ENVIRONMENTAL BIOSECURITY
RISK ASSESSMENT FOR CONSERVATION AREAS

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Terry Walshe[1], Matilda Davis[2], Kelly de Bie[1], and Tom Kompas[1]

[1] Centre of Excellence Biosecurity Risk Analysis, University of Melbourne

[2] Butchulla Aboriginal Corporation's Land and Sea Program

EXECUTIVE SUMMARY

Although management plans for protected areas typically include actions for established weeds and vertebrate pests, preparation of a dedicated biosecurity plan is rare. Biosecurity planning and responses have been highly detailed, diligent, and successful for a handful of island reserves. Still, the processes and tools behind these successes are not widely available.

There are likely many reasons for the modest uptake of advances in risk analysis among conservation managers, including limited resourcing for planning, limited availability of quantitative skills among personnel, and a shortage of high-quality high visibility applications upon which local managers can base their analyses. For many larger and possibly more complex conservation areas, including World Heritage Areas, added complexities include diffuse governance arrangements, the presence of a substantial tourism industry that may have little knowledge or capacity in biosecurity, and the cultural and livelihood needs and aspirations of Traditional Owners. In contrast to regulatory settings faced with acceptable risk problems, these complexities suggest that the management of biosecurity risks in conservation settings needs to be underpinned by decision support tools that emphasise and accommodate multiple objectives and trade-offs involving multiple stakeholders.

This report describes the development of a set of risk-based decision support tools for pre-border biosecurity planning, including:

- a template for estimating the cost of candidate actions;
- objective-specific indicators to characterise impact, including key conservation values, outcomes for Traditional Owners, and the visitor experience;
- elicitation of expert judgment to overcome challenges stemming from sparse or no data availability;
- sound logic in the treatment of probabilistic judgments and the aggregation of risk over multiple pests, and
- a coherent framework for combining technical and value judgments in progressing coarse consensus around a preferred biosecurity strategy.

These tools are synthesised and operationalised in accompanying excel-based spreadsheets.

We illustrate the use of the tools and spreadsheets with a pilot case study application at K'gari (Fraser Island).

Outcomes can be used to inform management plans and a business case for additional funding.

CONTENTS

1.0 CONTEXT

This report describes risk assessment tools to address key challenges in identifying effective and broadly supported biosecurity measures among conservation co-managers and stakeholders. The spreadsheet-based tools are designed for pre-border biosecurity threats – that is, pathogens, weeds, and pest species that are currently thought to have not become established in a protected area but could plausibly do so in the future[1]. Throughout this document we use the term *pests* to refer to all biological hazards that may be invoked in biosecurity planning, including pathogens, weeds, invertebrates and vertebrates. We explore a trial application at K'gari (Fraser Island), a world heritage property, but the tools are transportable to any conservation setting, terrestrial or marine.

There are two motivations for a pre-border focus. Firstly, this is often a gap for conservation managers, with less planning and effort in pre-border risk mitigation measures and considerably greater resourcing allocated to control or eradicate established weeds and pests. Secondly, preventive biosecurity measures can be more efficient and effective (Leung et al. 2005, Finnoff et al. 2007).

Just what might entail the best preventive action can be overwhelmingly difficult to grasp. There are typically many pests that pose material risk of harm, multiple pathways by which they may enter, and marked variability and uncertainty in the conservation values they impact. Similarly, the effectiveness of candidate quarantine measures, education and enforcement, surveillance and treatment may be speculative. Managers and stakeholders will hold different views on the relative importance of different ecological values. These views may be coloured by concerns over a compromised visitor or recreational experience through restrictions on movement or onerous quarantine measures. In short, there may be a bewildering array of factors to consider and the prospect of only modest additional resourcing to address risks. The tools we describe in this report help navigate this complex terrain.

In the design of risk assessment and decision support tools, we are mindful that conservation reserves, especially larger world heritage properties, can have complex governance arrangements. For K'gari, much of the island is administered by the Queensland National Parks & Wildlife Service within the Department of Environment and Science. But substantial land areas fall under the responsibility of local government or the Department of Resources in its dealings with crown land. There are also community organisations that have longstanding interests in the island and its ecological condition. Finally, and most profoundly, there are the custodial responsibilities and rights of Traditional Owners, the Butchulla peoples (Box 1). Although the tools we describe in this report can be used in conservation settings involving a sole manager, we have sought to develop an approach that accommodates a range of values and variable emphases on those values among co-managers and stakeholders. Our approach aims to provide insight into where there is broad support for specific biosecurity measures and where implementation of a subset of measures may be divisive or otherwise ill-advised.

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[1] The *border* in the context of this report refers to the boundary of a protected area. For clarity, it does not refer to state, territory or international borders as is often the case in biosecurity.

BOX 1. BUTCHULLA STATEMENT OF RESPONSIBILITY FOR K'GARI BIOSECURITY

The Butchulla people are the traditional custodians of K'gari (Fraser Island) and the adjacent mainland, from around Double Island Point in the south to the mouth of the Burrum River in the north, and west to Bauple Mountain.

All species of flora and fauna native to Butchulla country contribute to the healthy balance of country. While all are precious to the Butchulla people, we emphasise the protection of species that have edible, medicinal, and cultural properties. Culturally significant species include resources for ceremony, constructing shelters, utensils, tools, and weapons, species that serve as seasonal indicators, and/or contain spiritual connections to sacred stories. Weeds, pests, and pathogens threaten the health of our country, her inhabitants (flora and fauna), and certainly, our edible, medicinal, and culturally significant species. As traditional custodians, this impedes our ability to practise culture.

As Butchulla people, we have a responsibility to honour our first Lore, minyang galangoor gu djaa, kalim baya-m (what is good for the land comes first). We are committed to protecting our beautiful Butchulla country from weeds, pests, and pathogens. We can achieve this by working collaboratively with relevant stakeholders to develop sustainable solutions. We wish to develop positive partnerships that honour the Butchulla peoples' Lore, sovereignty, knowledge, connections to country, and cultural values, both tangible and intangible.

Galangoor nyin (thank you) to Aunty Josey Bonner, Butchulla Community Linguist, for the translation.

Written by Matilda Davis, Biosecurity Officer for the Butchulla Aboriginal Corporation's Land and Sea Program.

2.0 REVIEW – CURRENT PRACTICE IN PRE-BORDER PLANNING FOR CONSERVATION

With limited resources, conservation managers tend to focus on the more immediately visible problem of established pests rather than keeping potential new pests out of protected areas. In collating evidence of management response to invasive alien species, Shackleton et al. (2020) report that of 119 world heritage sites surveyed, 50% attempted some form of management intervention. The nature of intervention was overwhelmingly focussed on control or eradication of established invasives, with only 10% of the 119 sites, most of them islands, having biosecurity measures in place to prevent new introductions.

Nevertheless, the potential benefits of prevention are increasingly recognised among environmental managers. In Australia, nationally coordinated planning has been undertaken for biosecurity threats to *Acacia* species and mangrove communities (PHA 2020a,b). Risk mitigation actions were informed by (a) pest and pathway analyses and (b) general risks as identified by stakeholders.

For the *Acacia* risk mitigation plan (PHAa 2020), pest and pathway analyses included qualitative assessment of the potential for entry, establishment, and spread together with an attempt to assess impact potential. This attempt recognised difficulties in evaluating the environmental consequences of invasion and the bias resulting from reliance on descriptors of impact borrowed from agricultural or forest production settings. PHA (2020a) describes how (page 15),

> *"the project sought to develop a method to measure pest impact on taxa with environmental significance. The framework is based on the approach used by the International Union for Conservation of Nature (IUCN) for Environmental Impact Classification of Alien Taxa (EICAT)[2] and the ABARES development of the Priority List for Exotic Environmental Pests and Diseases[3]."*

In the end, the method was not used because there were only sparse data available documenting pests of *Acacia* overseas and their impacts, and what little was available did not address the breadth of *Acacia* species that occur in the Australian environment. Instead, the assessment relied on an earlier analysis focussed primarily on priority pests for industry.

Technical assessment in the mangroves project (PHA 2020b) highlighted pathways analysis in helping identify risk mitigation actions. The report recognised limitations in the approach, stating (page 51):

> *"It is important to note that though the relative risk of each pest family was ascribed in the pathways analysis, the relative risk of entry is not indicative of their establishment potential or impact. The literature was not comprehensive enough to ascribe impact adequately."*

Again, a dearth of available information led to key elements of the risk assessment being overlooked.

The risk mitigation actions identified by PHA (2020a,b) were not costed, nor their effectiveness explicitly assessed. However, PHA (2020b) acknowledges a *crucial consideration when examining entry pathways risk is whether the risk of a particular pathway can be managed* (page 51) . *If the risk cannot be managed then investment is better targeted elsewhere*. Prospects for implementation are likely improved by the emphasis on stakeholder involvement in the planning process, promoting co-ownership of the challenges and potential solutions. But it is unclear if or how the merit of actions nominated by stakeholders were explored or analysed.

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[2] See https://www.iucn.org/theme/species/our-work/invasive-species/eicat
[3] Available at https://www.agriculture.gov.au/biosecurity/environmental/priority-list

Among world heritage properties in Australia, perhaps the most detailed and diligent approach to pre-border planning has been the process underpinning the Lord Howe Island Biosecurity Strategy. AECOM (2016) documented environmental and economic values exposed to biosecurity risks, described status quo management, and conducted a threat analysis from which pathways and species of concern were identified. A qualitative risk assessment using a matrix was undertaken for each pathway and species of concern, with outcomes comprising a risk rating with and without specified risk mitigation measures. These mitigation measures clumped current actions together with additional candidate actions. It was unclear if and how the merit of additional investment was untangled from the contribution of status quo measures. Recommendations in AECOM (2016) were based on the perceived need to reduce 'high' and 'medium' risks and informal consideration of what actions might be the best value for money.

Shackleton et al. (2020) propose a monitoring and reporting framework for biosecurity of world heritage sites. These authors state: *The framework requires the collation of information and reporting on pathways, alien species presence, impacts, and management, the estimation of future threats and management needs, assessments of knowledge and gaps, and using all of this information allows for an overall threat score to be assigned to the protected area* (page 3327). The suggested approach to the characterisation of impacts is of particular interest, given the difficulties generally encountered in succinctly describing environmental consequences (Gregory et al. 2012) and the specific and seemingly insurmountable challenges encountered by PHA (2020a) in its attempt, outlined above.

Relative to other protected areas, the environmental values at world heritage sites may be better described by virtue of the nomination process and subsequent statement of 'Outstanding Universal Values' in any successful listing. But these statements may not readily lend themselves to the crisp characterisation of impact or consequence resulting from entry, establishment, and spread of a pest. For example, listing under criterion (ix) requires *outstanding examples representing significant ongoing ecological and biological processes in the evolution and development of terrestrial, freshwater, coastal, and marine ecosystems and communities of plants and animals.* For K'gari, the statement of Outstanding Universal Value[4] under criterion (ix) says, in part:

> *"The dynamic interrelationship between the coastal dune sand mass, hydrology, the ongoing processes of soil formation and the development of plant communities is remarkable in its scale and complexity given the uniform substrate. In particular, the development of rainforest vegetation communities, with trees up to 50 metres tall on coastal dune systems at the scale found on Fraser Island, is not known to occur elsewhere in the world. There is clear zonation and succession of plant communities according to salinity, water table, age and nutrient status of dune sands, exposure and fire frequency. The low shrubby heaths ('wallum') are of considerable evolutionary and ecological significance. Fauna including a number of threatened species of frog, have adapted to the highly specialised acidic environment associated with wet heathlands and sedgelands in this siliceous sand environment."*

It's not straightforward translating this biophysical complexity across several ecological entities into a readily accessible metric assessors can use to describe the impact of a pest or pathogen.

Shackleton et al. (2020) propose that to describe the impact, if possible, determine how many native species are threatened with extinction due to invasions and how the entire suite of invasions affect major ecosystem processes using guidance from the IUCN's Global invasive Species Database[5]. This database describes impact

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[4] See http://www.environment.gov.au/heritage/places/world/kgari-fraser-island

[5] See http://www.iucngisd.org/gisd/

according to the mechanism (e.g., competition, bio-fouling, flammability) and outcome. Outcomes include impacts on ecosystems (e.g., hydrological modification, modification of successional patterns, soil or sediment bioaccumulation), species populations (e.g. decline in population size, changes in geographic range, genetic alteration), and ecosystem services (comprising cultural, provisioning, regulating and supporting). While this guidance offers an exhaustive or near-exhaustive list of potential factors to consider in characterising the consequences or impact of pest invasion, the level of detail is onerous for most planning exercises, particularly in complex scenarios where a diverse set of stakeholders share responsibility.

3.0 TOWARDS A BETTER APPROACH

Environmental biosecurity is sometimes seen as the poor cousin of public health and agricultural biosecurity. Our view is that if environmental biosecurity is to succeed in securing a level of investment in management resources commensurate with the value of the assets and the magnitude of risk posed by pests, then greater rigour is needed in planning. We sought to develop a spreadsheet-based synthesis of tools that provides effective decision support for a group of co-managers and stakeholders, together with the core elements of a business case for investment in biosecurity.

From an environmental biosecurity perspective, the emergence of structured approaches to pre-border planning in recent years is encouraging (AECOM 2016, PHA 2020a,b). But much remains to be done to enhance and mature these approaches if they underpin substantial and widespread investment across the conservation estate. The review in the preceding section highlights difficulties and challenges in:

- characterising impact (i.e., consequences of pest invasion),
- making judgments with sparse or no data, and
- evaluation of the effectiveness of candidate actions, including the costs of implementation.

We propose a structured and systematic evaluation of candidate actions that use:

- objective-specific indicators to characterise impact,
- established protocols in the elicitation of expert judgment to overcome data limitations,
- sound logic in the treatment of probabilistic decisions and the aggregation of risk over multiple pests, and
- a coherent framework for combining technical and value judgments in progressing coarse consensus around a preferred biosecurity strategy.

Our formulation revolves around the specification of objectives and alternatives as the foundation for structured decision-making (Gregory et al. 2012). Objectives pertain to outcomes for Traditional Owners, the visitor experience, as well as key conservation values for the protected area at hand (see section 4.1 for further details).

Alternatives for management interventions are arranged under three headline actions:

- quarantine (Q),
- education and enforcement (E), and
- search and destroy (or more formally, surveillance and follow up treatment aimed at control or eradication, SD).

For our illustrative application at K'gari, we developed the alternatives shown in Table 1. Under each headline action, our spreadsheet-based decision support framework accommodates up to five candidate levels of investment. The user specifies what is entailed at each level and estimates the costs of implementation. Note that in our illustrative case study application, level 1 for each headline action represents current management, which serves as the base case against which the estimated payoff of all other candidates is compared. In other contexts, it may be more appropriate to make the Level 1 base case 'do nothing'.

Table 1. Candidate actions used in the illustrative K'gari case study application. Candidates were developed iteratively in stakeholder workshops.

Quarantine		
Level 1	status quo	Five inspection events per year at Riverheads.
Level 2	very lite	Inspection point at Riverheads that is attended for all barge departures during school holidays. Inspections for visitors.
Level 3	lite	Washdown bays at Riverheads. Voluntary wash down of vehicles. Inspection points that are attended for all barge departures during school holidays. Inspections for visitors.
Level 4	medium	Washdown bay and boot washing station at Riverheads and Inskip Point. Compulsory washdown of vehicles and boots before entering barge. Formalised inspection points that are attended for all barge departures (peak). Inspection of all vehicles (visitors, residents and commercial). Inspections at boat ramps in peak times.
Level 5	heavy	Formal terminus at Inskip Point. Multiple vehicle washdown bays and boot washing stations at Riverheads and Inskip Point. Compulsory washdown of vehicles and boots before entering barge. Formalised inspection points that are attended for all barge departures (peak and off peak). Inspection of all vehicles (visitors, residents, and commercial) and high-risk equipment. Inspections at boat ramps at times.
Education		
Level 1	status quo	Junior Ranger program to a small number of primary schools and biosecurity module 'Pesky Pests' delivered to one school per term. Signage at Riverheads. Presentations, newsletters, websites, and Facebook posts from FINIA partners highlighting risks and actions.
Level 2	very lite	Junior Ranger program to a small number of primary schools and biosecurity module delivered to two schools per term. Presentations, newsletters, websites, and Facebook posts from FINIA partners highlighting risks and actions. Signage and information leaflets at River Heads/check-in for Kingfisher Bay.
Level 3	lite	Dedicated 'Education Ranger' position (part-time) - Junior Ranger program to a moderate number of primary schools and biosecurity module 'Pesky Pests' delivered to three schools per term. Information is provided with bookings/tickets and on the USC K'gari-Fraser Island App. Signage and information leaflets at River Heads/check-in for Kingfisher Bay, Inskip Point. Education leaflets on the reporting mechanism for local outbreaks for locals and visitors. Some elements of enforcement.
Level 4	medium	Dedicated 'Education Ranger' position (full-time) - Schools program is rolled out to all primary schools in Fraser Coast and Cooloola schools. Signage and information leaflets at River Heads/check-in for Kingfisher Bay, Inskip Point, and Hervey Bay airport.

		Information leaflet on the risks of movement of firewood, soil, mulch, and plant material for locals and residents. Education leaflets on the reporting mechanism for local outbreaks for locals and visitors. Some elements of enforcement at entry points.
Level 5	heavy	Dedicated 'Education Ranger' position (full-time) - Schools program is rolled out to all primary schools in Fraser Coast and Cooloola schools. Signage at key water recreation sites across the island and region. Signage and information leaflets at River Heads/check-in for Kingfisher Bay, Inskip Point, and Hervey Bay airport. Information leaflet on the risks of movement of firewood, soil, mulch and plant material for locals & residents Information sessions on the risks of movement of firewood, soil, mulch, and plant material for locals & residents. Education leaflets on the reporting mechanism for local outbreaks for locals and visitors. Some elements of enforcement at entry points.
Search and destroy		
Level 1	status quo	Four Butchulla land and sea rangers and a biosecurity officer. BLSR are currently focusing on myrtle rust monitoring and response. Detection on K'gari is currently undertaken primarily by QPWS (Great Sandy: K'gari and Cooloola National Parks) and FCRC (2-3 visits per year) with some informal detection through FINIA partners.
Level 2	very lite	Four Butchulla land and sea rangers and two biosecurity officers.
Level 3	lite	A dedicated surveillance team of 5 FTE to conduct surveillance on K'gari. Additional training opportunities to rangers on the identification of pests, symptoms and response. K'gari-Fraser Island App is adapted to enable visitors to upload potential sightings.
Level 4	medium	Dedicated surveillance team of 10 FTE to conduct surveillance on K'gari. Early/emergency eradication attempts for pests and diseases with a known impact on OUV attributes or species. Use of drones and remote monitoring of inaccessible areas. Additional targeted surveillance at high use sites for recreational boaters on the west of the island, e.g., Garry's Anchorage and Wathumba Creek.
Level 5	heavy	A dedicated surveillance team of 10 FTE to conduct surveillance on K'gari with increased surveillance of the mainland and adjacent islands (e.g., Big Woody) looking specifically at high-risk sites for 'worry list' species, e.g., tramp ants. Use of drones and remote monitoring of inaccessible areas. Additional targeted surveillance at high use sites for recreational boaters on the west of the island, e.g. Garry's Anchorage and Wathumba Creek. Dedicated biosecurity citizen science program.

A *strategy* is any combination of levels, one from each of the three headline actions, and this equates to 5 × 5 × 5 = 125 base candidate strategies (with current management, S1E1SD1, being one of them). Now, individual actions within a strategy may or may not be implemented by Traditional Owners – for each level of each headline action, there is a variant involving implementation by Traditional Owners. We denote actions where Traditional Owners lead implementation with a prime symbol, so for example, a candidate strategy involving current management implemented exclusively by Traditional Owners is denoted S1'E1'SD1'. With two variants of each level (with or without TO implementation) we have in total 5 × 2 × 5 × 2 × 5 × 2 = 1,000 candidate strategies. This is clearly a large candidate set for evaluation. We make a number of simplifying assumptions to make the task tractable (see section 4.3).

We then propose using a formal but straightforward protocol for the elicitation of expert judgment to estimate the expected consequences of each candidate strategy against each objective (section 4.2), aggregated over a maximum of 20 pests of concern.

Co-managers and stakeholders will vary in their personal and organisational emphases on different objectives. We provide a tool for coherently weighting objectives that highlight the trade-offs implicit in identifying preferred strategies. Outcomes reveal the best strategy for each participating manager or stakeholder over a range of budget constraints (section 4.4).

4.0 ADDRESSING KEY CHALLENGES

The project worked with the Fraser Island Natural Integrity Alliance over four workshops to (a) formulate the planning problem and (b) develop an excel-based decision support framework to synthesise tools and analyse key judgments informing management priorities.

In this section we provide some technical detail on key challenges and how we addressed them in developing tools. In section 5, we illustrate the use of the spreadsheet-based synthesis with a subset of pests of concern to K'gari managers and stakeholders.

4.1 OBJECTIVES AND INDICATORS

Objectives were identified in a dedicated stakeholder workshop. To avoid double counting, it's important that fundamental ends objectives are identified. After unstructured brainstorming, means objectives (e.g. workplace training) were distinguished from ends objectives (e.g. economic opportunity via employment), process objectives, and strategic objectives. See Runge and Walshe (2014) for details on how to sort objectives and identify fundamental objectives.

In common with many protected areas in Australia and elsewhere, management objectives focus on:

- Key conservation values,
- outcomes for Traditional Owners, and
- the visitor experience.

Outcomes for Traditional Owners[6] include:

- economic opportunity, and
- connection to Country.

For a subset of visitors seeking a nature-based experience, that experience may be compromised by the presence of invasive pests and their impacts on natural values. In a biosecurity context, the visitor experience can also be compromised by risk mitigation measures, including the inconvenience of quarantine and the possibility of the restricted vehicle or pedestrian access as part of efforts to limit spread.

[6] These outcomes are plainly incomplete. Other values include culturally important species traditionally used for food, fibre and medicine (see Box 1). We assume the sharing and inclusion of these and other values in the analysis is inappropriate.

For conservation values, the list below includes the criteria under which ecological entities are invoked as a part of the Statement of Outstanding Universal Values (OUV) for K’gari:

- Rainforest and Syncarpia/brushbox on parabolic dunes - OUV (vii, viii, ix)
- Heath communities incl. those related to ground parrot habitat - OUV (ix)
- Perched, barrage & window lakes - OUV (vii, viii)
- Patterned fens & wetlands - OUV (ix)

INDICATORS FOR CONSERVATION VALUES

In decision-making and decision science, indicators are used to assess the performance of alternative candidate actions (von Winterfeldt and Edwards 1986). Also known as performance measures, evaluation criteria, or attributes, indicators clarify the meaning of an objective and provide metrics for expressing and communicating the implications of different management or decision alternatives.

Desirable properties of indicators include that they are (Keeney and Gregory, 2005):

- Unambiguous: a clear relationship exists between an objective and the description of (probability-weighted) consequences under each alternative using the indicator.
- Comprehensive: the indicator levels cover the range of possible consequences for the corresponding objective under all alternatives, and value judgments implicit in the indicator are reasonable.
- Direct: the indicator directly describes the consequences of interest.
- Operational: in practice, information to describe consequences can be obtained, and value trade-offs can reasonably be made.
- Understandable: consequences and value trade-offs made using the indicator can readily be understood and communicated.

Situations, where compromises among these desirable properties are needed, are common. In all cases, however, care in the development of indicators is essential.

The range of performance measures used in decision science typically incorporates input from three types of indicators: natural measures, proxy measures, and constructed measures (Keeney 1992; Keeney and Gregory 2005). Natural measures are in general use and have a common interpretation: just as the objective to ‘maximize profits’ is naturally measured in dollars, the objective to ‘reduce health impacts’ might count the number of hospital visits per year. Natural measures should be used whenever possible because they are unambiguous, easily understood, readily estimated, direct, and readily communicate what is at stake.

Proxy measures are also in common use. For example, ‘number of dead trees observed per hectare’ is sometimes used as a proxy for the health of a forest community, and air emissions (measured in ppm) are used as a proxy for health-related impacts that are harder to measure. However, proxy measures are less informative than natural measures because they only indirectly indicate the achievement of an objective.

Constructed metrics are used when no suitable natural measures exist, and proxies are uninformative. In such situations, analysts may develop a suitable, artificial scale. We developed constructed metrics for all objectives. For key conservation values, the performance of a strategy is the product of the likelihood of entry and establishment and spread (EES) and the value-specific consequences of spread. That is, expected damage = Pr{EES} × impact score|spread.

Impact scores were scaled from 0 to 100 and constructed using attributes of interest to Queensland Parks & Wildlife Service in its natural values health checks (Melzer 2019). Note that embedded in the scales shown in Figure 1 are value judgments (e.g., the local loss of faunal diversity is equivalent to the local dieback of trees/shrubs). The scales also contain substantial ambiguity. Those providing judgments on damage should define what is meant by 'local' and widespread' in their specific context or protected area before use. In short, there is no easy way to capture the complexity of environmental values without compromise on the desirable properties listed above. We regard the scales shown in Figure 1 as clearly imperfect but the best available.

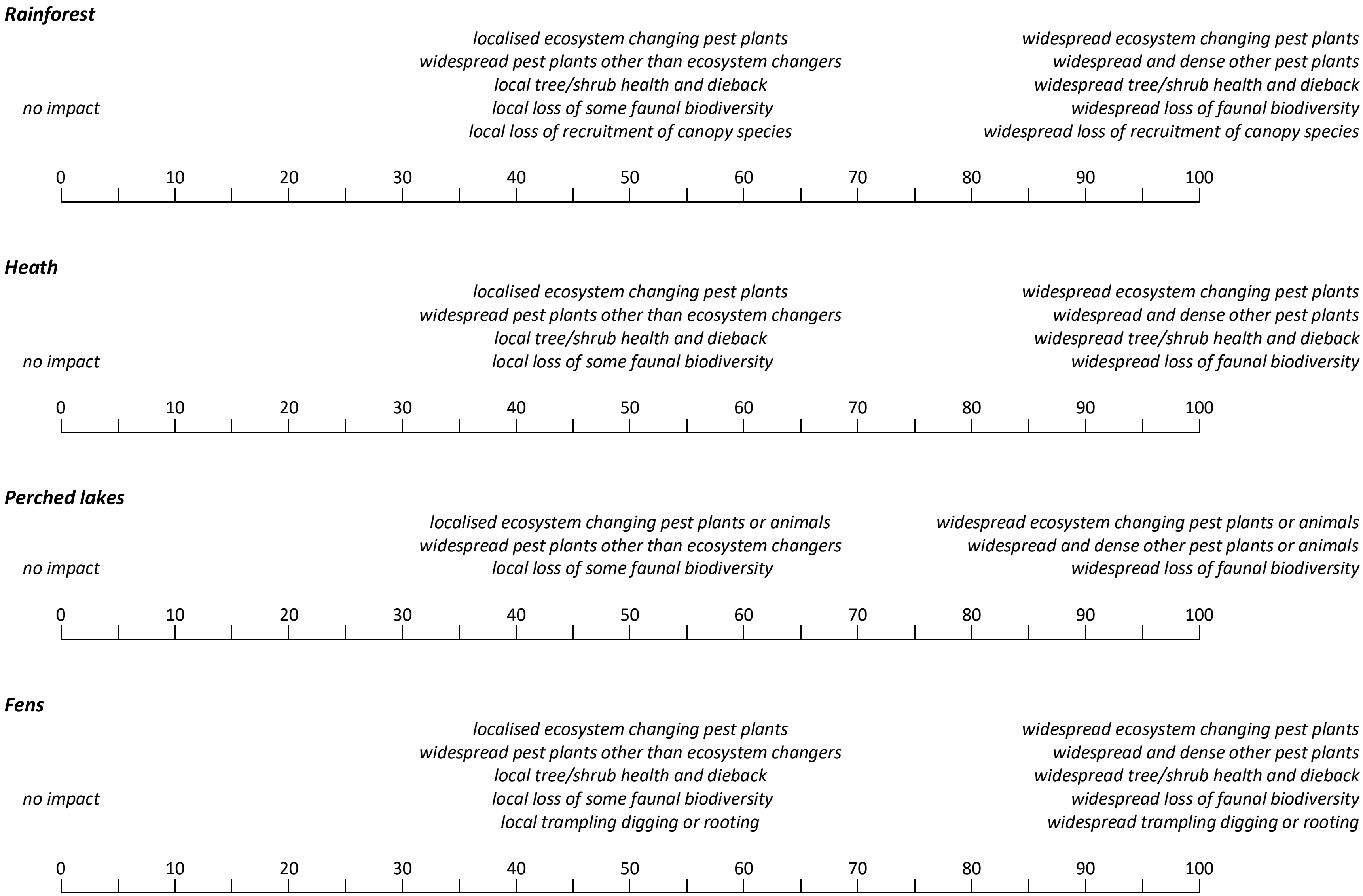


Figure 1. Constructed indicators for the four key conservation values associated with Outstanding Universal Values on K’gari.

OTHER INDICATORS

The objective of improving economic opportunity for Traditional Owners (TOs) also used a constructed indicator to describe, for each candidate strategy, the extent to which TOs would be satisfied (from the perspective of economic opportunity only) with the amount of work to be implemented by Indigenous rangers and organisations.

In the *Traditional Owner request* tab of the accompanying decision support spreadsheet, users specify how much of any potential new investment in biosecurity TO's have an interest and capacity in implementing, for each level of each headline action. For each strategy the spreadsheet then calculates the value of the work assigned to TOs as a percentage of the value of the work sought. For any single strategy there may be zero, complete or partial implementation by TOs. For example, let's say the TO request for a subset of actions is as shown in Table 2. The performance of each of the following strategies is calculated as:

Q2E2SD2 = $\frac{0 + 0 + 0}{10{,}000 + 2{,}000 + 8{,}000}$ = 0.00 = 0%,

Q2'E2SD2= $\frac{10{,}000 + 0 + 0}{10{,}000 + 2{,}000 + 8{,}000}$ = 0.50 = 50%,

Q2'E2SD2'= $\frac{10{,}000 + 0 + 8{,}000}{10{,}000 + 2{,}000 + 8{,}000}$ = 0.90 = 90%, and

Q2'E2'SD2' = $\frac{10{,}000 + 2{,}000 + 8{,}000}{10{,}000 + 2{,}000 + 8{,}000}$ = 1.00 = 100%.

Table 2. Example of Traditional Owner (TO) request for economic opportunity associated with candidate biosecurity action.

Action	Total cost over 20 years ($k)	TO request
Q2 – Quarantine level 2	$20,000	50%
E2 – Education level 2	$4,000	50%
SD2 – Search and destroy level 2	$10,000	80%

The indicator for the objective of improving connection to Country for TOs followed a similar logic. Here, the *Traditional Owner request* tab asks the user to estimate what proportion of each of the headline actions involves personnel in the field (i.e. on Country). The spreadsheet then calculates the performance of each strategy as above, except that instead of using monetary value of the work involved (i.e. cost of implementation), for connection to Country it calculates the percentage based on number of days on Country.

The visitor experience objective is constructed using a rule set that assigns points to each strategy. The higher the number of points the greater the adverse visitor impact. It countenances three factors that may compromise the visitor experience in the context of biosecurity and its management:

- Inconvenience arising from quarantine measures at or outside the boundary of the protected area (0 points for Q1 and a maximum of 4 points for level Q5),
- Restrictions on the movement of vehicles and people (up to 4 points), and
- A diminished experience of nature stemming from damage caused by pests (up to 2 points).

The latter two factors are conditioned by the strategy and pest specific calculations of the probability of entry, establishment and spread. The worst possible indicator score for any single strategy is 10 and the best is zero. Note that the rule set has value judgments embedded within it. For example, it assumes that on average, visitors value freedom of movement (4 points) twice as much as the nature-based experience (2 points).

4.2 ELICITATION OF EXPERT JUDGMENT

Conceptual models graphically summarise system understanding (Biggs et al. 2011). We developed conceptual models to support experts in their subsequent judgments about entry, establishment, spread, impacts and management effectiveness (van Gelder et al 2016). Figure 2 provides three examples of pests of concern to K'gari managers and stakeholders. Tilapia includes two pathways that may be amenable to management intervention and another that is not. The incidence of transport via fishing gear or recreational watercraft can be reduced through effective quarantine measures and/or education. But dispersal via flood plumes is clearly beyond management control. Similarly, the risk of seeds of bitou bush entering via clothing or machinery may be reduced by quarantine, but dispersal by birds is another matter. Cat's claw is a highly visible weed, so even if it were to enter and establish it is unlikely to spread in the presence of a substantial surveillance and treatment effort. We believe these simple models can assist in overcoming myopia and bias in the estimation of the likelihood of entry, establishment, spread, the consequences of spread, and the effectiveness of candidate management actions (Landis 2003, Wood et al. 2012).

A pervasive shortcoming in human judgment is overconfidence (Burgman 2015). Assisted by conceptual models, the elicitation of judgments follows the formal structured 'IDEA' protocol described by Hemming et al. (2018). In general, formal structured techniques provide answers that are more accurate than do unstructured approaches. The IDEA protocol emphasizes anonymity in judgments, feedback, discussion and subsequent revision in a second round of elicitation (Hanea et al. 2018). In each round and for each question, experts provide

- a plausible lower bound,
- a plausible upper bound,
- a best estimate (lying between the bounds), and
- the level of confidence the truth lies between the specified lower and upper bounds.

The unweighted average of a group of experts comprising independent judgments almost always outperforms the best performing expert within the group over multiple questions (Burgman 2015).

An example of judgements is shown in Figure 3. Responses were provided by 12 anonymous experts. Plausible bounds for each estimate represent 90% credible intervals (adjusted from the confidence assigned by each expert). The pooled outcome (unweighted average) over the 12 experts is used in subsequent analyses in the decision support tool. Note that there is potential for updating the information in the spreadsheets, as new information arises, a new threat (pest) is identified, or a new management option becomes available. The process should be iterative because the experts are predicting future events which inevitably involve uncertainty.

A separate excel file (see section 6) is available to assist in the elicitation of judgments for the set of variables listed at Appendix 1.2.

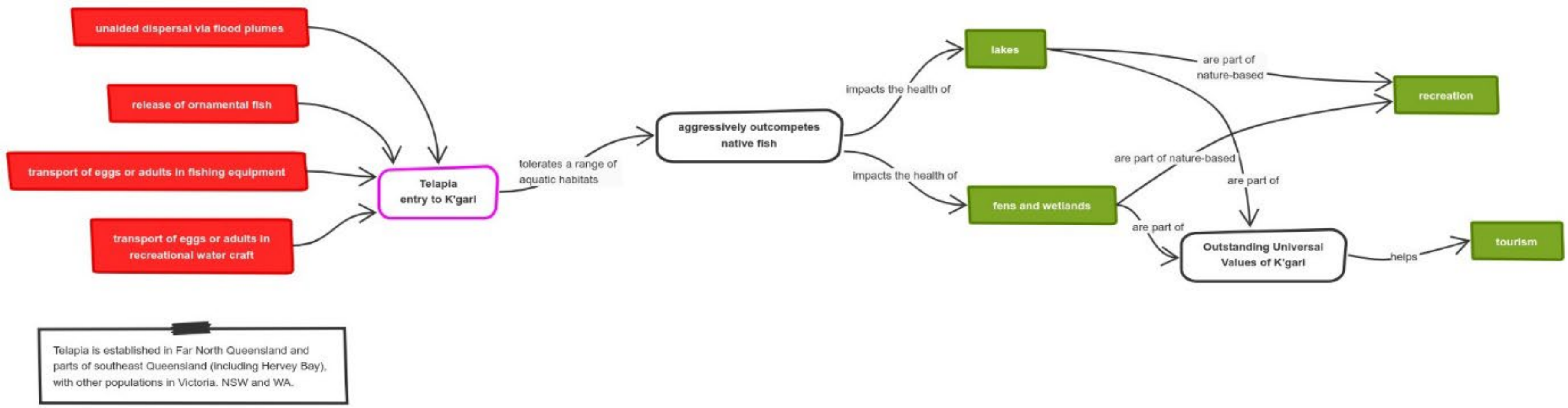


Figure 2a. Conceptual models describing pathways (red nodes) for entry of Telapia, and its impact on key conservation values and the visitor experience (green nodes).

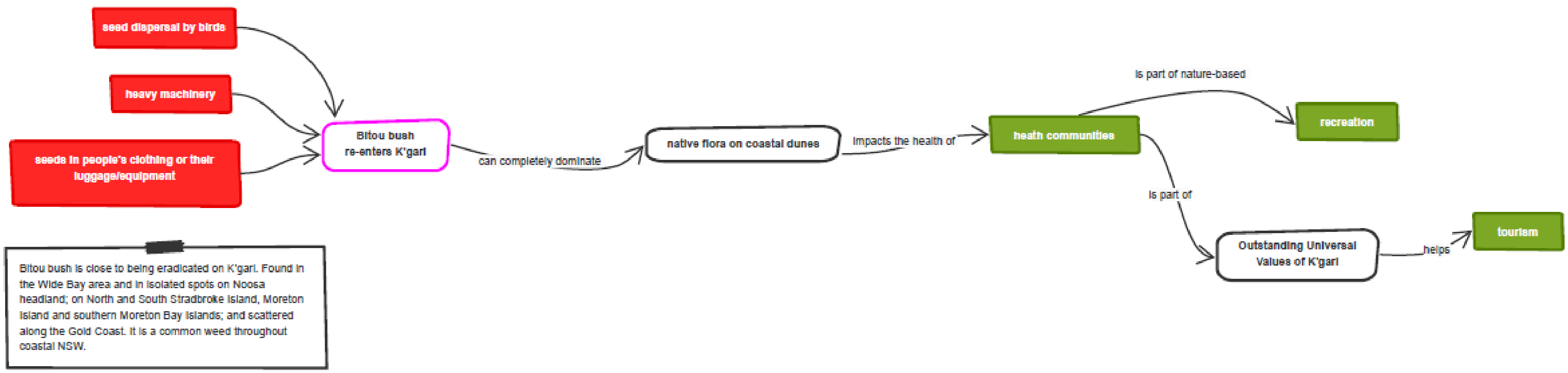


Figure 2b. Conceptual model describing pathways (red nodes) for entry of bitou bush, and its impact on key conservation values and the visitor experience (green nodes).

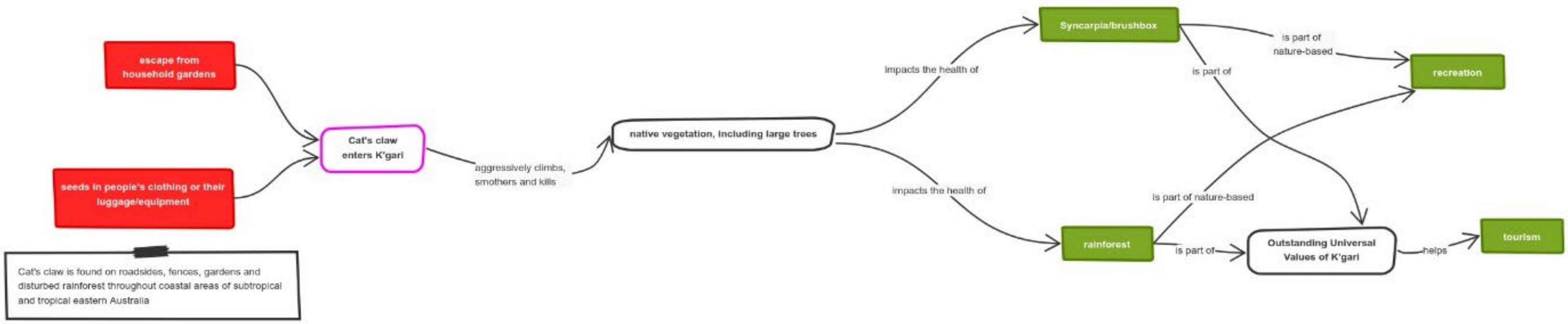


Figure 2c. Conceptual model describing pathways (red nodes) for entry of cat's claw, and its impact on key conservation values and the visitor experience (green nodes).

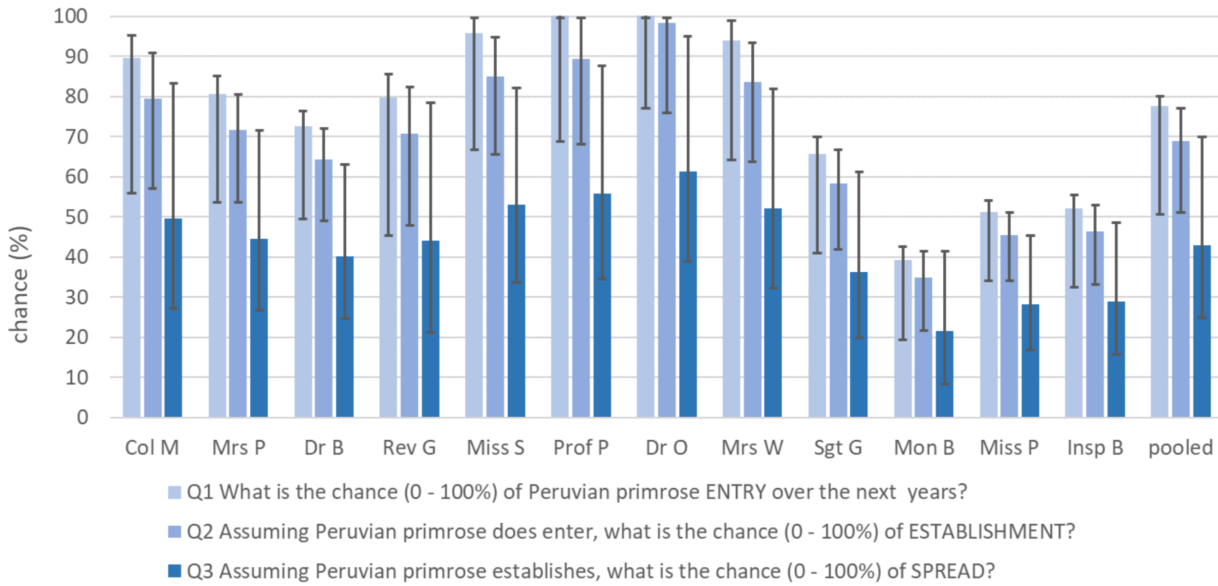


Figure 3. Example of outcomes of an expert elicitation involving 12 participants. Experts were assigned aliases (Cluedo characters in this instance) to preserve anonymity. Error bars represent 90% credible intervals, which are estimated from judgments of confidence that the truth lies between specified lower and upper bounds.

For further details on good practice in the elicitation of expert judgment, including the selection of experts, advice on what constitutes practical expertise, and the benefits of two rounds of judgment, see Burgman (2015) and Hemming et al. (2018).

4.3 PROBABILISTIC REASONING

The disaggregation of likelihood judgments into entry, establishment and spread is common practice in biosecurity risk assessments, with verbal descriptors (e.g. low, moderate, high) often used to describe magnitude (McCarthy et al. 2007, ABARES 2021). Here we use direct numerical probabilistic judgments, partly because we believe they are more informative (Hubbard 2009), and partly because they allow consistent arithmetic logic in aggregating the risks posed by multiple pests and their mitigation by multiple partially effective actions (Figure 4).

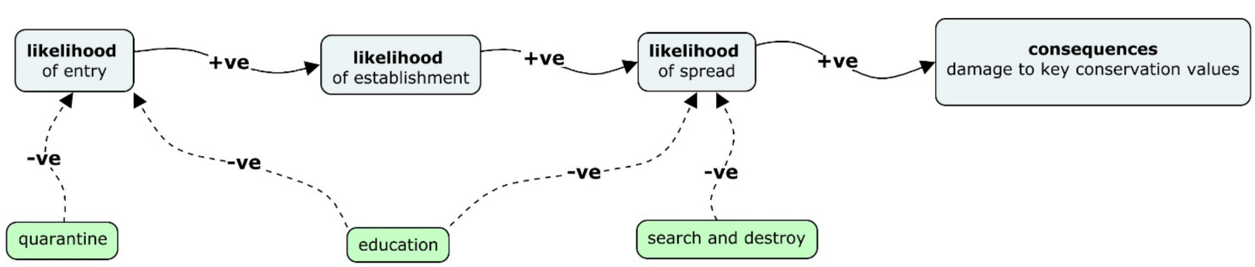


Figure 4. Conceptual model of how judgments of risk to conservation values and their mitigation via action (green nodes) are treated in the spreadsheet.

Our decision support tool provides a template for risk assessments for up to 20 pests of concern, with and without specified candidate actions. To estimate the aggregate risk to a conservation value over all pests (e.g. likelihood and consequences for heathland communities of myrtle rust establishment and spread, together with *Phytophthora* and fusarium wilt), we assume impacts are independent. More specifically, let's denote the probability weighted damage index score (see Figure 1) for pest *i* as d_i. Recall that the index ranges from 0 to 100 (Figure 1). The aggregate risk or damage *D* over *n* pests is estimated using the formula,

$$D_n = [1 - \prod_{i=1}^{n}(1 - d_i /100)] \times 100.$$

The spreadsheet-based tool also seeks to limit the number of judgments needed to assess management effectiveness by assuming that quarantine acts to reduce the likelihood of entry, search and destroy reduces the likelihood of spread, and education may have an effect on the likelihood of entry and/or spread (Figure 4). We avoid further judgments involving a reduction in consequences (from say a successful control effort under the headline action, search and destroy) for the sake of simplicity and to avoid conflation and double counting with its effect on reducing the probability of spread. Likewise, for the sake of simplicity, we assume the point of pest establishment is difficult to detect and is unaffected by management.

The elicitation of expert judgment can be laborious and time-consuming (Burgman 2015). For three candidate actions, *x, y* and *z*, there are six possible combinations for implementation:

- *x* alone,
- *y* alone,
- *z* alone,
- *x* and *y*,
- *x* and *z*,
- *y* and *z*, and
- *x*, *y* and *z*.

Where time and effort are unconstrained it would be desirable to elicit judgments of the benefit of all six scenarios, together with the current management or base case scenario. Our spreadsheet accommodates 1,000 strategies and 20 pests, making the burden of formal elicitation for the full set of combinations clearly overwhelming. To make the task less arduous, we use a simplifying assumption in the spreadsheet. Specifically, in the *with judgments* tab of our decision support tool, we require judgments of the effect of individual actions and compute estimates of the aggregate payoff of multiple actions making up a strategy automatically in the spreadsheet. In doing so, we again assume the effectiveness of any single action is independent of that of other actions.

The effect of an individual action *j*, described as a proportional reduction in the probability of entry or spread, is denoted r_j. The combined effectiveness over m actions, or the aggregate proportional reduction P in the probability of entry or spread, is,

$P_m = 1 - \prod_{j=1}^{m}(1 - r_j).$

4.4 TRADE-OFFS AND STRATEGY SELECTION

The decision support tool is an extension to established approaches to the characterisation of cost-effectiveness in conservation, where the merit of an action in a finite budget setting is the difference in risk with and without the action, conditioned by the cost of implementation (Joseph et al. 2009). A common feature of the planning context is that managers do not have a strong sense of what budget may be available for biosecurity management. Often, resource availability depends on (a) the magnitude of risks under current management, (b) the prospect for material improvement in risk with action and associated additional resourcing, (c) broad agreement among key stakeholders about how risk is to be mitigated, and (d) the ability to communicate these things clearly to those responsible for allocating resources within organisations. We have sought to design the decision support spreadsheet in a way that supports these elements.

To accommodate uncertainty in what level of resources might be made available (or the level of aspiration in a business case for further funding) the spreadsheet allows the user to set a lower and upper bound on an exploratory budget. It then reports outcomes for the lower bound, the 10th, 20th, 30th, 40th, 50th, 60th 70th 80th, 90th percentile of the range, and the upper bound. For each decile within the bounds the spreadsheet reports the best strategy for the corresponding notional budget constraint. The best strategy is the one with the greatest benefit aggregated across objectives.

Conservation assets and TO outcomes do not readily lend themselves to monetary valuation for use in a standard benefit: cost analysis. Instead, we use multi-attribute value theory to estimate total benefit (von Winterfeldt and Edwards 1986). Ignoring the cost of implementation for now, the value *V* of strategy *s* over *n* objectives is,

$$V_s = \sum_{i=1}^{n} w_i(x_i)$$

where w_i is the weight assigned to objective *i* and x_i is the normalised performance score describing the expected consequences of strategy s against objective *i*, where a score of 0 is the worst end of the range and 1.00 the best. Over *n* objectives $\sum w_i$= 1.

There are many methods for eliciting weights (Hajkowicz et al. 2000), not all of which are credible. The interpretation of the weights is critical. Methods that do not explicitly deal with compensatory judgments are prey to abuse (Steele et al. 2009). Users are inclined to specify weights that reflect the relative importance of the attributes, irrespective of the units or the range of consequences relevant to the decision context (Keeney 2002). The weights have units because the underlying attribute scales have units. A change of $-w_i^{-1}$ units on scale *i* is always compensated by a change of $+w_j^{-1}$ units on scale *j*. Changing the units or range of an attribute *must* lead to a change in the weights.

The swing weight method used in the accompanying decision support spreadsheet (*value judgments* tab) has been shown to be one of the more effective approaches to elicitation, both in terms of its efficiency and its insulation against abuse (Fischer 1995, von Winterfeldt and Edwards 1986). Nevertheless, use of experienced, trained workshop facilitators to assist in their elicitation is recommended.

The benefit of any strategy is the difference in value between it and current management (Q1E1SD1). That is, denoting current management V_0, benefit *B* is

$$B_s = V_s - V_0.$$

Now, for any notional budget constraint on the cost of implementation, the spreadsheet finds among the 1,000 candidate strategies the one with the highest benefit among the subset that satisfy the constraint. In the *outcomes for each participant* tab we then graph the magnitude of the benefit and cost (noting that these things are on different scales) for each decile within the range described by the lower and upper exploratory budget (Figure 5). Also plotted on the same tab is the magnitude of risk reduction for each best strategy at each notional budget threshold (Figure 6).

The business case for further resourcing can be built around outcomes in Figures 5 and 6. Identifying parts of the exploratory range where benefits are flat, the analyst may discern three preferred strategies (Figure 5):

- Q1'E5'SD1' for a modest budget,
- Q4'E5'SD1' for a moderate budget
- Q5'E5'SD1' for a larger budget.

The payoff of each of these high performing alternatives and the risk appetite of senior managers will shape the nature and magnitude of further resourcing. These factors are communicated clearly for each of the key conservation values under each of the three preferred strategies in Figure 6.

We note that the outcomes in Figure 5 depend in part on the weights assigned to objectives. Co-managers and stakeholders will vary in their weightings and hence their preferred strategies. In the next section we illustrate how the spreadsheet communicates variability in outcomes and its implications for progressing consensus.

Figure 5. Summary graph of outcomes showing the identity of the best strategy, the magnitude of its benefit, and cost of implementation, at each notional budget constraint. Note that costs are total costs over 20 years.

Figure 6. Example of three (of the 11) accompanying graphs showing the magnitude of risk reduction for key conservation values for the best strategy at three notional budget thresholds. 'Without' refers to expected damage under the base case (i.e. level 1 for each of the three headline actions). 'With' refers to expected damage with implementation of the identified strategy. Q1'E5'SD1' is the optimal strategy when the budget is $10 million, comprising quarantine level 1, education and enforcement level 5, and search and destroy level 1, with the prime symbol indicating a preference for all actions to be implemented by Traditional Owners. In this example, as the budget increases, a greater allocation to quarantine is optimal.

5.0 DEMONSTRATION

This section provides an illustrative application of the decision-making process that is based on collaboration with the Fraser Island Natural Integrity Alliance. The starting point is drafting a list of up to 20 pests of concern, a process that we iteratively developed over multiple stakeholder workshops. We limit the number of pests to 20 because the assessment of likelihood, consequence and management effectiveness becomes onerous indeed if we were to include all pests that may enter and conceivably cause harm to natural values in a protected area. Because there are many pests with low likelihood of entry or establishment, or low consequences if they do spread, we assume that 20 of the highest risk pests represents a reasonable basis for identifying good management strategies. A good resource for identifying pests of concern is the recently compiled National Priority List of Exotic Environmental Pests, Weeds and Diseases[7]. Note that this list comprises species that are thought to be currently absent in the whole of Australia. For an individual conservation property there will be many species of concern that are absent in the reserve or area of interest but have become established elsewhere in the region or beyond.

The collaboration drafted a full list of 20 pests of concern (Appendix 2). Here we illustrate application with a subset of four pests – the weeds bitou bush[8] and cat's claw, the aquatic vertebrate mosquito fish, and the group of pathogens in the genus *Phytophthora*.

The illustrative example and its outcomes are included in the accompanying spreadsheet, *conservation_biosecurity_decisionsupport_demo.xslx.* The table and figures shown in this section are taken directly from the spreadsheet. Details of judgments for the probability of entry, establishment and spread and consequences for each pest, together with judgments of the effectiveness of actions can be viewed in the spreadsheet. These judgements were made by the authors and presented at a stakeholder workshop. A formal analysis would require these judgments to be revisited.

Like many protected areas, the managers of K'gari share concern over the sparse resources available for biosecurity, but are uncertain about the magnitude of risk posed by pest species that are currently alien to the island. They are also uncertain about what level of resourcing might be appropriate. Using a time horizon of 20 years for our analysis, we explored speculative budgets within the range of $0.5 million and $2.5 million per annum. We were interested in identifying preferred strategies for a set of notional budget thresholds within this range.

The outcome of many risk assessments is effectively a wish list of mitigation actions for future funding. Actions are rarely costed. We regard this as an inadequate basis for investment in the protection and management of important environmental values and assets. The spreadsheet provides a template for estimating costs of each level under each headline action. Users input personnel and equipment details for up-front and ongoing costs. The sheet then calculates total costs as present values using a user-specified discount rate (Table 3). We've populated the spreadsheet with coarse judgments to illustrate functionality. Again, these judgments will need to be reviewed and revised when used to inform a management plan.

[7] See https://www.agriculture.gov.au/biosecurity/environmental/priority-list

[8] Bitou bush is already established on K'gari, but we included it in pre-border planning because there is an eradication program in place on the island.

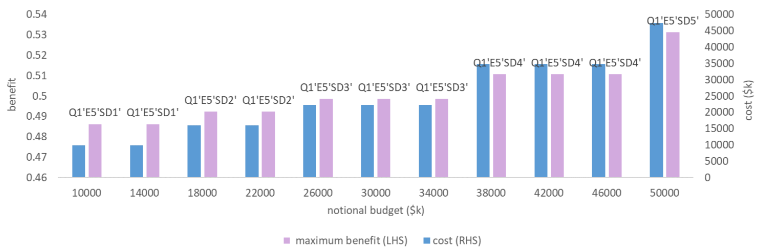
Table 3. Hypothetical cost estimates for each level under each headline action. Users are required to provide estimates in orange cells. The spreadsheet calculates total cost.

				UP-FRONT COSTS				ANNUAL MAINTENANCE COSTS		
				Personnel time p.a.	Equipment p.a.			Personnel time p.a.	Maintenance materials p.a.	TOTAL COST
ACTION		Start year	End year	(person days)	($k)	Start year	End year	(person days)	($k)	($k)
Q1	Quarantine - status quo									0
Q2	Quarantine - very lite	0	1	100	$100	1	20	1100	$100	$9,922
Q3	Quarantine - lite	0	3	200	$200	2	20	2300	$200	$20,078
Q4	Quarantine - moderate	0	3	300	$1,000	2	20	3000	$300	$29,943
Q5	Quarantine - heavy	0	3	400	$2,000	2	20	3600	$400	$39,948
E1	Education - status quo									0
E2	Education - very lite	0	1	100	$20	1	20	145	$40	$1,918
E3	Education - lite	0	2	150	$40	2	20	290	$90	$3,903
E4	Education - moderate	0	2	200	$100	2	20	350	$165	$5,957
E5	Education - heavy	0	2	300	$200	2	20	400	$230	$7,927
SD1	Search and destroy - status quo									0
SD2	Search and destroy - very lite	0	1	40	$20	1	20	400	$105	$4,950
SD3	Search and destroy - lite	0	2	80	$40	2	20	840	$220	$9,935
SD4	Search and destroy - moderate	0	2	120	$80	2	20	1700	$440	$19,960
SD5	Search and destroy - heavy	0	2	160	$150	2	20	2500	$680	$30,059

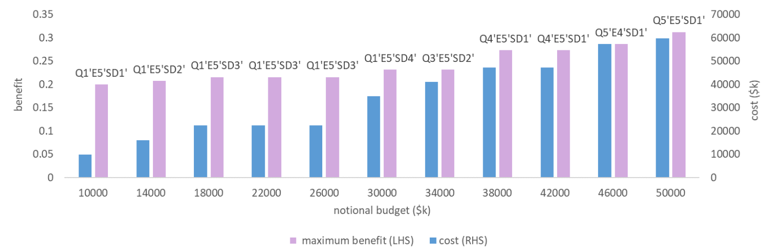
As noted in section 4.4, the preferred strategy at any specified budget constraint may vary among co-managers and stakeholders because of variability in how individuals and organisations weigh objectives. The strongly contrasting weightings of six hypothetical participants are shown at Appendix 3. We use these contrasting weights to illustrate sensitivity of the outcomes to trade-off judgments. The greatest contrast is between participant DD (who assigns equal weight to the four key conservation values and zero weight elsewhere) and participant EE (who assigns highest weight to the visitor experience and equal weight to all else). Strong contrasts in value judgments need not always imply strong contrasts in strategy preference. Figure 7 shows the outcomes for each of our six hypothetical co-managers and stakeholders. Figure 8 provides a graphical summary of the level of agreement among participants around preferred strategies.

Figures 7 and 8 can be considered side by side in the development of a broadly supported business case to support additional funding for biosecurity, together with summary graphs describing risk with and without implementation (Figure 6). The plateauing of benefits in Figure 7 indicates ranges within the exploratory budget bounds for which there is little or no additional benefit with increased cost. Figure 8 shows meagre support for additional quarantine effort. Most participants preferred level 1 (current management), because the large amount of resourcing required for quarantine (Table 3) could be better spent in education and enforcement, and as the budget increases, in search and destroy. The low level of support for levels 3, 4 and 5 quarantine come exclusively from participant DD, where the absence of any weight for the visitor experience implies a perception of no downside to quarantine measures and the inconvenience or access issues they may impose. In this hypothetical worked example there is strong support for very substantial investment in education, even under modest budget settings. Support for greater investment in search and destroy was proportional to budget threshold.

Participant AA



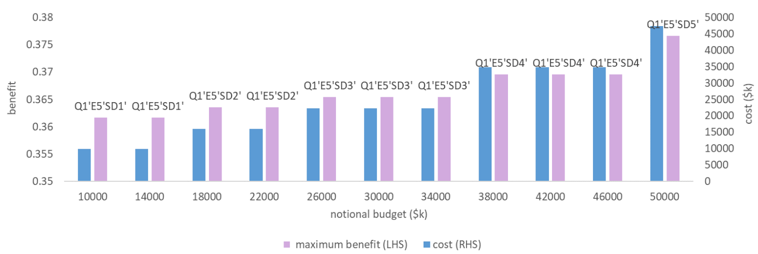
Participant DD



(a) Participant BB

Participant EE

Participant CC



Participant FF

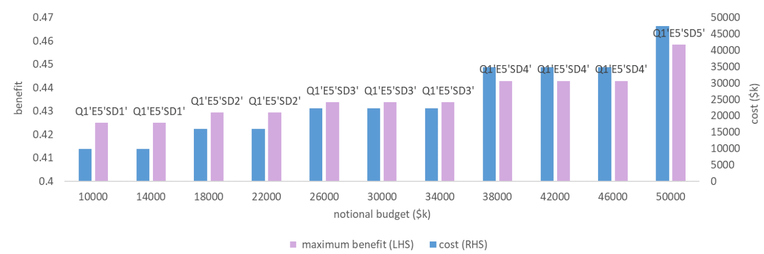


Figure 7. Outcomes for each of the six hypothetical participants. Differences stem from contrasts in value judgments (see Appendix 3)

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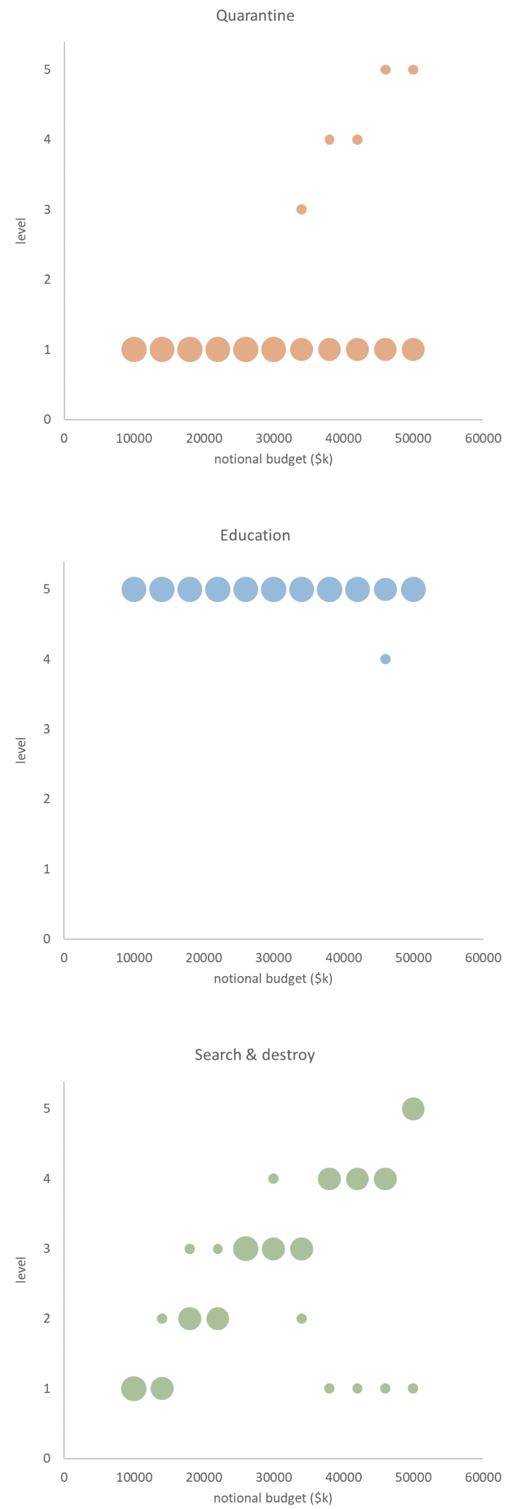

Figure 8. Hypothetical group outcomes showing the degree of support for each headline action at each level and each notional budget. The size of the bubbles indicates degree of support (i.e. the number of participants that had that level in their best mix of actions at that notional budget). Notional budgets refer to total budget over 20 years.

The business case for increased biosecurity funding may flesh out the argument for two alternatives:

- Level 5 investment in education at a modest cost of $10 million over 20 years.
- Level 5 investment in education and level 3 or 4 investment in search and destroy at a more substantial cost of $30 - $40 million over 20 years.

The foundations for these arguments can be sourced from the inputs and logic captured in the spreadsheet.

We emphasise that this outcome is based on an analysis involving only four pests of concern and hypothetical weights. An analysis that includes the full set of pests of concern shown in Appendix 2 and the priorities of K'gari co-managers and stakeholders may very well arrive at very different outcomes.

6.0 ACCESSING THE DECISION SUPPORT TOOLS

The main product of this research is an excel-based decision support tool:

- conservation_biosecurity_decisionsupport.xlsx

There are two accompanying files,

- conservation_biosecurity_expert_judgments.xlsx - to assist in formal elicitation of expert judgment, and
- conservation_biosecurity_decisionsupport_demo.xlsx - a pre-populated demonstration file that includes the details of the illustrative application described in this report.

The files have been submitted to CEBRA and are available from Terry Walshe on request, email twalshe@unimelb.edu.au

Further guidance on use of the spreadsheets is provided at each tab.

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Appendix 1.1 Inputs describing formulation of the risk assessment and biosecurity planning setting.

Decision element	Descriptor
Exploratory annual budget – lower and upper bounds	$k
Time horizon of assessment	Years
Decision-makers and stakeholders involved in the assessment	Name and organisation
List of up to 20 pests of concern	Common and scientific names
Conservation objectives – up to six key values	Text
Description of actions - for status quo and four discrete levels for each of quarantine, education and search and destroy.	Text

Appendix 1.2 Technical judgments required for each pest on the *list of concern.* These judgments can be formally elicited from experts and recorded using the accompanying spreadsheet, *conservation_biosecurity_expert_judgments.xlsx*

Without additional management	Descriptor
Chance of entry	Percentage chance (0 – 100%)
Chance of establishment	Percentage chance (0 – 100%)
Chance of spread	Percentage chance (0 – 100%)
Consequences of spread for each of up to 6 conservation values	Damage index (0 – 100)
With additional management	**Descriptor**
Effectiveness of quarantine (at each of four discrete levels) in reducing chance of entry	Proportional reduction in chance (0 – 100%)
Effectiveness of education (at each of four discrete levels) in reducing chance of entry	Proportional reduction in chance (0 – 100%)
Effectiveness of education (at each of four discrete levels) in reducing chance of spread	Proportional reduction in chance (0 – 100%)
Effectiveness of search and destroy (at each of four discrete levels) in reducing chance of spread	Proportional reduction in chance (0 – 100%)

Appendix 1.3 Other judgments required in the analysis.

Judgement	Descriptor
Cost of actions	$k
Traditional Owner requests for action implementation	Percentage of each action (by cost)
Value judgments – relative importance of outcomes for conservation, Traditional Owners and the visitor experience	Weights (0 – 100)

APPENDIX 2 – K'GARI DRAFT LIST OF PESTS OF CONCERN

This list was iteratively developed in stakeholder workshops.

Pathogens

- Ceratocystis wilt (*Ceratocystis manginecans* and other exotic *Ceratocystis* spp.)
- Exotic strains of myrtle rust (*Austropuccinia psidii*)
- Polyphagous shot hole borer associated fusarium wilt (*Fusarium euwallaceae*)
- Phytophthora spp
    - *Phytophthora ramorum*
    - *P. multivora*
    - *P. cinnamomi*
- Chytrid fungus (*Batrachochytrium dendrobatidis*)

Invertebrates

- Tramp ants
    - Red imported fire ant (*Solenopsis invicta*)
    - Electric ant (*Wasmannia auropunctata*)
    - Yellow crazy ant (*Anoplolepis gracilipes*)
- Brown marmorated stink bug (*Halyomorpha halys*)

Weeds

- Bitou bush (*Chrysanthemoides monilifera* subsp. *rotundata*)
- Aquatic weeds
    - Duckweed (*Lemna disperma*)
    - Water hyacinth (*Eichhornia crassipes*)
    - Cabomba (*Cabomba caroliniana*)
- Peruvian Primrose (*Ludwigia peruviana*)
- Cat's claw (*Uncaria tomentose*)

Vertebrates

- Mosquitofish (*Gambusia holbrooki* and *Gambusia affinis*)
- Tilapia (several spp)
- Domestic dogs

APPENDIX 3 – WEIGHTS ASSIGNED TO OBJECTIVES BY SIX HYPOTHETICAL PARTICIPANTS

The weights reported here do not reflect the judgments of any stakeholders. They are included here for illustrative purposes only.

Participant AA

Objective	raw weight	normalised weight
Rainforest - OUV (vii, viii, ix)	100	0.32
Heath - OUV (ix)	20	0.06
Perched lakes - OUV (vii, viii)	20	0.06
Fens - OUV (ix)	20	0.06
Visitor experience	50	0.16
Traditional Owners - connection to Country	50	0.16
Traditional Owners - economic opportunity	50	0.16
Total	310	1.00

Participant BB

Objective	raw weight	normalised weight
Rainforest - OUV (vii, viii, ix)	20	0.06
Heath - OUV (ix)	100	0.32
Perched lakes - OUV (vii, viii)	20	0.06
Fens - OUV (ix)	20	0.06
Visitor experience	50	0.16
Traditional Owners - connection to Country	50	0.16
Traditional Owners - economic opportunity	50	0.16
Total	310	1.00

Participant CC

Objective	raw weight	normalised weight
Rainforest - OUV (vii, viii, ix)	20	0.05
Heath - OUV (ix)	20	0.05
Perched lakes - OUV (vii, viii)	100	0.26
Fens - OUV (ix)	100	0.26
Visitor experience	50	0.13
Traditional Owners - connection to Country	50	0.13
Traditional Owners - economic opportunity	50	0.13
Total	390	1.00

Participant DD

Objective	raw weight	normalised weight
Rainforest - OUV (vii, viii, ix)	100	0.25
Heath - OUV (ix)	100	0.25
Perched lakes - OUV (vii, viii)	100	0.25
Fens - OUV (ix)	100	0.25
Visitor experience	0	0.00
Traditional Owners - connection to Country	0	0.00
Traditional Owners - economic opportunity	0	0.00
Total	400	1.00

Participant EE

Objective	raw weight	normalised weight
Rainforest - OUV (vii, viii, ix)	50	0.13
Heath - OUV (ix)	50	0.13
Perched lakes - OUV (vii, viii)	50	0.13
Fens - OUV (ix)	50	0.13
Visitor experience	100	0.25
Traditional Owners - connection to Country	50	0.13
Traditional Owners - economic opportunity	50	0.13
Total	400	1.00

Participant FF

Objective	raw weight	normalised weight
Rainforest - OUV (vii, viii, ix)	90	0.14
Heath - OUV (ix)	90	0.14
Perched lakes - OUV (vii, viii)	90	0.14
Fens - OUV (ix)	90	0.14
Visitor experience	100	0.16
Traditional Owners - connection to Country	90	0.14
Traditional Owners - economic opportunity	90	0.14
Total	640	1.00