NSW GOVERNMENT
Office of Environment & Heritage

Saving our Species Technical report

Together we can secure threatened species in NSW

saving our species

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1 A new approach to threatened species management

The Threatened Species Priorities Action Statement (PAS) was introduced by the NSW Government in 2007 in response to a growing number of threatened entities listed on the schedules of the *Threatened Species Conservation Act 1995*. The recovery planning process was not keeping pace with the management requirements of these species and communities, so a simple list of proposed management actions for *all* threatened entities was developed to be more effective in meeting recovery goals.

A statutory review of the PAS was conducted after three years (*Review of the NSW Threatened Species Priorities Action Statement*), which made several recommendations for its redevelopment, including to:

- establish six new management streams to better target the management of each threatened species (Rec. 1)
- target investment at the minimum set of actions that are crucial for securing a species (Rec. 5)
- develop a sound, repeatable and transparent process for prioritising effort between species statewide (Rec. 6)
- develop a process for monitoring and reporting on the outcomes of projects and actions for threatened species (Rec. 7)
- develop a simple, user-friendly database to support program delivery (Rec. 8).

Saving Our Species (SOS) has been developed based on the findings and recommendations of the PAS review. The new program aims to provide an overarching framework for threatened species management in NSW, define more targeted management, clearly articulate objectives, and provide a transparent and objective process for prioritising management that is accessible to all stakeholders in NSW. The prioritisation described in this report will be used, along with other considerations such as regional priorities, current capacity and community engagement, to inform OEH priorities for investment in threatened species recovery across NSW.

Decisions regarding investment in threatened species management in NSW (and many other jurisdictions) are generally made in relative isolation (i.e. without coordination across regions or organisations), and are generally driven by factors acting at a fine scale with respect to space (i.e. local priorities) and time (i.e. short-term urgency). Furthermore, the scale and extent of implementation of management actions is determined primarily by short-term and often ad-hoc funding allocation.

The new program represents a significant improvement, as it provides a structured framework for all stakeholders to efficiently contribute to statewide objectives with a long-term focus. To be effective, threatened species management should be driven by a single objective that is target-based, specific and clearly defined, so that effectiveness of management can be measured and reported in the future. Specifically, the program-wide objective is '*to maximise the number of threatened species that are secure in the wild in NSW for 100 years*'. It also provides a centralised resource (the conservation projects database) where information on species' ecology, status and management effectiveness can be captured over time to facilitate adaptive management by all conservation practitioners in NSW.

The framework, objectives and justifications for the new program are presented in more detail in the *Introducing the* Saving Our Species *program* document, which provides a general introduction to the program and provides context for the information presented here. This technical report builds on the information provided in that document and explains in more detail the processes and underpinning science related to the development of the program and its constituent components, such as expert elicitation, cost-effective prioritisation and uncertainty analyses.

1.1 Targeting threatened species management

There are currently almost 1000 species listed on the schedules of the Threatened Species Conservation Act (TSC Act). Specific management requirements will obviously vary between species; however, as a first step towards targeting management based on ecological and/or intrinsic characteristics, the *Saving Our Species* program has categorised all listed species into six distinct management streams.

The first stage of the program will only address a subset of TSC Act listed *species*. Targeted strategies for populations, ecological communities and key threatening processes and for some threatened species will be developed as part of stage two.

The process for assessing and allocating each threatened species to a particular management stream is described in Figure 1.

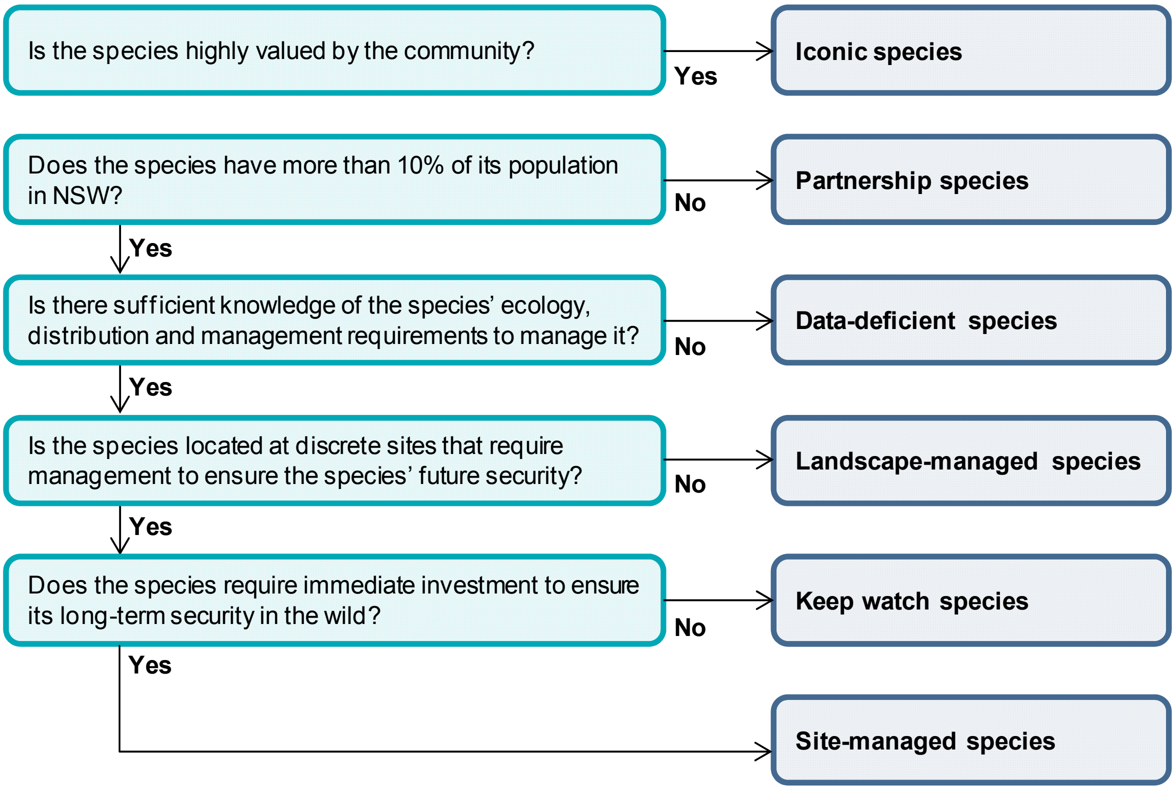

Figure 1: Flow chart illustrating the process by which species are allocated to management streams

The definitions and detailed criteria against which species are assessed for allocation to particular management streams are outlined below.

Iconic species

A small number of species that have intrinsic value to the NSW community, either statewide or regionally and/or have attracted significant investment from government and/or the community in their management were allocated to the iconic species stream.

These species, the koala, brush-tailed rock-wallaby, malleefowl and the corroboree frog were identified based on OEH experience in working with threatened species. OEH will have the capacity to gauge community interest in particular species via public interaction with the *Saving Our Species* website and database, which will provide a basis for allocating species to the iconic species management stream in the future.

Partnership species

Species with less than 10% of their total population occurring in NSW were identified as partnership species. In this context, 'population' sizes and proportions should be assessed using the highest resolution data available for the species; i.e. the NSW proportion of total species abundance in the first instance, followed by area of occupancy, extent of occurrence (IUCN 2010) and count of sighting records, respectively. For migratory species, this assessment should be based on the period when the species inhabits NSW (e.g. species with >10% of their population breeding in NSW, even if only for a short season, would *not* be considered partnership species).

There are two reasons for distinguishing *partnership* species from *site-managed* species: (i) the proportion of partnership species that are threatened nationally (11%) are unlikely to be effectively secured via activity undertaken in NSW alone (especially considering some NSW populations are likely to be marginal and/or at the edge of their geographic range, although some may be of high conservation value) and therefore could not meet the site-managed objective without the collaboration of other jurisdictions; and (ii) the remaining species (89%), which are likely to be abundant and/or not threatened in other jurisdictions, should be identified as lower priority for investment than those whose security depends predominantly on management in NSW.

Data-deficient species

Data-deficient species are those for which there is insufficient knowledge or published information about their management requirements to develop a conservation project that is likely to secure the species in the long term (see *Developing site-managed species conservation projects*). This is not the same as having insufficient data to determine the species' threat status (e.g. *Data Deficient* status under the IUCN Red List guidelines; IUCN 2010), which does not necessarily require an understanding of the species' management response and/or requirements. Typically, *data-deficient* species are those for which research into aspects of life history, distribution and threats and/or survey have a higher priority than active management.

Landscape-managed species

The viability of landscape-managed species is inextricably linked to the quality and extent of suitable habitat across large areas. These species are characterised by having large home ranges, being sparsely distributed or being highly mobile or nomadic. Critical threats to the viability of landscape-managed species are generally loss or degradation of habitat, or widespread pervasive factors such as climate change or disease. These species will largely be managed through protecting the broader landscape via vegetation management programs under the *Native Vegetation Act 2003,* regulation of water under the *Water Management Act 2000* and conservation programs in national parks and reserves under the *National Parks and Wildlife Act 1974*. It is recognised that the distinction between site-managed and landscape-managed species is relatively arbitrary, and in reality represents a continuum. Allocation of species should be based on the practical implications of threats and their management (i.e. if the species is most appropriately managed in discrete, geographically defined units, it should be allocated to the site-managed species stream).

Keep watch species

These are species for which long-term security in the wild can be achieved without targeted investment in management, either because there are few known threats or because they are known to be more abundant than previously assumed. Experts have predicted that these species meet the recovery objective (i.e. have a 95% probability of having a viable population in NSW in 100 years) without targeted management (i.e. additional to existing management of biodiversity in reserves and on private lands). Some of these species require a review of their threat status under the TSC Act; however, many also meet the criteria for being threatened because of their rarity or limited distribution (and the effects of stochastic threats), and therefore require regular monitoring to ensure they continue to be secure.

Site-managed species

Site-managed species are those for which discrete populations can be geographically defined, critical threats at these sites can be identified and feasibly managed (given resources), and where the mitigation of these threats at a selection of sites is likely to secure the species in NSW in the long term (i.e. meet the objective a 95% probability of having a viable population in 100 years).

Allocating species to management streams

All current TSC Act listed species were provisionally allocated to one of the six management streams by OEH operational staff experienced in their management, using a qualitative assessment of data (e.g. sighting records, management reports, scientific literature) where available. These allocations were then reviewed by various experts (operational and scientific) in the ecology of each species. This process will apply to all species newly listed on the schedules of the TSC Act by the NSW Scientific Committee. Management stream allocations are intended to be dynamic, representing the most appropriate strategy at any point in time, based on best available knowledge on the species' ecology and management requirements. Figure 2 illustrates the initial allocation of threatened species to each stream.

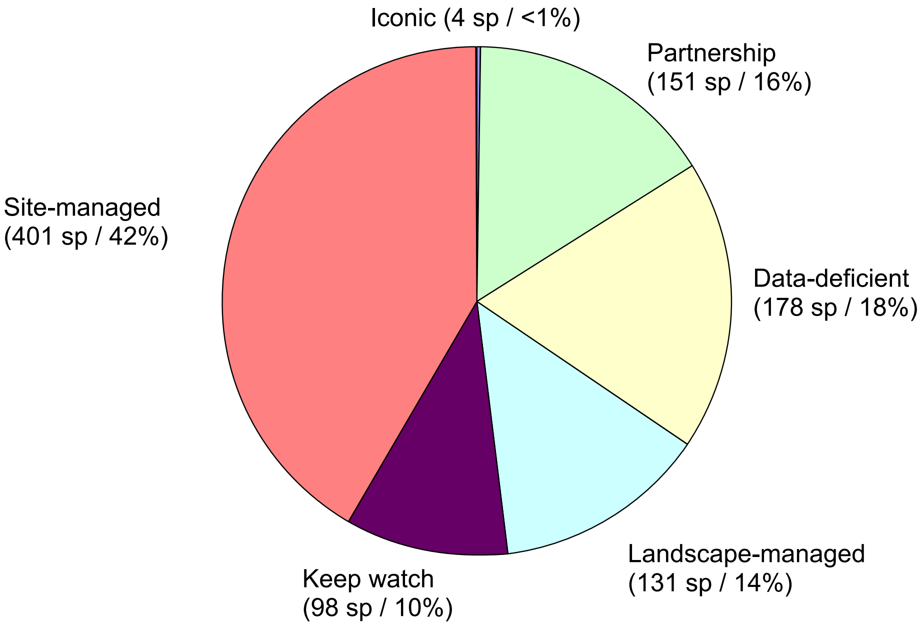

Figure 2: Initial allocation of species to management streams

1.2 Directing investment in management streams

Resources available for the adequate management of threatened species generally fall far short of what is required (Balmford et al. 2003; McCarthy et al. 2012). Therefore a method for prioritising investment is essential.

Categorisation using the six different management streams provides an initial basis for targeting, streamlining and more efficiently managing threatened species in NSW. Species in the site-managed, iconic and landscape-managed streams are considered the highest priority for investment. Site-managed and landscape-managed species have identified threats to their viability, which without management are likely to cause population decline or extinction. Iconic species have a history of high community interest and engagement and an expectation from the community that they will be managed.

Data-deficient species are considered to be second tier priority for investment due to existing key knowledge gaps, which if they remain unanswered will inhibit the species' management, potentially leading to population decline or extinction. Within the data-deficient stream, species will be prioritised for research based on their threat status (NSW and national) as well as the likelihood that the outcomes of the proposed research will facilitate effective management of the species.

Partnership species (except those listed as threatened nationally under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*) are generally considered third tier priority for management in NSW, considering that they are likely to be relatively abundant and/or not threatened in other jurisdictions (i.e. the species' security is not dependent on the viability of populations in NSW). Partnership species listed as threatened nationally, with one or more populations in NSW requiring management, will be prioritised for investment based on the relative importance of NSW populations to the species' security in Australia and on the cost of management.

For keep watch species, relevant experts have advised that investment in targeted management is unlikely to provide any significant benefit to viability, therefore this stream is not a priority for investment. If, however, the status of these species changes due to emerging threats, they will be reassessed for allocation to a higher priority management stream (e.g. *site-managed*).

It is a statutory requirement under the TSC Act that all threatened entities listed under the schedules of the Act have a strategy for their management identified within the Priorities Action Statement (PAS). Therefore, management of landscape-managed species, partnership species, endangered populations, endangered ecological communities and key threatening processes will continue to be guided by existing actions developed in 2007.

At this stage of the program, only species in the site-managed and data-deficient species streams have had their PAS strategies reviewed and redeveloped to include more specific and measureable actions. Only conservation projects for site-managed species have undergone a cost-effectiveness prioritisation (see *Project priority score*).

2 Site-managed species

OEH has adopted cost effective prioritisation as an objective method for ensuring that benefits are maximised for the greatest number of species. This methodology has been adopted in varying degrees by government agencies beyond NSW, including Tasmania (Department of Primary Industries, Parks, Water & Environment 2010), Western Australia (Carwadine et al. 2012) and New Zealand (Joseph et al. 2008).

The strategy for site-managed species contributes to meeting the *Saving our Species* program objective to maximise the number of threatened species that are secure in the wild in NSW for 100 years by having an objective that clearly defines when a species can be considered '*secure*':

> *'That there is a 95% probability of having a viable population of the species in 100 years from now, and that the species' threat status under the TSC Act will not decline'*

A '*viable population*' is defined here as a (sub)population where:

- all deterministic threats (predictable frequency and effects) are controlled
- the size of the population is sufficient to avoid demographic problems (i.e. minimum viable population size, e.g. Traill et al. 2010; Brook et al. 2011)
- the population trajectory is stable or growing (i.e. recruitment ≥ mortality)
- there is sufficient available habitat for the population to persist and grow.

This equates, effectively, to reducing a given species' 100-year extinction risk to 5%.

The aim of defining such an objective is to articulate the *minimum* required long-term outcome of any given project. This can then inform the development of a management prescription designed to meet the objective. Given the long timeframe and consequent likely effects of climate change and stochastic processes on subpopulation viability, a precautionary approach has been adopted. In practice, this means that (where they are known) multiple subpopulations of a species should be managed, in order to buffer against these types of threats.

Furthermore, the objective is perpetual with respect to ensuring species' security for 100 years into the future. For example, if a site-managed species conservation project were to be re-evaluated 20 years into implementation (i.e. 2033) and monitoring indicated that one or more subpopulations under management were not viable or on track to be viable in the short term, then the project would not be meeting the objective (i.e. 95% probability of having a viable population in 2133). Such a project would consequently be reviewed and amended (potentially enhancing the scale or extent of proposed management).

Given a variable but finite budget for managing threatened species in NSW, there is an implicit trade-off between the number of species that can be managed and the amount of resources invested in each species. Therefore, in order to meet the program objective, the amount of resources proposed to manage any given site-managed species must represent the *minimum* (number of subpopulations and actions) required to meet the site-managed species stream objective. This logic has informed the development of objectives for the management of site-managed species.

Investing in management at sites representing only a subset of a species' geographic range inherently increases extinction risk, compared to managing the species everywhere it is known to occur. This risk, however, must be weighed against the benefit of securing a larger number of species afforded by taking a cost-effective approach. If and how this risk is realised for each species will be the focus of a systematic assessment planned to occur within the first 12 months of implementing the program.

2.1 Developing site-managed species conservation projects

Conservation projects comprise a suite of management and monitoring actions proposed at a set of identified sites within NSW. The term '*site*' has a practical definition for the purposes of project development; it refers to a spatially defined area which encompasses one or more locations where a particular threatened species is known to occur and where any given threat to that species is managed in a consistent way.

To develop a project**,** an interview of 1–3 hours duration, consisting of a structured series of questions (Figure 3), was conducted with a panel of up to eight experts on the species' ecology, distribution, threats and management requirements. Interviews were mediated by OEH staff members, who captured both text and spatial data based on panel responses.

To identify relevant experts, formal scientific and informal 'grey' literature (e.g. government reports) was reviewed and authors were contacted. Also, OEH operational staff, natural resource management agency (e.g. catchment management authorities, local councils), academic and environmental consultancy networks were canvassed. Over a period of 18 months, 542 species interviews were conducted involving 262 different experts.

Threatened species vary significantly with respect to the availability of relevant data on their ecology, demography and management requirements. Wherever possible, published scientific evidence was used to inform the development of conservation projects; however, where this was insufficient expert opinion was relied upon.

Prior to each interview, a review of all available information pertaining to the species in question and/or its management was undertaken. This included data from sources such as:

- peer-reviewed scientific literature
- approved / draft recovery plans
- commissioned survey reports
- existing PAS actions
- Scientific Committee determinations (where available)
- regional pest management plans
- NSW Wildlife Atlas / Atlas of Living Australia.

The aim of each interview was to identify the minimum (in line with the program objective) number of appropriate management sites, threats impacting the species at those sites, and critical actions required to meet the recovery objective. Therefore each project should represent the minimum number of management sites and actions (i.e. minimum implementation cost) required to meet this objective.

Experts were selected from a variety of backgrounds, including:

- OEH
- members of relevant recovery teams
- government operational and scientific staff (e.g. NPWS, Royal Botanic Gardens)
- individuals with relevant knowledge (e.g. researchers, consultants).

All members of each expert panel were interviewed together in order to facilitate discussion and information exchange. Generally it is recommended that expert elicitation of this type be structured (e.g. using Delphi techniques) to minimise bias and the potential for participants to influence each other's estimates, as well as to accurately quantify confidence intervals (Burgman 2005). The nature of much of the information being sought, however, precluded the use of this technique. The expertise of individual participants, particularly conservation practitioners / operational staff was sometimes site-specific, with no single participant on the panel having expert knowledge of the species' ecology or habitat requirements across its entire range. Therefore, when making complex decisions requiring the integration of this knowledge, such as determining the relative importance of management sites to the species' statewide viability, group discussion was important.

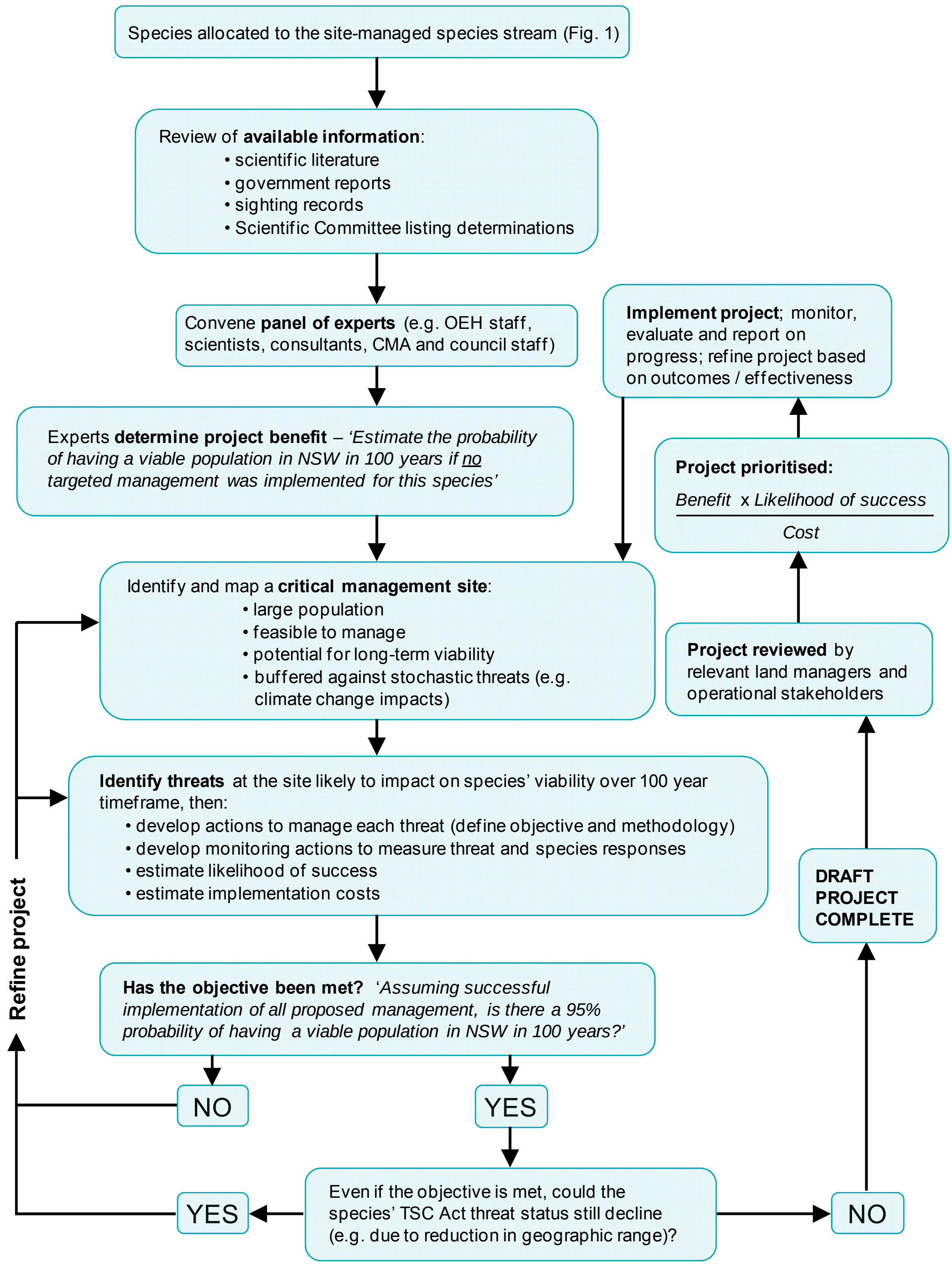

Figure 3: Conservation project development process

Ultimately, empirical evidence is preferable to expert opinion when informing management. Given that data collected during interviews represent a baseline only, project data can be updated in response to the outcomes of implementation (e.g. likelihood of success scores can be refined over time based on actual implementation success). Ideally, as the program progresses, the increased availability of management effectiveness data compiled via outcome monitoring can gradually reduce the dependency on expert estimates.

2.2 Site selection

Identifying the number and location of management sites to be included in any species conservation project is a key aspect of the process, which significantly influences cost, probability of meeting the objective and between-species comparability. Therefore, it requires careful consideration by experts as well as guiding principles.

Sites were selected in order to meet the project objective while maximising likelihood of success and minimising management effort required. Experts were asked explicitly to consider the following factors:

- population size
- habitat condition
- extent / severity of threatening processes
- feasibility of management (e.g. sites on public tenure will be more feasible / less costly to secure than those on private land).

Following the development of actions at the first nominated site, experts were asked the following question:

> *'Assuming that all the actions at nominated site/s are successfully implemented, adequately controlling human-induced threats likely to occur at these sites over a 100 year timeframe, is the probability of having a viable population of the species in NSW in 100 years at least 95%?'*

If the answer to this question was *yes*, the project objective had been met, and no more sites were added. If the answer was *no*, the expert/s were asked to select a second critical site for management and to develop actions as per the first site.

When evaluating the addition of sites to a project, it was important for experts to make decisions under the assumption that all management actions developed for sites already included would be implemented with *100% effectiveness* over a 100 year timeframe. Uncertainty or risk associated with the outcome of actions is to be captured only once, via the likelihood of success estimates (see *Likelihood of success* below). Therefore developing additional management sites to buffer against the potential failure of actions to control deterministic processes would bias the process. Experts were asked to only take into account the likelihood of ***stochastic*** or ***unpredictable*** (i.e. unmanageable) threats (e.g. infectious disease, wildfire, climate change impacts) when determining the requirement to add sites to a project. Susceptibility to these threats can be inferred via biological variables known to affect extinction risk, e.g. population size, population decline, geographic range, and number of extant populations (O'Grady et al. 2004; Mace et al. 2008). Experts were asked to consider these factors throughout the site selection process.

When the experts agreed on a given set of management sites / actions, they were asked to confirm that the nominated project is also predicted to meet the second part of the project objective:

> *'…that the species' threat status under the TSC Act will not decline.'*

If implementing *only* the management outlined in the nominated project is predicted by the experts to affect the species' population in such a way as to cause a worsening of its TSC Act threat category (e.g. via decline in abundance, reduction in extent of occurrence / area of occupancy in NSW), the project should be reviewed in the context of adding sites/actions to reduce the risk of this occurring.

2.3 Action development

At each nominated management site, experts were asked to identify the *critical* threats to the species (i.e. threatening processes that are likely to impact on the long-term viability of the subpopulation). For each of these threats, one or more management actions were identified, each with a defined objective and proposed methodology. Where multiple methodologies exist for controlling a particular threat, the most feasible option for achieving the stated objective (based on available information) was adopted.

Management actions (as well as management sites) were spatially defined; each action is associated with a polygon representing the scale / extent of implementation. These polygons are used for both planning implementation activity and identifying opportunities for multi-species benefits.

Once all management actions had been developed, monitoring actions were developed with the following objectives:

- to regularly measure the species abundance at each management site (or a validated proxy index such as habitat condition/extent if measuring abundance is not feasible), to establish population trends over time
- to regularly (and directly) assess the extent and severity of threatening processes being managed at each site.

The effort and resources associated with monitoring are incorporated into the total project cost. This information will facilitate tracking the status of individual species as well as evaluating the effectiveness of management at the site, and threat and program levels.

2.4 Project review

Following completion of the interview, all participating experts as well as relevant species experts unable to be involved on the day, were provided with a draft of the project to review. This was to ensure that all information had been captured accurately and to confirm that all species experts agree that the project meets the stated objective.

Details of all management actions (location, methodology, feasibility estimates and costs) in the draft projects were also provided to all appropriate operational agencies/staff (i.e. those likely to be involved in their implementation) for review. The key agencies involved in the operational review were:

- OEH Regional Operations Division
- OEH National Parks and Wildlife Division
- catchment management authorities
- Forestry Corporation of NSW
- local councils
- Livestock Health and Pest Authority.

The objective of this round of review was to refine and ground-truth project details, especially with respect to the feasibility of management actions and their associated effort/cost. This also allowed for the clarification of spatial data describing management site boundaries and clarification of the appropriateness of nominated sites. In many instances, experts involved in the species interviews may not have personally visited the site in question recently (or at all), therefore it was imperative for local land managers to confirm the locality information as well as the described scale and intensity of threatening processes.

3 Project priority score

In order to prioritise investment in site-managed species (~42% of species) objectively and transparently, the *Saving our Species* program has adopted a Project Prioritisation Protocol (PPP), developed by the Australian Research Council Centre of Excellence for Environmental Decisions (University of Queensland) and already implemented by the New Zealand Department of Conservation (Joseph et al. 2008). The prioritisation incorporated values associated with the benefit (marginal increase in species' viability attributable to the project), likelihood of success (of each proposed management action) and cost (of action implementation) of projects. PPP will allow OEH to maximise efficiency in conserving threatened species while making transparent, objective decisions with respect to managing the >400 site-managed species for which it is responsible.

All site-managed species projects were given a priority score based on the following equation:

$$\textbf{Priority score} = \frac{\textbf{Benefit} \times \textbf{Likelihood of success}}{\textbf{Cost}}$$

The three respective components of the score are defined and derived as follows.

3.1 Benefit

The benefit value is defined as the difference between the species' probability of having a viable population in 100 years *with* full and successful implementation of the project and the equivalent probability *without* any targeted management being implemented for the species over this timeframe. A maximum probability of viability of 0.95 is used to account for inherent uncertainty.

Benefit = Prob. viability with mgt (objective = 0.95) – Prob. viability without mgt (range = 0–0.95)

This value attempts to quantify the likely effect of management on a species' long-term viability, but also represents the relative urgency with which action is required.

Estimating a species' long-term viability without management requires predicting the dynamics of threatening processes and their effects on populations in the future. Therefore estimates based solely on expert opinion are likely to be both highly variable and highly uncertain. In order to help minimise such error and standardise the calculation of benefit, guidelines were developed based on published interpretation of the IUCN Red List criteria (*sensu* Kindvall & Gärdenfors 2003; outlined below). This allows each species to be assessed against the criteria, where data are available (e.g. population size and decline, extent of occurrence, area of occupancy, etc.) and allocated to a threat category (Vulnerable, Endangered or Critically Endangered), which is in turn associated with a standard probability of viability value.

Probability of viability without management is effectively equivalent to the inverse of extinction risk. IUCN Red List Criterion E attributes a 10% extinction risk over 100 years to species categorised as Vulnerable (based on Population Viability Analysis) (IUCN 2010). However, extinction risks for species in the Endangered or Critically Endangered categories are provided only over 20 and 10 year timeframes respectively. Kindvall and Gärdenfors (2003) provide a method for extrapolating extinction risk for these threat categories to a 100 year timeframe (which has been independently supported by Mooers et al. 2008). Based on this model (Figure 4), standard values for probability of viability without management (with corresponding benefit score) have been adopted as follows:

- Vulnerable (V) = 0.9 (benefit=0.95–0.9=0.05)
- Endangered (E) = 0.3 (benefit=0.95–0.3=0.65)
- Critically Endangered (CE) = 0.05 (benefit=0.95–0.05=0.9)

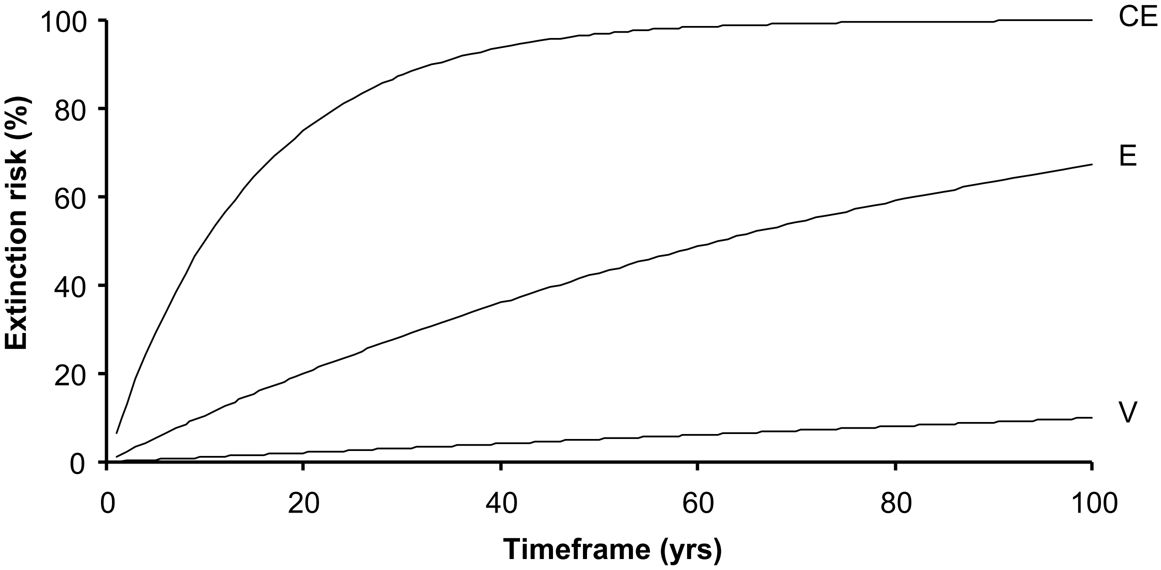

Figure 4: Cumulative extinction risk curves for three IUCN Red List categories, reproduced from Kindvall & Gärdenfors (2003)

During interviews, experts were given the opportunity to revise the standard value based on their knowledge of factors not addressed by the IUCN criteria, e.g. emerging threats, life-history or relative protection on land managed for conservation purposes. They were then asked for a qualitative measure of confidence in their estimate (*Very confident*, *Confident* or *Not confident*).

Following the completion of interviews, benefit scores across all species were analysed by comparing individual estimates to predicted/standard values based on TSC Act status. Individuals showing significant departure from this value (large residuals) required specific justification before the score could be confirmed for the prioritisation. This was true for a small number of species, for which justifications were provided (e.g. emerging threats had caused significant declines since the species' listing).

3.2 Likelihood of success

For every action at each management site, experts were asked to estimate the likelihood of success of the action in three different contexts:

Input success (Can the action be done?) describes the likelihood that managers can successfully proceed with implementing the action, given physical, legal or socio-political constraints, e.g. how feasible is conducting fox baiting, given proximity to residential areas?

Threat outcome success (Will the action work?) describes the likelihood that the action will successfully control the threat to the extent defined by the threat objective, e.g. how likely is fox baiting to reduce local fox densities to <5% activity level?

Species outcome success (Will the action benefit the species?) describes the likelihood that the action increases the species' viability (via improving survival and/or reproduction) at the site, assuming that the threat outcome success equals one (1), e.g. if fox densities are reduced, how likely is it that the species' population will increase in response?

Within a given action, each score is assumed to be independent of the other two (i.e. threat outcome success is estimated based on the assumption that the action can be implemented, and species outcome success is estimated based on the assumption that the threat can be effectively controlled). Therefore the product of all three scores equates to the probability of the action achieving its ultimate objective.

Obviously making predictions about the long-term likelihood of success of any action is difficult, especially where experts have limited direct knowledge or experience to draw on. Therefore, an additional qualitative score measuring expert uncertainty was collected for each estimate (*Very confident*, *Confident* or *Not confident*). A high level of disagreement between experts was generally interpreted as being indicative of low confidence in the final estimate.

The possible range of scores is 0–0.95 (assuming that for all actions there is a non-zero probability of failure). The overall likelihood of success score for a given project is calculated as the product of all individual scores (for every action) therein. For the purposes of this calculation, scores of 0.95 (maximum possible) are transformed to 1, so as not to artificially penalise projects with large numbers of high feasibility actions.

3.3 Cost

For all management and monitoring actions included in a project, the cost of implementation over a 50 year timeframe was calculated and summed to establish a total project cost. These costs were estimated for particular projects by relevant operational experts where possible. Alternatively, a schedule of standard costs associated with frequently-employed management actions was developed using relevant sources including:

- NPWS Asset Maintenance System (AMS)
- NPWS Pest and Ecological Management Unit (PEMU)
- NPWS Fire Ecology Unit
- BioBanking scheme
- catchment management authorities (CMAs).

These costs were applied to all actions as a first estimate where possible. Regional and species-specific variation is likely to limit the accuracy of standard costs when applied to any given action. Hence, a key function of the operational review stage (see above) is to refine and ground-truth management costs based on local knowledge and experience.

For some costs, a standard rate will be applied to all relevant projects, for example:

- travel @ $0.92/km (based on average fuel consumption @ 8L/km, driving speed @ 80km/h and fuel cost @ $1.50/L)
- officer liaison with an external agency @ 2 days full time equivalent (FTE) / year.

The schedule of standard costs will be reviewed on an annual basis to ensure all costs are up-to-date and align with OEH and relevant industry standards. The majority of costs associated with human resources and equipment will be aligned with those in the AMS.

Given the long timeframe over which costs are estimated for the prioritisation (50 years), a discounting factor was used to accurately calculate the present value of future costs. A static discounting factor of 0.01 per year was applied following Joseph et al. (2008). For example, if a weed control action costs $10,000 p.a. in 2013, it would be valued at $395,881 over 50 years using a discounting factor of 0.01.

3.4 Cost-sharing

Species conservation projects have the capacity to incorporate efficiencies associated with multiple-benefit actions via cost-sharing. Where actions are shared by two or more species projects and at the same location (determined via action polygon geometry) and involve an identical methodology targeting the same threat, the costs associated with implementing the action are shared between the relevant projects.

If the cost (scale) of each of the actions is identical (i.e. they have perfectly overlapping action polygons), this cost is divided equally among the relevant projects. For example, if three different species conservation projects each included a fox control action costing $15,000 to implement, at the same location, the cost attributed to each project would be $5000.

If the cost (scale) of each of the actions is not the same, but affected areas (action polygons) overlap, the cost attributed to each overlapping action represents a fraction of the cost of the most expensive action proportional to its relative cost. For example, if three action polygons occur as illustrated in Figure 5, the proportion attributed to Action 1 is 3000/(3000+2000+1000) = 0.5, the total cost is calculated as equivalent to the most expensive action ($3000), and therefore the cost allocated to each species' conservation project that includes Action 1 is 0.5 * $3000 = $1500. Likewise, the shared costs allocated to each project that includes Actions 2 and 3 are $1000 and $500 respectively.

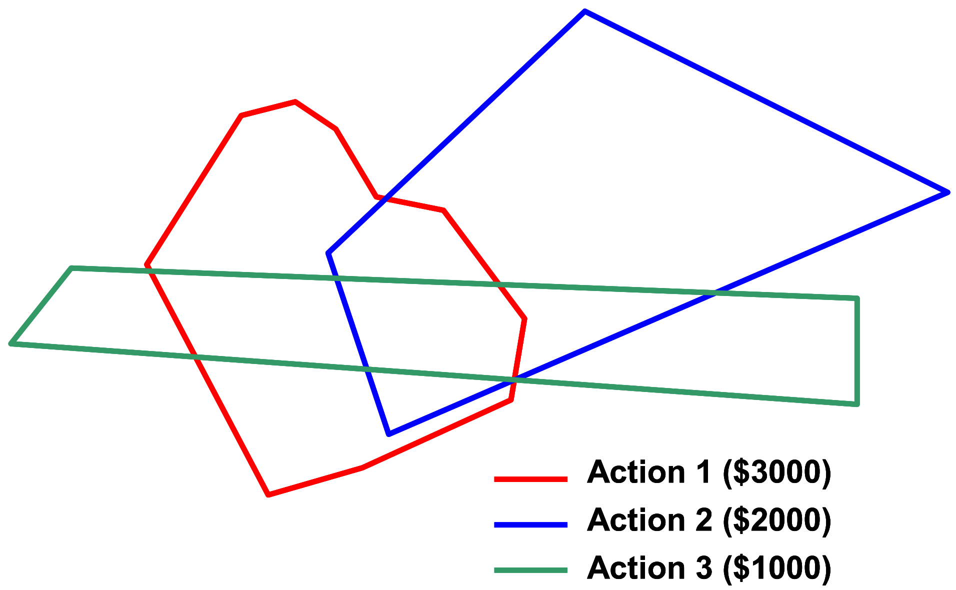

Figure 5: Example cost-sharing scenario

Using this method there are particular circumstances where the algorithm will underestimate the true total cost of implementing an action to meet the requirements of multiple species. For example, where costs are proportional to area and action polygons have a small overlapping area. This is illustrated by Figure 5, where if the actions refer to weed control costed per hectare, the cost of implementing all actions is likely to be greater than $3000. This error can be minimised by setting a proportion threshold (e.g. 50%) for overlap area, at which action polygons will share costs.

In the prioritisation, the application of cost-sharing to any given action is dependent on the project being proposed for implementation under a given budget scenario. Actions within projects that are ranked outside those identified as achievable for a proposed budget are unlikely to be implemented (in a pure application of the prioritisation), therefore sharing implementation costs with these actions would be unrealistic.

3.5 Continual reassessment

Both the listing and management of threatened species in NSW are dynamic processes. Nominations are continually being assessed by the NSW Threatened Species Scientific Committee, leading to the addition and removal of entities to/from the schedules of the TSC Act. Threatened species management requirements are also continually changing, either in response to environmental changes or improvements in knowledge. Considering this, conservation project data will require updating on an ongoing basis, as will investment priorities. Therefore the prioritisation analysis will be run annually (incorporating current best available knowledge) to support decisions related to continuing or discontinuing investment in particular conservation projects.

4 Post-hoc analyses

4.1 Standardising inputs

Following the collection of all interview data and prior to running the prioritisation algorithm, a manual review of variation in estimates of *benefit*, *likelihood of success*, and *cost* values across all species conservation projects was undertaken. Over 250 different experts were involved in the project development process; therefore between-expert variation in value estimates was expected. To ensure that this variation was not excessive and to prevent outlier effects (primarily for *likelihood of success* estimates), we determined absolute maximum and minimum values for particular action types that were applicable irrespective of the species, habitat or location. The values were determined by groups of internal (OEH) experts with experience in implementing the relevant action type across NSW (as well as having participated in a significant number of interviews in the project development process). This applied to the following types of actions:

- vertebrate pest control
- weed control
- private landholder agreements
- ex-situ flora management.

These values were then used to truncate variation in expert estimates within action types for the purposes of project prioritisation. By manipulating the data in this way there is an increased risk of imposing motivational biases shared by the internal expert groups, potentially artificially skewing (and reducing) the variation in likelihood of success values (consequently affecting species' relative priority scores). This risk was deemed acceptable, given the significant benefit of ensuring a level of standardisation of estimates between conservation projects being prioritised.

4.2 Sensitivity analysis

To assess the relative effects of each different input parameter in the prioritisation equation on the output, we used standardised regression coefficients. This involved using a simple linear regression model. The analysis is designed to indicate the relative effect of change in variance of a particular input parameter (*B*, *L* and *C*) on the change in variance of the output (*P*).

The resulting coefficients were:

Benefit = 0.135

Likelihood of success = 0.287

Cost = 0.060

This indicates that *likelihood of success* is the most influential parameter, having approximately twice the effect of *benefit* on the priority score and more than four times the effect of *cost*. This analysis was based on a single data set in 2013, therefore results are likely to be indicative of the model dynamics, and may change under future iterations of the prioritisation.

4.3 Uncertainty analysis

When eliciting information from experts, there is inevitable uncertainty (producing error) associated with each estimated value. This generally comes from two different sources: structural uncertainty (e.g. incomplete understanding of how a species responds to a threat or management), and unpredictability (e.g. inability to accurately predict how the environment will change over 50 years).

To quantify and assess the effects of uncertainty in estimations of species' projected viability, likelihood of success of management actions and cost on project priority scores and rank, we used Monte Carlo simulation models (Burgman 2005). Using the prioritisation equation:

$$P_i = \frac{B * L}{C}$$

potential uncertainty was quantified in the following ways for each model parameter:

B – during interviews, experts were asked for an assessment of confidence in their estimate of a species' probability of viability over 100 years (0–1) *without* management. Responses were categorised: *Very confident, Confident* or *Not confident*. These responses were transformed into intervals of ±0.05, ±0.1 and ±0.2 respectively, around their estimate.

L – for each likelihood of success estimate, experts were asked to assess their confidence in an identical way to that for benefit (see above). Confidence intervals were calculated as above.

C – potential uncertainty around cost estimates for most projects was fixed at ±30%, based on an analysis of actual spending compared to planned costs for NPWS implementation of environmental management activity (data sampled from the Asset Maintenance System database for the 2011–12 financial year). For a subset of projects known to have increased uncertainty due to lack of recent on-ground experience at management sites, the uncertainty interval was fixed at +100%/–30%.

Monte Carlo simulations were run sampling from a triangular distribution (there being no theoretical basis for assuming a normal distribution) with the mode equal to the expert estimate and maximum and minimum values set by the respective uncertainty intervals defined above.

Following each of 10,000 simulations, a priority score (*P*) was calculated for each project and all projects were ranked, giving a distribution of simulated ranks for every project. Using the 2.5 and 97.5 percentile values from these distributions, a 95% confidence interval for project rank was determined.

4.4 Priority bands

Ranking the projects by priority score allows for the development of a priority list, however, the results of the uncertainty analyses demonstrate that there is not enough resolution in such a list to confidently discern relative priority between individual conservation projects (i.e. determine a project ranked 37 to be higher priority than the project ranked 38). Therefore, for the purposes of selecting conservation projects for investment by OEH and for communicating the output of the prioritisation to program stakeholders and the general public, the ranked priority list was transformed into five priority bands. The thresholds for inclusion in each band were defined by the 95% confidence interval for priority rank determined via the uncertainty analysis.

All projects with 95% confidence of being ranked in the top 30% (i.e. 95% confidence interval maximum ≤70th percentile rank) were allocated to Band 1. All projects for which the 95% confidence interval was entirely within the next ranked 40% (i.e. 30th to 70th percentile rank) were allocated to Band 3. All projects with 95% confidence of being ranked in the lower 30% (i.e. 70th to 100th percentile rank) were allocated to Band 5. All projects with 95% confidence intervals spanning Bands 1 and 3 or Bands 3 and 5 were allocated to Bands 2 and 4 respectively (Table 1).

Table 1: Example allocation of conservation projects to priority bands based on priority rank uncertainty

Conservation project	Priority score	Priority rank	Rank range (95% C.I.)*	Priority band
Species A	19.8	1	1–3	1
Species B	19.0	2	1–7	2
Species C	18.9	3	2–5	1
Species D	16.7	4	3–6	1
Species E	15.9	5	2–10	2
Species F	14.2	6	4–12	2
Species G	13.5	7	3–9	2
Species H	12.7	8	5–11	2
Species I	12.6	9	8–13	3
Species J	10.3	10	9–16	4
Species K	8.7	11	9–13	3
Species L	8.5	12	11–14	4
Species M	8.1	13	10–15	4
Species N	6.7	14	12–19	4
Species O	6.6	15	13–18	4
Species P	6.4	16	14–20	5
Species Q	5.7	17	15–20	5
Species R	4.2	18	14–19	5
Species S	3.7	19	17–20	5
Species T	2.5	20	18–20	5

* C.I. = confidence interval

5 Implementation

5.1 Monitoring, evaluation and reporting

One of the critical findings of the PAS Review was that there was insufficient monitoring and/or reporting on action implementation or outcomes to adequately evaluate the success of the program. This problem is not unique to NSW; there has been an increasing focus in Australia on environmental management agencies having to demonstrate return on investment for conservation programs. For example, the Australian National Audit Office (ANAO) recently concluded that after spending $6.51 billion on natural resource management programs, Australian government reporting was insufficient to make an informed judgment about outcomes achieved (Hajkowicz 2009).

In order to properly evaluate program success, data that allows for the assessment of progress against stated program objectives must be collected and reported. Under the SMART approach, these objectives should be Specific, Measurable, Achievable, Relevant and Time-bound. Different objectives at different scales should also relate to each other and contribute to higher level objectives under a program logic framework (Roughley 2009).

The monitoring, evaluation and reporting (MER) framework for the *Saving our Species* program is based on program logic that links action and species level objectives to the overall program objective (Figure 6). As with all program logic, there are assumptions and risks associated with each defined link. In order to continuously test these assumptions and manage the risks associated with links in the program logic being broken, every conservation project includes actions to monitor outputs/outcomes at three levels:

1. Outputs (financial expenditure; in-kind resources; implementation effort/activity, e.g. hectares of weed control)
2. Threat outcomes (habitat condition; improved land management; pest/weed response, e.g. reduced pest species abundance)
3. Species outcomes (species abundance; reproductive success; individual condition).

These data will be collected for any action/site where management is being undertaken. Results will be reported to the conservation projects database (see *The conservation projects database*) for collation and to inform evaluation of progress against site, project and program level objectives.

Objectives have been defined (and will be refined over time) at the species level, given the variation between species with respect to demographics and biological response to management. It is important that progress is evaluated with respect to expected interim outcomes for threat abatement and species response. Using these metrics, the success of the program can be evaluated based on the number of threats and species at nominated sites that are *on track* to meet their long-term objectives (e.g. for site-managed species, secure for 100 years).

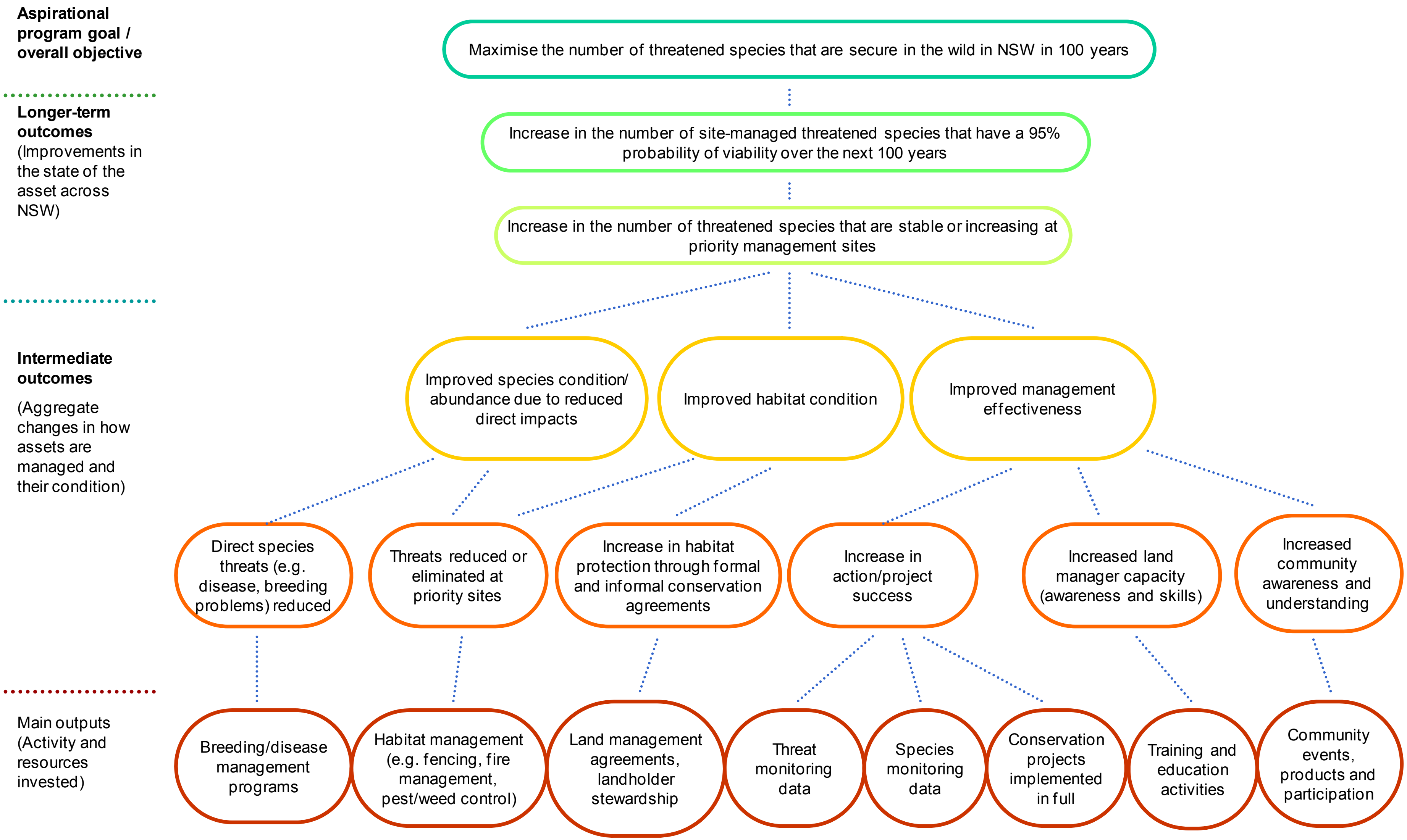

Figure 6: ***Saving our Species*** **program logic**

5.2 The conservation projects database

The conservation projects database is an essential component of the new program, required for collecting, storing and communicating data relevant to species conservation projects. The main purpose of the database is to inform all program stakeholders of OEH investment priorities for threatened species management and facilitate improved reporting of project outcomes. The database will house data describing all conservation projects and species, site, action and cost data (including spatial data).

The application has been developed using Microsoft web-based technology ASP.NET 4.0, C# and SQL Server 2008 as the database. It is hosted within the OEH secure hosting environment.

The database is web-enabled, has a spatial viewer function, and will have the following functions:

- viewing and updating project information (including spatial information)
- browsing/searching by species type and geographical filters
- developing financial year action plans to facilitate project planning
- storing outcome data, including monitoring results
- generating reports to facilitate evaluation of project and overall program success
- creating conservation projects for any newly-listed threatened species or currently listed species shifted to the site-managed species stream.

A subset of data held in the database will be accessible by the general public via the OEH website, however, detailed project information (e.g. specific methodologies) and sensitive spatial information (e.g. geographical locations of species defined as Category 1, 2 or 3 under the OEH Sensitive Species Data Policy, or sites on identifiable private properties) will only be accessible by registered database users. User privileges can be assigned to both OEH staff and external partners. Each user will be assigned a (project-specific) role which will determine their level of permission to view or update project data (Table 2).

To ensure data security, the assignment of user privileges to external partners will be managed by the Ecosystems and Threatened Species team, Environmental Programs Services (OEH) via the OEH internal security portal (ASMS). Once user privileges have been granted, Species Project Coordinators will have authority to assign users to various roles within the conservation projects that they are responsible for (e.g. site manager, action implementer).

To ensure quality and consistency of data being entered, all changes to project data must be approved by the relevant Species Project Coordinator before they are confirmed in the database.

Eventually, the *Saving our Species* database will house data on the proposed management of all threatened entities listed under the schedules of the TSC Act, including those being developed as stage 2 of the program, including: landscape-managed species, endangered populations, threatened ecological communities and key threatening processes.

Table 2: Roles and user privileges applicable to the conservation projects database

Role	Criteria	Project	Site details	Action methodology
Administrator	OEH Ecosystems and Threatened Species, Regional Operations	CREATE/ UPDATE	CREATE/ UPDATE	CREATE/ UPDATE
Species Project Coordinator	Officer responsible for coordinating the project and delegating finances (predominantly OEH)	UPDATE (species specific)	CREATE/ UPDATE	CREATE/ UPDATE
Species expert	Persons involved in developing projects (e.g. OEH staff, consultants, scientists)	VIEW ONLY (species specific)	VIEW ONLY	VIEW ONLY
Site manager	Persons with on-ground experience of the site who can coordinate action implementation	VIEW ONLY	UPDATE (site specific)	CREATE/ UPDATE (site specific)
Action implementer	Persons actively involved in implementing actions on-ground	VIEW ONLY	VIEW ONLY	UPDATE (action specific)
Interested party	Persons with a specific involvement in the site or action, non-implementing (e.g. landholder, financial sponsor)	VIEW ONLY (site specific)	VIEW ONLY (site specific)	VIEW ONLY (site specific)

6 Conclusion

Saving our Species represents a significant departure from the current strategy for managing threatened species in NSW. The new program will improve outcomes by clearly articulating to all stakeholders what is required, where and when in order to meet specific objectives, and how much it will cost. This framework also allows for the communication of priorities from a statewide perspective and in a transparent and objective fashion. Furthermore, by refining the planning stages of species management (management stream allocation and project development) down to what is critical, the new program shifts a greater proportion of available resources into implementation.

By considering explicitly the cost, benefit and feasibility of management in a quantitative prioritisation, the new program also has the ability to maximise the outcomes of investment in threatened species across NSW. The prioritisation as well as the management stream framework will also allow the government to clearly justify how and where resources are invested for threatened species and be accountable for these decisions.

The development of dynamic prescriptions for managing particular species, as opposed to static planning documents (e.g. recovery plans), will allow the evidence base to improve over time, facilitating adaptive management. Knowledge management for *Saving our Species* will be through the conservation projects database, which will act not only as a planning tool, but as a repository of outcome data that can improve learning, and a means to engage land managers, conservation practitioners and the public in threatened species conservation.

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