Threatened Species Recovery Hub

National **Environmental Science** Programme

A user guide to the PACES tool: Planning and Assessment for Conservation through Ex-Situ management

The University of Queensland Australia · The University of Western Australia · The University of Melbourne · Queensland Government · Government of Western Australia Department of Biodiversity, Conservation and Attractions · Biodiversity and Conservation Science

How-to guide – A user guide to the PACES tool: Planning and Assessment for Conservation through Ex-Situ management

Cover image: Numbat. Image: dilettantiquity, FlickrCC2-0, PerthZoo

Table of contents

Background

Ex-situ (literally, "off-site") conservation management of a threatened species of plant or animal involves taking and maintaining the species away from its natural setting, ideally in an environment which is free of the threats that are impacting the species in its original location.

Ex-situ actions can increase the long-term persistence of a species in the wild by supplementing or creating new wild populations. Botanical gardens and zoos, for example, house individuals and populations of plants and animals for captive breeding, and reintroduce them to the wild, when necessary and possible.

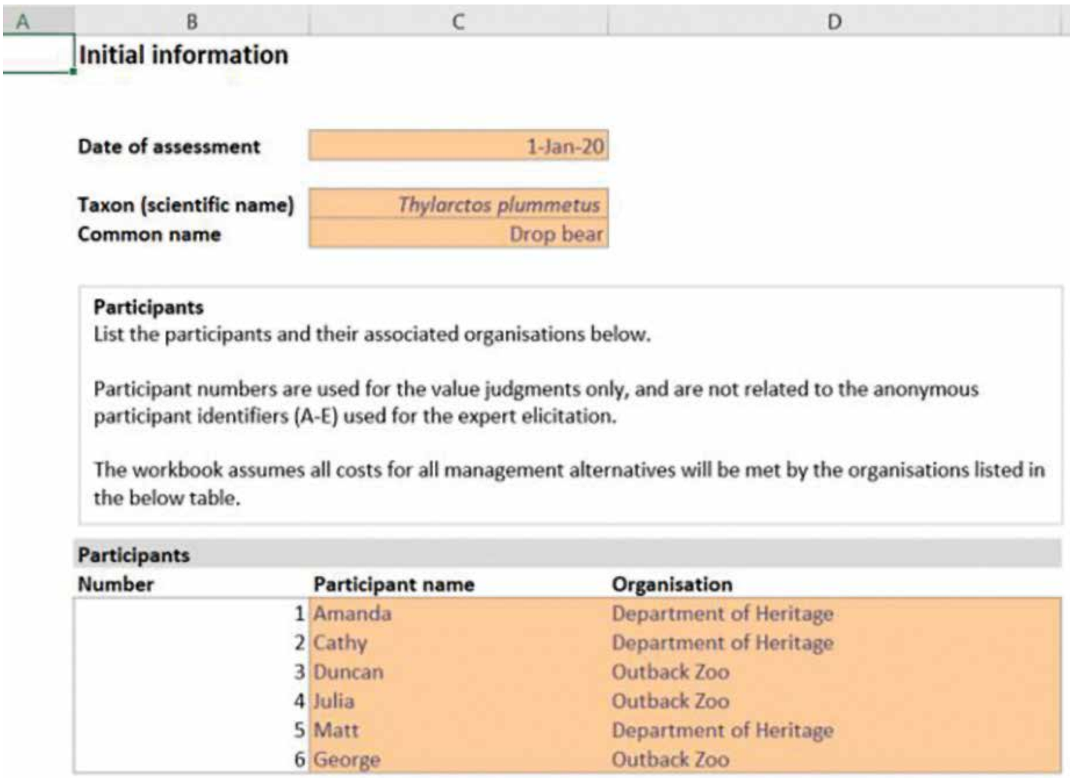
As with any management intervention, there is a chance that ex-situ management will fail to produce the desired conservation outcomes. Also, there is a risk that sourcing individuals from wild populations could decrease their viability in the short term. These factors must be considered when evaluating whether an ex-situ management plan is the best strategy for conserving a species in the wild over the long term.

To address this challenge, we have created an Excel-based ex-situ decision tool that provides support for decisions about whether or not to initiate or continue an ex-situ management plan for a species. It can be used in workshop settings with a group of managers and/or experts using expert knowledge to make predictions about likely conservation outcomes, or it can be stepped through by an individual decision-maker to gain clarity around a decision or to document the reasoning underpinning a decision. You can use expert knowledge, data or model outputs within the tool, according to their availability to you.

The PACES tool allows you to define and compare three management alternatives:

1. An **in-situ "status quo" plan**. This is the set of in-situ management actions currently being undertaken, or the actions proposed to be taken from now into the future.
2. An **ex-situ management plan**. By default, this includes the in-situ actions identified in Alternative 1.
3. An **"in-situ plus" management plan**. This is a hypothetical scenario where the resources that would be needed for ex-situ management are instead allocated to increase resourcing for in-situ actions. (In our experience, many decision-makers have found this a useful thought exercise and analysis.)

In addition to these three management alternatives, we ask for predictions of species outcomes if all current management were to be removed, that is, a fourth "do nothing" scenario. This allows decision-makers to see the predicted benefit of all management alternatives over a scenario of no intervention.



Initial information

Date of assessment	1-Jan-20
Taxon (scientific name)	*Thylarctos plummetus*
Common name	Drop bear

Participants
List the participants and their associated organisations below.

Participant numbers are used for the value judgments only, and are not related to the anonymous participant identifiers (A-E) used for the expert elicitation.

The workbook assumes all costs for all management alternatives will be met by the organisations listed in the below table.

Participants

Number	Participant name	Organisation
1	Amanda	Department of Heritage
2	Cathy	Department of Heritage
3	Duncan	Outback Zoo
4	Julia	Outback Zoo
5	Matt	Department of Heritage
6	George	Outback Zoo

Figure 1. Partial screenshot of the initial information tab in the decision tool.

Before you get started

Although the tool is an Excel workbook, it requires only basic knowledge of Excel. The workbook is a simple one without macros, so it should be possible to use it in environments with security restrictions around installing and running software.

We have tested this tool primarily within a workshop setting, using expert knowledge to make predictions about likely conservation outcomes from the scenarios. These workshops require a facilitator to manage the process and enter data into the decision tool, and a group of up to six participants to define the alternatives and make predictions and judgments.

Facilitators will be advantaged in their role by some background knowledge of structured decision-making (SDM – see Figure 2 in the box below) and expert elicitation. Other than expert knowledge, you can also use the outputs of Population Viability Analyses (PVA). We have listed further reading on these topics at the end of this guide.

To evaluate whether ex-situ management will be a good option (and good value for money), the ex-situ management plan must first be clearly defined, so that it may offer a useful basis for comparison. You can prepare by answering or discussing the questions in the IUCN guidelines on ex-situ management (IUCN/SSC 2014), which we have reproduced in the tool under Tab S1 (Figure 9).

Structured decision making

Structured decision making (SDM) refers to the application of formal decision analysis tools to decisions in the realm of environmental management (Gregory et al. 2012). More loosely, SDM is a "formalisation of common sense for decision problems which are too complex for informal use of common sense" (Keeney 1982).

A wide range of decision analysis tools have been used to solve SDM problems, but underlying these is a common logical framework based on breaking a decision down into its component steps (Figure 2). The steps are: clarifying the decision context, defining the objectives of the decision-maker and how they will be measured, defining the alternatives available to the decision-maker, estimating the likely outcomes of each alternative, and evaluating trade-offs with the aim of identifying the alternative that will best achieve the objectives.

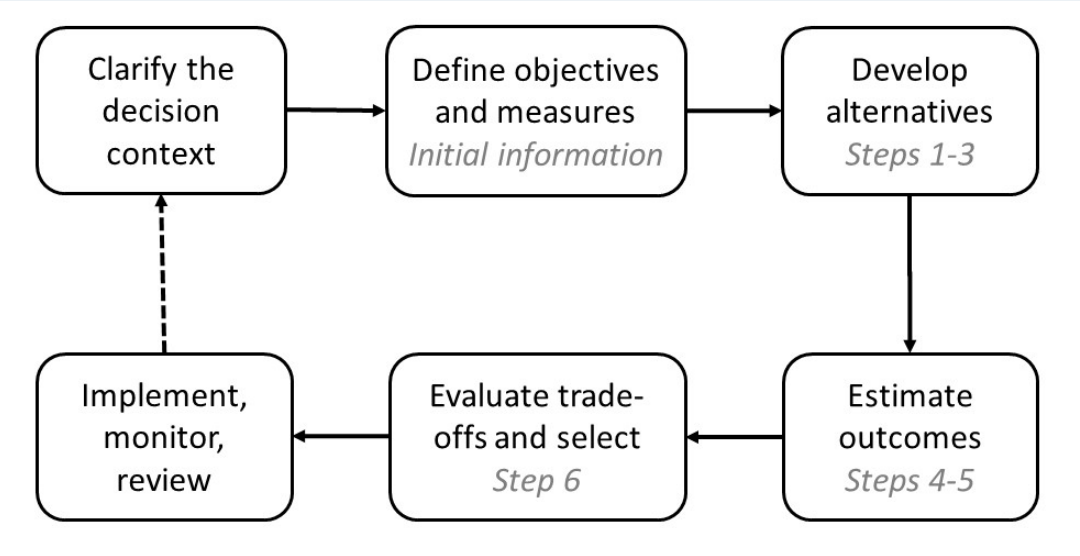


Figure 2. Steps involved in the SDM process (in black) and corresponding sections in the decision tool (in grey). Based on Gregory et al. (2012).

How you do it

Method at a glance

- Define objectives and choose your conservation payoff
- Enter initial information
- Define alternatives
- Estimate consequences
- Evaluate trade-offs

Introduction

The tool steps the user through defining and costing each management alternative, and then defining the pathways in a decision tree (see Figure 3). Decisions around ex-situ management can be difficult because the conservation benefits are often delayed, while the impact of removing individuals from their natural setting to found the ex-situ population is immediate. Decision trees are a useful method for dealing with such problems, and feature several steps that can determine an eventual outcome to a specific scenario.

When comparing in-situ and ex-situ management, the events that determine their eventual outcomes are:

- Whether the in-situ management plans can be implemented successfully
- Whether removing individuals for ex-situ management will have a material impact on the source population
- Whether ex-situ breeding will be successful
- Whether release back into the wild will be successful.

Ex situ program/captive breeding	
At what year of the program do you think successful breeding needs to be achieved?	2
What do you think is an appropriate threshold for describing offspring survivorship in the first year of successful breeding, expressed as months of survivorship?	11
At year 2 of the program, what percentage of offspring need to survive to 11 months to give the program some chance of success?	80
Notes on captive breeding program	An enclosure has been built near Drop Bear National Park and currently houses 3 individuals (2 adults, 1 pouch young) as part of the captive breeding trial. This facility could be expanded to house up to 20 individuals. Outback Zoo can house up to 10 individuals in an additional facility.

Outline | Quick guide | Initial information | 1. In-situ status quo plan | **2. Ex-situ plan** | 3. In-situ plus plan | 4. Expert elicitation | 4.1 Elicita

Figure 3. Partial screenshot showing the type of questions used to define the branches on the decision tree.

The decision-maker is able to view the predicted outcomes of each management alternative in terms of its benefit for species conservation in the wild (expressed as percentage change in relative population size in the wild or probability of persistence in the wild; see Figure 4). The tool also has capacity to elicit participants' subjective trade-offs between conservation outcomes and management costs, that is, their willingness to pay for the likely conservation outcomes of different management options.

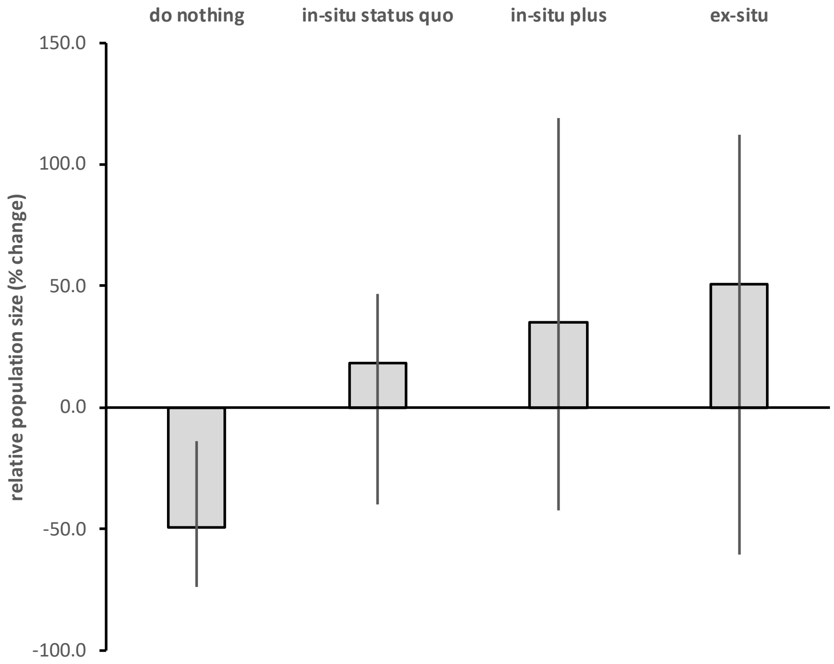


Figure 4. Example output from the decision tool: predicted relative population size (% change over a defined time period) under a "do nothing" alternative and three defined management alternatives. The bars represent best estimates while the lines represent 90% credible intervals.

Decision trees help to structure and analyse problems where the outcomes of a decision are determined by events that may be uncertain. They are recognised as a useful tool for many conservation problems, including decisions about ex-situ management and conservation introductions. We used a decision tree to frame the problem (Figure 5), as it can capture the gap between the initiation of ex-situ management and the realisation of its benefits, and the events along the way.

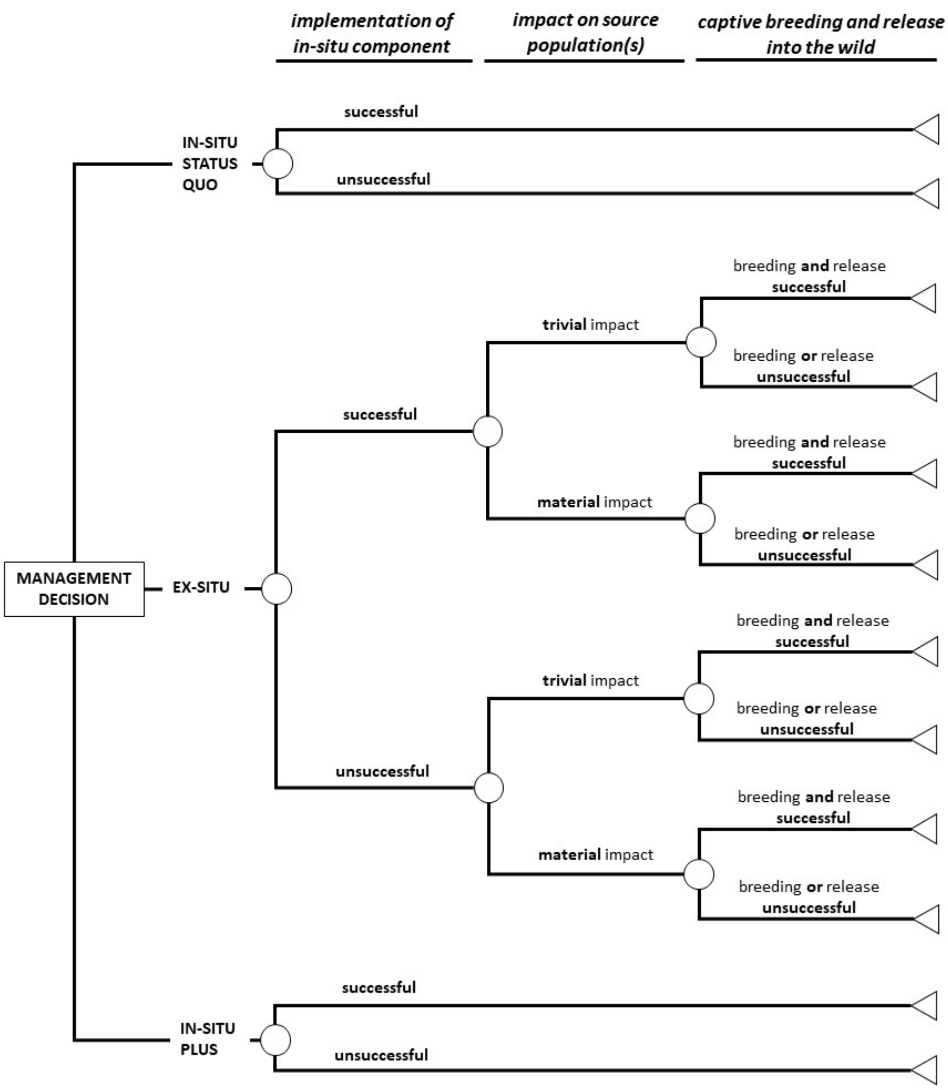


Figure 5. Decision tree for the three management alternatives: in-situ status quo, ex-situ, and in-situ plus. Events are represented by circles, and occur from left to right in the tree. Outcomes (also termed consequences) are represented by triangles. Event outcomes (e.g., successful, unsuccessful, trivial impact, material impact) are defined by the user.

Define objectives and choose your conservation pay-off

While the SDM process can accommodate many competing objectives, this decision tool considers two: the conservation outcomes for the species, and the cost of management.

Conservation outcomes can be difficult to measure in a way that applies to all species in all scenarios. To accommodate this, we have created two workbooks using different ways of measuring conservation pay-offs. These are:

- The relative change in population size in the wild over a defined time horizon
- The probability of species persistence in the wild over a defined time horizon.

Note that both pay-offs refer only to conservation of the species in the wild. While we note that ex-situ management has many types of conservation benefits, this decision tool is primarily concerned with species status in the wild.

The most suitable measure of conservation pay-off for a given problem will depend on individual circumstances – the life history of the species, the management decision being analysed, and the type of information available to you (expert elicitation or otherwise).

If you are going to use expert elicitation (whether individual or in a group workshop setting) to inform predictions of species outcomes, you will probably find the relative change in population size to be the most suitable measure. In our experience, this measure is more easily understood and interpreted than probability of persistence. In addition, it allows use of the best-practice four-point elicitation method, while the probability of persistence does not (see the reference provided for expert elicitation in Further reading, below). The example workbook provided alongside this factsheet is a population size workbook.

Probability of species persistence may be the most suitable measure if you are informing predictions with the outputs of Population Viability Analysis models (See *Estimate consequences*, below), which are a commonly used predictive tool for managing threatened species and listing species under the IUCN Red List Categories and Criteria.

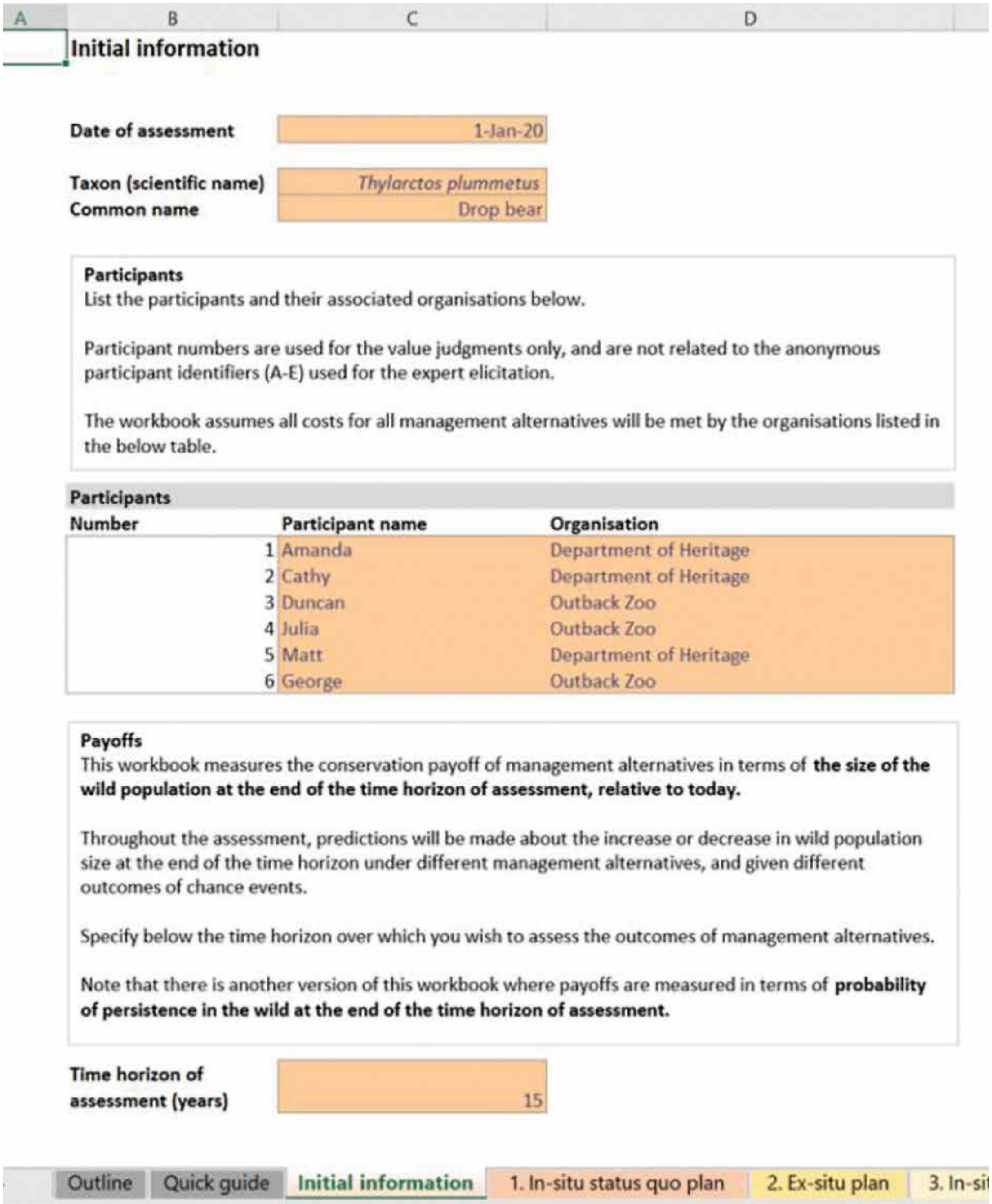
The time horizon of predictions, that is, the number of years over which you wish to predict the outcomes of management, may also influence the relative suitability of the two measures for your scenario. We have found that using relative change in population size can enable discrimination between alternatives over shorter time horizons (e.g., 10 to 20 years), while probability of persistence pay-off may require a longer time horizon to show a difference (e.g., 50 to 100 years). This, of course, depends on the circumstances of the species being analysed.

Enter initial information

Once you have chosen a suitable measure of conservation pay-off for your problem, open the associated workbook.

Cells where you can enter data are shaded orange, while those that contain formulae or transferred data are shaded green.

The first tab that asks you to enter data is the "Initial information" tab (Figure 6). Here, you enter the date of the assessment, the species' scientific name and common name, and (for a workshop setting) the participants' names and organisations. You will also be asked for the time horizon of the assessment. When choosing a time horizon, you should consider the overall goal of the ex-situ management plan (e.g., to release captive-bred individuals back into wild populations) and the length of time needed to see a discernible benefit for wild populations.



A B C D

Initial information

Date of assessment	1-Jan-20
Taxon (scientific name)	*Thylarctos plummetus*
Common name	Drop bear

Participants
List the participants and their associated organisations below.

Participant numbers are used for the value judgments only, and are not related to the anonymous participant identifiers (A-E) used for the expert elicitation.

The workbook assumes all costs for all management alternatives will be met by the organisations listed in the below table.

Participants

Number	Participant name	Organisation
1	Amanda	Department of Heritage
2	Cathy	Department of Heritage
3	Duncan	Outback Zoo
4	Julia	Outback Zoo
5	Matt	Department of Heritage
6	George	Outback Zoo

Payoffs
This workbook measures the conservation payoff of management alternatives in terms of **the size of the wild population at the end of the time horizon of assessment, relative to today.**

Throughout the assessment, predictions will be made about the increase or decrease in wild population size at the end of the time horizon under different management alternatives, and given different outcomes of chance events.

Specify below the time horizon over which you wish to assess the outcomes of management alternatives.

Note that there is another version of this workbook where payoffs are measured in terms of **probability of persistence in the wild at the end of the time horizon of assessment.**

Time horizon of assessment (years)	15

Outline | Quick guide | Initial information | 1. In-situ status quo plan | 2. Ex-situ plan | 3. In-si

*Figure 6. Screenshot of the **Initial information** tab, filled in for a hypothetical example.*

Define alternatives

Tabs 1, 2 and 3 of the Excel workbook step you through defining the three alternative management plans.

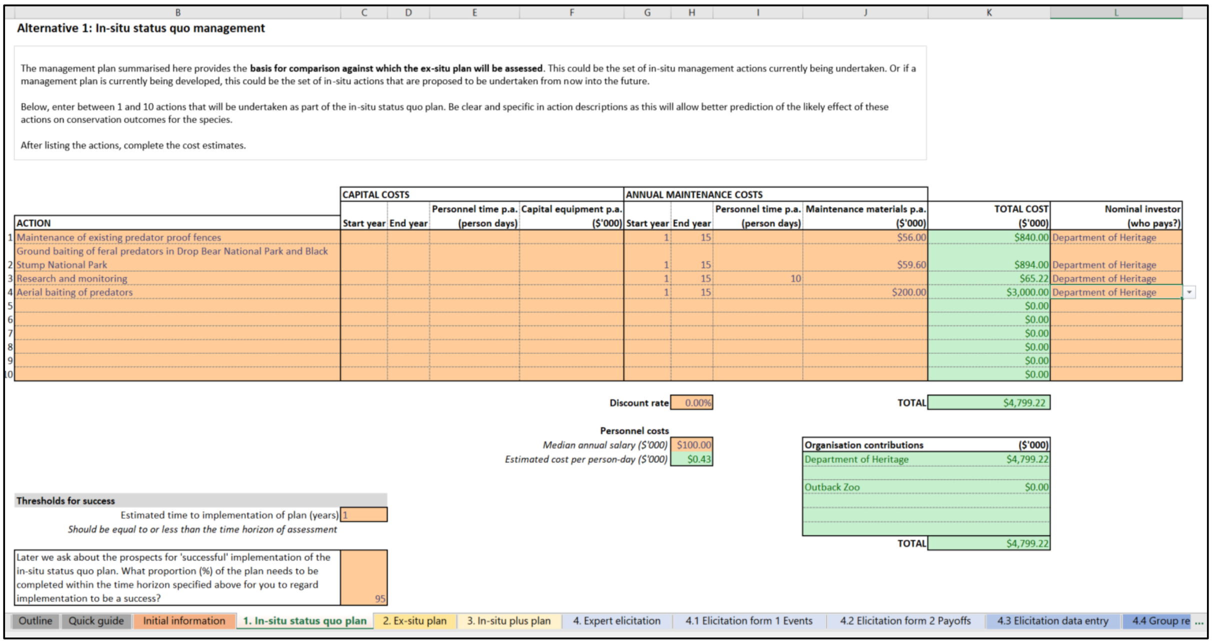
Tab 1: Defining the "status quo" management plan

In Tab 1, you define the in-situ "status quo" management plan by listing and costing between 1 and 10 actions you can undertake as part of the plan. Headings in the costing table assist you to calculate the total costs of actions. On the right-hand side of the costing table, drop-down menus enable you to specify the nominal investor for each action, that is, the organisation responsible for paying the cost. The total contributions of each organisation will appear in the green table below the costing table.

Future costs can be discounted by entering an annual discount rate (%). If you do not wish to discount future costs, simply enter 0.

The workbook also asks you here to specify thresholds for success. These thresholds are necessary to define the branches in the decision tree, that is, what is meant by "successful" and "unsuccessful" implementation of the management plan. For example, in the hypothetical example shown in Figure 7 below, the in-situ "status quo" management plan would be considered successful if at least 95% of the plan is completed (or in place) within one year. Conversely, if less than 95% of the plan is completed within one year, this would be considered unsuccessful implementation.

Don't confuse this threshold with the likelihood that a plan can be implemented within a time frame. It is rather the threshold over which you can consider implementation to be successful. The threshold works best if you set it so that there is some chance of successful implementation and some chance of unsuccessful implementation, that is, for a non-zero chance of each of the two outcomes.



Alternative 1: In-situ status quo management

The management plan summarised here provides the **basis for comparison against which the ex-situ plan will be assessed**. This could be the set of in-situ management actions currently being undertaken. Or if a management plan is currently being developed, this could be the set of in-situ actions that are proposed to be undertaken from now into the future.

Below, enter between 1 and 10 actions that will be undertaken as part of the in-situ status quo plan. Be clear and specific in action descriptions as this will allow better prediction of the likely effect of these actions on conservation outcomes for the species.

After listing the actions, complete the cost estimates.

		CAPITAL COSTS				ANNUAL MAINTENANCE COSTS					
	ACTION	Start year	End year	Personnel time p.a. (person days)	Capital equipment p.a. ($'000)	Start year	End year	Personnel time p.a. (person days)	Maintenance materials p.a. ($'000)	TOTAL COST ($'000)	Nominal investor (who pays?)
1	Maintenance of existing predator proof fences					1	15		$56.00	$840.00	Department of Heritage
2	Ground baiting of feral predators in Drop Bear National Park and Black Stump National Park					1	15		$59.60	$894.00	Department of Heritage
3	Research and monitoring					1	15	10		$65.22	Department of Heritage
4	Aerial baiting of predators					1	15		$200.00	$3,000.00	Department of Heritage
5										$0.00	
6										$0.00	
7										$0.00	
8										$0.00	
9										$0.00	
10										$0.00	

Discount rate 0.00%

TOTAL $4,799.22

Personnel costs

Median annual salary ($'000) $100.00

Estimated cost per person-day ($'000) $0.43

Organisation contributions	($'000)
Department of Heritage	$4,799.22
Outback Zoo	$0.00
TOTAL	$4,799.22

Thresholds for success

Estimated time to implementation of plan (years) 1

Should be equal to or less than the time horizon of assessment

Later we ask about the prospects for 'successful' implementation of the in-situ status quo plan. What proportion (%) of the plan needs to be completed within the time horizon specified above for you to regard implementation to be a success? 95

Outline | Quick guide | Initial information | 1. In-situ status quo plan | 2. Ex-situ plan | 3. In-situ plus plan | 4. Expert elicitation | 4.1 Elicitation form 1 Events | 4.2 Elicitation form 2 Payoffs | 4.3 Elicitation data entry | 4.4 Group re ...

*Figure 7. Screenshot of tab **1. In-situ "status quo" plan**.*

Tab 2 and Tab S1: Defining the ex-situ management plan

In Tab 2, you define Alternative 2, the ex-situ management plan that is being assessed (Figure 8 below). This tab first asks you to define thresholds for success for the three stages of the program:

(a) Sourcing individuals from the wild to found the ex-situ program

(b) The ex-situ program itself

(c) Releasing individuals back into the wild.

These thresholds define each stage of branching in the decision tree (Figure 5). The thresholds will usually be based on biological considerations but, if possible, it is best to once more set thresholds so that the chances of success and non-success are both non-zero.

The tool then provides a costing table where you can list up to 10 cost items for the ex-situ component of this management plan and nominate the institution responsible for meeting the cost of each item. By default, the ex-situ management plan also includes the in-situ actions listed under the in-situ "status quo" plan. These actions and costs replicate here as the "in-situ component", and you add them to the ex-situ costs to give a total cost for the ex-situ management plan.

Sourcing from the wild	
How many founders are required from the wild to give the ex-situ program some chance of success?	20
To obtain the required number of founders above, how many individuals do you think will need to be taken from the wild over the full year time horizon of this assessment? Express this as a multiple of the estimated number of founders specified above; e.g. for double enter '2'	1
Notes, e.g. where will founders be sourced from?	Founders should be sourced from both Drop Bear NP and Black Stump NP, to maximise genetic diversity.

Ex situ program/captive breeding	
At what year of the program do you think successful breeding needs to be achieved?	1
What do you think is an approriate threshold for describing offspring survivorship in the first year of successful breeding, expressed as months of survivorship?	11
At year 1 of the program, what percentage of offspring need to survive to 11 months to give the program some chance of success?	80
Notes on captive breeding program	An enclosure has been built near Drop Bear National Park and currently houses 3 individuals (2 adults, 1 pouch young) as part of the captive breeding trial. This facility could be expanded to house up to 20 individuals. Outback Zoo can house up to 10 individuals in an additional facility.

Outline | Quick guide | Initial information | 1. In-situ status quo plan | 2. Ex-situ plan | 3. In-situ plus plan | 4. Expert elicitation | 4.1 Elicit

Figure 8. Screenshot of tab ***2. Ex-situ plan****.*

To specify thresholds and complete the costings table, you will need a clear understanding of the purpose, scale and scope of the ex-situ management you are considering. We therefore recommend that users answer or discuss the questions in the IUCN guidelines on ex-situ management (IUCN/SSC 2014), which we have reproduced in the tool under Tab S1 (Figure 9). The IUCN guidelines provide a comprehensive set of questions for planning and assessing ex-situ interventions, under the following subsections:

- **Role of ex-situ management.** What role/s will ex-situ management play in the conservation of the species? What will the ex-situ population be used for and how will this increase persistence in the wild?
- **Characteristics of the ex-situ population.** What are the required characteristics of the ex-situ population that will enable it to fulfil its conservation role/s? For example, how many founders are needed to meet genetic and demographic goals?
- **Resources and expertise.** What resources and expertise are needed for the ex-situ management program to fulfil its conservation role/s? For example, what facilities, infrastructure and space are required?
- **Feasibility and risks.** What is the feasibility of, and what are the risks involved in, the proposed program, including the likelihood of success? For example, what is the probability of obtaining the required resources, including experts with the required skill set?

You should make any answers to these questions available, or discuss them with species experts before they perform an expert elicitation. The questions can also serve as a useful record of any knowledge gaps for the species.

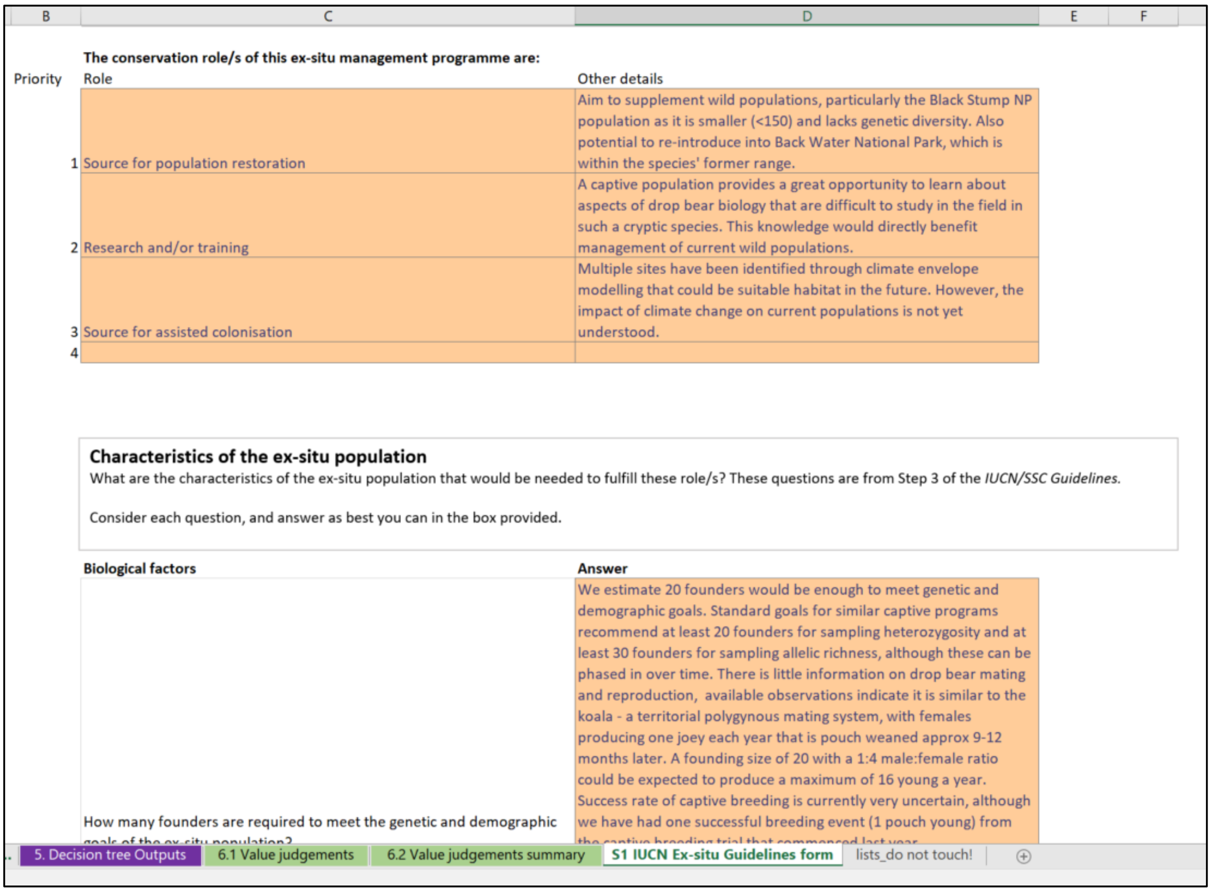


*Figure 9. Screenshot of tab **S1. IUCN Ex-situ Guidelines Form**.*

Tab 3: Defining the “in-situ plus” management plan

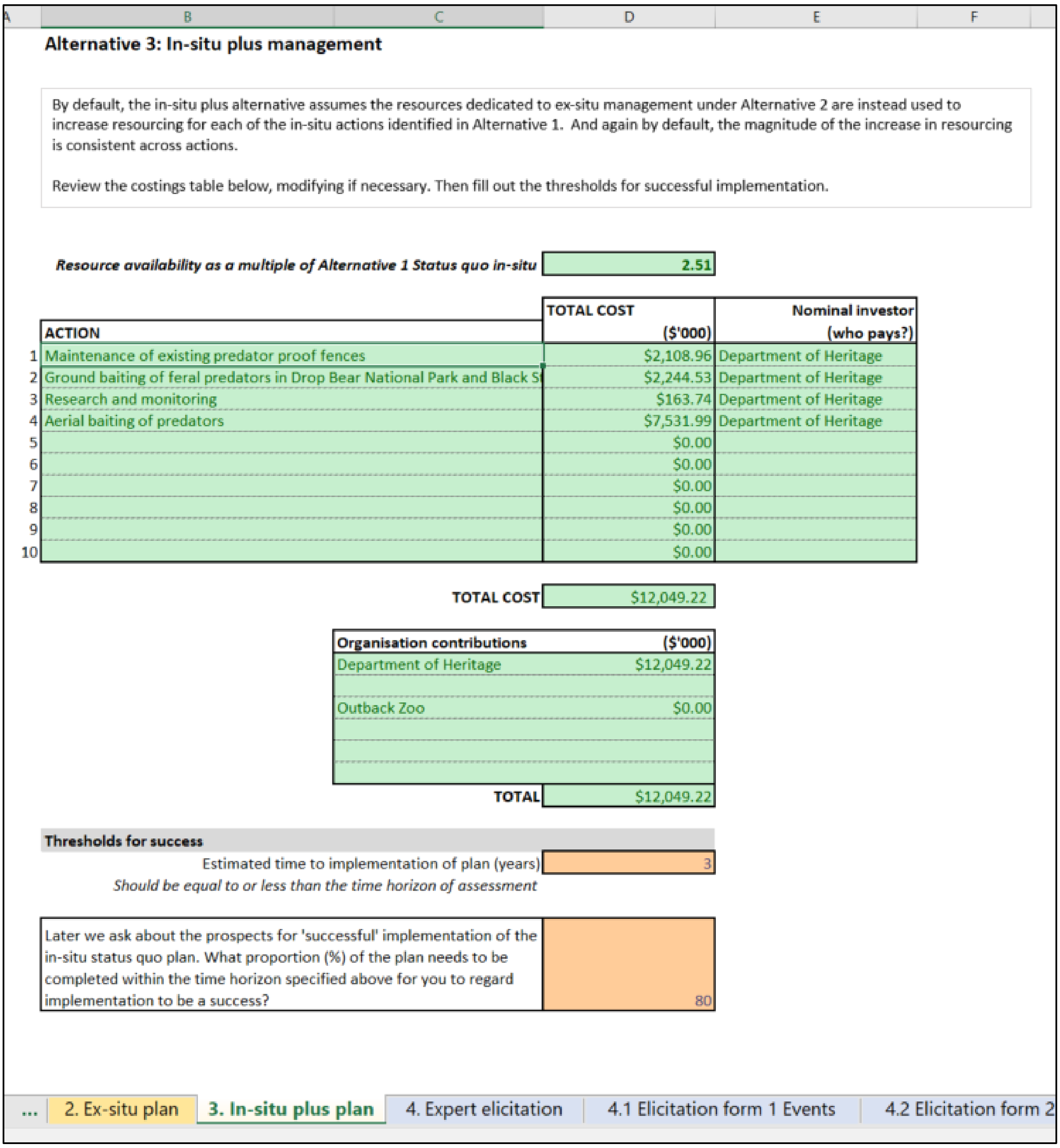
In Tab 3, you define Alternative 3, the “in-situ plus” management plan. “In-situ plus” is a hypothetical plan that explores a scenario where the resources dedicated to ex-situ management under Alternative 2 (ex-situ) could instead be used to increase resourcing for the in-situ actions identified in Alternative 1 (in-situ status quo).

Tab 3 first shows the resource availability under this third alternative – calculated as the total cost of the ex-situ alternative divided by the cost of the in-situ “status quo” alternative. For example, in the screenshot below (Figure 10) the entire ex-situ management plan costs 2.51 times the cost of the in-situ “status quo” management. This alternative allows you to explore what the species outcomes could be if those resources were instead spent on in-situ management alone.

The main table of this tab lists the actions under the in-situ "status quo" plan, and calculates the amount that could be spent on each one, given the increased resources available. These calculations assume that resources would be allocated to each action in proportion to the amounts allocated under the in-situ "status quo" plan. The calculations are made automatically in the green cells, but you can override them if the assumptions are incorrect.

The smaller table below the main table looks at the nominal investor for each action, and adds up the total amount paid for by each organisation. Again, the nominal investor for each action is assumed to be the same as for the in-situ status alternative, but you can change this if necessary using the drop-down menus.

At the bottom of this tab are the thresholds for successful implementation of this management plan. Users should consider whether these thresholds will be the same as for the in-situ status quo alternative, or whether they should be altered to reflect changes you may have made to the actions. How will increasing the amount of resources available for each action affect the scale and logistics of the actions you implement? One example is that it may take longer to successfully set up a larger research and monitoring program.



Alternative 3: In-situ plus management

By default, the in-situ plus alternative assumes the resources dedicated to ex-situ management under Alternative 2 are instead used to increase resourcing for each of the in-situ actions identified in Alternative 1. And again by default, the magnitude of the increase in resourcing is consistent across actions.

Review the costings table below, modifying if necessary. Then fill out the thresholds for successful implementation.

Resource availability as a multiple of Alternative 1 Status quo in-situ **2.51**

	ACTION	TOTAL COST ($'000)	Nominal investor (who pays?)
1	Maintenance of existing predator proof fences	$2,108.96	Department of Heritage
2	Ground baiting of feral predators in Drop Bear National Park and Black S	$2,244.53	Department of Heritage
3	Research and monitoring	$163.74	Department of Heritage
4	Aerial baiting of predators	$7,531.99	Department of Heritage
5		$0.00	
6		$0.00	
7		$0.00	
8		$0.00	
9		$0.00	
10		$0.00	

TOTAL COST $12,049.22

Organisation contributions	($'000)
Department of Heritage	$12,049.22
Outback Zoo	$0.00
TOTAL	$12,049.22

Thresholds for success

Estimated time to implementation of plan (years) 3

Should be equal to or less than the time horizon of assessment

Later we ask about the prospects for 'successful' implementation of the in-situ status quo plan. What proportion (%) of the plan needs to be completed within the time horizon specified above for you to regard implementation to be a success? 80

... | 2. Ex-situ plan | 3. In-situ plus plan | 4. Expert elicitation | 4.1 Elicitation form 1 Events | 4.2 Elicitation form 2

Figure 10. Screenshot of tab ***3. In-situ plus management plan****.*

Estimate consequences

In the context of this decision tool, estimating consequences refers to estimating the parameters in the decision tree: the probabilities of chance events (i.e., the circles on the branches of the decision tree), and the conservation pay-offs (i.e., the triangles at the end of the branches). In this decision tree, there are five probabilities of chance events and 13 conservation payoffs to be estimated. You can estimate these through expert elicitation, or by other forms of information, according to their availability to you.

Expert elicitation

Tabs 4 through to 4.5 facilitate a formal, structured elicitation of the decision tree parameters from a group of up to six species experts. Structured elicitation protocols help reduce the influence of psychological biases on expert judgements, improving their quality, transparency and defensibility. We use the IDEA protocol, a structured expert elicitation protocol that has a history of use in environmental decision-making. IDEA stands for *Investigate, Discuss, Estimate and Aggregate*. The IDEA protocol has been tested and shown to deliver relatively reliable judgements. A detailed, practical guide to conducting an expert elicitation using the IDEA protocol is included in the "Further reading" section below (Hemming et al., 2018). You can conduct IDEA elicitations in person, in group workshops or remotely.

To follow the IDEA protocol in the context of this decision tool:

Step 1. Ensure experts are aware of the details of the three management alternatives being assessed (i.e., they have completed Tabs 1–3, and optionally S1), and that they have access to relevant information about the species.

Step 2. Provide experts with the expert elicitation forms to complete (Tabs 4.1 and 4.2, Figure 11).

Step 3. Give experts an opportunity to ask questions about the expert elicitation form and the alternatives, or to discuss general information about the species. Ask them to provide their individual, private, best estimates (and intervals, if using the relative population size workbook) for the parameters on the form.

Step 4. Enter these first-round estimates into Tab 4.3 ,"Elicitation data entry". The results will be displayed in Tab 4.4, "Group results Events", and 4.5, "Group results Pay-offs". If you are using the relative population size pay-off workbook, the elicited confidence intervals will adjust automatically to become 90% credible intervals around the pay-off estimates.

Step 5. Show the graphs to the experts, to give them feedback about where their estimates sit in relation to those of the other experts. Allow the experts to discuss their estimates and the reasoning behind them with each other, in person or via email or other electronic platforms. A useful list of questions for facilitating this discussion is available in Supplement A of Hemming et al. (2018).

Step 6. Ask the experts to provide a second round of individual, private, best estimates and intervals for the parameters on the expert elicitation forms (Tabs 4.1 and 4.2).

Step 7. Enter these second-round estimates into Tab 4.3, "Elicitation data entry". Show the new graphs in Tabs 4.4 and 4.5 to the experts, and provide a final chance for discussion and clarification. The aggregated estimates are shown in red in the graphs (Figure 12), and will automatically populate Tab 5, "Decision tree Outputs" (Figure 13).

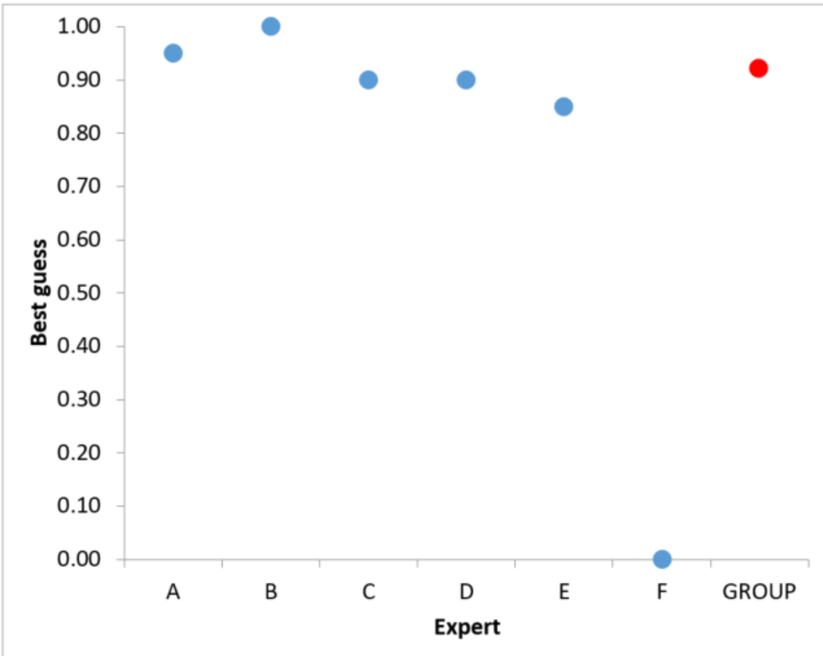
Form for individual expert elicitation - chance events

ANONYMOUS PARTICIPANT IDENTIFIER (LETTER A-F, ASSIGNED BY FACILITATOR):

	In-situ status quo plan	
1	What is the probability that the 'in-situ status quo' plan for the Drop bear will be 95% implemented in 1 years from now? Please provide your best estimate.	
	In-situ plus plan	
2	What is the probability that the 'in situ plus' plan for the Drop bear will be 80% implemented in 3 years from now? Please provide your best estimate.	
	Ex situ plan	
3	What is the probability that the ex situ plan will have a TRIVIAL impact on the wild source population, i.e. a take of 20 individuals will not threaten the viability of wild source population(s)? Please provide your best estimate.	
4	What is the probability that the captive breeding component of the ex situ plan will be successful, i.e. ≥ 80% of offspring born in year 2 of the ex-situ breeding program will survive to 11 months? Please provide your best estimate.	
5	What is the probability that captive individuals will be successfully released into the wild, i.e. ≥ 25% of released individuals survive in the wild 5 months after release? Please provide your best estimate.	

Figure 11. Screenshot of ***Tab 4.1 Elicitation form 1 events****.*

Chance Q1 What is the probability that the 'in-situ status quo' plan for the Drop bear will be 95% implemented in 1 years from now?



		Experts	Best estimate
Chance Q1	What is the probability that the 'in-situ status quo' plan for the Drop bear will be 95% implemented in 1 years from now?	A	0.95
		B	1.00
		C	0.90
		D	0.90
		E	0.85
		F	
	AVERAGE OF	**GROUP**	0.92
		S.E.	0.025495098

... 4.1 Elicitation form 1 Events | 4.2 Elicitation form 2 Payoffs | 4.3 Elicitation data entry | **4.4 Group results Events**

Figure 12. Screenshot of tab ***4.4 Group results Events****.*

We use the best-practice four-point elicitation method for eliciting pay-offs with the relative population size measure. This method elicits a plausible lower limit, a plausible upper limit, a best estimate, and a level of confidence that the true value lies within the range described by the lower and upper limits. We do not recommend using a four-point elicitation method when eliciting probabilities from experts, as experts can find it difficult or confusing to provide a percentage level of confidence in their probability estimate (Hemming et al. 2018). For consistency, we elicit only best estimates for all probabilities – this includes the chance events in the decision tree, as well as the probability of persistence payoffs.

Other forms of information

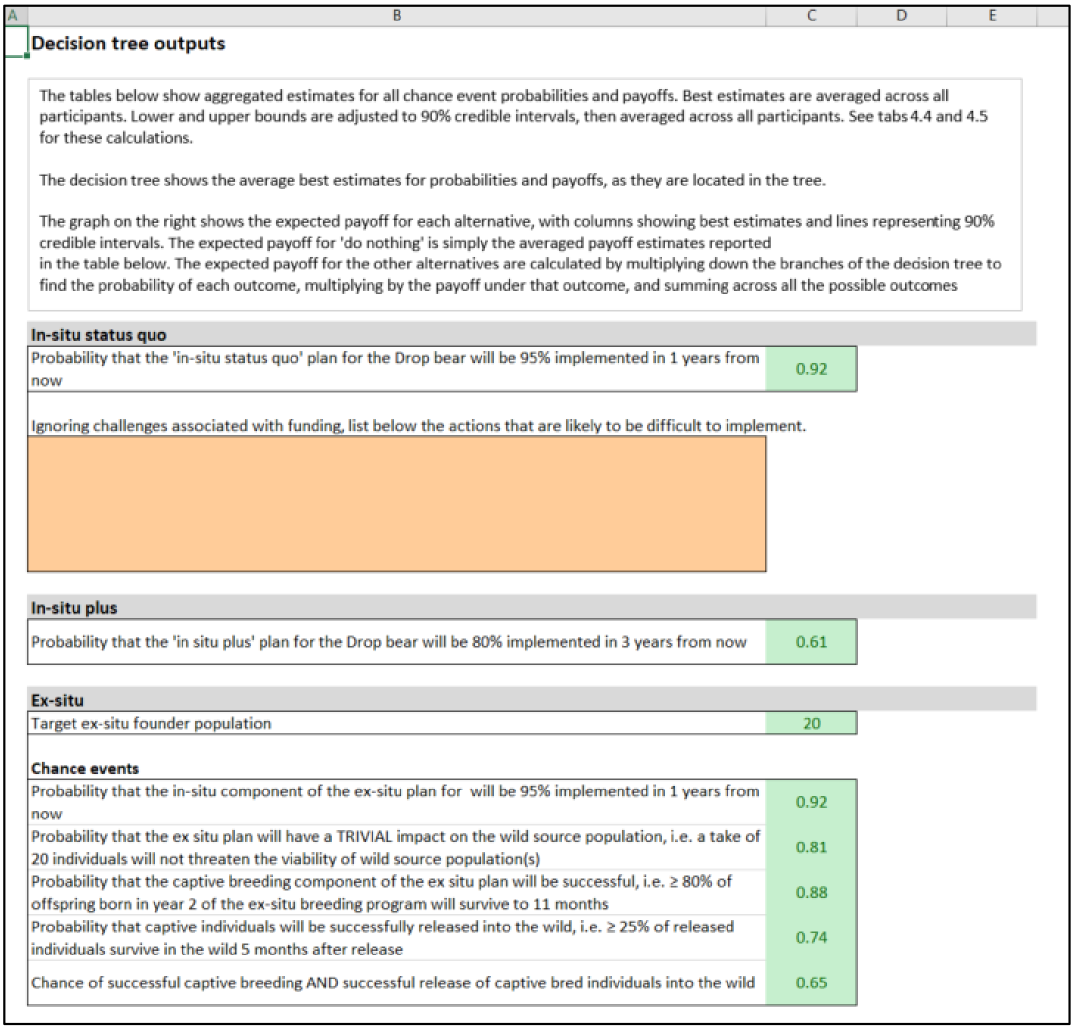
You can enter other forms of information generated outside the decision tool directly into Tab 5, "Decision tree outputs" – for example, information derived through modelling and simulation, statistical analysis or previous expert elicitations (Figure 13).

The Red Hot Lists of species at most acute risk of extinction (TSR Hub Projects 2.1 and 2.4) is a great resource for expert estimates of Australian animal persistence under status quo management. Geyle et al. (2018) elicited probabilities of extinction over the next 20 years under status quo management for Australia's most imperilled birds, mammals, freshwater fish, lizards and snakes. Researchers are currently applying the methodology to frogs and invertebrate groups. While the Red Hot List for plants (TSR Hub Project 2.4) does not provide direct probabilities of extinction for threatened Australian plant species, it does collate and summarise useful information that could be used to inform management planning or further expert elicitation within the PACES tool (Silcock & Fensham 2018).

Population Viability Analysis (PVA) is a widely used quantitative method for estimating a species' risk of extinction within a given timeframe under different management scenarios. It can provide estimates of conservation payoffs of the different management alternatives.

You can also use PVA and other simulation models to estimate the probabilities of chance events. For example, researchers estimated the likelihood of success of an ex-situ program for the Critically Endangered Vigors great Indian bustard (*Ardeotis nigriceps*) by simulating the number of adult females that could be bred for release given different egg collection rates and breeding success rates (Dolman et al., 2015).

You can also use statistical analysis of data derived from previous ex-situ programs to estimate success rates. For example, another group of researchers analysed 15 years of captive breeding data for the whooping crane (*Grus americana*) to predict and maximise hatching success rates (Smith et al., 2011).



Decision tree outputs

The tables below show aggregated estimates for all chance event probabilities and payoffs. Best estimates are averaged across all participants. Lower and upper bounds are adjusted to 90% credible intervals, then averaged across all participants. See tabs 4.4 and 4.5 for these calculations.

The decision tree shows the average best estimates for probabilities and payoffs, as they are located in the tree.

The graph on the right shows the expected payoff for each alternative, with columns showing best estimates and lines representing 90% credible intervals. The expected payoff for 'do nothing' is simply the averaged payoff estimates reported in the table below. The expected payoff for the other alternatives are calculated by multiplying down the branches of the decision tree to find the probability of each outcome, multiplying by the payoff under that outcome, and summing across all the possible outcomes

In-situ status quo

Probability that the 'in-situ status quo' plan for the Drop bear will be 95% implemented in 1 years from now	0.92

Ignoring challenges associated with funding, list below the actions that are likely to be difficult to implement.

In-situ plus

Probability that the 'in situ plus' plan for the Drop bear will be 80% implemented in 3 years from now	0.61

Ex-situ

Target ex-situ founder population	20

Chance events

Probability that the in-situ component of the ex-situ plan for will be 95% implemented in 1 years from now	0.92
Probability that the ex situ plan will have a TRIVIAL impact on the wild source population, i.e. a take of 20 individuals will not threaten the viability of wild source population(s)	0.81
Probability that the captive breeding component of the ex situ plan will be successful, i.e. ≥ 80% of offspring born in year 2 of the ex-situ breeding program will survive to 11 months	0.88
Probability that captive individuals will be successfully released into the wild, i.e. ≥ 25% of released individuals survive in the wild 5 months after release	0.74
Chance of successful captive breeding AND successful release of captive bred individuals into the wild	0.65

Figure 13. Partial screenshot of Tab 5, ***Decision tree outputs.*** *Expert elicitation data entered in Tab 4.3 is automatically aggregated in the green cells here. Alternatively, you can enter data directly into these cells.*

Decision tree outputs

Tab 5 displays a graph showing the outputs of the decision tree, that is, the predicted conservation outcomes for the species under each management alternative. For example, the best estimate prediction for the Drop Bear under the "do nothing" alternative is a 39% decline in the size of the wild population over the nominated time horizon of 15 years (Figure 14). The 90% credible interval around this estimate is between a 77% decline and a 5% increase. The species is therefore predicted to almost certainly decline if the current management were removed.

For this hypothetical example of the Drop Bear, the ex-situ alternative has the best predicted outcome, according to the best estimates (the bars in Figure 14). However, all three active management alternatives (in-situ status quo, in-situ plus, and ex-situ) feature a large amount of uncertainty associated with these predictions (the lines in Figure 14). While it has the best outcome according to best estimates, the ex-situ alternative also has the worst worst-case outcome of any of the active alternatives, that is, the lowest lower bound, according to the 90% credible intervals. The in-situ plus alternative has the best best-case outcome, that is, the highest higher bound.

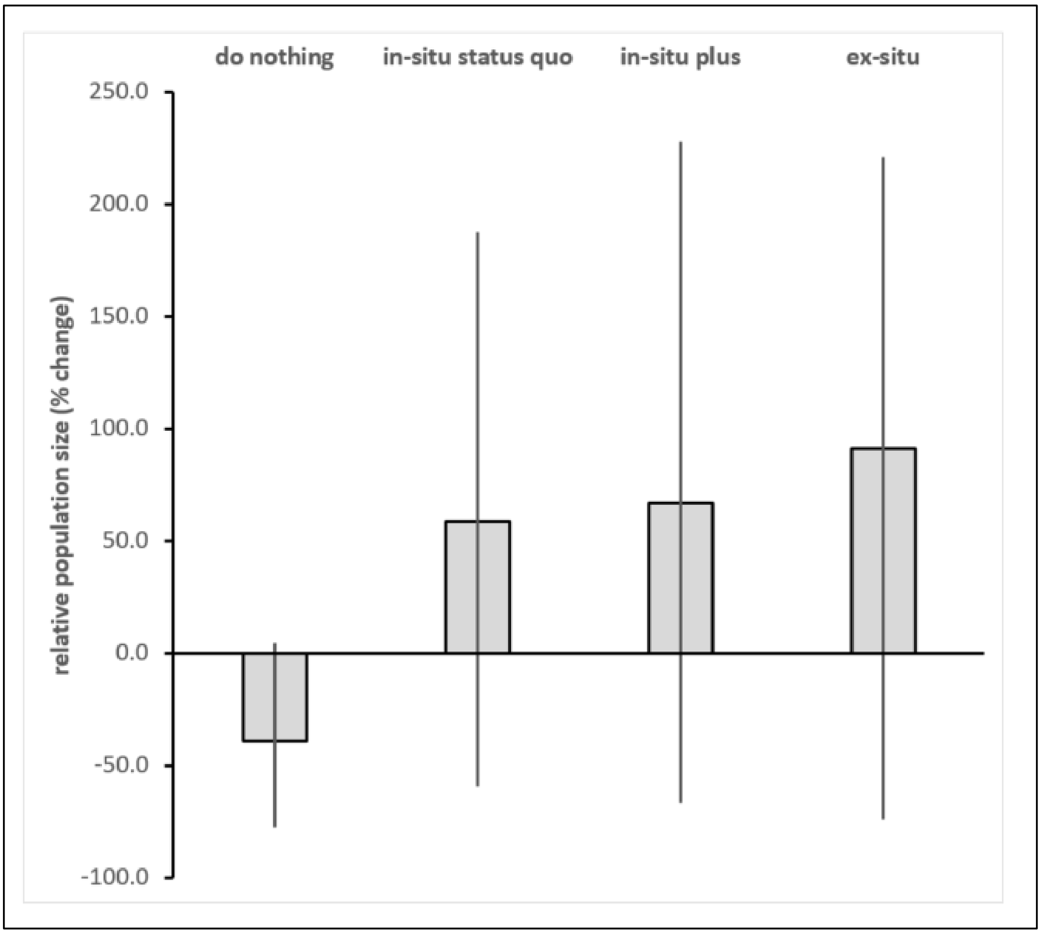


Figure 14. Partial screenshot of Tab 5, ***Decision tree outputs****, showing the expected outcomes of each management alternative. Bars show best estimates and lines show 90% credible intervals.*

Decision-makers have varying levels of risk tolerance, so will make different choices given predictions featuring uncertainty. Risk-averse decision-makers are pessimistic, and seek to avoid bad outcomes. They may choose to avoid alternatives that could result in the worst possible outcome. In this example, the do nothing alternative has the lowest lower bound on the predicted outcome, according to 90% credible intervals, followed by the ex-situ alternative. These two alternatives may be avoided by risk-averse decision-makers. Risk-tolerant decision-makers are optimistic, and may seek out an alternative with some chance of the best possible outcome. In this example, the in-situ plus alternative has the highest upper bound on the predicted outcome, so might be embraced by risk-tolerant decision-makers. Risk-neutral decision-makers focus only on maximising the expected outcomes, ignoring the bounds around predictions. In this example, a risk-neutral decision-maker would choose the ex-situ alternative as it has the highest best estimate prediction.

Evaluate trade-offs

The decision tree predicts the likely conservation outcomes of management decisions, enabling decision-makers to see which management alternative is likely to deliver the best outcome, the level of uncertainty around each outcome, and how similar or different the outcomes are under different alternatives.

The next question for a decision-maker is whether the conservation outcome of an alternative is worth its cost. This is of course a subjective value judgement – there is no right or wrong answer, and the answer could be different for each participant, depending on their willingness to pay.

Tab 6.2 provides a structure for eliciting these value judgements from participants. Unlike the expert predictions of chance events and payoffs, value judgements are not combined or averaged, and are not kept anonymous. The "Initial information" tab provides a template for each participant.

The structure we use here is based on the "swing weighting" method, and has two steps, as follows.

Step 1 of the value judgment elicitation: Assessing the relative value of conservation outcomes

The conservation pay-off in the decision tree focuses on species outcomes in the wild, namely the relative change (%) in population size or the probability of species persistence. For this objective, a higher number is better, that is, a bigger increase in wild population size or bigger probability of persistence is better than a smaller increase or smaller probability.

When considering ex-situ management, there is another relevant conservation outcome that could be assigned value, which is whether a successfully breeding ex-situ population has been established. For simplicity we will call this an "insurance population". In terms of insurance population status, we assume that the best outcome is to have an insurance population, and the worst outcome is not to have one.

When participants assess the value of these conservation outcomes (wild population status and insurance population status) they may not be independent, that is, how much you value the insurance population may depend on the status of the population in the wild. The first step of the value judgement focuses on eliciting these dependencies in value, by eliciting values for scenarios with different combinations of the best and worst outcomes for wild population status and insurance population status.

The table associated with this step (Figure 15) lists four scenarios that are different combinations of best and worst conservation outcomes. For example, the worst plausible scenario comprises the worst outcomes for both wild population status and insurance population status. For the hypothetical Drop Bear, this is a 77% decrease in population size in the wild and no insurance population ex-situ. This worst scenario has been automatically assigned a value of 0. The best plausible scenario for the Drop Bear is a 228% increase in population size in the wild plus an insurance population ex-situ. This best scenario has been automatically assigned a value of 100.

The two other scenarios in the table are the intermediate combinations of outcomes. The first intermediate scenario is a 228% population increase in the wild but no insurance population. In the example in Figure 15, participant Amanda has given this a value of 5, compared with the best plausible scenario value of 100. This means that she values this scenario 5% (or one-twentieth) as much as she values the best plausible scenario. The second intermediate scenario is a 77% decrease in wild population size but with an insurance population. Amanda has given this scenario a value of 10, meaning that she values this scenario 10% as much as the best plausible scenario, or twice as much as the first intermediate scenario.

PARTICIPANT 1 Amanda
Organisation Department of Heritage

Step 1. Assessing the relative value of conservation outcomes

The worst and best plausible conservation outcomes for the species are listed in the table below.
Let's say we give the worst outcome a value of 0, and the best outcome a value of 100.

Now keeping in mind a scale of 0 to 100 for these bookend outcomes, rate the other two intermediate scenarios below:

	Relative change (%) in population size in the wild	Insurance population	Value
worst	-77	no	**0**
intermediate A	228	no	5
intermediate B	-77	yes	10
best	228	yes	**100**

*Figure 15. Partial screenshot of Tab 6.1 **Value judgments**, showing Step 1 of the value judgment elicitation.*

Step 2 of the value judgment elicitation: Weighting of conservation outcomes and cost

This second step of the value judgment elicitation draws out values for the different scenarios of combined conservation outcomes and cost. In this step, participants must imagine they are given a chance to change either the conservation outcomes from the worst to the best outcomes, or the cost outcome from the worst to the best outcome. They need to specify which of these changes they would prefer or value the most, and by how much.

In the example below (Figure 16), Amanda would most prefer to change the conservation outcomes from worst to best, so she has ranked this her number 1 objective and given it a value of 100. Cost is therefore her number 2 objective and she has given it a value of 65. This means that she values the change in cost (from worst to best outcome: $9,954,000 to $0) 65% as much as she values the change from the worst to best conservation outcomes.

Step 2. Weighting of conservation outcomes and cost

The worst and best plausible outcomes for two objectives are listed below: species conservation (a combination of species status and insurance population) and cost.

Imagine that the worst outcomes under both objectives has occurred (listed in WORST column). **If you were given a chance to change EITHER the conservation outcomes (species status and insurance population) OR the cost outcome from the WORST to the BEST outcome, which would you prefer to change?** This is your top-ranked objective. Place a 1 in the Rank column for this objective, and a 2 in the Rank column for the other non-preferred objective.

Your top-ranked objective gets a value of 100. Place a 100 in the Value column for this objective.

How much do you value the change from the worst to the best outcome in your non-preferred objective, relative to the change from the worst to the best outcome in your top-ranked objective? Place a number between 0 and 100 in the Value column for your non-preferred objective.

	WORST	BEST	Rank	Value	Weight
Species status (% change in wild population)	-77	228	1	100	0.61
Insurance population	no	yes			
Cost ($'000)	9954	0	2	65	0.39

*Figure 16. Partial screenshot of Tab 6.1, **Value judgments**, showing Step 2 of the value judgment elicitation.*

Participants should complete this elicitation privately without discussion to ensure that their answers reflect their own opinions only. If participants are comfortable with it, you can show their individual results to the group. Unlike the case of the expert elicitation, there is no need for anonymisation or formal discussion followed by a second round of elicitation; we are not aiming to build collaborative knowledge, rather, to view the diversity of subjective opinion.

Once this elicitation is completed, you can view the merit or utility of each alternative for this participant. Tab 6.1 displays three graphs, based on the point estimates for expected outcomes from the decision tree, the worst case predicted outcomes, and the best case predicted outcomes. For example, based on the point estimates of predicted outcomes (the bars in Figure 14), Amanda's value judgements (Figures 15 and 16) result in her having the highest utility for the ex-situ alternative (Figure 17).

Some of this utility comes from the value she places on conservation outcomes (shaded green) and some of it comes from the value she places on cost (shaded blue). Amanda has the second-highest utility for the "do nothing" alternative, which comes solely from the value she placed on the cost objective. That is, the 'do nothing' option is cheap!

Note that the cost here for each alternative is the cost that is attributable to this participant's organisation only. In the example in Figure 17 below, the in-situ plus alternative and the ex-situ alternative cost the same overall, but the cost of the in-situ plus alternative is attributed solely to Amanda's organisation (Department of Heritage) while the cost of the ex-situ alternative will be shared between the Department of Heritage and Outback Zoo. From Amanda's perspective, the in-situ plus alternative is therefore most expensive and does not receive any utility from the cost.

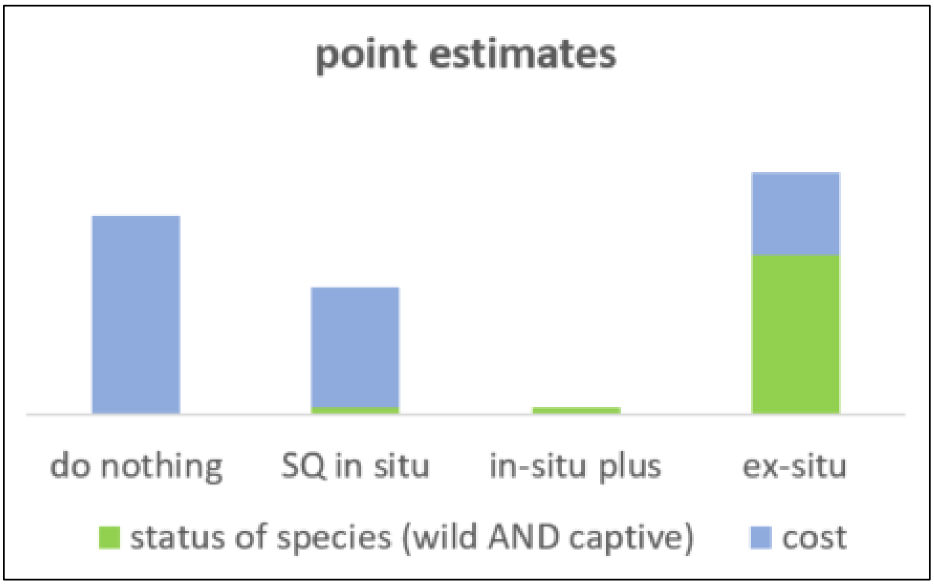


Figure 17. Partial screenshot of Tab 6.1 ***Value judgments****, showing the utility of each alternative given Amanda's value judgments, calculated using the point estimates for the predicted outcome under each alternative (the bars in Figure 14).*

Tab 6.2 summarises the value judgements data by characterising a participant as "supporting" an alternative if it is within their top two ranked alternatives (out of four, shaded green in Figure 18 below) and as "opposing" an alternative if it is within their bottom two ranked alternatives (shaded red). This can be a useful summary for a decision-maker, showing the overall level of support or opposition for each alternative. For example, Figure 18 shows that a decision-maker choosing the ex-situ alternative would receive overall support from the participants, while a choice of any of the other alternatives would have some opposition.

	do nothing	status quo in situ	in situ plus	ex situ
Participant 1	2	3	4	1
Participant 2	4	2	3	1
Participant 3	4	3	1	2
Participant 4	4	3	2	1
Participant 5	4	2	3	1
Participant 6	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
	do nothing	status quo in situ	in situ plus	ex situ
supported	1	2	2	5
opposed	4	3	3	0

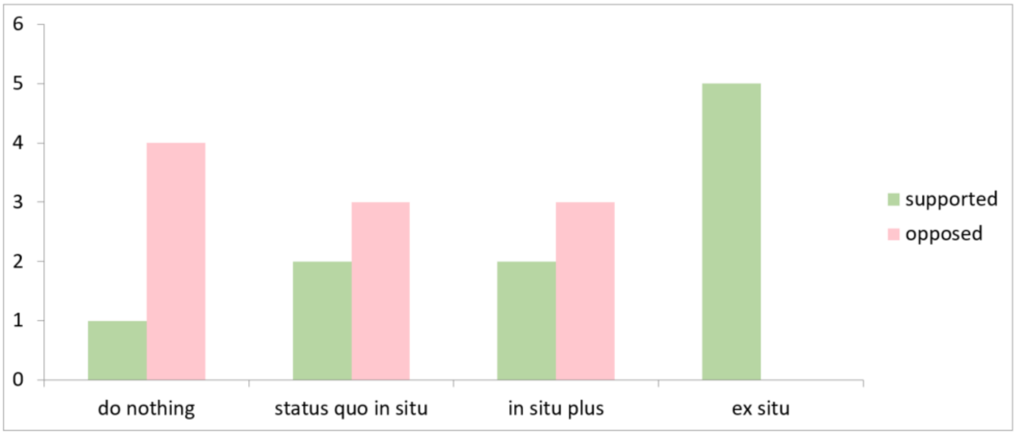


Figure 18. Screenshot of Tab 6.2 ***Value judgments*** *summary.*

Applications

The PACES tool can be applied to a range of management scenarios for both animal and plant species. We have tested it on the dibbler (*Parantechinus apicalis*), northern hairy-nosed wombat (*Lasiorhinus krefftii*), Nangur skink (*Nangura spinosa*), plains wanderer (*Pedionomus torquatus*), Richmond birdwing butterfly (*Ornithoptera richmondia*), bridled nailtail wallaby (*Onychogalea fraenata*), western ground parrot (*Pezoporus flaviventris*), numbat (*Myrmecobius fasciatus*), hairy marron (*Cherax tenuimanus*) and western swamp tortoise (*Pseudemydura umbrina*).

Participants found the tool useful for analysing a range of different scenarios, including species for which ex-situ management has never before been conducted, species for which little information is available about in-situ or ex-situ conservation, and species with continuing ex-situ programs that need re-evaluation.

Case study: Western swamp tortoise

The western swamp tortoise (*Pseudemydura umbrina*) is listed as Critically Endangered in Western Australia and nationally. Its historic distribution was reduced to two ephemeral swamps on the Swan Coastal Plain, before translocation efforts successfully established a further two populations. A longstanding and successful captive breeding program has underpinned translocation. Threats include land clearing, predation, inappropriate fire regimes and climate change. These threats imply severe limitations to the availability of new sites for translocation of captive-bred individuals.

Current management was captured under the "ex-situ" alternative in the tool. It includes captive breeding and translocation, and a set of actions aimed at managing habitat at each location the tortoise is known to occur. Under this ex-situ option, we explored a scenario where the current captive breeding program was extended for a further 25 years. The "in-situ" option included only habitat management at tortoise locations at the current estimated level of investment. The "in-situ plus" option involved these same actions but an approximate 20% greater investment.

To account for the long life-cycle of the species and its exposure to risks associated with climate change, participants considered an extensive time horizon appropriate for the assessment. Judgments of the consequences of each alternative were assisted by a population viability analysis run in real time. Outcomes for estimated conservation pay-offs 100 years hence are shown at Figure 19. The best estimate for "do nothing" was a 91% decline, with extinction plausible."In-situ" and "in-situ plus" were anticipated to lead to 47% and 41% declines, respectively. Only the "ex-situ" option was estimated to lead to an improvement in conservation status, at least for the best estimate.

Despite considerable uncertainty, the conservation pay-off of the ex-situ option is clearly better than the other alternatives. This outcome was driven by the success of the captive breeding program in making individuals available for release, and the pooled judgment of workshop participants that there was a 61% chance of successful release in to the wild, where success was described as at least 10% of released individuals surviving for 10 years post-release.

Outcomes after participants traded off anticipated conservation pay-offs and costs are shown in Figure 20. All five participants involved in the exercise had "ex-situ" as their top ranking alternative. The substantial costs and poor conservation pay-off of in-situ options resulted in the "do nothing" option being the second choice of three of the five participants.

Take home findings:

- Although climate change and other threats may limit the future availability of new sites for translocation of western swamp tortoise, there are reasonably good prospects for the survival of the species with continuation of captive breeding.
- The costs of captive breeding and habitat management at release and remnant sites are significant. But for workshop participants these costs are reasonable because the tortoise is an iconic and taxonomically distinct species.

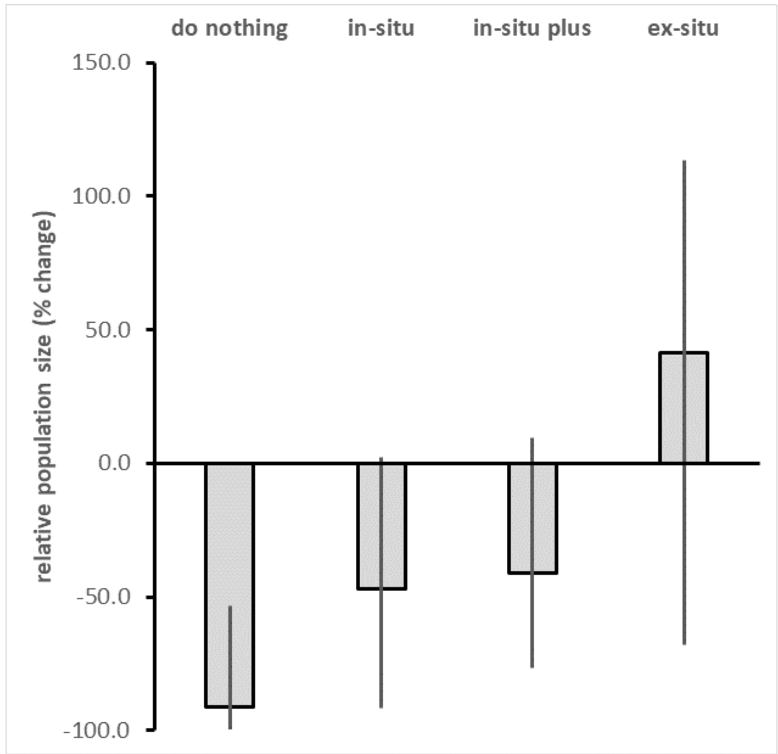


Figure 19. Expected outcomes of alternatives for the western swamp tortoise in terms of population size in the wild in 100 years' time relative to today (bars – best estimates, lines – range).

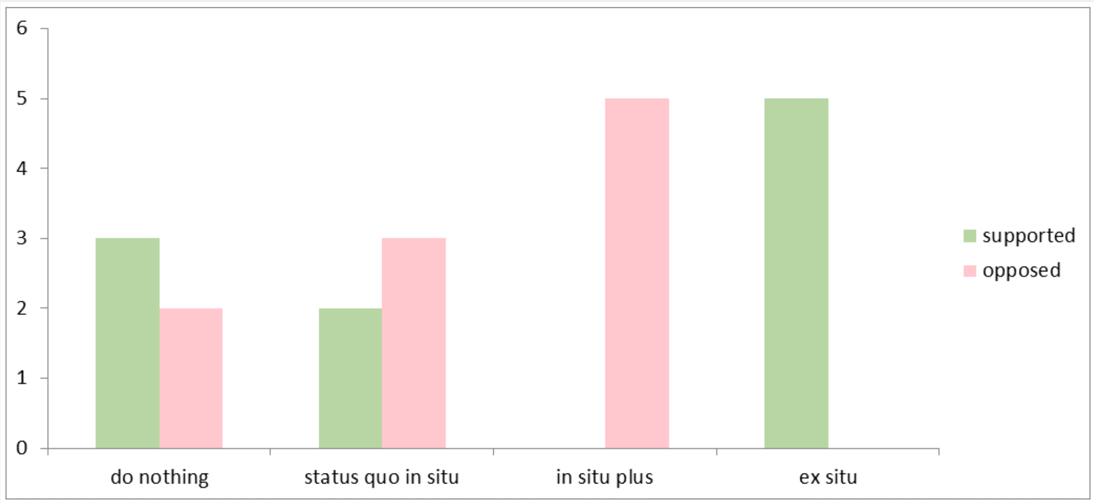


Figure 20. A summary of participants' value judgments, showing the number of participants supporting and opposing each alternative for the western swamp tortoise. Value judgements express the relative value a participant assigns to the conservation outcomes (predicted relative population size and the presence of an ex-situ "insurance" population) versus the cost of the management alternative. Expected value of each alternative is calculated from the best estimate predictions in Figure 14. A participant was characterised as "supporting" an alternative if it was in their top 2 favoured alternatives (out of 4), and "opposing" an alternative if it was in their bottom 2.

Benefits and limitations

This is a decision tool, and the key benefit is the aid it gives to decision-making under complex and high-stakes conditions. Analysing decisions in a structured way, as facilitated by this tool, results in decisions that are more likely to achieve their objectives, and are transparent, explicit, and able to be defended and explained to others. The tool enables decision-makers to separate predictions (based on science or expert knowledge) from subjective evaluation of outcomes (how good or bad the predicted outcomes are), thus enabling evidence-based decisions that can also account for differing stakeholder perspectives.

A limitation to using the tool could be the requirement for time, information and expertise. We found that applying the tool to one species in an in-person workshop took a full day. In order to predict and compare the outcomes of different management plans, it is necessary to define them in some detail, which can be time-consuming. Collating management costings and current information on the species also takes some time and effort. A minimum level of skills and knowledge of the tool and methods are required by the facilitator in a group setting or by other decision-makers using it alone. We have tried to mitigate this by providing user support and suggestions for further reading on specific topics (below).

Further reading

For more information on:

- ***Structured decision making***, see:
  Gregory R, Failing L, Harstone M, Long G, McDaniels T, Ohlson D 2012. *Structured Decision Making: A Practical Guide to Environmental Management Choices*, John Wiley & Sons, Chichester.
  Keeney RL. 1982. Decision analysis: An overview, *Operations Research* 30(5):803–838.
- ***Expert elicitation***, see:
  Hemming V, Burgman MA, Hanea AM, McBride MF, Wintle BC, Anderson B 2018. A practical guide to structured expert elicitation using the IDEA protocol, *Methods in Ecology and Evolution* 9(1):169–180.
- ***Planning ex-situ management***, see:
  IUCN/SSC 2014. *Guidelines on the Use of Ex-situ Management for Species Conservation*, Version 2.0. Gland, Switzerland: IUCN Species Survival Commission.
- ***Population Viability Analysis***, see:
  McCarthy MA, Possingham HP 2013. Population viability analysis. Pages 2016–2020 in *Encyclopedia of Environmetrics* Second Edition, John Wiley & Sons Ltd, UK.
- ***Estimating probabilities of success***, see:
  Dolman PM, Collar NJ, Scotland KM, Burnside RJ 2015. Ark or park: The need to predict relative effectiveness of ex-situ and in-situ conservation before attempting captive breeding. *Journal of Applied Ecology* 52:841-850.
  Smith DH, Converse SJ, Gibson KW, Moehrenschlager A, Link WA, Olsen GH, Maguire K 2011. Decision analysis for conservation breeding: Maximising production for reintroduction of whooping cranes. *The Journal of Wildlife Management* 75(3):501-508.
- ***Quantifying extinction risk***, see:
  Geyle HM et al. 2018. Quantifying extinction risk and forecasting the number of impending Australian bird and mammal extinctions, *Pacific Conservation Biology* 24: 157–167.
- ***Red Hot Lists***, see
  Silcock, J and Fensham, R 2018. Using evidence of decline and extinction risk to identify priority regions, habitats and threats for plant conservation in Australia, *Australian Journal of Botany* 66(7): 541–555.
  Lintermans M et al. 2020. Big trouble for little fish: Identifying Australian freshwater fishes in imminent risk of extinction. *Pacific Conservation Biology* 26(4):365-377.
  Geyle HM et al. 2020. Reptiles on the brink: Identifying the Australian terrestrial snake and lizard species most at risk of extinction. *Pacific Conservation Biology* 27(1): 3–12.

Further information

Tracy Rout
t.rout2@uq.edu.au

Bridled nailtail wallaby. Image: Diver Dave, Wikimedia Commons, CC BY SA 3.0

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 NESP Threatened Species Recovery Hub. 2021.
A user guide to the PACES tool: Planning and Assessment
for Conservation through Ex-Situ management, Report