box 1.8: General steps of structured decision making (Gregory, 2012)

- What is the **context** for (scope and bounds of) the decision?
  e.g., deciding what and how much action is are required to offset a particular impact on a threatened species at the site scale over a 20-year time frame
- What **objectives** and performance measures will be used to identify and evaluate the alternatives?
  e.g., achievement of a benefit at least as large as the loss for the same threatened species, relative to what would otherwise have occurred
- What are the alternative **actions or strategies** under consideration?
  e.g., either investing in a fire management program or focussing on feral predator baiting at the potential offset site (compared to no management actions)
- What are the **expected consequences** of these actions or strategies?
  e.g. what is the best guess of the outcome for the threatened species under each alternative action, after 20 years of management?
- What are the important **uncertainties** and how do they affect management choices?
  e.g. what are the highest and lowest plausible outcomes for the threatened species under each alternative action, after 20 years of management?
- What are the key **trade-offs** among consequences?
  e.g. investment in fire management is less expensive, but its effectiveness is more uncertain than for feral predator control
- How can the decision be implemented in a way that promotes learning over time and provides opportunities to revise management actions based on what is learned?
  e.g. if uncertainty is high, increase the management effort proportionately, and monitor to see if the response is tracking as estimated

Section 2. Estimating the benefit of offset actions

As discussed in Section One, there are many circumstances where there is little available data to inform what actions could be taken to deliver a measurable benefit for biodiversity that has been impacted by development.

There are a number of situations where we may wish to use expert elicitation to determine the likely benefits of biodiversity offset strategies. For example:

- a government agency may wish to develop a portfolio of “off the shelf” offset strategies that can be used as part of conditions of environmental approval;
- a proponent may need to determine what actions will be required to fulfil offset requirements and how much this will cost;
- a research team may be contracted to inform the establishment of a trust fund and the pricing of its offset payments.

In this Section, we will describe the steps to generate estimates of the benefit derived from a range of biodiversity actions, including the logistical, technical, and scientific considerations. We illustrate the process with reference to a particular case (such as a species or ecological community in a particular context), in which decisions might be being made about which is the most cost-effective action to generate benefits for an impacted biodiversity feature. However, because this process generates estimates of benefits per unit of offset action, it also be used to build up a portfolio of "off the shelf" offset strategies with pre-estimated benefits per unit of effort for a range of biodiversity features. Combined with the approach for costing these offset actions described in Section Three, this can then be an important input to the pricing of offset payments for a given unit of impact on a particular species, to help ensure that proponents pay enough so that an amount of benefit adequate to offset their impact on a biodiversity feature can be achieved by the eventual offset provider.

2.1 Logistics and project management

Since this process involves social research methods, there are a number of things to consider.

(1) Timeline and resourcing

The duration of an expert elicitation process will depend on a range of factors, particularly the financial and human resources available, familiarity with the process, and accessibility of experts. The project timeline needs to include time for unanticipated delays associated with research ethics approvals (if applicable), late responses from experts (who in some cases may be providing their time pro bono) and delays in the analysis (Hemming et al., 2017), and may need to be amended as circumstances change (e.g. changes in staffing/resourcing). From start to finish, an elicitation process may take up to three to four months for a single species or species group, but for parts of this period (such as when the survey is being completed by the experts) the staff commitment would be less than 1 FTE. An overview of the 8 step process is shown in Box 2.1.

(2) Project team

Typically, an expert elicitation team includes the problem owner, facilitator, analyst and expert(s) (Martin et al., 2012). One person can have several roles.

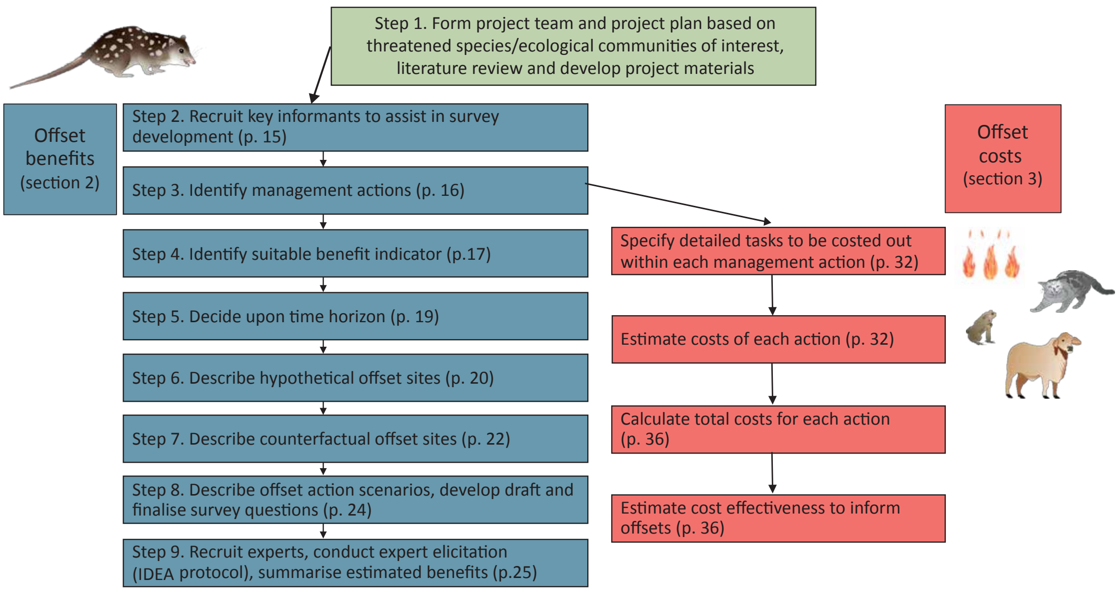
Generally, the roles are:

- **Problem owner:** person who identifies the relevant threatened species and the experts, and assists with the drafting of the survey questions.
- **Facilitator:** manages the interaction amongst experts and oversees the elicitation process. It is beneficial if this person has training in expert elicitation methods, or has been involved in an elicitation process in the past. Alternatively, it is highly advisable to seek assistance from an experienced facilitator, who has used these methods in the past.
- **Analyst:** handles calibration, elicitation procedures, processing of responses, and analysis of elicited information. This person should be experienced at data analysis in R or Excel.

If the process will also include consideration of costs, the project team could also include an additional analyst with expertise in collating and analysing cost information.

Box 2.1: Process for using expert elicitation to derive offset benefits and costs

Each box corresponds to a step outlined in this report, with steps for estimating offset benefits in blue, and steps for estimating the costs of offset actions in red.



Not all elicitation processes will require costs to be elicited.

2.2 Survey and question design

The survey includes several elements, and the design of each requires some careful thought and consultation (Box 2.2). These elements include:

a. A description of the benefit indicator that tells us about the species or ecological community in question

b. A description of the hypothetical site(s) at which offset actions might be implemented

c. A specified time horizon at which the benefit of the offset action at the sites(s) is to be measured. In the example below, we use a timeframe of 20 years (consistent with the 'risk-related time horizon' in the EPBC Act Offset assessment guide (Commonwealth of Australia, 2012)

d. A description of the scenario in which no offset actions are implemented at the site(s) (the 'counterfactual scenario')

e. A description of the scenario(s) in which offset actions are implemented at the site(s) (the 'offset action scenario(s)')

f. A set of questions about the value of a benefit indicator for the species or ecological community in question under both the counterfactual and offset action scenarios at the time horizon.

Box 2.2: Elements of the survey and question design for deriving offset benefits for the northern quoll

Note that key informants have a key role in determining an appropriate benefit indicator, site size, and the management actions to be considered. In this example, the size of the hypothetical offset sized is based on input from the key informants, many of whom were familiar with northern quoll habitat in the Pilbara, where property sizes are very large, and where quolls occur at a low density in the landscape. It is recognised that offsets may comprise much smaller areas in other parts of their range.

Hypothetical offset site 1:
We would like you to think of a site which contains northern quoll habitat. The site is roughly 200,000 ha in size and has had minimal human disturbance. In 2018, ten adult individuals (female) were trapped on site from monitoring of **200 trap nights** A number of potential threats to northern quoll exist on the site, including cat & fox predation, impacts from domestic and feral herbivores and inappropriate fire regimes. Cane toads are absent from the region and will not invade within the next **20 years**.

Question 1 (counterfactual scenario):
*How many **northern quoll individuals (female)** will be trapped at this site in 20 years with the same trap effort (**200 trap nights**), excluding any additional impacts from development (e.g. mining, infrastructure, large-scale agriculture) requiring approval under the EPBC Act 1999?*

In 2018, the site is designated as a **protected area** and grazing activities cease. **Fencing** and **removal of domestic stock**, water source management and habitat maintenance will occur, but no northern quoll-specific management actions will be implemented.

Question 2 (offset action scenario):
*Assuming the site is designated as a protected area, and remains protected for the next 20 years, how many **northern quoll individuals (female)** will be trapped at this site in 20 years with the same trap effort (**200 trap nights**), excluding any additional impacts from development (e.g. mining, infrastructure, large-scale agriculture requiring approval under the EPBC Act 1999?*

In this example, the benefit indicator is the number of female northern quolls trapped from 200 trap nights, and the time horizon is 20 years. We ask about the value of the benefit indicator under the counterfactual (do nothing) and offset action (protected area) scenarios.

Step 1. Literature review

Consult the available literature to determine the threats and possible offset actions that might help abate these threats for each relevant species or ecological community (e.g. National Recovery Plans, Conservation Advices, IUCN Red List Assessments, Action Plans). It is useful to compile available literature, unpublished reports and additional information on species biology, habitat requirements, monitoring methods, population parameters (if available), geographic range, current offset approaches (if available) and threats in a centralised location available to the project team.

Things to consider:

- identify the most influential threatening processes affecting the relevant species or ecological community
- link these threats to the management actions that address them, and which could form part of an appropriate offset
- distinguish between 'background' threats, which site-level actions are unlikely to influence (e.g., climate change), and threats that could be managed using actions at a potential offset site (e.g., weed invasion). Background threats are things that experts consider in all scenarios equally, and so do not contribute to the estimate of benefit.

Ideally, management actions should be matched to specific threats (Table 1), noting logical combinations of management actions can also be included. **If the objective of the elicitation is to elicit the likely benefit of a specific, pre-defined action or set of actions, the identification of literature can be limited to that relevant to those actions.**

Table 1: Threatening processes (Benshemesh et al., in press) and associated management actions that could form part of an appropriate offset, using the malleefowl as an example

Threats to malleefowl	Actions to abate these threats
Inappropriate fire regimes – probably killing birds as well as removing suitable habitat structure and leaf litter for nesting, reducing food availability and making birds more prone to predation	Fire management, including prescribed burning and maintenance of fire breaks
Habitat loss – most quality habitat has been cleared for agriculture	Protection of habitat, through nature reserves or private land holder agreements
Habitat destruction by introduced herbivores – goats, rabbits and other herbivores compete with malleefowl for food, destroy understorey cover and deplete nesting materials	Control of introduced herbivores that are present at potential offset sites, through specific means depending on species
Predation by foxes – malleefowl eggs and chicks are taken	Aerial or ground fox baiting using best-practice guidelines for the terrain and spatial scale

Step 2. Recruit key informants

Concurrently with the literature review, the problem owner should seek to identify 1-2 key informants who are known to hold significant expertise around the case study ecological community or species' ecology and management, potentially using their existing networks (researchers and project partners). Such individuals are often well connected with other relevant experts – for example, as members of the relevant species' recovery team.

It is critically important to develop the survey text with these key informants prior to recruiting further experts for the elicitation, to ensure the survey questions are logical and relevant for the species and proposed management options being considered are suitable. Minor refinement of the survey is possible once the larger and more diverse group of experts is involved (Section 2.3) but the majority of the work is done with key informants.

Things to consider:

- If you work as part of a research institution, you will likely require Human Ethics Approval to develop the survey with key informants and run the expert elicitation process.
- It's okay if key informants have divergent views about species management, because survey questions can include a range of possible approaches to management.
- Be wary of social dynamics. In some cases the key informants may know each other and can work productively together, whereas in some cases it may be best to consult them individually.
- Manage expectations—key informants work more closely with the project team than experts who only participate in the elicitation. Key informants might need to dedicate several hours to phone discussions, revising survey text and discussion over email. This time commitment will vary depending on the species/ecological community in question.
- It is generally recommended that experts who are very closely engaged with developing survey questions do not also participate in the elicitation, because ideally the first engagement with the questions is during the elicitation itself. However, in some cases the pool of experts is very small, and so including the key experts in the formal elicitation process would be better than missing out on their expertise.

Step 3. Identify management actions

In your consultation with key informants, refine the list of threats and management actions derived from the literature review at Step 1. The objective of this step is to generate a short list of management actions, with enough detail about how each of those actions would be carried out (and in what combinations) so that experts will be able to envisage the likely effectiveness of the action. **If the objective of the elicitation is to elicit the likely benefit of a specific, pre-defined action or set of actions, this step can be skipped.**

Through this process, the list of potential management actions can be refined to those considered most feasible in an offsetting context, as well as those most likely to result in a substantial or at least measurable benefit for the species in question. Discussion with experts may also reveal threats and/or actions not previously identified based on the literature search.

Management actions identified need to be those with a clear mechanism though which they might affect the species in question. For example, the benefit of "developing a management plan" is impossible to estimate without making other assumptions about the actions that would then done under that management plan. Questions should instead focus on actions implemented, rather than planning mechanisms or research alone.

In this step, it is important to capture information about the method or type of material used in the action (for example, fence design, approach to control a specific feral animal), the duration of the action (is it a once-off action, or ongoing, and does it require regular maintenance?), and any other actions that automatically occur alongside it (for example, if a conservation covenant is to be established, does this require some basic management actions to be done even if they aren't specifically aimed at benefiting the species in question?). Consider whether you want to elicit estimates of the combined effects of several actions, even if they don't necessarily occur together.

Detailed actions will provide experts with clarity and will assist when estimating costs, if that step is to be included in the exercise (Section 3). However, if the aim of the expert elicitation process is to develop an 'off the shelf' product, the actions should be general enough to be applicable at typical sites (further described in Step 6).

Things to consider

- What management actions are within the scope of and permitted under the offset policy?
- What is feasible and would result in measurable benefits at a site level?
- What does the action involve? Balance detail with generality so that the description can apply across a range of typical offset sites
- What actions are always done in combinations? Are there particular combinations that should be considered?

Avoid the temptation to include all possible actions – each action will add several questions, and too many questions will make the survey unmanageable for experts.

Step 4. Identify suitable benefit indicator

In order to determine the kind of benefit a management action could deliver for the species, a suitable ecological indicator of that benefit needs to be identified. Offsets (and the impacts that trigger them) are usually actions done at a site level, which usually translates to only a small part of the range or population of a species, or a small part of an ecological community. Therefore, the benefit indicator should be something that can be **measured at the site level**, can be monitored at that scale easily, and that is **highly likely to relate to the viability of the species or ecological community**.

For many ecological communities, a benefit indicator takes the form of an area-weighted condition score, with condition elements benchmarked against undisturbed or 'best on offer' characteristics of that ecological community. Examples of these types of scores include Habitat Hectares (Department of Environment, 2016) and BioCondition (Eyre et al., 2015).

For species, a benefit indicator might relate to the abundance of a species or the number of active nest sites at the site in question. It should be a value that can be estimated for the impact sites as well – because both losses at the impact site and benefits at the offset site need to be able to be calculated using the same index, so that they can be directly compared (Table 2).

For some species, the abundance of the species at a site will be the most appropriate benefit indicator (for example, the number of individuals of a tree species). For others, an index of habitat condition might be more appropriate. This might be the case for species that are cryptic, or whose presence within any given area of habitat is unpredictable (for example, nomadic species). For other species, the abundance of a particular habitat feature or of a sign of its presence (e.g., nests or scats) might be a better indicator.

In some cases, experts may feel more comfortable with providing a judgement about the number of individuals detected using specific monitoring techniques, rather than simply how many they expect to be present.

Table 2: Examples of benefit indicators

Threatened species	Benefit indicator	Rationale
Malleefowl	Number of active mounds (currently maintained nests) – this is likely to be appropriate for larger areas of habitat that contain entire home ranges. For smaller areas, a habitat quality index might be used instead.	Malleefowl occur at low density, and are well-camouflaged, so surveying for the birds directly provides imprecise estimates. Nest mounds are prominent and long-lasting features, and an active mound reliably indicates the presence of a breeding pair (Benshemesh, 2007). Note: mounds are also monitored as indicators in an existing long-term survey program, so experts could easily and consistently envisage the value of a site based on a description that included the number of active mounds present.
Night parrot	Number of long term stable roost sites in which night parrots have been recorded consistently at the same location for 6 months.	Night parrots occur at very low densities, are cryptic and elusive, so surveying for the birds directly provides imprecise estimates. They may also be detected fleetingly in a location they do not occupy on an ongoing basis. Research to date shows that night parrots have specific roost sites in *Triodia* hummocks (Murphy et al., 2017). These sites include a horizontal tunnel (25cm long) constructed of leaves (Murphy et al., 2017). Occupancy is readily detected when birds emerge in the evenings. An occupied roost site is currently the most reliable indication of night parrot presence suitable for use as a benefit indicator.
Northern quoll	Number of female quolls trapped in 200 trap nights	Northern quolls occur at low density in the landscape. The standard survey methodology for the species is the use of cage traps over a set time period (Hill & Ward, 2010). Male northern quolls experience immune systems collapse and death after mating (Hill & Ward, 2010), so the number of female quolls trapped in a trap effort of 200 trap nights is a useful benefit indicator.
Semi-evergreen vine thicket ecological community	Quality hectares based on area x BioCondition score	BioCondition is an existing method for scoring the condition of Regional Ecosystems in Queensland, one state where SEVT occurs. Key ecosystem components and spatial context are scored for a site relative to benchmark values for the relevant Regional Ecosystem, and summed using component weightings. The score (out of 100 for wooded ecosystems) is then used to provide a quality hectare measure (e.g. 10 ha of 60% quality = 6 quality hectares).
Ormeau bottle tree	Count of individuals	The Ormeau bottle tree is an easily-detectable, long-lived tree. Estimating or measuring directly the number of individuals is better than use of an indirect proxy, such as ecosystem condition, which may not relate reliably to the population of the species. For this slow-growing species, both mature and juvenile individuals might be counted, but for a species that often has large numbers of juveniles that do not survive into adulthood, mature individuals only might be considered.

It is important that the benefit indicator be applicable to all sites that constitute the same category of habitat for a species. For example, if a species feeds in two different woodland types, then a foraging habitat indicator would ideally be able to be calculated in the same way for both those woodland types. In some situations, however, it may be appropriate to establish separate benefit indicators for substantially different habitat types that cannot be measured in the same way, or for feeding and breeding habitat which might have very different important features. In these cases, expert elicitation will need to be done for each habitat type, using separate parts of the questionnaire.

In some cases, a habitat index (rather than a direct measure of abundance) might be an appropriate benefit indicator for a species, but no pre-existing habitat model or index exists. In this case, it may be possible to develop a simple index with experts. For example, experts might be given a description of a site and asked to score its habitat condition, from the perspective of the species, on a scale of 1-10, where a score of 10 represents the best known habitat for the species and 1 represents the minimum for a site to support even a tiny number of the species, even if only rarely. Offset-related management actions might then target improving the habitat condition of that site. So, where a habitat index is used as a benefit indicator, it is important the potential offset actions are likely to affect the value of the index.

Things to consider:

- The benefit indicator needs to be reliably related to the species of interest, and be measurable at the site level (the scale at which impacts and offset actions are likely to occur).
- The relative value to the species of different sites within the same category of habitat (e.g. feeding, breeding) should to be able to be measured using the same benefit indicator.
- Some species may require more than one benefit indicator - for example, if they have very different feeding, roosting and/or breeding habitats.

Step 5. Decide upon time horizon

The experts will be asked about the value of the benefit indicator for your species at a specific point in the future. This point is called the time horizon.

Under many offset policies, there is a time horizon by which the benefits of the offset action are required to have achieved a ‘no net loss’ outcome. This time horizon is usually chosen to balance the need to allow time for management interventions to take effect, but to disincentivise actions that take a very long time to be effective.

Note that the actions usually need to be implemented for the duration of the impact to ensure this benefit is maintained – the time horizon we focus on here is the time until those actions start to achieve the benefit, not the time over which the actions are done.

In many Australian offset policies, the time horizon is 20 years. For simplicity, we have used a time horizon of 20 years in our examples. (Some offset policies apply a time discount factor, such that benefits not expected to accrue for a long time are discounted relative to benefits likely to occur quickly. These sorts of adjustments can be applied to the elicited benefit score at the end of the process if required).

It may be appropriate to use a different time horizon, depending on the policy context, the species in question, and the management actions that are appropriate. However, if benefits of alternative actions are to be compared, it is important that comparable time horizons are used. And of course, the time horizon chosen must be the same for all scenarios being compared.

It may be useful to include survey questions about the value of the benefit indicator at multiple points in time. This can help experts to visualise the progress of the benefit indicator over time at each hypothetical offset site, and improve logical coherence of responses (Mayfield & Maron, 2020). However, this also increases the length of the survey.

Things to consider:

- How might temporal variability affect the estimated outcome? For highly temporally variable systems, experts might need to be asked about an average outcome, or an outcome in an average year.

Step 6. Describe hypothetical offset sites

The next step is to develop a simple description of one or more hypothetical sites where offset actions might be undertaken. (Alternatively, if the elicitation is to estimate outcomes at a particular site, then this site can be described in this step). The hypothetical site, or series of sites, will provide the context for the experts to envisage the benefits delivered by potential management actions. We use a hypothetical site to avoid experts envisaging one particular site and describing only outcomes they would expect at that site – we want to maintain focus on the general, or average, outcomes expected at a typical site, so that it is more likely to be applicable to a larger range of sites.

The facilitator and problem owner should work with the key informants to describe a site that is realistic, but generic enough to allow all experts to be able to envisage something similar. The description should also be consistent with a site likely to be used to provide offsets for this species. It should contain information about important context most likely to influence how effective the offset actions might be and how a species might fare in the absence of those actions.

The hypothetical offset site description might include the area of the site, the type and quality of habitat at the site and the presence or absence of threatening processes or management regimes relevant to the species in question. The description should also clearly state the current value of the benefit indicator at the site (see Box 2.4). This current value will give a starting point for the scenarios that experts will estimate. It is important that the current value of the benefit indicator is plausible to experts, given the site conditions described.

Box 2.4: Example text to describe a hypothetical site

We would like you to think of a 400 ha site which contains malleefowl habitat. In 2018, there were 5 active mounds on site. A number of potential threats to malleefowl exist on the site, including fox predation, vehicle strikes, impacts from herbivores and inappropriate fire regimes.

There are a number of ways in which malleefowl respond to management, so there is always uncertainty. For the sake of this survey, we want you draw on your experience and knowledge and have a go at every question.

6.1 Account for significant variation among site types

In many cases, there are important differences among the types of sites at which offsets are likely to be implemented. For example, a site that is in good condition, with minimal threats, might be suitable for one set of offset actions, whereas a poor-condition site with many threats present might be more suitable for other actions. Similarly, only sites over a certain area or sites in a particular region might be suitable for certain actions. Key informants should therefore be asked about whether there are likely to be substantially different site types and contexts that would have large impacts on the effectiveness of a given management action, or on what action is suitable (see Box 2.5).

For example, some sites within the range of the northern quoll have been invaded by cane toads, whereas other sites are outside the current cane toad distribution. Because of the impact of cane toads on quolls, different management scenarios need to be considered for these different contexts, and offset actions for northern quoll might reasonably be expected to be implemented both within and beyond the cane toad distribution. In this case, at least two hypothetical offset sites should be included in the survey, to ensure both contexts are covered.

Box 2.5: Examples of eliciting information for two different hypothetical offset sites

Malleefowl

Hypothetical offset site 1: current malleefowl habitat

Good malleefowl habitat with active malleefowl mounds. A range of common potential threats were present (fox predation, vehicle strikes, impacts from herbivores and inappropriate fire regimes).

Hypothetical offset site 2: Degraded cropping land, adjacent to mallefowl habitat

Highly degraded cropping land, with no active malleefowl mounds, and adjacent to malleefowl habitat (so it was possible for malleefowl to disperse). The same potential threats to malleefowl described for site 1 were also present here, but experts would need to adjust their estimate of the benefit of management actions based on the different starting conditions of hypothetical offset site 2.

Northern quoll

Hypothetical offset site 1: current northern quoll habitat

Northern quoll habitat on a large grazing property with low grazing pressure and minimal human disturbance. A range of potential threats were present (including feral cats and inappropriate fire regimes).

Hypothetical offset site 2: Degraded grazing land, adjacent to northern quoll habitat

Grazing property with substantial disturbance from grazing and fires, adjacent to northern quoll habitat. No northern quolls occur at the site, but with implementation of active land management, could move in from the adjacent site. The same threats to the northern quoll described for site 1 were also present here, but experts would need to adjust their estimate of the benefit of management actions based on the different starting conditions of hypothetical offset site 2.

Many species are widely distributed and occur in a range of different habitats and contexts. Some of this variation can best be captured by describing different hypothetical offset sites. However, in some cases, a species might be expected to respond differently to a management action in different parts of its distribution – even if the sites at which the action is done are broadly similar.

In these cases, it is important that expert judgements capture substantial regional variations in the expected benefits of management actions. If possible, facilitate the participation of species experts working across the full geographic range of a species. You can divide the survey so that it is completed separately for different geographic regions, and by any experts comfortable with providing answers for those regions. One way to manage this is to ask experts at the end of the survey whether they believe their estimates would differ substantially if they considered a site in a different geographic location (e.g. Victoria versus Northern Territory). If so, ask experts to submit a second survey with their answers modified accordingly, noting the region they were envisaging. This allows calculation of different benefit estimates for a given action done in different locations.

Things to consider:

- For each hypothetical offset site, experts will be asked at least two survey questions: one about the counterfactual scenario in which no management is changed at the site, and at least one describing the offset management scenario/s in which each management action identified in Step 3 are implemented. The more hypothetical offset sites and the more regional differences to be captured, the longer the survey will need to be. An additional survey question is added for each additional action proposed at each site.

As part of the survey, it can be useful to provide a space for experts to briefly describe a site containing the species habitat that they are familiar with, to help ground experts' answers. This can then be checked for any assumptions that were not consistent with the hypothetical offset site, or that are likely to lead one expert to give very different judgements from others. We suggest providing this opportunity, for example:

If you wish, you can briefly describe a site containing malleefowl habitat that you are familiar with here, to help ground your answers (e.g. approximate location and size):

Step 7. Describe the counterfactual scenario

In the survey, the first set of information presented to the experts will be the description of a hypothetical offset site, with its current benefit indicator value. Then, in the first survey question, the experts will be asked to estimate what is likely to happen to the value of the benefit indicator at that site in the specified time horizon, if there are no changes to the management of the site. This is called the **counterfactual scenario**.

The counterfactual scenario describes what would happen at a site if we do not implement an offset action (Box 2.6). It is important to capture this information from the experts, because the benefit of an offset action is the difference between the value of the benefit indicator if the offset action is implemented and the value of the benefit indicator if the offset action is NOT done, under the counterfactual scenario.

Although it is often appropriate that the counterfactual scenario involves no particular conservation management, in some situations, conservation management may be part of the counterfactual scenario. It is important that the scenario includes any such conservation actions that would occur regardless of whether the site became an offset. For example, if in a region that already has an ongoing fox control program that should be part of the description of the scenario.

Box 2.6 Example text for a counterfactual scenario

We would like you to think of a 400 ha site which contains malleefowl habitat. In 2018, there were 5 active mounds on site. A number of potential threats to malleefowl exist on the site, including fox predation, vehicle strikes, impacts from herbivores and inappropriate fire regimes.

We want you to ignore the possibility of any additional human development (mining, infrastructure, large-scale agriculture) requiring approval under the EPBC Act 1999 that may occur in the site vicinity over the next 20 years.

An "active mound" is one which is likely to have been used as an incubator in October.

Assume that it will be an average, non-drought year in 20 years.

7.1 Draft the first survey question: value of the benefit indicator under the counterfactual scenario

Once the counterfactual scenario is clearly described, the first question can be drafted. As with all questions in the survey, it takes the form in Box 2.7.

Box 2.7. Example text for the first survey question.

How many malleefowl mounds will be present at a site containing malleefowl habitat in 20 years, excluding any additional impacts from mining, agriculture, urban development that may occur over the next 20 years?

An important step in asking this question, and all subsequent questions in the survey, is to ensure that the wording excludes any impacts on the site due to actions likely to trigger an offset requirement themselves (Maron et al., 2018; Maseyk et al., 2020). For example, if a hypothetical offset site is important habitat for a threatened species, and the clearing of that site for a development would be likely to trigger the requirement for an offset, then it is important that experts do not include that risk of clearing in their envisaged future scenario for the site.

Because of this, for each counterfactual and action scenario, we recommend you include the statement: *"We want you to ignore the possibility of any additional human development (mining, infrastructure, large-scale agriculture) requiring formal approval that may occur in the site vicinity over the next 20 years."* as described in the template spreadsheet (Appendix 1). You can clarify for the experts that formal approval should refer to any approvals that are likely to require offsets for substantial impacts, such as under the EPBC Act, or you can specifically name the types of approval that are relevant.

If the value of the benefit indicator is likely to be strongly affected by stochastic events, such as catastrophic drought, fire or flood, it may be appropriate to clarify for the experts how such events should be considered in their judgements. A simple way to manage this risk is to include in the question a request that experts "assume that it will be an average, non-drought year" at the time horizon of interest, or you can state that stochastic events are not to be considered as they are equally likely to occur under all scenarios.

Step 8. Describe the offset action scenarios

The next set of questions in the survey will ask the experts to envisage the value of the benefit indicator at the hypothetical offset site under a series of different offset action scenarios – one scenario for each offset action or combination of actions that were identified in Step 3, and that are relevant to the hypothetical site in question.

Some management actions are more relevant in certain scenarios than others. For example, it doesn't necessarily make sense to implement habitat restoration on a site where habitat is already in good condition. The most promising and reasonable offset action scenarios for each hypothetical offset site should be determined in consultation with the key informants.

Often, it is useful to ask about combinations of actions as well as individual actions. This is because some actions may work poorly on their own, but in combination with other actions, they can be more effective. Protecting habitat on a site that is highly degraded might be unlikely to deliver a conservation benefit unless a range of other actions are implemented concurrently (e.g. control of invasive species, active habitat restoration, introduction of captive bred individuals). For example, replanting of nectar-bearing food plants may benefit regent honeyeaters, but only if aggressive noisy miners are also controlled at the site.

For each survey question about the offset action scenario, clearly describe the management actions to be done, with enough detail that the experts can envisage their likely effect on the target species. The question then asks the expert what the value of the indicator is likely to be at the same point (or points) in time as used at Step 7 for the counterfactual scenario.

8.1 Draft the subsequent survey questions: value of the benefit indicator in the offset action scenario/s

Questions about the offset action scenarios take the form in Box 2.8.

In drafting the questions, it is important to strike a balance between providing enough information about the management action for experts to envisage how it will be done, but not so much that the description is relevant to only a very particular subset of places. For example, you may choose not to specify the intensity and frequency of application of particular management actions (e.g. fox baiting) in the survey, since these factors are likely to vary geographically. Instead, experts could be asked to assume that management was implemented to a 'best practice' standard, which allows them to make their own judgement about what type of implementation would apply in the context they are familiar with. The survey can provide space for experts to record this detail if they chose, which can then be shared (anonymously) with other experts during the 'discussion' phase. The questions should be free of linguistic ambiguity and framing that may generate unwanted bias (Hemming et al., 2017).

Note that, as with the survey question about the counterfactual scenario, the question wording must exclude the risk of impacts on the hypothetical offset site that would, if they occurred, themselves trigger an offset requirement.

The survey questions are developed in the four-step format (Speirs-Bridge et al., 2010) which involves asking experts to provide upper and lower plausible bounds, a best guess, and an estimate of how confident they are that the correct answer is within the upper and lower bounds they gave (between 50 % and 100%) (Hemming et al., 2017). This allows an expert's responses to the four-step format questions to be interpreted as best guess within a credible interval (usually standardised to 90% probablity), based on their current knowledge (Hemming et al. 2017).

The survey should be checked for flow, logic and to ensure that the questions comprehensively cover the spectrum of management actions (or combination of actions) that need to be considered. It is recommended that the length of the survey should not exceed 15-20 questions for a species or ecological community, in order to avoid expert fatigue (Speirs-Bridge et al., 2010). Survey text is best developed in a word processing document, before being transferred to an appropriate survey template (either a spreadsheet or online survey; for an example, see Appendix 1). It is ideal to have the final survey text double-checked by two members of the project team, to ensure the survey text is correct.

Box 2.8 Worked example of the four-step question format

Recall the site from Question 1, the 400 ha site which contains malleefowl habitat and 5 active mounds in 2018. Assume the existing site and regional pressures (e.g. fox predation, vehicle strikes, impacts from herbivores and inappropriate fire regimes) remain in place.

In 2018, the site is placed under a permanent conservation covenant. General weed control and habitat maintenance will occur as part of the covenant, but no malleefowl specific management actions will be implemented.

We want you to ignore the possibility of any additional human development (mining, infrastructure, large-scale agriculture) requiring approval under the EPBC Act 1999 that may occur in the site vicinity over the next 20 years.

An "active mound" is one which is likely to have been used as an incubator in October.

Assume that it will be an average, non-drought year in 20 years.

Question: Assuming the site is place under a permanent conservation covenant, how many active malleefowl mounds will be present at a site containing malleefowl habitat in 20 years, excluding any additional impacts from mining, infrastructure, large-scale agriculture that may occur over the next 20 years?

i. Realistically, what do you think the **lowest** plausible number of mallleefowl mounds will be in 20 years?

ii. Realistically, what do you think the **highest** plausible number of malleefowl mounds will be in 20 years?

iii. Realistically, what is your **best guess** for the number of active mounds in 20 years?

iv. How **confident** are you that your interval, from lowest to highest, could capture the number of active mounds? Please enter a number between 50 and 100%.

2.3 Recruit the experts

Experts for the elicitation process can be undertaken using a targeted (non-random) sampling approach (Drescher et al., 2013), based on existing networks and the recommendations of key informants. A snowball sampling approach (Drescher et al., 2013) can then be adopted for additional participant recruitment, with the aim to reach a final sample of >10 experts per elicitation. Snowball sampling involves asking each expert identified to identify other experts to ask, and continues until no new experts are identified.

It is ideal to recruit experts who have worked, or are currently working, in the management of the case study species, including scientists and managers from research institutes, environmental non-government organisations, government agencies, consultants, industry and representatives of species recovery teams. This expert elicitation method can be used even if only small numbers of experts can be recruited, but the robustness of the results will be greater with more experts.

Evidence shows that expert judgements produced by a group of diverse participants tend to outperform individual judgements of "esteemed" experts (Carey & Burgman, 2008; Hong & Page, 2004; Wintle et al., 2013). This means that expert elicitation processes will provide more robust estimates when they draw on the expertise of people who work across a range of sectors (e.g. research, consulting, industry) and geographic locations, have varying years of experience and different educational backgrounds (e.g. high school certificate to PhD). So, although often constrained by a relatively small pool of experts with sufficient knowledge of the species, aim for a diversity of experts within your sample.

Experts can be recruited with short introductory emails about the project and an invitation to participate in an introductory teleconference. The introductory email should include a project statement, the project team contact details and a consent form if required for ethics.

2.4 Conduct the elicitation

Step 1. Hold an inception meeting

Once the expert group are identified and established, the draft survey questions and participant information sheet should be circulated, and an inception meeting is undertaken via group teleconference (with video and a screen-sharing presentation as an option). This initial meeting is important for establishing a rapport with the experts, explaining the motivations for, and expectations of, the elicitation (Hemming et al., 2017). The most appropriate format for the elicitation process and associated meetings will depend on the time and budget, location and availability of experts (Hemming et al., 2017). If multiple species are being considered, a workshop may be a more suitable option.

During the inception meeting, the facilitator or problem owner describes the justification for the elicitation and the process of the IDEA protocol (see Box 1.7). They describe the alternative scenarios, the questions about the management actions and the counterfactual scenarios, and the instructions for the completing the survey. This provides an opportunity to ensure the wording of the questions and the requirements of the process are clearly understood.

The four-step format of providing quantitative estimates (minimum, maximum, best estimate and credible interval, Box 1.7 (Hemming et al., 2017; Speirs-Bridge et al., 2010), needs to be clearly explained, with potential training to ensure all experts understand the rules of participating and what is expected.

The facilitator should explain that experts must not speak to each other about the process until the discussion phase, but may speak to anyone else for advice, and use any relevant information sources available (Hemming et al., 2017). It may be useful to develop a library of relevant publications which can be shared amongst the group, particularly for species which have a broad distribution and different threatening processes across their distribution (such as the northern quoll). It is important to clarify at the start of the inception meeting that participants can ask questions to clarify the task or the wording of the questions, but cannot express any opinions about the effectiveness of any of the actions, that may influence others' estimates.

At the end of the inception meeting, the facilitator should ensure the experts are clear about the survey requirements, reiterate the timeline and procedures for the first round of the expert elicitation process, and allow for any questions to be addressed (Hemming et al., 2017).

Step 2. Conduct Round 1 elicitation

In the first round of elicitation, the survey (Appendix 1) is circulated via email to the experts, together with instructions, and given a fixed period (suggested 2-3 weeks) to complete the survey. All responses remain anonymous to reduce bias among experts, and experts are asked not to confer with one another prior to completing the survey.

Step 3. Complete analysis and data aggregation

It is recommended for a project team member to review the responses as they come in, to ensure numbers were entered in the correct boxes, that surveys are complete and include the correct units (if applicable).

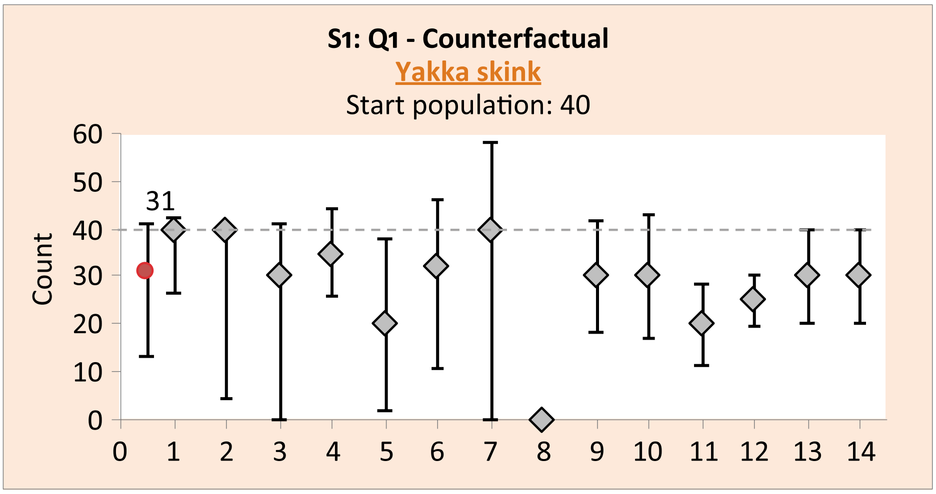
The analysis phase involves cleaning the data, standardisation of the levels of uncertainty that experts indicated, and aggregating judgements. The estimates of uncertainty are standardised to reflect the same uncertainty level (for e.g., a belief that there is a 90% chance that the true estimate is within the upper and lower estimates). The average 'best guess' outcome for each scenario is calculated as the unweighted mean of all best guess estimates across the group of experts.

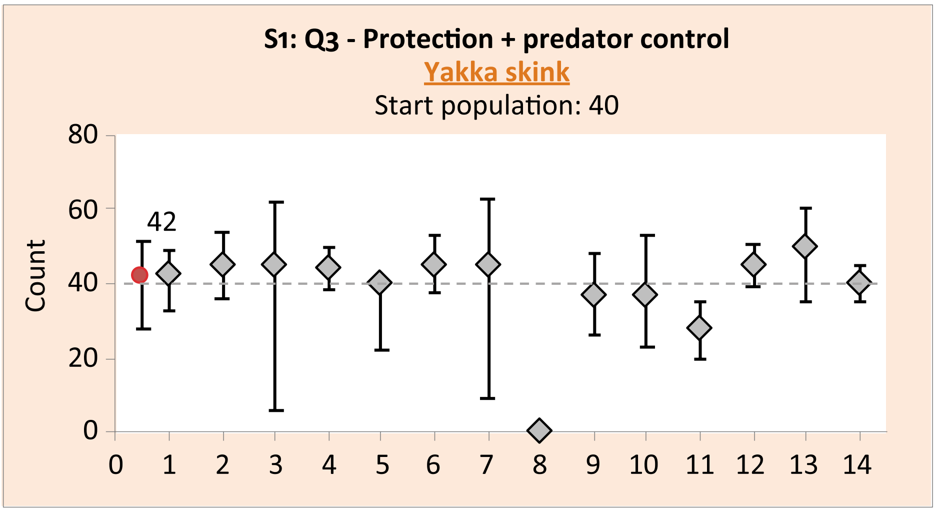
Data analysis can be undertaken using R, a free software environment for statistical computing and graphics. A specific R code developed by Hemming (Hemming et al., 2017; Hemming et al., 2018), for analysis structured expert elicitation data is available through the Open Science Framework (https://osf.io/xwzkc/)

Once this analysis is complete, simple graphics showing the results of Round 1 (but in anonymised form, in Box 2.9) can be shared with experts.

Box 2.9

Results of Round 1 expert elicitation for the yakka skink. The red dot indicates the group average. The diamond indicates the 'best guess' for the individual experts, and the lines show the 90% credible intervals for the number of yakka skinks in response to no change (the counterfactual) and protection and predator control in high quality habitat after 20 years of each scenario (starting with 40 yakka skinks in Year 1). Note expert 8 did not provide responses to this question.





Step 4. Conduct the group discussion

The discussion phase is an integral part of the protocol, takes place after the anonymised results of Round 1 are distributed to the experts. The purpose of the discussion is to ensure that all experts have a common understanding of the hypothetical offset sites and actions, and have interpreted the questions in the same way. It also allows identification and resolution of any problems with the questions that were not evident until the survey was attempted. For example, as part of an expert elicitation process for threatened black cockatoos in Western Australia, we asked experts to provide responses with a benefit indicator score between 1 and 10, from poor to high quality foraging habitat. Following the first round of the survey, experts advised that the scoring system should allow for a value of 0, and allow for 0.5 increments, to allow them to reflect the scale of changes they believed were likely. These adjustments were made for Round 2 of the expert elicitation, and experts could then update their estimates.

The discussion phase can occur via teleconference (with the option for video) or face-to-face. If a face-to-face workshop is held, time to complete the Round 2 estimates could be scheduled following the group discussion.

It is important to plan the discussion phase with adequate time to go through all of the results, including discussion of outlier estimates, why they might occur, and plausible sources of variation amongst the results. It is also important that anonymity is maintained throughout the discussion in terms of which participant contributed which data point, unless experts voluntarily identify their own data point in the results for the purposes of the discussion.

One common reason for outliers or large variation in results is participants have different interpretations of the question, or different assumptions about the action described in the question. Identifying these inconsistencies allows clarification of any ambiguities in meanings/interpretation, so that the question context and assumptions made by experts are consistent for Round 2 of the elicitation. In some cases, some additional information about the benefit indicator, counterfactual scenario conditions, or the management actions being considered might need to be provided and agreed upon by the experts.

Things to remember:

- Explain to experts how the standardisation of the credible intervals works, and that because of this, the upper and lower bounds around their standardised estimate may be different to their raw estimate.
- Draw attention to any apparently contradictory results. For example, one management action alone might have been estimated to have a benefit of x, but that action in combination with a second management action might have been estimated to yield x-1. This might be because of either a genuine antagonistic effect when the two actions are done together, or a misstep in reasoning. The group discussion can clarify which is the case.

Step 5. Conduct Round 2 elicitation

Following the discussion, the second round of the survey is distributed to experts, who have the option of providing an updated, anonymous and independent estimate for each question in the light of the discussion. Often, the group discussion can increase the confidence of experts in their estimates, and so the credible bounds might reduce and outliers might converge on the group estimate (Hemming et al., 2017).

Step 6. Documentation and reporting

Once the elicitation process is completed, the experts' final individual (anonymised) judgements and the group's aggregate estimates should be circulated again to the group for final review, to help pick up any errors. Graphical display format similar to that provided to inform the group discussion after Round 1 should be used (Box 2.9), with clarity on what sites and actions each set of results refers to. Once experts are satisfied that the results reflect their true beliefs, the data can be used to estimate benefits of alternative offset actions.

2.5 Summarise estimated benefits of offset actions

The aggregated judgements from Round 2 form the final results of the expert elicitation process.

The approach generates the average 'best guess' about the outcome under each scenario, based on the average of the estimates across the group of experts. It also summarises inter-and intra-expert uncertainty about those mean estimates (Hemming et al., 2017). The average best guess and the standardised uncertainty bounds are generated for both the counterfactual scenario, and the offset action scenario.

To estimate the mean **benefit** expected from a given set of offset actions, there is one more step to complete. The estimated mean benefit is the difference between the two average 'best guess' outcomes – those for the management action scenario and the counterfactual scenario. This difference provides information on the expected benefit of the management action (or combinations of actions) described in the offset action scenario:

Estimated mean benefit = average best guess outcome under the management scenario– average best guess outcome under the counterfactual scenario

This difference can be calculated for a range of alternative offset action scenarios, so that the estimated mean benefit of different biodiversity offset options can be compared. It can also be used to guide expectations about the likely benefit from a specific proposed offset action or set of actions at a site, as long as that action and the offset site align with the description presented to the experts. If the actions or the site's characteristics differ from this, then appropriate adjustments to estimated benefits should be made – and if they differ a lot, the elicitation results may not be a useful guide. It is important to note that the benefit of an offset is unlikely to scale linearly with offset site size or effort – smaller sites are likely to yield disproportionately lower benefits, and so it is best to ensure the scenarios presented to experts reflect a minimum unit of area/effort for a given offset.

Things to remember:

- Be very wary of making assumptions about downscaling estimates of benefit to smaller sites. It may be reasonable to assume that doubling the amount of offset area and effort might double the expected benefit (as long as other offset site conditions are unchanged) – but halving them probably more than halves the expected benefit or could even eliminate benefit entirely.

Uncertainty around the mean benefit

Uncertainty surrounding the estimated mean benefit can be presented as a range, incorporating the lowest and highest expected values from the counterfactual and management scenarios. To ensure the uncertainty for both sets of estimates is reflected in this range, the following approach can be used:

Minimum plausible benefit = minimum management scenario estimate – maximum counterfactual scenario estimate

Maximum plausible benefit = maximum management scenario estimate – minimum counterfactual scenario estimate

This results in a range around the estimated mean benefit, in which the minimum plausible value is the benefit we would expect from a management scenario if both the worst outcome (based on the standardised credible interval from expert elicitation) from the offset management actions and the best outcomes from the counterfactual scenario were true. The maximum plausible value reflects the combination of the best outcomes from management and the worst outcomes from the counterfactual scenario.

Things to remember:

- It is important to recognise that the estimated mean benefit at this stage is not yet adjusted for any potential time lag between the time of an impact and the offset benefit being fully realised, nor is it yet adjusted for the uncertainty that the experts have indicated that is associated with their best guesses (i.e. their upper and lower estimates). Both of these are important steps to ensure that estimates of benefit are realistic and expressed in present value terms.

Adjusting the estimated mean benefit for uncertainty

As described above, an important advantage of this expert elicitation method is that it explicitly captures the uncertainty around each estimate. There may be substantial uncertainty about the way that a species will respond to an offset action and about the counterfactual scenario. This uncertainty can be both within individual experts, and across the judgements of different experts. Intra and inter-expert uncertainty may be high for a range of reasons, such as a lack of definitive ecological knowledge about relative contributions of threatening processes (e.g. malleefowl, night parrot), or uncertainty regarding the response of the species to some management actions.

It is important that this uncertainty is not only recognised, but appropriately dealt with, when making decisions about the suitability and adequacy of offsets. Actions that have highly uncertain outcomes, or benefits based on averting a loss that itself is highly uncertain, might not be acceptable, as robust evidence is required to support offset actions.

However, moderate uncertainty may be able to be accounted for by penalising the benefit estimate proportionally (for example, as is done under the EPBC Act offsets assessment guide). An outcome about which experts are only 80% certain might be penalised by 20%, for example.

Given the way that uncertainty is elicited in this approach to expert elicitation, it is not straightforward to convert the estimates of uncertainty about the counterfactual and offset action scenarios, or the uncertainty around the estimated mean benefit, into a penalty to apply to the estimated mean benefit.

One approach is to use the triangular distribution generated by the estimated mean benefit and the maximum and minimum plausible benefit to adjust the estimated benefit, with greater uncertainty resulting in larger adjustments (meaning that a larger amount of offset action would be required to deliver a given benefit).

There are three components to this (see Box 2.10).

- The first component of the adjustment relates to whether the estimated mean benefit is more likely to be an underestimate or an overestimate. The adjustment value is the difference between the estimated mean benefit and the mean of the three values: maximum plausible, minimum plausible, and estimated mean benefit. If the estimated mean benefit is higher than this mean, then this adjustment is applied.
- The second component considers the range between the minimum and maximum plausible estimates, with larger adjustments for wider distributions, which reflect higher uncertainty.
- The final component considers the confidence that the true value falls within the range given, based on the standardised confidence level (e.g., 90%).

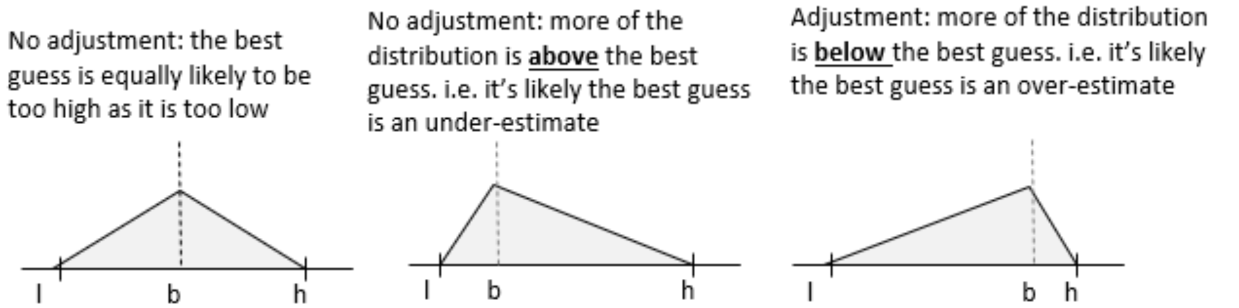
Under this method, the overall adjustment is the sum of these three values, and this is then subtracted from the estimated best guess benefit. A worked example is given in Box 2.10.

Box 2.10: Example of adjusting gain to account for uncertainty

An expert elicitation workshop was held to estimate the benefit of additional management at an offset site. Experts were asked to estimate what would be the highest, lowest and most likely number of nest hollows where pairs of a threatened cockatoo bred successfully on a 400 hectare site under both the additional management and counterfactual 'do nothing' scenarios. After expert elicitation results were aggregated, and the following estimated mean benefit and minimum and maximum plausible values were calculated as per Section 2.5, reflecting a 90% confidence that the actual gain in successful nest hollows would be between the lowest and highest estimates.

	Minimum plausible estimate (l)	Estimated mean benefit (b)	Maximum plausible estimate (h)
Number of successful nest hollows	5	8	10

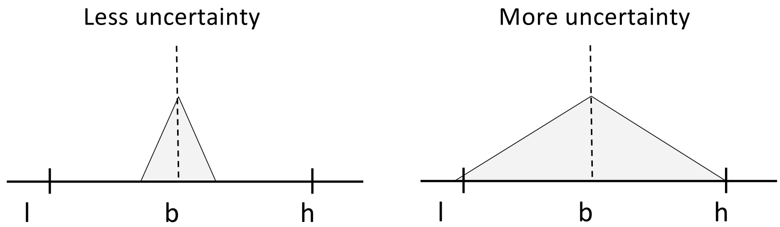
A simple approach to deciding on the expected benefits is to simply use the estimated mean benefit. However, this fails to account for the uncertainty expressed by the experts, and carries a high risk that the agreed offset action will fail to sufficiently compensate for the loss at the impact site. To correct for this, we can make some adjustments to account for the uncertainty surrounding this estimate based on the distribution of all three values. First, we can use the distribution of the best guess (b), minimum (l) and maximum (h) estimates to calculate if the mean benefit is more likely an under or over-estimate, based on the mean of the three values: (l+b+h)/3.



We adjust the estimated mean benefit if the best guess is higher than the mean. In the above example, we would subtract 0.33 from the expected raw benefit ((5 + 8 + 10)/3 = 7.67; 8-7.67 = 0.33).

Estimated mean benefit (b)	mean (l+b+h)/3	Adjustment 1 (penalty)
8	7.67	0.33

The second source of uncertainty comes from the range between the minimum and maximum plausible values.



This can be accounted for by multiplying the standard deviation of the range by an arbitrary amount, such as 10%, reflecting the maximum penalty for this component. For the above values this gives an overall adjustment of 0.1, i.e. 1.0 * 10%

Range	Standard deviation	Adjustment 2 (penalty)
5	1.0	0.1

Finally, we are only 90% sure that the actual increase in the number of successful nest hollows will be between the highest and lowest estimates. This means that there estimated to be a 5% chance that the actual achieved benefit will fall below the lowest estimate. We can adjust for this by subtracting a further 5% adjustment from the raw estimated benefit.

Estimated mean benefit	Adjustment 3 (penalty)
8	0.4

The adjusted estimated mean benefit of the offset action becomes the estimated mean benefit, minus the adjustment for each of the three amendments.

Adjustment			Adjusted estimated mean benefit	
1	2	3	Total penalty (=sum of adjustments)	=estimated mean benefit -adjustments (=8-0.83)
0.33	0.1	0.4	0.83	7.17

This adjusted estimate mean benefit (of 7.17 successful nest hollows) accounts for the level of uncertainty expressed by the experts.

Section 3. Estimating the costs of offset actions

Estimating the costs of offset actions is useful for situations when you want to ensure that the most cost-effective action is selected. This might not be relevant to some situations – such as when an offset approach is already decided, and the task is to estimate the expected benefit from that approach; or when costs of alternatives are known. However, it is often useful to estimate approximate costs so that the least cost-effective options can be excluded early in a decision or policy development process. This process provides a ranking of the relative cost-effectiveness of actions, which can provide a guide as to what actions to choose. However, it shouldn't be relied upon for site-specific costs.

We recommend following the standardised methods (Carwardine et al., 2019; Iacona et al., 2018) for estimating the costs, which we describe in the following six sections. This standardised method allows for the costs to be compared across management actions and species, and provides the data in a format that can be modified for use in different situations in the future. The template spreadsheet (Appendix 2) has been adapted from these sources.

Cost estimation can be conducted before, after, or alongside the estimation of benefits, however, it is important to clearly specify the detailed nature of the actions before the benefits and costs are estimated (see Section 2.2, Step 3).

3.1 Specify detailed tasks within each action

For each scenario, the specific actions required for effective implementation should be outlined based on best-practice methods aligned with the hypothetical scenario. This is best completed with assistance from experts who have implemented this action in the past, to clarify which specific tasks would be involved. For example, the 'protect habitat' offset action for malleefowl would involve several tasks, including establishing a permanent conservation covenant or protected area, ongoing weed management and fencing. Each of these tasks need to be costed.

If best-practice methods vary across typical sites or circumstances, the most appropriate or typical method should be selected, or the differences across methods should be accounted for in the uncertainty estimates of cost. For example, ground mammalian predator control would be appropriate in small sites or near urban areas, while aerial baiting would be selected in more remote, larger areas. The most likely action could be chosen to estimate costs, or the both options could be costed, and presented as a range of possible costs.

3.2 Estimate costs of each action

Estimate the costs of continuing each action or task over the time horizon required by the offset as specified in Step 5 when defining the scenarios (Section 2.2). Specify the costs required for each of the following: labour, consumables, equipment, overheads, monitoring, coordination, planning, and lost production if applicable (Table 3). Record the currency and date for when the costs would be incurred (Carwardine et al., 2019). If possible, record the 'best-guess' cost, along with minimum and maximum costs. In most cases, it is easiest if the costs are provided in a 'per hectare' format, so it can be converted and scaled to different scenarios quickly. Some tools to assist with this are provided by the NSW Government: https://www.environment.nsw.gov.au/topics/animals-and-plants/biodiversity/biodiversity-offsets-scheme/total-fund-deposit-discount-rate.

Sometimes, only the total cost of an action is known and it is not possible to itemise the costs in to the specific categories. This can occur if a contractor is hired to implement the action, and the cost is all inclusive of labour, equipment and consumables. If this is the case, estimate the total cost/ha/year so it can be scaled accordingly to new scenarios of different area and duration.

For each of these categories, specify whether the cost is a:

1. Start-up cost (i.e., only required in the first year), which may include costs of establishing a baiting program, erecting fences or infrastructure, or administration and planning costs,
2. Annual cost (i.e., once every year for the duration of the project),
3. Biennial cost (i.e., every two years for the duration of the project),
4. Less frequent cost (e.g., every 5 or 10 years), or
5. Irregular costs (e.g., only the first 3 years).

Table 3: Items to include in the cost estimates for each category

Item	Data required	Notes
Labour	Specify the number of people required (and their salary level or role), and the number of days/weeks required or proportion of a full time equivalent position (FTE).	Include time required for planning, implementation, management, administration and training. Record the time volunteers would spend on the project. Include on-costs (such as superannuation, leave pay and benefits) in addition to salary. Consider whether the labour would be in-house or contracted, and adjust costs accordingly.
Consumables	Transport (e.g. rental of helicopter or earth moving equipment), fuel, construction materials, costs of travel and meetings, baits or herbicide, etc.	Includes costs for materials, transport, and travel. Distance from site to nearest town or city should be factored into the travel costs.
Capital assets and equipment	Vehicles, equipment required for intervention (e.g. weed sprayers, cameras, bait stations), personal protection equipment, staff offices/accommodation.	Organisations usually have these available for use. It may be fair to assume that a new car is not required for the project, but maintenance costs may be included under consumables. Or a proportion of the cost could be included if used for other projects. Depreciation costs could be included.
Overheads	Organisation administration costs, e.g. electricity and water, and support staff not directly involved in the project.	Often, organisations estimate the overhead as a percentage of the total project cost, e.g. 20% of labour, consumables and equipment, if it hasn't already been included elsewhere.
Monitoring	Labour, consumables and equipment required for ongoing monitoring progress of the offset. This is kept separate, to emphasise its importance for inclusion in the overall project cost.	Specify the monitoring program design, and include the costs of all aspects, including set up and ongoing monitoring. Only include monitoring costs here that aren't already included in categories above.
Planning, coordination	Permits, labour costs for planning, coordination and reporting. Only include if these are not included elsewhere.	This section is added separately as time spent on these activities can be forgotten. This could include contracting or legal fees, permits, administration, or training courses for staff.
Lost production	Includes the profit that would be lost as a result of the conservation action (e.g. profit lost from sheep or cattle that were removed from the site).	This is difficult to estimate, and may be excluded. It may also not be appropriate to include this in the context of an offset.

3.3 Methods for collecting the cost data

There are several methods of how costs could be collected, depending on the scale of the project, the collaborators and stakeholders involved and the resources available. Given that costs vary dramatically across projects, where possible, capture data from multiple people per action to provide a more accurate range of possible costs. Experts involved in this section should have previously implemented these management actions, or have access to past budgets or reports that state the actual costs.

In a workshop setting: multiple experts could work in groups to compile their data and their past experiences to develop single estimates for the average, minimum and maximum costs of each action for the hypothetical sites. This method is used in applications of the Priority Threat Management framework (Carwardine et al., 2019; Wenger et al., 2018).

Interviews with individual experts: If a workshop is not possible, natural resource managers could be interviewed individually, and the data recorded into separate spreadsheets. This may be more appropriate than a workshop if each expert has experience with different interventions. This method has been conducted by past researchers looking for in-depth information (Wenger et al., 2018).

Review of reports and budgets: Compile data from past literature, reports and budgets, as a desktop review, if resources and time are limited. The costs extracted from these reports need to be adjusted to be relevant for the scenario in question (e.g. convert cost to appropriate area, based on a cost/area estimate).

Where possible, ask experts to provide the exact estimates for your hypothetical scenario. Instead, they will often provide estimates based on past budgets for real projects, which may differ in area or context to the hypothetical scenario of interest. If time permits, work through the calculations with them to convert their costs into a cost per hectare, and then the relevant cost estimate for the hypothetical scenario (offset area x cost/ha), while outlining the assumptions made.

There are many factors associated with the site and the management action that cause the costs of conservation actions to vary. Recording assumptions is important as this allows people in the future to understand which costs were included or excluded, and the relevance of the reported costs to their situation. Ideally, the costs should reflect a typical situation, but we acknowledge that it is often difficult to provide specific details for a hypothetical site. Asking experts for their best approximation while recording their assumptions and making consistent decisions across each action is recommended. Below is a list of factors that could be considered to assist when specifying the assumptions used.

For details regarding the context of the site, define the assumptions surrounding:

- current habitat condition as defined in the hypothetical scenario (e.g. pristine or degraded),
- general location where the costs were estimated (different states or regions have different costs involved, e.g. the Pilbara region is known to be more expensive than other regions in Australia due to its remoteness and presence of mining),
- presence and density of weeds or feral animals (as this determines extent and intensity of management required),
- topography of the land (flat vs steep or mountainous terrain) and available water sources, as this may change labour and material costs and
- distance from nearest town (as this determines travel time, fuel costs, transport of equipment and whether staff need to stay on-site).

In terms of the management context, identify:

- existing infrastructure on the site, such as fences, staff facilities or buildings, and whether it would be required as part of the offset action as this will determine what is included in the initial set-up costs,
- existing resources or equipment, such as cars and machinery, as this determines whether it needs to be purchased,
- existing land tenure (and level of protection), as this determines need for land acquisition or protection costs if necessary,
- current and past land use (which links back to habitat condition of the site), and
- existing management actions (which determines the condition of site in the counterfactual 'no management' scenario).

For each action, define the assumptions used about the:

- method of action chosen, (e.g., is aerial or ground shooting more appropriate for goat control in this context?),
- area and scale required for each specific action (e.g., would the entire offset site be managed, or is it only needed on 10% of the site?),
- number of years required (e.g., is it ongoing annually, or only required in the first 5 years, or every 4 years?),
- intensity, duration and frequency of the action per area (e.g., how long would it take to survey 100 hectares during a feral goat campaign, how many times would an area need to be surveyed during a campaign, and how many campaigns per year would occur?),
- spatial configuration of the intervention, as this may change the costs (e.g., in dispersed patches or a single continuous area), and
- the organisation responsible for implementing the action (e.g., is the work carried out by a contractor, an NGO, or a government agency, as costs of labour and overheads vary dramatically between these).

Defining these sources of variation in hypothetical scenarios is difficult, given the potential variation across potential real cases. We recommend specifying a typical scenario, and note any key variations that might be also plausible. The costs could be captured for multiple scenarios to give a range of upper and lower possible costs. However, limit the scenario permutations to a manageable number, by only selecting the most probable scenarios that would significantly alter the costs involved.

The following methods will ensure consistency when calculating costs across actions:

- Use standardised costs of staff FTE at different levels and roles across all interventions (e.g. professional, manager, ranger and labour roles), at hourly, daily or weekly rates, to estimate labour costs. This could also vary across government, private and NGO sectors, depending on the level of specificity required, and this variation could be captured in the upper and lower estimates. There is a separate tab in the template spreadsheet (Appendix 2) that can be used to specify the standardised labour costs. Standard costs could also be used for fuel and travel, or any other expenses that occur across different actions.
- Include the cost of labour (in FTEs) that might not have been accounted for because it is usually part of someone's existing role. e.g. the time required to plan a prescribed burn may normally be included as part of an existing staff member's responsibility, and would not have been included in their cost estimate, but is important to include, given the additional workload required for this new offset site. Avoid double counting (i.e., including the same cost twice) within actions, e.g. if overheads are already included in salary estimates. Record the date that cost estimates were incurred or reported, and decide whether to convert these past prices to current price accounting for inflation. For example, if a report stated costs of an intervention from 2010, you could account for inflation based on the consumer price index, and use the present value in the calculations. For transparency, report the original cost estimate in the Notes section in the spreadsheet, and note the calculations used to establish the updated cost.
- Ensure that the assumptions made when estimating costs are consistent across actions, so they are comparable.
- Ensure that cost estimates for each offset action are standalone so each scenario could be fully implemented, even if other actions are not. For combinations of actions, cost-efficiencies can be accounted for, e.g. if two actions could be conducted at the same time, separate travel costs to the site would not be required in the combined action scenario.

3.4 Tips for compiling the costs across multiple experts

If data on an action is collected from multiple experts, their costs must be compiled into a summary spreadsheet, recording the average (or best-guess estimate), minimum and maximum costs per item. Given the costs in each situation are extremely variable, this is difficult and requires several behind-the- scenes calculations, which should be explained in the notes section of each item within the spreadsheet.

Experts can provide large ranges of estimates, or in a format that does not follow the itemised formula in Table 3. They may only provide a total cost per action (including all or some of the cost categories), which requires manipulation to be comparable with other experts' estimates. In some cases, such costs are incompatible, and cannot be incorporated into the estimates. These costs should still be reported, in the notes section, with a justification for why these estimates were not used.

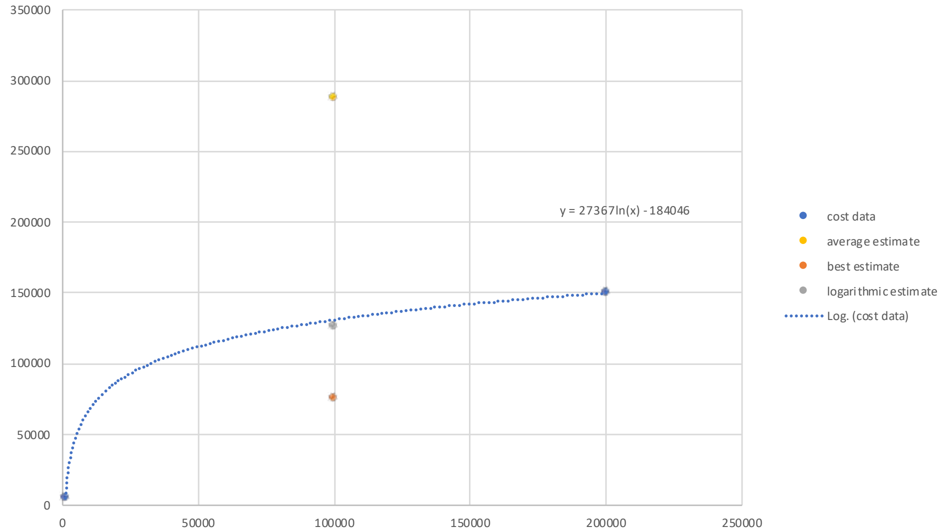
Another difficulty is the non-linearity of costs as the area of management increases. Due to the economy of scales, the cost per unit area may be lower for interventions implemented across large scales compared to if implemented in smaller areas. This is illustrated in the worked example below. Specify which assumptions you make.

Scenario: Expert 1 provides a total cost of a management action across 200 000ha of $150 000 ($0.75/ha), while Expert 2 provides a total cost of $5 000 for 1 000ha (i.e. $5/ha) (shown as blue data points in Box 3.1). If the hypothetical scenario is for 100 000ha, you could either:

1. Record the minimum cost as $75 000 (using $0.75/ha estimate), maximum cost as $500 000 (using $5/ha estimate), and the average as $287 500 for 100 000ha of management (however, this creates much higher and possibly unrealistic estimates – yellow data point in Box 3.1); or
2. Select the most appropriate cost estimate for the hypothetical scenario (in this case, let's say $0.75/ha, given the similar magnitude of spatial scale) and provide that as the average cost. If possible, ask experts which option would be most appropriate. Keep a record of the other cost estimate in case it is useful in a future scenario, and provide justification as to why only one cost estimate was used (orange data point in Box 3.1); or
3. If the cost does not increase linearly with area, fit a curve to the area vs cost data (e.g. Box 3.1, grey data point), to account for non-linearity in the cost estimate. For example, a logarithmic or power-law model can be fit in Microsoft Excel using 'format trendline' in the x-y plot plotting function. This would be more accurate if there are three or more data points, and could provide a better estimate than taking the average cost/ha estimate if economies of scale applies.

Box 3.1: Non-linearity of costs in relation to area under management

Effect of non-linear costs as spatial extent increases. There are three options of how to compile two cost estimates from different scenarios or experts (blue circles): taking the average cost/ha (yellow circle); using only the most relevant cost estimate, based on linear scale (orange circle); or fitting a logarithmic or power-law curve to the data points to account for economies of scale (blue line – logarithmic in this case).



3.5 Calculate total costs per action

Once the cost data for each action have been collated across experts, take the sum of the itemized costs from each cost category for each year of the specified offset time horizon, e.g. over 20 years. This will give a total cost of management in that year. Then calculate the total present value, given a discount rate, so that the cost-effectiveness of each action in the future can be compared in present day values (formulae provided in Appendix 2). The discount rate will depend on who will fund the offset, but for our examples, we have used a 5% discount rate.

The total cost of each action can be presented as the present value of implementing the action across the full time period, or an average annual cost (formulae provided in Appendix 2). Also calculate the total upper and lower cost estimates to account for uncertainty.

3.6 Estimate cost-effectiveness to inform offsets

The cost-effectiveness of an offset action can be calculated by dividing the costs by the benefits. This calculates the cost per individual of the species (or other unit of biodiversity), e.g., cost per additional malleefowl resulting from an action, over the offset time horizon. Actions can then be ranked by their cost-effectiveness, and proponents might then be able to be guided toward the types of offset actions that are likely to be more cost-effective. In the context of a specific offset, there is usually a set amount of benefit required, and the amount of action and/or the area over which it is done will need to be scaled to ensure it is expected to adequately deliver that requirement (after allowing for uncertainty and time delay). Examples of these cost-effectiveness calculations are provided in the case studies (Section Four).

Each benefit estimate has uncertainty associated with it, and the degree of uncertainty is relevant to decisions about what type of offset and how much offset action is required. It is therefore important to understand how the uncertainty of the benefits and costs changes an action's cost-effectiveness ranking. Comparing these four scenarios in a sensitivity analysis is a fair assessment of the uncertainty:

- Minimum benefit estimates with the best-guess cost estimates
- Maximum benefit estimates with the best-guess cost estimates
- Minimum cost estimates with best-guess benefit estimates
- Maximum cost estimates with best-guess benefit estimates

Other sensitivity analyses could include using different discount rates if there is uncertainty in the most appropriate rate to use (Carwardine et al., 2019).

Section 4: Case studies

To develop the methods we describe in this guidance, we conducted elicitation processes for a selection of species for which:

(i) there are currently limited data available to inform offset strategies;

(ii) offsets have been challenging to identify or particularly costly; and/or

(iii) habitat protection alone may be of limited benefit.

The case study species were selected through discussions with staff from Federal and State government agencies who work on biodiversity offset assessments and approvals. Here, we describe in detail the steps taken to conduct elicitations for two of our case study species, the malleefowl and night parrot.

Case study 1. Malleefowl

Background

The malleefowl (*Leipoa ocellata*) is a large ground-dwelling bird that is distributed across the semi-arid, mallee eucalypt woodland of southern Australia. The species is renowned for its construction of large nesting mounds with leaf litter and sand, which incubate its eggs as the leaf litter composts and generates heat. The malleefowl is listed as Vulnerable under the EPBC Act, and is a listed threatened species in New South Wales, Victoria, South Australia, Western Australia and the Northern Territory.

Figure 1: Malleefowl (Image: Donald Hobern CC 2.0_Flickr), malleefowl mound (Bush Heritage Australia). Map shows location of the long term malleefowl monitoring sites (black dots) distributed across its historical range in WA, SA, Victoria and NSW with the number of site-years of monitoring data for each state. Source: (Benshemesh et al., 2020)

Why are offsets difficult for malleefowl

For controlled development actions that result in a significant residual impact to malleefowl habitat, offsets may be required by the Commonwealth to deliver a conservation outcome that improves or maintains the viability of the malleefowl. Potential offsets for the malleefowl could involve actions such as the protection of habitat, herbivore control, fire management, fox control, captive breeding and a combination of these.

A major challenge for malleefowl conservation is that the relative contribution of key threatening processes to malleefowl is unknown. The most commonly applied management action applied for malleefowl is fox control; however, it is currently unknown whether reducing fox abundance leads to increases in malleefowl populations (Gillam et al., 2018).

Suitable habitat availability is a key limiting factor for the malleefowl, and even where habitat exists it may not be of sufficient quality to support breeding, in addition to the threats posed by invasive species and fire. Therefore, protection of habitat alone will usually not deliver an 'improve or maintain' outcome for malleefowl. The information needed to determine what combination of actions are required to achieve a conservation outcome for malleefowl, including their likely costs, frequency of application and other details are unfortunately not readily available to regulators who develop conditions of approval.

Table 3. Stages and steps in the process of eliciting benefits of alternative offset actions, and associated costs, for malleefowl.

Stage and step	Process and rationale	Decision
Stage 2.1 Logistics and project management	This was the first test case and so we sought a full team for project support with complementary expertise in benefit and cost elicitation.	The roles of problem owner, facilitator, and analyst were shared among the project team which included ME, JW, MM, TN and SS.
Stage 2.2 Survey and question design		
Step 1. Literature review	The project team compiled the available literature (including unpublished reports) on the malleefowl in a shared online library.	This information was used to determine the threats and possible offset actions for malleefowl (Section 2.2).
Step 2. Recruit key informants	We sought two key informants who had familiarity with both the ecology of the species and with the expert network that we would need to tap into.	We worked with 2 longstanding members of the National Malleefowl Recovery Team, including the national recovery coordinator.
Step 3. Identify management actions	The key informants helped develop a list of common management actions thought to assist in the conservation of the malleefowl. The project team refined this list of management actions and added potential management actions whose efficacy had not yet been fully captured within the peer reviewed or grey literature, but had previously formed part of Commonwealth conditions of approval for impacts on the species (e.g. captive breeding for the malleefowl).	Management action scenarios included in the survey (individually, and in different combinations) included: • Establishment of a protected area • Control of foxes • Fire management • Control of introduced herbivores • Establishment of a protected area + captive breeding • Control of foxes + control of introduced herbivores + fire management • Control of foxes + control of introduced herbivores + captive breeding + fire management • Restoration of habitat • Restoration of habitat + fire management + control of foxes + control of introduced herbivores
Step 4. Identify suitable benefit indicator	Malleefowl occur at low density, and are cryptic, so surveying for the birds directly provides imprecise estimates. Nest mounds are prominent and long-lasting features, and an active mound reliably indicates the presence of a breeding pair (Benshemesh, 2007). Mounds are also monitored as indicators in an existing long-term survey program, so experts could easily and consistently envisage the value of a site based on a description that included the number of active mounds present.	The benefit indicator for malleefowl was: *Number of active mounds within a 400 ha site* (an active mound is defined as one which is likely to have been used as an incubator in the most recent or current breeding season)

Stage and step	Process and rationale	Decision
Step 5. Decide upon time horizon	The time horizon was chosen to align with that commonly used under Australian policies.	20 years
Step 6. Describe hypothetical offset sites	Malleefowl occur in different habitats across southern Australia. Therefore, the description of the hypothetical offset sites needed to be very generic, while being consistent with potential offset sites for the species.	A key consideration is that there is limited suitable habitat for the malleefowl. Therefore, the two hypothetical offset sites were: existing malleefowl habitat, and degraded cropping land. Description of existing malleefowl habitat: *We would like you to think of a 400 ha site which contains malleefowl habitat. In 2018, there were 5 active mounds on site.* Description of degraded cropping land: *We would like you to think of a 400ha site which is currently degraded cropping land. The site was completely cleared 50 years ago, and is adjacent to malleefowl habitat. In 2018 there were 0 active mounds on site.*
Step 7. Describe the counterfactual scenario	The counterfactual scenario is the "do nothing" or "business as usual" option for the hypothetical offset site for malleefowl.	The counterfactual scenario for existing malleefowl habitat: *How many malleefowl mounds will be present at a site containing malleefowl habitat in 20 years, excluding any additional impacts from mining, agriculture, urban development that may occur over the next 20 years?* The counterfactual scenario for degraded cropping land: *How many active malleefowl mounds will be present at a site containing degraded cropping land in 20 years, excluding any additional impacts from mining, agriculture, road or urban development that may occur over 20 years?*

Stage and step	Process and rationale	Decision
Step 8. Describe the offset action scenarios	The key informants identified a range of actions that might be of benefit to malleefowl. The offset action scenarios relate to the implementation of different management actions (or combinations of actions) for malleefowl (conservation covenant, fox control, introduced herbivore control, fire management, captive breeding, habitat restoration) at the relevant hypothetical site/s.	For each Offset action scenario for existing malleefowl habitat, the general text was included: *Recall the site from Question 1, the 400 ha site which contains malleefowl habitat and 5 active mounds in 2018. Assume the existing site and regional pressures (e.g. fox predation, vehicle strikes, impacts from herbivores and inappropriate fire regimes) remain in place.* The different offset actions for malleefowl habitat were described as follows: Conservation covenant: *In 2018, the site is placed under a permanent conservation covenant. General weed control and habitat maintenance will occur as part of the covenant, but no malleefowl specific management actions will be implemented.* Protect existing habitat + captive breeding: *In 2018, the site is placed under a permanent conservation covenant. General weed control and habitat maintenance will occur as part of the covenant.* *In 2018, 10 young adult malleefowl raised from a captive breeding program (5 male, 5 female) are introduced to the site. No other malleefowl-specific management actions are implemented.* Fox control: *In 2018, a standard fox control program is implemented on site and is continued for 20 years. No other malleefowl-specific management actions are implemented.* Herbivore control: *In 2018, a standard herbivore control program (i.e. removal of goats and sheep) is implemented on site, and continued for 20 years. No other malleefowl-specific management actions are implemented.* Fire management: *In 2018, a fire management program is implemented on site and is continued for 20 years. No other malleefowl-specific management actions are implemented.* For each Offset action scenario for degraded cropping land, the general text was included: *Recall the site from Question X, which contains degraded cropping land and zero active mounds in 2018.* The different offset actions for degraded cropping land were described as follows: Restore degraded farmland: *In 2018, cropping will cease, and the site will be allowed to restore to its original habitat. No other malleefowl-specific management actions are implemented.* Restore degraded farmland + combine fire, herbivore and fox control: I*n 2018, cropping will cease, and native vegetation allowed passively to regrow at the site. In 2018, a combined fire, herbivore (i.e. removal of goats and sheep) and fox management program is implemented on site and continued for 20 years.*

Stage and step	Process and rationale	Decision
Stage 2.3 Recruit the experts	We recruited experts using a targeted approach, largely comprised of recommendations from our key informants. We contacted 28 people and 15 experts accepted the invitation to participate.	Of the 15 experts who accepted the invitation to participate, 13 experts completed Round 1, and 9 experts completed both rounds of elicitation. As outlined in the protocol, experts who dropped out following Round 1 were excluded from the final aggregation. The group of nine experts participating included 4 males and 5 females, and 4 from WA, 2 from Vic, and 3 from NSW.
Stage 2.4 Conduct the elicitation		
Step 1. Hold an inception meeting	As the participants were widely geographically distributed, an in-person workshop was not considered the most efficient approach, given the short period of discussion required.	We held an inception meeting via video conference over a period of 1.5 hours, allowing for explanation of the process and discussion of the questions.
Step 2. Conduct Round 1 Elicitation	We circulated the survey (via email in an Excel spreadsheet) to 15 experts, together with instructions.	13 experts returned their estimates, and each provided responses to each question.
Step 3. Complete analysis and data aggregation	The project team analyst completed the data analysis and data aggregation for Round 1. The results of Round 1 were sent to the experts.	The aggregate results showed general agreement about the relative benefit of the different actions, but wide uncertainty about the outcomes of each scenario.
Step 4. Conduct the group discussion	Again, it was considered more efficient to conduct the discussion via teleconference rather than in person.	We held a group discussion (via video conference). This included discussion about the efficacy of fox baiting for malleefowl, and any other questions that had large uncertainty.
Step 5. Conduct Round 2 Elicitation	We circulated Round 2 surveys (via email).	9 experts completed the second round of estimates. 5 changed at least one of their estimates and 4 changed none.
Step 6. Documentation and reporting		The project team analyst completed the data analysis and data aggregation for Round 2, and results were sent to the experts for review and 'sign off'. All individual experts were comfortable that the individual results reflected their beliefs.

Stage and step	Process and rationale	Decision
Stage 2.5 Summarise estimated benefits	The average 'best guess' across the group of experts for each offset action scenario was compared with the counterfactual scenario. The difference between these two estimates was the estimated benefit from the offset action scenario. This allowed ranking and comparison of the likely benefit of different actions in terms of the number of additional active malleefowl mounds attributable to each action (or combination of actions).	The final results following the second round had somewhat reduced uncertainty. The ranking of the actions in terms of the size of the benefit expected did not change. For existing malleefowl habitat, the greatest benefit was expected from the combination of fox and herbivore control, fire management and captive breeding (6.7 additional malleefowl mounds compared with the counterfactual scenario) and the smallest from protection of habitat (0.4 additional malleefowl mounds compared with the counterfactual scenario).
Stage 3.0 Estimating the costs of offset actions	We compiled the costs of different management actions for malleefowl, obtaining information from relevant experts.	We obtained costs data for the management actions considered in the expert elicitation to inform offsets for malleefowl (establishing a protected area, captive breeding, fox management, herbivore control, fire management, and passive restoration of land).
Stage 3.1 Specify detailed tasks within each action	For each management action, the project team made an initial attempt to break each of these into individual items and tasks.	For each management action, we specified the detailed tasks involved (e.g. tasks for establishing a protected area included the initial reserve purchase, fencing, ongoing general weed and property management)
Stage 3.2 Estimate costs of each action	We collected cost data through interviews with individual experts and from published and grey literature. When information was from older papers, we adjusted costs based on inflation rates to reflect the equivalent cost now. We collected itemised costs for labour, consumables, capital assets, equipment, overheads, monitoring, coordination and planning.	We recorded the separate cost data from multiple sources into a spreadsheet. Costs of some management actions varied substantially across geographical areas (with significantly higher costs in remote areas) and across specific techniques used (e.g. intensity or frequency of 1080 baiting for predator control, or the shape of the hypothetical site altered the length of the property fence needed); we attempted to capture this variation in the upper and lower estimates where possible.
Stage 3.3 Compile the costs across multiple experts and verify assumptions	We compiled the costs from multiple sources into the appropriate cells in the spreadsheet, making notes to justify if some costs were/were not included or combined, using methods described in Section 3.4.	We compiled cost data for malleefowl in the template spreadsheet (see Appendix 2). All assumptions were recorded.
Stage 3.4 Calculate total costs per action	We tallied the sum of itemised costs from each cost category for each year of the offset time horizon in Australia (20 years) (for full details, see section 3.5).	The summary spreadsheet contains formulas to compile start-up costs, annual costs, and total cost of action based on the length of intervention (20 years), the present value and average annual present value.
Stage 3.6 Estimate cost-effectiveness to inform offsets	We assessed the cost-effectiveness of offset actions for malleefowl by dividing the costs by the benefit gained, to obtain the cost required to result in one malleefowl ($ per malleefowl for each action).	We used a separate spreadsheet to assess the cost effectiveness of offset actions for the malleefowl, by dividing the total cost of a management action over 20 years, by the benefit of the conservation action.

Case study 2. Night parrot

Background

The night parrot is a small (<100g), cryptic, nocturnal parrot endemic to the arid zone of Australia. Very few sightings have been made in recent decades, and no breeding population was confirmed until 2013.

A sighting in 2005 in WA led to the first biodiversity offset for potential disturbance to night parrot habitat in the Fortescue Marsh, and subsequent searches for the species. In 2013, there was another sighting (accompanied by a photograph) of the night parrot, and a small population was located in remote Western Queensland. In 2017, the species was found at separate sites in central and northern Western Australia, with further records from the site in northern Western Australia made by the Paruku Indigenous Rangers in 2018. Since then the species has been detected at a further three sites in northern Western Australia.

There is little known about the behaviour and habitat use of the night parrot. Recent research suggests that the night parrot uses a mosaic of habitats including roost sites with persistent low, thick cover (e.g. spinifex hummocks) located close to feeding grounds with specific seed-producing species.

The available information indicates that night parrots have undergone a precipitous decline (Murphy et al., 2018). While the primary cause of the decline of the night parrot is still unclear, most ecologists agree that it was likely to involve interaction of factors rather than a sole threatening process (Murphy et al., 2018). Threats to the night parrot are still not well known but include vegetation clearing, impacts of grazing, predation by cats and foxes and changed fire regimes (Murphy et al., 2018).

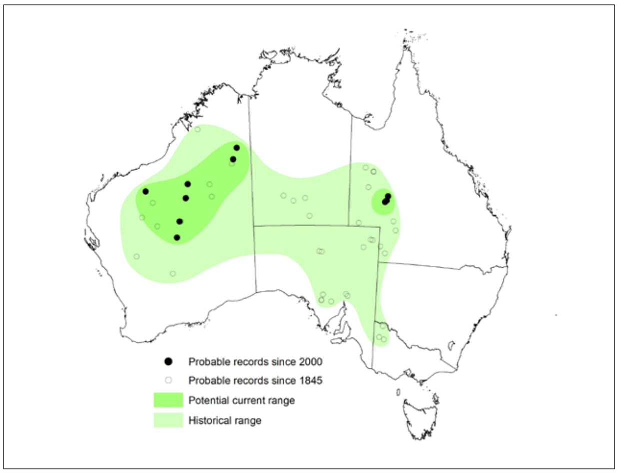


Figure 2: Night parrot (Image: Steve Murphy) and distribution map for night parrots (Map: Nick Leseberg et al 2020)

Why are offsets difficult for night parrots

The night parrot has only recently been able to be studied. Suitable habitat occurs over a vast area in Australia's arid zone, which is a strong focus for various development activities (such as mining). There is limited data to reliably inform the offset strategies.

Given the lack of available information, the current approach to biodiversity offsets for the night parrot is to provide a monetary contribution towards a regional conservation initiative or research plan. Offsets from mining have funded a national research plan for the night parrot (2014-2016) and surveys where it was re-discovered in Queensland.

The 2014 plan provides a useful framework to guide research for the recently re-discovered night parrot, and there has been a substantial body of research that has been undertaken from 2014-2020. However, unless research is incorporated into an adaptive management framework, it alone does not achieve a direct benefit for the night parrot, and cannot counterbalance impacts. Threatening processes likely impact remaining habitat and potential offset sites of the night parrot, making the development of offsets that directly benefit the species critical.

Table 4. Stages and steps in the process of eliciting benefits of alternative offset actions, and associated costs, for night parrots.

Stage and step	Process and rationale	Decision
Stage 2.1 Logistics and project management	This was the first test case and so we sought a full team for project support with complementary expertise in benefit and cost elicitation.	The roles of problem owner, facilitator, and analyst were shared among the project team which included ME, JW, MM, TN and SS.
Stage 2.2 Survey and question design		
Step 1. Literature review	The project team compiled the available literature (including unpublished reports) on the night parrot. Note: for this elicitation, we added a step of making the relevant literature available to participating experts in a shared online library.	This information was used to determine the threats and possible offset actions for malleefowl (Section 2.2).
Step 2. Recruit key informants	We sought two key informants who had familiarity with both the ecology of the species and with the expert network that we would need to tap into.	We worked with 2 members of the Night Parrot Recovery Team who have been involved in research on the species since 2013-14.
Step 3. Identify management actions	The key informants helped develop a list of common management actions thought to assist in the conservation of the night parrot.	Management action scenarios included in the survey (individually, and in different combinations) included: • Protect habitat • Control of cats • Control of foxes • Fire management • Control of cats + control of foxes + fire management • Protect habitat + control cats + control foxes + fire management • Restoration of habitat • Restoration of habitat + control cats + control foxes + fire management

Stage and step	Process and rationale	Decision
Step 4. Identify suitable benefit indicator	Night parrots occur at very low densities, are cryptic and elusive, so surveying for the birds directly provides imprecise estimates. They may also be detected fleetingly in a location they do not occupy on an ongoing basis. Night parrots have specific roost sites in *Triodia* hummocks (Murphy et al., 2017). These sites include a horizontal tunnel (25cm long) constructed of leaves (Murphy et al., 2017). Occupancy is readily detected when birds emerge in the evenings. An occupied roost site is currently the most reliable indication of night parrot presence suitable for use as a benefit indicator.	The benefit indicator for night parrot was: *Number of long term stable night parrot roost sites per site.* A "long term stable roost site" is one in which night parrots have been recorded consistently at the same location for 2 years.
Step 5. Decide upon time horizon	The time horizon was chosen to align with that typically used in the EPBC Act offsets assessment guide.	20 years
Step 6. Describe hypothetical offset sites	Night parrots formerly occurred over a wide area in Australia's interior. They have been found in western Queensland and in Western Australia. The most likely options for offset sites are on existing habitat, or on degraded pastoral land.	The two hypothetical offset sites were: 1. Existing night parrot habitat 2. Degraded, potential night parrot habitat. Description of existing night parrot habitat: *We would like you to think of a site which contains night parrot habitat. The site is a large cattle property which has had low grazing pressure, minimal human disturbance, and is roughly 100,000 ha in size. In 2018, acoustic monitoring recorded night parrots calling at two long term stable roost sites.* Description of degraded, potential night parrot habitat: *We would like you to think of a site which is currently degraded pastoral land. The site has been intensively grazed and is burnt regularly (so very little unburnt spinifex remains) but is adjacent to occupied night parrot habitat. The degraded site has the appropriate matrix of both spinifex and floodplain herb field vegetation and may be suitable for night parrots is rehabilitated. In 2018 there were 0 long term stable night parrot roost sites onsite.*

Stage and step	Process and rationale	Decision
Step 7. Describe the counterfactual scenario	The counterfactual scenario is the "do nothing" or "business as usual" option for the hypothetical offset site for night parrots	The counterfactual scenario for existing night parrot habitat: *How many long term stable night parrot roost sites will be present at the site in 20 years, excluding any additional impacts from mining, agriculture, urban development that may occur over the next 20 years?* The counterfactual scenario for degraded habitat: *How many long term stable night parrot roost sites will be present at a site containing degraded pasture land in 20 years, excluding any additional impacts from mining, agriculture, urban development that may occur over the next 20 years?*
Step 8. Describe the offset action scenarios	The offset action scenarios relate to the implementation of different management actions (or combinations of actions) for night parrots (conservation covenant, cat/fox control, fire management) at the hypothetical site.	For each offset action scenario for existing night parrot habitat, the general text was included: *Recall the site from Question X, which contains night parrot habitat and two long term stable roost sites in 2018.* The different offset actions for night parrot habitat were described as follows: Protect existing habitat: *In 2018, the site is protected as a nature reserve. General fencing, grazing management and habitat maintenance will occur as part of the nature refuge designation and dingo persecution will be minimised. No night parrot-specific management actions will be implemented.* Cat control: *In 2018, an effective cat control program is implemented across the entire site, and is continued for 20 years. Cats will be predominantly controlled through shooting and trapping, supported by seasonal baiting when necessary. No other night parrot specific management actions are implemented.* Fox control: *In 2018, and effective fox control program is implemented across the entire site and is continued for 20 years. Foxes will be predominantly controlled using aerial and ground distributed baiting. No other night parrot specific management actions are implemented.* Fire management: *In 2018, a fire management program is implemented on site to prevent large scale fires and encourage a variety of habitat ages that include long unburn spinifex patches and is continued for 20 years. A spatial management approach of patchwork burning is used to prevent large scale fires and promote older habitat ages. No other night parrot specific management actions are implemented.* For each Offset action scenario for degraded habitat, the general text was included: *Recall the site from Question X, which contains degraded pasture land and zero long term stable roost sites in 2018.*

Stage and step	Process and rationale	Decision
Step 8. Describe the offset action scenarios CONTINUED	The offset action scenarios relate to the implementation of different management actions (or combinations of actions) for night parrots (conservation covenant, cat/fox control, fire management) at the hypothetical site.	The different offset actions for degraded, potential night parrot habitat were as follows: Restore degraded land: *In 2018, grazing and regular burning will cease, and the site will be allowed to recover. Dingo persecution will be minimised but no other night parrot specific management actions are implemented.* Restore degraded land + combined fire management, cat and fox control: *In 2018, grazing and regular burning will cease, and the site will be allowed to recover. Dingo persecution will be minimised but no other night parrot specific management actions are implemented.* *In addition, a combined fire (to reduce large scale fires) and effective cat and fox management program is implemented across the entire site and is continued for 20 years. No other night parrot specific management actions are implemented.*
Stage 2.3 Recruit the experts	We undertook recruitment of experts using a targeted approach, largely comprised of recommendations from our key informants. We contacted 23 people and 12 experts accepted the invitation to participate.	Of the 12 experts who accepted the invitation to participate, 12 experts completed Round 1, and 11 experts completed both rounds of elicitation surveys. As outlined in the protocol, results from experts who dropped out following Round 1 were excluded from the final aggregation (Hemming et al., 2017).
Stage 2.4 Conduct the elicitation		
Step 1. Hold an inception meeting	As the participants were widely geographically distributed, an in-person workshop was not considered the most efficient approach, given the short period of discussion required.	We held an inception meeting via video conference over a period of 1 hour, allowing for explanation of the process and discussion of the questions.
Step 2. Conduct Round 1 Elicitation	We circulated the survey (via email) to 12 experts, together with instructions.	12 experts returned their estimates, and each provided responses to each question.
Step 3. Complete analysis and data aggregation	The project team analyst completed the data analysis and data aggregation for Round 1. The results of Round 1 were sent to the experts.	The aggregate results showed general agreement about the relative benefit of the different actions, but wide uncertainty about the outcomes of each scenario.

Stage and step	Process and rationale	Decision
Step 4. Conduct the group discussion	Again, it was considered more efficient to conduct the discussion via teleconference rather than in person.	We held a facilitated group discussion (via video conference). This included discussion about the efficacy of different cat management techniques. Following the discussion, we amended the survey text to include an additional two management actions for existing night parrot habitat: Cat control (Indigenous hunting, and Felixer groom traps): *In 2019, a cat control program is implemented across the entire site and is continued for 20 years. Cats will be controlled though expert Indigenous hunters tracking and removing the cats, as well as strategic placement and maintenance of Felixer cat control devices. The control program is as effective as likely to be achieved with best-practice implementation for these methods.* Protected area + combined fire management + cat and fox control: *In 2019, the site is designated as a protected area. General grazing management will occur as part of the protected areas designation, erecting new fencing, removing redundant internal fencing and stock exclusion. Dingo persecution will be minimised.* *In 2019, a combined fire management (tailored for night parrot, to reduce large scale fires and encourage a variety of habitat ages that include long unburnt spinifex patches) and a cat and fox management program is implemented across the entire site and is continued for 20 years. Cats will be predominantly controlled through shooting and trapping, supported with seasonal baiting when necessary. Foxes will predominantly controlled through shooting and trapping, supported with seasonal baiting.*
Step 5. Conduct Round 2 Elicitation	We circulated Round 2 surveys (via email).	11 experts completed the second round of estimates.
Step 6. Documentation and reporting		The project team analyst completed the data analysis and data aggregation for Round 2, and results were sent to the experts for review and 'sign off'. All experts were comfortable that the results reflected their beliefs.
Stage 2.5 Summarise estimated benefits	The average 'best guess' across the group of experts for each offset action scenario was compared with the counterfactual scenario. The difference between these two estimates was the estimated benefit from the offset action scenario. This allowed ranking and comparison of the likely benefit of different actions in terms of the number of additional long term stable night parrot roosts attributable to each action (or combination of actions)	The final results following the second round had reduced uncertainty bounds. The ranking of the actions in terms of the size of the benefit expected did not change. For the existing night parrot habitat, the greatest benefit was expected from the combination of protection of habitat, cat management, fox management and fire management (5.5 additional long term, stable night parrot roosts compared with the counterfactual) and the smallest from control of foxes (0.6 additional long term night parrot roosts compared with the counterfactual).

Stage and step	Process and rationale	Decision
Stage 3.0 Estimating the costs of offset actions	We compiled the costs of different management actions for night parrots, obtaining information from relevant experts.	We obtained costs data for the management actions considered in the expert elicitation to inform offsets for night parrot (establishment of a protected area, standard cat management, intensive cat management, fox management, and fire management). We attempted to include costs associated with an Indigenous Land Use Agreement (ILUA), required for the establishment of a protected area on Indigenous lands, however experts were unable to provide cost data for this type of reserve. We were also unable to include accurate opportunity costs (i.e. lost profits) of converting land from a pastoral property to a reserve.
Stage 3.1 Specify detailed tasks within each action	For each management action, we specified the detailed tasks involved (e.g. for establishment of a protected area, this included the costs of establishing a ranger base/research facility, equipment, staffing).	For each management action, the project team made an initial attempt to break each of these into individual items and tasks.
Stage 3.2 Estimate costs of each action	We collected costs data through interviews with individual experts, from literature and from other relevant experts. We collected itemised costs for labour, consumables, capital assets, equipment, overheads, monitoring, coordination and planning.	The night parrot was only re-discovered recently; there is limited information available on the costs associated with parrot-specific management actions. For this elicitation, we sought information from government, non-government conservation and Indigenous organisations involved in night parrot work undertaken to date. We filled in gaps with information from generic management programs, e.g. for ecological fire management and standard baiting programs for cat control. We recorded all cost data in a spreadsheet.
Stage 3.3 Compile the costs across multiple experts and verify assumptions	We compiled the costs from multiple sources into the appropriate cells in the spreadsheet, recording why some cost estimates were/were not included.	We compiled cost data and assumptions for night parrot in the template spreadsheet (see Appendix 2).
Stage 3.4 Calculate total costs per action	We tallied the sum of itemised costs from each cost category for each year of the offset time horizon in Australia (20 years) (for full details, see section 3.5).	The summary spreadsheet contains formulas to compile start-up costs, annual costs, total cost of action based on the length of intervention (20 years), the present value and average annual present value.
Stage 3.5 Estimate cost-effectiveness to inform offsets	We assessed the cost-effectiveness of offset actions for night parrots by dividing the costs by the benefits, to calculate the cost per parrot for each action.	We used a separate spreadsheet to assess the cost-effectiveness of offset actions for the night parrot, by dividing the total costs of a management action over 20 years, by the benefit of the conservation action.

Section 5. Implications and caveats

Biodiversity offsets must only occur after all previous steps in the mitigation hierarchy have been considered. The design of better biodiversity offsets for threatened species will remain an ongoing challenge for policy makers, particularly for species where the relative contribution of key threats are poorly known, or for which limited quality habitat remains. A well-designed biodiversity offset is one that is based the principles of the IUCN policy, and incorporates:

- Current ecological knowledge (action plans, recovery plans, management plans, peer reviewed literature, where available) and
- Full consideration of cumulative impacts (geographically and over time).

Expert elicitation is not a perfect tool or solution for addressing issues with biodiversity offsets in Australia. This approach does not replace the urgent need to undertake empirical studies to improve management. However, when a decision is required despite scarce information, it can be a useful tool to underpin a 'best guess' of how a species may respond to alternative offset actions. It is designed to be an improvement on unstructured, single-expert estimates of offset benefit, which can be subject to strong bias.

Using a structured decision making process such as the IDEA protocol improves the quality of expert judgements by drawing upon the knowledge of experts, and mitigating against the most pervasive sources of bias (Hemming et al., 2017). However, the reliability of expert judgement will always depend on which experts participate and how questions were asked (Hemming et al., 2017).

A key challenge for threatened species conservation is assessing the relative importance of the various threats to species and ecosystems, and consequently identifying the actions that will most effectively conserve those species and ecosystems (Hauser et al., 2019). There is typically significant uncertainty about the relative level of different threatening processes, and which conservation actions will be most beneficial for different species, for recovery planning, management and in the design of biodiversity offset programs. Our case studies revealed very wide credible intervals around estimates of most management actions, demonstrating that the uncertainty associated with offset actions is likely to be very high.

The process proposed herein is very simplified, with elicitation relating to a site at a particular scale. This can be used to estimate a per unit area/per unit effort response (for example), but careful judgement is required when extrapolating this estimate to larger or smaller areas or management efforts.

Undertaking a costs elicitation in conjunction with the use of expert elicitation to derive information of the benefits of different management actions is often worthwhile. We found that there was a high degree of variation of costs; for many actions, we were unable to develop upper and lower estimates of costs reliably. The main source of uncertainty was determining the most appropriate way of implementing an action for the hypothetical scenarios. The scenarios were made vague intentionally to be able to capture variation in possible offset sites across a species range, but this lead to uncertainty about the specific details of how an action would be best implemented (which often depends on habitat condition, topography, local policies/regulations, etc), which in turn made it difficult to estimate accurate costs.

In some cases, decision making on biodiversity offsetting may be made on the basis of perceived benefits to biodiversity, or cost-effectiveness. A costs elicitation can be undertaken with a small amount of additional effort (for example, through a half-day workshop, or through remote elicitation with a subset of experts involved in benefits elicitation) to complement discussions about offset benefits. For some management actions, it may be necessary to contact subject matter experts about costs (for example, on ex-situ cane toad aversion training for northern quolls, and captive breeding costs for target threatened species).

The methods we present here are relatively quick, inexpensive and repeatable ways to capture the current and best available knowledge to inform decision making on biodiversity offsets. They can have an important role in the development of biodiversity offsets that have better conservation outcomes for threatened species.

Glossary

Averted loss: the estimated amount of expected future loss that is prevented due to the protection and maintenance of habitat.

Averted loss offsets: secure the protection of a proposed offset site that is currently unprotected and would remain unprotected if it were not for the offset, to prevent its loss in the future. Protection is generally achieved by a change in tenure.

Benefit indicator: A measure of the kind of benefit a management action could deliver for a species. The benefit indicator should be something that can be measured at the site level, it can easily be monitored using standard survey methods, and that is highly likely to relate to the viability of the species or ecological community.

Biodiversity offset: a conservation tool that is designed to counterbalance losses in biodiversity in one place due to development with equivalent benefits to biodiversity elsewhere.

Business as usual: Often abbreviated BAU, this is another name for the counterfactual scenario – the scenario under which the offset-related management actions do not occur.

Controlled action: a proposed action that is likely to have a significant impact on a matter of national environmental significance, such as a threatened species or threatened ecological community

Counterfactual scenario: the scenario (e.g. a biodiversity trajectory) expected to occur in the absence of some defined action or set of actions (such as an impact and an offset), also known as 'business as usual' 'do nothing' or 'baseline'

the IDEA protocol: the 'Investigate-Discuss-Estimate-Aggregate' (IDEA) protocol, in which a structured expert elicitation process is used to inform science

Maintenance offset: offsets involving threat abatement activities. The maintenance benefit is the difference between the likely condition of the habitat if the threat abatement activity was not undertaken, and the current condition of the site, which will be maintained.

Offset metric: type of units used in offsets calculations (eg counts or habitat index). Different metrics (also known as currencies) are suitable for use in calculations of impacts and benefits (losses and gains) for different species-for some, area x habitat condition indices are suitable proxies for benefit to a species; for others, population size or density may be a more appropriate and direct way to measure losses and gains.

Offset mechanism: the enabling legal or financial means by which some biodiversity offsets are specified in condition of development approval, such as a management plan, monetary contribution, or intention to protect/purchase land.

Mitigation hierarchy: The process by which environmental impacts from development are avoided, unavoidable impacts are then minimised, and residual impacts are then offset.

No Net Loss: an outcome in which the total amount of some target biodiversity does not decline below the level expected under some counterfactual (or without offset) scenario.

Restoration offset: offsets focused on improving the quality of habitat or an ecological community, such as by planting native habitat species at a degraded site. The enhancement benefit is the difference between the current and future condition of the vegetation for habitat.

Appendix 1: Benefits survey template (malleefowl)

Scenario One: Malleefowl habitat

The following seven (7) questions will ask you to estimate how malleefowl may respond to a range of management scenarios.

We would like you to think of a site which contains malleefowl habitat. In 2018, there were 5 active mounds on site. A number of potential threats to malleefowl exist on the site, including fox predation, vehicle strikes, impacts from herbivores and inappropriate fire regimes.

There are of course a number of ways in which malleefowl responses to management may vary, so there is always uncertainty. For the sake of this survey, we want you draw on your experience and knowledge and have a go at every question.

If you wish, you can briefly describe a site containing malleefowl habitat that you are familiar with here, to help ground your answers (e.g approximate location and size):

For the management scenarios we provide, we want you to assume 'best practice' management.

You have space at the end of every question to add any comments you wish to make, which will be shared with the group for discussion before Round 2 of the survey.

Box A1: Worked example of four-step question format

i Realistically, what do you think the **lowest** plausible number of **active** malleefowl mounds will be in 20 years?

ii Realistically, what do you think the **highest** plausible number of **active** malleefowl mounds will be in 20 years?

iii Realistically, what is your **best guess** for the number of **active** mounds in 20 years?

iv **How confident are you** that your interval, from lowest to highest, could capture the number of **active** mounds? Please enter a number between 50 and 100% %

Please enter any comments, additional knowledge or justification that you have about the question and/or your estimate. This will be shared with the group in Round 2.

Question 1: Counterfactual scenario, malleefowl habitat

Background:

For this question, we would like you to think of a site which contains malleefowl habitat. In 2018 there were 5 active mounds on site. Assume the existing site and regional pressures (e.g fox predation, vehicle strikes, impacts from herbivores and typical fire regimes) remain in place, as does the current land use.

We want you to **ignore** the possibility of any **additional** human development (mining, infrastructure, large-scale agriculture) requiring approval under the *EPBC Act 1999* that may occur in the site vicinity over the next 20 years.

For reference, an "active mound" is one which is likely have been used as an incubator in October.

Assume that it will be an **average, non-drought year** in 20 years.

Question:

How many **active** malleefowl mounds will be present at a site containing malleefowl habitat in 20 years, **excluding any additional impacts from mining, agriculture, road or urban development that may occur over the next 20 years?**

Question 2: Protect existing habitat

Background:

Recall the site from Question 1, which contains malleefowl habitat and 5 active mounds in 2018. Assume the existing site and regional pressures (e.g fox predation, vehicle strikes, impacts from herbivores and typical fire regimes) remain in place.

In 2018, the site is placed under **a permanent conservation covenant**. General weed control and habitat maintenance will occur as part of the covenant, but no malleefowl-specific management actions will be implemented.

We want you to **ignore** the possibility of any **additional** human development (mining, infrastructure, large-scale agriculture) requiring approval under the *EPBC Act 1999* that may occur in the site vicinity over the next 20 years.

For reference, an "active mound" is one which is likely have been used as an incubator in October.

Assume that it will be an **average, non-drought year** in 20 years.

Question:

Assuming the site is placed under a permanent conservation covenant, how many **active** malleefowl mounds will be present at a site containing malleefowl habitat in 20 years, **excluding any additional impacts from mining, agriculture, road or urban development that may occur over the next 20 years?**

Question 3: Protect existing habitat + captive breeding

Background:

Recall the site from Question 1, which contains malleefowl habitat and 5 active mounds in 2018. Assume the existing site and regional pressures (e.g fox predation, vehicle strikes, impacts from herbivores and typical fire regimes) remain in place.

In 2018, the site is placed under **a permanent conservation covenant** in 2018. General weed control and habitat maintenance will occur as part of the covenant, but no malleefowl-specific management actions will be implemented.

In 2018, 10 young adult malleefowl raised from a captive breeding program (5 male, 5 female) are introduced to the site.

We want you to **ignore** the possibility of any **additional** human development (mining, infrastructure, large-scale agriculture) requiring approval under the *EPBC Act 1999* that may occur in the site vicinity over the next 20 years.

For reference, an "active mound" is one which is likely have been used as an incubator in October.

Assume that it will be an **average, non-drought year** in 20 years.

Question:

Assuming the site is placed under a permanent conservation covenant and 10 young adult malleefowl (5 male, 5 female) are introduced to the site, how many **active** malleefowl mounds will be present at a site containing malleefowl habitat in 20 years, **excluding any additional impacts from mining, agriculture, road or urban development that may occur over the next 20 years?**

Question 4: Fox control

Background:

Recall the site from Question 1, which contains malleefowl habitat and 5 active mounds in 2018. Assume the existing site and regional pressures (e.g fox predation, vehicle strikes, impacts from herbivores and typical fire regimes) remain in place.

In 2018, **a standard fox control program is implemented on site and is continued for 20 years**. No other malleefowl-specific management actions are implemented.

We want you to **ignore** the possibility of any **additional** human development (mining, infrastructure, large-scale agriculture) requiring approval under the *EPBC Act 1999* that may occur in the site vicinity over the next 20 years.

For reference, an "active mound" is one which is likely have been used as an incubator in October.

Assume that it will be an **average, non-drought year** in 20 years.

Question:

Assuming a standard fox control program is implemented on site and is continued for 20 years, how many **active** malleefowl mounds will be present at a site containing malleefowl habitat in 20 years, **excluding any additional impacts from mining, agriculture, road or urban development that may occur over the next 20 years?**

Question 5: Herbivore control

Background:

Recall the site from Question 1, which contains malleefowl habitat and 5 active mounds in 2018. Assume the existing site and regional pressures (e.g fox predation, vehicle strikes, impacts from herbivores and typical fire regimes) remain in place.

In 2018, **a standard herbivore control program (i.e, removal of goats and sheep) is implemented on site and continued for 20 years.** No other malleefowl-specific management actions are implemented.

We want you to **ignore** the possibility of any **additional** human development (mining, infrastructure, large-scale agriculture) requiring approval under the *EPBC Act 1999* that may occur in the site vicinity over the next 20 years.

For reference, an "active mound" is one which is likely have been used as an incubator in October.

Assume that it will be an **average, non-drought year** in 20 years.

Question:

Assuming a standard herbivore control program is implemented on site and is continued for 20 years, how many **active** malleefowl mounds will be present at a site containing malleefowl habitat in 20 years, **excluding any additional impacts from mining, agriculture, road or urban development that may occur over the next 20 years?**

Question 6: Fire management

Recall the site from Question 1, which contains malleefowl habitat and 5 active mounds in 2018. Assume the existing site and regional pressures (e.g fox predation, vehicle strikes, impacts from herbivores and typical fire regimes) remain in place.

In 2018, **a fire management program is implemented on site and is continued for 20 years.** No other malleefowl-specific management actions are implemented.

We want you to **ignore** the possibility of any **additional** human development (mining, infrastructure, large-scale agriculture) requiring approval under the *EPBC Act 1999* that may occur in the site vicinity over the next 20 years.

For reference, an "active mound" is one which is likely have been used as an incubator in October.

Assume that it will be an **average, non-drought year** in 20 years.

Question:

Assuming a fire management program is implemented on site and is continued for 20 years, how many **active** malleefowl mounds will be present at a site containing malleefowl habitat in 20 years, **excluding any additional impacts from mining, agriculture, road or urban development that may occur over the next 20 years?**

Question 7: Combined fire, herbivore and fox control.

Recall the site from Question 1, which contains malleefowl habitat and 5 active mounds in 2018. Assume the existing site and regional pressures (e.g fox predation, vehicle strikes, impacts from herbivores and typical fire regimes) remain in place.

In 2018, **a combined fire, herbivore (i.e, removal of goats and sheep) and fox management program is implemented on site and is continued for 20 years.** No other malleefowl-specific management actions are implemented.

We want you to **ignore** the possibility of any **additional** human development (mining, infrastructure, large-scale agriculture) requiring approval under the *EPBC Act 1999* that may occur in the site vicinity over the next 20 years.

For reference, an "active mound" is one which is likely have been used as an incubator in October.

Assume that it will be an **average, non-drought year** in 20 years.

Question:

Assuming a combined fire, herbivore and fox management program is implemented on site and is continued for 20 years, how many **active** malleefowl mounds will be present at a site containing malleefowl habitat in 20 years, **excluding any additional impacts from mining, agriculture, road or urban development that may occur over the next 20 years?**

Question 8: Combined fire, herbivore and fox control + captive breeding

Background

Recall the site from Question 1, which contains malleefowl habitat and 5 active mounds in 2018. Assume the existing site and regional pressures (e.g fox predation, vehicle strikes, impacts from herbivores and typical fire regimes) remain in place.

In 2018, **a combined fire, herbivore (i.e, removal of goats and sheep) and fox management program is implemented on site and is continued for 20 years**.

In 2018, 10 young adult malleefowl raised from a captive breeding program (5 male, 5 female) are introduced to the site.

We want you to **ignore** the possibility of any **additional** human development (mining, infrastructure, large-scale agriculture) requiring approval under the EPBC Act 1999 that may occur in the site vicinity over the next 20 years.

For reference, an "active mound" is one which is likely have been used as an incubator in October.

Assume that it will be an **average, non-drought year** in 20 years.

Question:

Assuming a combined fire, herbivore and fox management program is implemented on site and is continued for 20 years, and 10 young adult malleefowl (5 male, 5 female) are introduced to the site, how many **active** malleefowl mounds will be present at a site containing malleefowl habitat in 20 years, **excluding any additional impacts from mining, agriculture, road or urban development that may occur over the next 20 years?**

Scenario Two: Degraded cropping land

The following three (3) questions will ask you to estimate how malleefowl may respond to a range of management scenarios.

We would like you to think of a site which is currently degraded cropping land. The site was completely cleared 50 years ago, and is adjacent to malleefowl habitat. In 2018 there were 0 active mounds on site. A number of potential threats to malleefowl exist on the site, including fox predation, vehicle strikes, impacts from herbivores and inappropriate fire regimes.

There are of course a number of ways in which malleefowl responses to management may vary, so there is always uncertainty. For the sake of this survey, we want you draw on your experience and knowledge and have a go at every question.

If you wish, you can briefly describe a site which is currently degraded cropping land that you are familiar with here, to help ground your answers (e.g approximate location and size):

For the management scenarios we provide, we want you to assume 'best practice' management.

You have space at the end of every question to add any comments you wish to make, which will be shared with the group for discussion before Round 2 of the survey.

Question 9: Counterfactual scenario, degraded cropping land

Background:

For this question, we would like you to think of a site which is currently degraded cropping land. The site was completely cleared 50 years ago, and is adjacent to malleefowl habitat. In 2018 there were 0 active mounds on site. Assume the existing site and regional pressures (e.g fox predation, vehicle strikes, impacts from herbivores and typical fire regimes) remain in place, and **cropping continues for the next 20 years**.

We want you to **ignore** the possibility of any **additional** human development (mining, infrastructure, large-scale agriculture) requiring approval under the *EPBC Act 1999* that may occur in the site vicinity over the next 20 years.

For reference, an "active mound" is one which is likely have been used as an incubator in October.

Assume that it will be an **average, non-drought year** in 20 years.

Question:

How many active malleefowl mounds will be present at a site containing degraded cropping land in in 20 years, excluding any additional impacts from mining, agriculture, road or urban development over the next 20 years?

Question 10: Restore degraded farmland

Background

Recall the site from Question 9, which contains degraded cropping land and zero active mounds in 2018. Assume the existing site and regional pressures (e.g fox predation, vehicle strikes, impacts from herbivores and typical fire regimes) remain in place.

In 2018 **cropping will cease**, and the site will be allowed to restore to its original habitat. No other malleefowl-specific management actions are implemented.

We want you to **ignore** the possibility of any **additional** human development (mining, infrastructure, large-scale agriculture) requiring approval under the EPBC Act 1999 that may occur in the site vicinity over the next 20 years.

For reference, an "active mound" is one which is likely have been used as an incubator in October.

Assume that it will be an **average, non-drought year** in 20 years.

Question:

Assuming this site is allowed to restore to its original habitat, how many **active** malleefowl mounds would be present in 20 years, **excluding any impacts from mining, road or urban development over the next 20 years?**

Question 11: Restore degraded farmland + combined fire, herbivore and fox control

Background

Recall the site from Question 9, which contains degraded cropping land and zero active mounds in 2018. Assume the existing site and regional pressures (e.g fox predation, vehicle strikes, impacts from herbivores and typical fire regimes) remain in place.

In 2018 **cropping will cease**, and the site will be allowed to restore to its original habitat.

In 2018, **a combined fire, herbivore (i.e, removal of goats and sheep) and fox management program is implemented on site and is continued for 20 years**.

We want you to **ignore** the possibility of any **additional** human development (mining, infrastructure, large-scale agriculture) requiring approval under the EPBC Act 1999 that may occur in the site vicinity over the next 20 years.

For reference, an "active mound" is one which is likely have been used as an incubator in October.

Assume that it will be an **average, non-drought year** in 20 years.

Question:

Assuming this site is allowed to restore to its original habitat, and a combined fire, herbivore and fox management program is implemented on site and is continued for 20 years, how many **active** malleefowl mounds would be present in 20 years, **excluding any impacts from mining, road or urban development over the next 20 years?**

Appendix 2: Costs survey template

The costs survey template can be found at: https://www.nespthreatenedspecies.edu.au/publications-and-tools/estimating-the-costs-of-offset-actions-spreadsheet

Project name: Biodiversity offsets for threatened species x

Area of land (ha)	100000
Currency	AUD
Date of present value calculations	Jan-19
Discount rate (%)	5%
Unknown Min/Max Variation	20%
Min, Max or Estimate?	Estimate

Specify the area of management and discount rate here, and they will be automatically copied to Strategy spreadsheets, to faciliate modifications of these variables.

Select 'Min', 'Max', or 'Estimate' from the drop-down to get a summary of the summary of each cost value.

Cells in pale yellow are the cells to fill in.

Strategy	**Total cost (NPV)**	**Average Annual Present Value (AAPV)**
Number of years	**20**	**20**
Example	$ 88,571.43	$ 4,428.57
Strategy 1	$ -	$ -
Strategy 2	$ -	$ -
Strategy 3	$ -	$ -

Figure 11: Screenshot of Excel spreadsheet used for collection of cost data, with a worked example for large herbivore management

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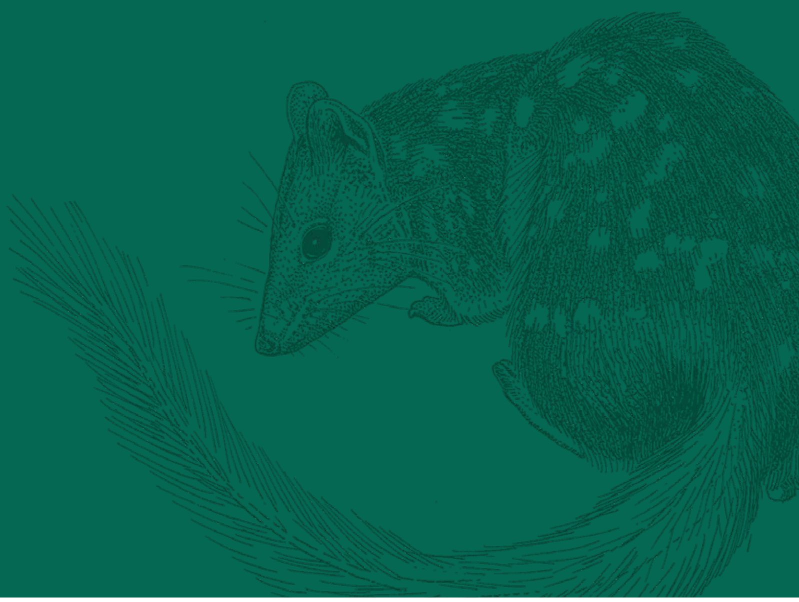
Night parrot. Image: Steve Murphy

Further information:

http://www.nespthreatenedspecies.edu.au



This project is supported through funding from the
Australian Government's National Environmental Science Program.

Threatened Species Recovery Hub

National Environmental Science Programme

Cite this publication as: Maron, M., Evans, M.C., Nou, T., Stone, Z.L., Spillias, S., Mayfield, H.J., Walsh, J. 2021. Guidance for estimating biodiversity offset benefits and costs using expert elicitation. NESP Threatened Species Recovery Hub Project 5.1 report.