Received: 15 August 2018 | Accepted: 26 March 2019

DOI: 10.1002/pan3.27

RESEARCH ARTICLE

PEOPLE AND NATURE BRITISH ECOLOGICAL SOCIETY

Integrating local knowledge to prioritise invasive species management

Hernan Caceres-Escobar[1,2,3] | **Salit Kark**[1,2,3] | **Scott C. Atkinson**[1,2,4] | **Hugh P. Possingham**[1,2,5] | **Katrina J. Davis**[1,2,6,7]

[1]Centre for Biodiversity and Conservation Science, School of Biological Sciences, University of Queensland, St. Lucia, Queensland, Australia; [2]ARC Centre of Excellence for Environmental Decisions, University of Queensland, St. Lucia, Queensland, Australia; [3]NESP Threatened Species Recovery Hub, School of Biological Sciences, University of Queensland, St. Lucia, Queensland, Australia; [4]United Nations Development Programme (UNDP), New York, New York; [5] The Nature Conservancy, Arlington, Virginia; [6]Land, Environment, Economics and Policy Institute, University of Exeter Business School, Exeter, UK and [7]Centre for Environmental Economics and Policy, UWA School of Agriculture and Environment, University of Western Australia, Crawley, Western Australia, Australia

Correspondence
Hernan Caceres-Escobar, Centre for Biodiversity and Conservation Science, School of Biological Sciences, University of Queensland, St. Lucia, Queensland, Australia.
Email: h.caceres@uq.edu.au

Funding information
Chilean Doctoral Fellowship Programme: CONICYT PFCHA/Doctorado Becas Chile/2014, Grant/Award Number: 72150114; Australian Government's National Environmental Science Program, through the Threatened Species Recovery Hub

Handling Editor: Olivier Gimenez

Abstract

1. Invasive species management involves complex and multidimensional challenges. There is considerable uncertainty regarding how to identify management strategies that will achieve invasive species control to enhance biodiversity, local economies and human well-being. Invasive species management on inhabited islands is especially challenging, often due to perceived socio-political risks and unexpected technical difficulties.
2. Failing to incorporate local knowledge and local perspectives in the early stages of planning can compromise the ability of decision makers to achieve long-lasting conservation outcomes. Hence, engaging the community and accounting for stakeholder perceptions are essential for invasive species management, yet, these processes are often overlooked as they can be perceived as too difficult to implement, too costly and/or too slow for management timeframes.
3. To address this gap, we present an application of invasive species management based on structured decision-making, and INFFER—a cost-benefit analysis tool—on Minjerribah-North Stradbroke Island (Australia). We assessed the cost-effectiveness of six management scenarios, co-developed with local land managers and community groups, aimed at preserving the environmental and cultural significance of the island by eradicating European red foxes (*Vulpes vulpes*) and feral cats (*Felis catus*). Information was collected in a survey that elicited local stakeholders' perspectives regarding the significance of the Island, their perception of the benefits of the proposed management scenarios, funding requirements, technical feasibility of implementation and socio-political risk.
4. We found that low budgets achieve less cost-effective results than higher budgets. The best strategy focussed on controlling the European red foxes on

Minjerribah. However, our results also highlight the need for more research on feral cat management.

5. This work demonstrates how to use a structured decision support tool, such as INFFER, to assess contesting management strategies. Using appropriate decision support tools is particularly important when stakeholders' perceptions regarding management outcomes are heterogeneous and uncertain.

KEYWORDS

community engagement, European red foxes, feral cats, INFFER, invasive species, islands, local knowledge

1 | INTRODUCTION

Rates of species extinction and decline are increasing, and are likely to continue to rise worldwide unless we address the key threats to biodiversity (Barnosky et al., 2011; Jones et al., 2016; De Vos, Joppa, Gittleman, Stephens, & Pimm, 2015). Invasive species are one of the main causes of species decline and extinctions (Bellard, Genovesi, & Jeschke, 2016; Clavero & García-Berthou, 2005; Doherty, Glen, Nimmo, Ritchie, & Dickman, 2016). Approximately, 75% of recorded terrestrial extinctions have occurred on islands (Tershy, Shen, Newton, Holmes, & Croll, 2015), and invasive species have been identified as the leading factor (Clavero & García-Berthou, 2005; Courchamp, Chapuis, & Pascal, 2003; Doherty et al., 2016). Islands occupy around 5% of the Earth´s total land area, but support 41% of all critically endangered and endangered terrestrial vertebrates, 19% of all bird species and 17% of all rodents (Spatz et al., 2017; Tershy et al., 2015), which makes them important safe havens for global biodiversity.

Islands, and other isolated habitats, are particularly susceptible to invasive species and their impacts (Simberloff, 1995, 2009). This can be explained by higher rates of endemism, specialised biota and isolation from the mainland (CBD, 2019; MacArthur & Wilson, 1967; Moser et al., 2018), as described in the Equilibrium Theory by MacArthur and Wilson (1967). In response to the threat posed by invasive species, more than 1,000 eradication programmes have been implemented on islands around the world (Simberloff, Genovesi, Pyšek, & Campbell, 2011). Most of these programmes have resulted in positive outcomes for native species (Innes & Saunders, ; Jones et al., 2016; Zavaleta, Hobbs, & Mooney, 2001). However, most invasive species eradication programmes have been implemented on uninhabited islands, mostly due to operational difficulties, such as perceived health hazards or financial burdens on the local community (Oppel, Beaven, Bolton, Vickery, & Bodey, 2011). A global challenge is to shift the focus of invasive species control from uninhabited islands to populated islands (Glen et al., 2013; Oppel, Beaven, Bolton, Vickery, et al., 2011), since many of the highest priority islands for eradication are inhabited (Brooke, Hilton, & Martins, 2007). Inhabited islands pose particular difficulties due to the presence of companion animals and livestock species, which hamper eradication actions (Glen et al., 2013). At the same time, commonly used eradication methods cannot be employed close to communities, or the existing methods can be substantially more expensive to implement than on uninhabited islands, mostly due to logistic difficulties and implementation restrictions around populated areas (Glen et al., 2013). Thus, eradication programmes on inhabited islands need to account for local environmental, social and economic conditions, as well as the biological and technical expertise required to remove invasive species (Oppel, Beaven, Bolton, Bodey, et al., 2011).

Community engagement has a major role to play in determining the outcomes of future efforts to improve invasive species management programmes on inhabited islands (Aguirre-Muñoz et al., 2008; Campbell et al., 2011; Ford-Thompson, Snell, Saunders, & White, 2012). Calling for engagement of local stakeholders is not new (Aguirre-Muñoz et al., 2008; Campbell et al., 2011), because the preferences and opinions of all people affected by conservation actions should be integrated in any environmental decision-making process that might affect them and the surrounding environment (Crowley, Hinchliffe, & McDonald, 2016; Estévez, Anderson, Pizarro, & Burgman, 2015; Reed, 2008). Public opposition can hinder the success of eradication programmes (Bremner & Park, 2007) and is common where the target species is valued by people (e.g. pets, livestock) (Glen et al., 2013). Consequently, lack of involvement and communication with the local community has been linked to the failure of previous eradication efforts (Campbell & Donlan, 2005). Hence, to halt biodiversity decline caused by invasive species, it is imperative that we advance not only with eradication protocols (Saunders, Coman, Kinnear, & Braysher, 1995) and reporting strategies (Iacona et al., 2018), but also with techniques to engage with local stakeholders when eradication plans are undertaken (Braysher, 2017; Toomey, Knight, & Barlow, 2017).

Incorporating local values and preferences into early planning stages can be challenging (Ford-Thompson et al., 2012; Oppel, Beaven, Bolton, Vickery, et al., 2011). However, through engagement it is possible to clarify and diminish any safety or social concerns, such as fear of water supply contamination, risks to pets and children from poisoned baits, visually unappealing signs, animal welfare concerns or closure of tourist areas (Glen et al., 2013). Engaging with local stakeholders and the general community can mitigate possible opposition to the implementation of eradication projects, and ensure the local community is informed of the socio-economic, health and ecological benefits (and costs) (Vane & Runhaar, 2016) that could arise through the implementation of eradication plans. This is particularly important in invasive species management, given that the survival of few—invasive—individuals can undermine the whole project (Glen et al., 2013).

Existing approaches to incorporate the preferences and values of local communities and practitioners have often targeted a single-stage of the eradication planning process (Ford-Thompson et al., 2012; Novoa et al., 2018) for example: engagement (Luyet, Schlaepfer, Parlange, & Buttler, 2012), eliciting information (Larson et al., 2011) or informing perceptions (Bardsley & Edwards-Jones, 2006). In this work, we present a novel systematic approach based on adaptive management (Holling, 1978) to address the multidimensional challenges posed by invasive species management on inhabited islands (Berkes, 2007; Glen et al., 2013; Kerr, Baxter, Salguero-Gómez, Wardle, & Buckley, 2016). On inhabited islands, the social preferences of local communities must be addressed, in addition to ecological components and economic constraints. Here, we incorporate local knowledge and management preferences throughout the eradication planning process. We engaged with multiple stakeholders, elicited local knowledge, included natural resource managers' perceptions and budgetary constraints to compare contrasting management scenarios using a cost-benefit analysis tool, the Investment Framework for Environmental Resources (INFFER) (Pannell et al., 2012).

Adaptive management is a special instance of structured decision making, which is a step-wise decision support framework that promotes the integration of scientific information and stakeholder's values to assist decision makers identify optimal management strategies (Bower et al., 2018; Gregory et al., 2012; Murphy & Weiland, 2014). The main principle of adaptive management is 'learn while doing', which makes it particularly useful for iterative approaches (Holling, 1978; USGS, 2019; Williams, 2011). We use INFFER (Pannell et al., 2012) as it complements an adaptive management approach and can be easily implemented by decision makers to: (a) assess the perceptions and preferences of stakeholders regarding invasive species management (social dimension); (b) assess the feasibility, cost and impacts of alternative projects (economic dimension); and (c) incorporate stakeholders' expertise and perceptions to better inform invasive species management plans and their possible conservation benefits (ecological dimension).

We applied the proposed approach on Minjerribah-North Stradbroke Island, located in Queensland, Australia (hereafter Minjerribah), where we co-developed and evaluated six management scenarios, with different investment levels, each designed to control the impacts of European red foxes (*Vulpes vulpes*, Linnaeus, 1758) and feral cats (*Felis catus*, Linnaeus, 1758). We elicited stakeholder data through a semi-structured online survey (eSurvey) (Appendix S1) to assess six different scenarios and define which scenario would deliver the most cost-effective benefits to threatened and culturally relevant species (Appendix S2), and to the local community on Minjerribah.

2 | METHODOLOGICAL ANALYSIS AND CONTEXT

The objective of this study was to evaluate the cost-effectiveness of management strategies to control the impacts of invasive species on

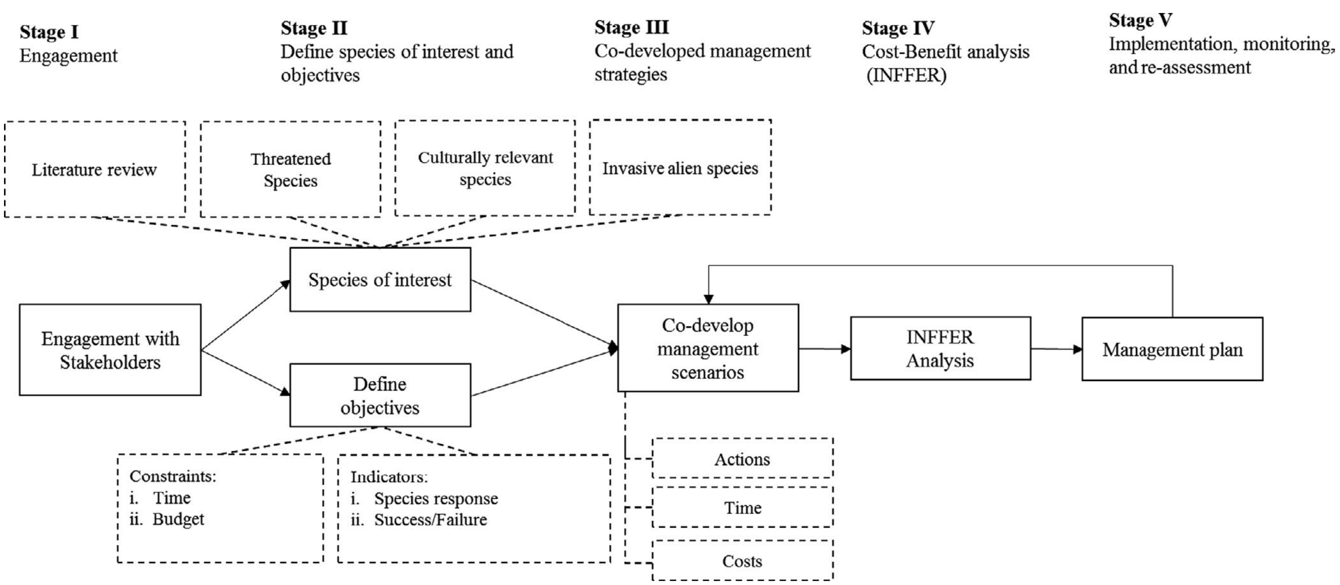

FIGURE 1 Stages of the proposed framework to develop, assess and select invasive species management strategies. Boxes with broken outlines represent complementary actions that need to be undertaken to complete the main goal in every stage, which is represented by boxes with solid outlines

the threatened and culturally relevant species of Minjerribah. In this section, we provide details about our case study, Minjerribah, the stakeholder-engagement process, application of INFFER (Pannell et al., 2012), data collection and development and analysis to select the best strategies to control invasive species impacts on native and culturally relevant species. This wider process is described in Figure 1.

2.1 | Study area: Minjerribah-North Stradbroke Island (Queensland, Australia)

Minjerribah has unique ecological, economic and culturally relevant values for the local and national Australian population. These values are currently being impacted, directly or indirectly, by invasive species. Minjerribah's ecological uniqueness and internationally important cultural heritage make it one of the top 50 offshore islands prioritised for protection in Australia (Ecosure, 2009). The Island is located approximately 40 km east of Brisbane (Queensland, Australia) (Figure 2). It is the second largest sand island in the world (approximately 285 km^2) (Laycock, 1978), and the largest of the Moreton Bay Islands (Queensland, Australia) (27°30′S, 153°28′E). Minjerribah hosts a wide variety of habitats (Queensland Herbarium, 2009) that support many native sedentary and migratory species. The island is a stepping stone along the East Asian–Australian Flyway and is a 'Wetland of International Importance' (Ramsar Convention, 1971) making it an important site for Australian bird resident species as well as for intercontinental migrants (Wilson, Kendall, Fuller, Milton, & Possingham, 2011).

The Island has been inhabited by the Quandamooka people for at least 21,000 years (Barram, Carew, Hill, & Phillips, 2016). The Quandamooka people are the historical custodians of the Moreton Bay. In 2011, this was recognised by the Federal Court of Australia (National Native Title Tribunal, 2011), highlighting the cultural significance of the area. Since the 1940s, the Island has also been the source of extensive sand mining operations. The mining activities are scheduled to end by late 2019; a period which marks the end of an industrial era on Minjerribah, and the prospect of major change and potential economic growth for local businesses, tourism and the local community.

Fifteen vertebrate invasive species have been recorded on the island, including red foxes and cats (Appendix S2) (Threatened Island Biodiversity Database Partners, 2014). Red foxes and feral cats are two of the most damaging invasive species in the world (Courchamp et al., 2003; Doherty et al., 2016; Lowe, Browne, Boudjelas, & Poorter, 2000), and on Australian islands they are a main driver of native species decline (Doherty et al., 2015; Glen & Dickman, 2005; Legge et al., 2016; Saunders, Gentle, & Dickman, 2010). Red foxes and feral cats species not only have direct and indirect impacts on the threatened and culturally relevant species of the Island, but also affect its cultural heritage, and economically valuable local industries, such as tourism (Gong, Sinden, Braysher, & Jones, 2009; Jones, Saunders, & Balogh, 2006). In response to this threat, the local pest management authorities formed the *Straddie Pest Management Group* (SPMG). The aim of this group was to manage the impacts of invasive species on the Island. The diversity of local stakeholders, including indigenous and non-indigenous residents, and economic activities, as well as its biological uniqueness make Minjerribah the perfect location to assess optimal invasive species management approaches.

2.2 | Stakeholder engagement

The goal of this process was to engage with a representative sample of local stakeholders that actively participate or could be affected by the implementation of conservation actions that target invasive species on Minjerribah-North Stradbroke Island. The first step of this study was to contact (through email and phone) senior managers from a wide range of federal and local government authorities and non-government organisations. These managers were all involved in the development, assessment and implementation of invasive

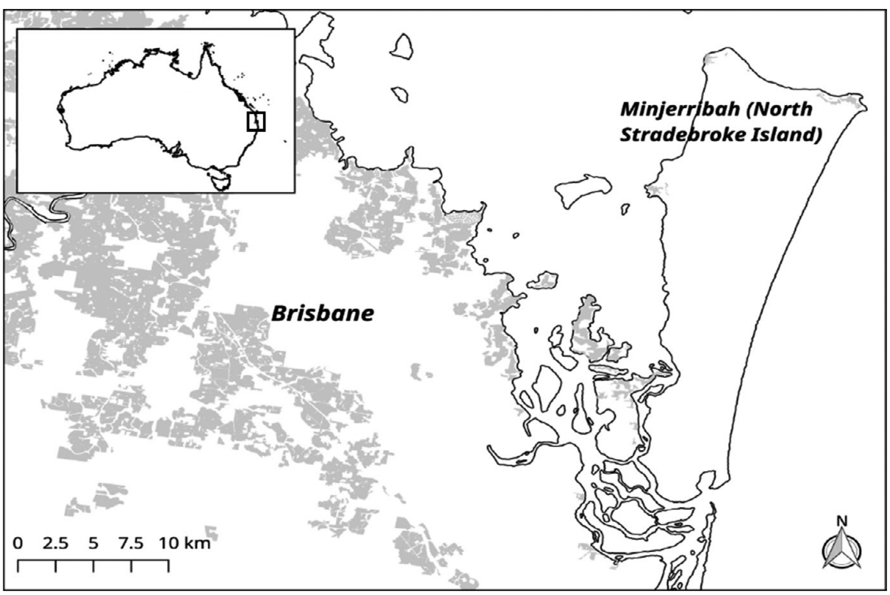

FIGURE 2 Location of Minjerribah (North Stradbroke Island) in Queensland, Australia. Light grey areas indicate urban development

species management strategies on Minjerribah. Initial meetings with these groups and individuals were unstructured and, after a process known as Snowballing Sampling (Atkinson & Flint, 2004), we were able to identify and engage with a broader group of local stakeholders involved in SPMG (Stage I in Figure 1), with whom we collaborated throughout all stages of our study. We communicated with the members of the SPMG through a gatekeeper who oversaw the distribution of information regarding our research project (according to the requirements of the Human Research Ethics Committee (HREC) of The University of Queensland), but the members of the SPMG could directly contact us for general queries.

The SPMG, at the time of this study, was formed by 13 representatives from six government agencies, five non-government organisations and community groups and two private organisations. SPMG members have been working on invasive species management for almost 10 years. Collectively, members have extensive experience managing invasive species on the Island and are familiar with the views of the local community regarding invasive species management. In consultation with members of the SPMG, we jointly defined a Species of Interest list by reviewing the existing literature (i.e. grey and scientific literature) and discussed not only invasive and threatened species that are found on the Island, but also species that have some cultural or local significance (Appendix S2). We used the Species of Interest list to design and assess a set of management scenarios to control the impacts of red foxes and feral cats on Minjerribah's Species of Interest (Table 1).

2.3 | Scenario development

Over a 2-year period (2015–2017), we met biannually with the SPMG and attended the group's annual general meeting. The meetings started with an open forum, where members of the community expressed their queries regarding conservation management projects that would take place on the island. Following the open forum, we met with members of the SPMG to discuss management strategies to control the impacts of invasive species (i.e. red foxes and feral cats) on the native and culturally relevant species of Minjerribah. During the meetings, we initially discussed broad topics, such as the latest management approaches, then focused on specific details, such as which actions were considered acceptable by the community, the effectiveness of past actions and the effectiveness of similar plans implemented in other locations. During this period, we also received direct email-based feedback from individuals and organisations, although most of the information was collated and then transmitted by the gatekeeper. All information was incorporated in the co-development of the six proposed management strategies (Stage III in Figure 1).

During this 2-year period, we co-developed six scenarios to manage invasive species by reviewing relevant literature and drawing on the previous experience of the SPMG members (Stage III in Figure 1). In conjunction with members from the SPMG, we defined relevant attributes for the proposed management scenarios, such as cost, timeframe, feasibility according to local regulations, and accounted for management concerns from the public. All the information we gathered was treated equally (not weighted) and all members of the SPMG had an equal opportunity to contribute to the co-development process during our study (Stage III in Figure 1). The final six proposed scenarios were based on different investment levels (i.e. the total cost of the management strategy over a period of 25 years) defining the *management intensity* (i.e. low, medium and high). The *management intensity* varied according to the frequency of baiting campaigns (i.e. low = 1 campaign p.a.; medium = 2 campaigns p.a.; and high = 3 campaigns p.a.) and bait density that would be used (i.e. low = 2 baits/km^2; medium = 5 baits/km^2; and high = 10 baits/km^2) throughout the year over a 3-year implementation window (a summary of the scenarios can be found in Table 1). The goal of the different scenarios was to diminish the impacts caused by red foxes and feral cats, by eradicating these species from the Island, hence increasing the probability of survival of culturally relevant and threatened species. Three scenarios were designed to target only red foxes (Scenarios 1 to Scenario 3) and three more scenarios that target red foxes and feral cats (Scenarios 4 to Scenarios 6). We did not develop management scenarios aimed at 'only cat' control as this action was deemed 'infeasible' in the absence of long-term commitments to control resident pet cat populations.

Each scenario varied in its management intensity (i.e. number of traps deployed, number of baits/km^2, number of stations/km^2 and number of baiting campaigns per annum), and length of implementation of the different control methods throughout the year (i.e. baiting, trapping, hunting and den fumigation; see Appendix S3 for a detailed description, including cost information). The cost of each scenario was constructed using a combination of data provided by members of the *SPMG*, scientific and grey literature and quotes by private distributors of the consumables, goods and capital assets (Auerbach, Tulloch, & Possingham, 2014; Holmes et al., 2015, 2016; Mcleod & Saunders, 2010). We report in detail the costs in

TABLE 1 Summarised proposed scenario of actions. For more details see Appendix S3

Target species	Scenario #	Investment level	Management intensity
Only red foxes (*Vulpes vulpes*)	1	Low	Low
	2	Medium	Medium
	3	High	High
Red foxes (*Vulpes vulpes*) and feral cats (*Felis catus*)	4	Low	Low
	5	Medium	Medium
	6	High	High

Appendix S4, following the recommendations made by Iacona et al. (2018). We assessed the present value of each scenario over a 25-year period. Cost data for each scenario included three main stages (i.e. planning, implementation and monitoring) and their costs over 25 years (which assumed 10 years of active management and 15 years of maintenance costs). We applied a discount rate of 5%. This rate is consistent with similar studies (Roberts et al. 2012; Pannell et al. 2013; Rout & Walshe 2013) and government recommendations for environmental projects (Wise & Capon, 2016).

2.4 | Data collection

To identify which of the scenarios would offer the greatest return on investment, we used INFFER (described below). We elicited the input parameters for INFFER (Stage IV in Figure 1) by sending out an online, semi-structured questionnaire (eSurvey, found in Appendix S1). Following the requirements of the Human Research Ethics Committee (HREC) of The University of Queensland (Approval number: 2016001001), a gatekeeper oversaw the distribution of the eSurvey to the stakeholders participating in the SPMG. This questionnaire was based on INFFER's Project Assessment Form (*PAF*) (Pannell et al., 2012). The data collected from the eSurvey recorded basic information about respondents (e.g. sector, invasive species' knowledge and years of experience working on invasive species management) and collected the INFFER input parameters for the *PAF*.

2.5 | Analysis framework: INFFER analysis

We then used the PAF from the Investment Framework for Environmental Resources (INFFER™) (http://inffer.org/, verified 1 April 2018; Pannell et al., 2012) to evaluate the six proposed scenarios (Stage IV in Figure 1). INFFER was primarily designed to help managers evaluate and prioritise competing projects. It provides an organised approach based on a benefit-cost ratio (BCR) to identify management actions that will achieve the most cost-effective environmental outcome (Pannell et al., 2012), the steps of the INFFER approach are shown in Table 2.

By defining SMART (Specific, Measurable, Achievable, Relevant and Time-Bound) projects, INFFER helps clarify what is required to achieve proposed outcomes (Bottrill et al., 2008). This assessment process is the core of INFFER, and provides the basis to assess whether a project is cost-effective (i.e. if BCR > 1, then a project is deemed cost-effective), as calculated by the BCR (Equation 1):

$$\mathrm{BCR} = \frac{V \times W \times A \times B \times F \times P \times G \times \mathrm{DFb}(L) \times 20}{C + \mathrm{PV}(M) \times G} \tag{1}$$

where *V* is the value that users assign to the asset on a scale of 0–100 (where a score of one equates to a monetary value of 20 million of currency, in this case Australian Dollars). The significance of the asset was obtained from the eSurvey ('What is the significance of Minjerribah (North Stradbroke Island) to you?'). *V* does not vary according to the different scenarios as it represents a baseline significance to assess the potential positive impacts of the implementation of the different proposed management scenarios. *W* represents the effectiveness of management works and is defined as the potential change in the asset's significance if all the actions were implemented according to the different scenarios. This value was obtained from respondent's answers to the eSurvey ('If the works and actions specific to each scenario were implemented, in overall, how much damage (loss to environmental, social and/or economic values) would be avoided in Minjerribah (North Stradbroke Island)?') based on their understanding of the effectiveness of previous actions and on-ground experience. *A* is the adoption rate by private land managers (if required). *B* represents the risk of adoption of adverse practices. *F* is the multiplier for technical feasibility risk. *P* is the probability that socio-political factors will not derail the project, and that the required changes take place; this value was obtained from the eSurvey ('What do you think is the chance that one of the social or political situations described below will prevent eradication from being achieved?'). Socio-political risks include: non-cooperation by the different organisations and the impacts of social, administrative or political constraints. *G* is the probability of obtaining long-term funding. DFb is the discount factor. *C* is the short-term project cost ($ million in total, over the life-span of the project). *M* is the total cost of maintaining the outcomes ($ million per year, beyond the immediate project). PV*(M)* is the present value to convert a stream of future annual maintenance costs (assumed constant in real terms) to their present-day value (in $ millions) (Pannell et al., 2012). Further information about the rationale for the BCR algorithm and the underpinning theoretical background can be found in Pannell et al. (2012, 2013). Subsequently, the results from the INFFER analysis were sent out to the *SPMG* members for review, and to assess whether the scenarios were appropriate (Stage V in Figure 1). The INFFER parameters were collected from the eSurvey that was sent to the participants as described in Section 2.42.3 (Data Collection). It is

TABLE 2 Steps of INFFER (Investment Framework for Environmental Resources) (Pannell et al., 2012)

1. Asset identification
2. Asset filtering and/or refine list of assets using pre-set criteria
3. Definition and assessment of projects
3.1. Asset significance (value)
3.2. Threats
3.3. Activities
3.4. Effectiveness
3.5 Costs
4. Selection of priority projects
5. Develop investment plans and/or funding bids
6. Implement funded projects
7. Monitoring, evaluation, adaptive management

worth noting that obtaining estimates regarding *V*—the value of environmental assets (e.g. species or habitats)—can be very difficult in practice. There can be a lack of relevant studies for benefit transfer (Bateman, Mace, Fezzi, Atkinson, & Turner, 2011), and in the case where primary values are sought, these can be highly influenced by individual preferences, and are often overestimated by local stakeholders (Jakobsson & Dragun, 2001; Portney, 1994). Heterogeneous responses can also confound the proper interpretation of this parameter.

We used a ranking-based assessment for the six proposed scenarios. We obtained an *Overall ranking* for the six scenarios and two, more detailed, *Internal rankings*: one for red fox-only control, and a second for joint-management. By using a structured decision-making approach based on INFFER, we were able to account for intrinsic biases, information-gaps and respondents' valuation heterogeneity, thereby facilitating the overall analysis and increasing the robustness of policy recommendations.

3 | RESULTS

3.1 | Respondents summary

All sectors involved in invasive species management on the Island were represented in the surveyed respondents: 46% were representatives of government agencies (six responses); 39% were from community or non-government organisations (five responses); and 15% were from private organisations (two responses), which matches the total number of representatives we initially identified (i.e. 13). A key aspect of the INFFER assessment is to define the significance of the environmental asset that a project will affect. Respondents held varied views about the significance of Minjerribah (asset valuation–*V*; *Question 1 of the eSurvey*): 31% indicated it has 'International' significance, 38% said 'National' significance, 8% noted a 'Very High State' and 23% gave a mark of 'High State' significance. Respondents justified their choices with a wide range of reasons, including: (a) Minjerribah is a RAMSAR site (international significance), (b) it is part of the East Asian–Australian Flyway (international significance), (c) the island has a genetically distinctive and healthy koala (*Phascolarctos cinereus*) population (national significance), and (d) provides habitat for threatened species and culturally relevant species (national significance), (e) Minjerribah is the second largest sand island in the world (international significance) and (f) historical indigenous heritage (international significance). Around one third of the respondents (31%) said they would have estimated a higher value if it was not for the disturbances caused by mining on the Island.

All respondents scored their knowledge regarding invasive species management as medium or better (5-point scale from 'comprehensive' to 'uncomprehensive'). Most respondents (84%) stated that the most important reason to be involved in invasive species management is to protect biodiversity, while 16% stated statutory or legal obligations (8%) and 8% held Traditional Owners values as most important.

The respondents also assessed the *Quality of the available information* regarding red fox management, feral cat management and joint-management of these species. For red fox management, approximately 38% of respondents scored the information as *good or sufficient*, 31% as *medium* and 31% as *low or insufficient*. For feral cat management, approximately 23% scored the information as *good or sufficient*, and 77% as *low or insufficient*. Approximately, 31% scored information regarding joint-management as *good or sufficient*, 15% as *medium* and 54% as *low or insufficient*.

Respondents scored the probability of eradication of red foxes under Scenario 1 as *low*—77% (*medium*—23%), Scenario 2 as *medium*—46% (*low*—23% and *high*—31%) and Scenario 3 as *high*—85% (*medium*—15%). The probability of joint-eradication (red foxes and feral cats) under Scenario 4 was scored as *low*—77% (*medium*—23%), Scenario 5 as *medium*—54% (*low—23%* and *high*—23%) and Scenario 6 was scored as *high*—77% (*low*—15% and *medium*—8%).

3.2 | INFFER analysis

We present the results of the INFFER parameters in Table 3. We found that respondents' asset valuation–*V* was highly heterogeneous. Hence, we assessed the BCR of each scenario under three different assumptions regarding the value of this parameter, the (a) mode ($V = 50$), (b) minimum ($V = 15$) and (c) lower bound ($V = 1$). When *V* is equal to 1, the BCRs are less than one for all scenarios, except for Scenario 3. When the BCR value is higher than 1, it represents the 'break even' point of the project, meaning that project benefits exceed project costs. When $V = 15$ and $V = 50$, all scenarios have BCRs higher than 1. Despite the changes in the BCR according to changes of the asset value, the rankings do not change.

By comparing the scenarios under different perspectives of the asset value (*V*), we were able to assess the robustness of our results to different stakeholders' values. Table 3 shows the INFFER cost-benefit analysis of the six proposed invasive species' management scenarios at all values of *V*. We found that the *Overall* and *Internal Rankings* of actions were constant across the values of *V*. In what follows, we describe results for the lower bound of *V* (most conservative assumption). A complete table with the parameters used in the INFFER BCR can be found in Appendix S5.

Across all six scenarios, the highest-ranking strategy was Scenario 3 (BCR = 1.15), as shown in *Overall* and *Internal ranking* for fox-only management in Table 3, which was the fox-only 'High' management intensity Scenario. For fox-only management scenarios, Scenario 3 was also the most expensive approach (AU$m 5.33). Scenario 1 (AU$m 3.48) was approximately 35% cheaper than Scenario 3, whereas Scenario 2 (AU$m 4.08) was 24% cheaper than Scenario 3. Across all three scenarios targeting only red foxes there was little variability in the socio-political risk (*P*), however, the impact of works–*W* varies considerably. For the 'Low' intensity scenario (Scenario 1), *W* was 0.21, and this increased to 0.61 in the 'High' intensity scenario (Scenario 3), with the 'Medium' intensity scenario having a $W = 0.41$. The estimated Lag time (*L*) was lower for high-intensity Scenario 3 ($L = 3$ years), whereas for Scenarios 1 and 2 it was estimated as 7 years.

TABLE 3 Results of benefit-cost ratios and correspondent parameters calculated in INFFER

Scenarios	Intensity	Cost[a] (AU$M)	Impacts of the works (W)	Socio-political risk (P)	Lag time (L)	Benefit:Cost Ratio (BCR)			Overall ranking	Internal ranking
						$V = 1$[b]	$V = 15$[c]	$V = 50$[d]		
1. Only fox management	Low	$3.48	0.21	0.85	7	0.52	7.79	25.96	3	3
2. Only fox management	Medium	$4.08	0.41	0.88	7	0.88	13.18	43.94	2	2
3. Only fox management	High	$5.33	0.61	0.85	3	1.15	17.19	57.28	1	1[e]
4. Joint-management	Low	$4.03	0.21	0.85	30	0.08	1.13	3.77	6	3
5. Joint-management	Medium	$5.84	0.61	0.85	10	0.39	5.83	19.44	4	1[e]
6. Joint-management	High	$7.76	0.61	0.85	10	0.29	4.31	14.37	5	2

[a]Expected present value (AU$ million) of costs over 25 years.
[b]INFFER lower bound for Asset Valuation–*V*.
[c]Minimum value for Asset Valuation–*V* by respondents.
[d]Mode for Asset Valuation–*V* by respondents.
[e]Selected scenarios.

For joint-management (eradication of both red foxes and feral cats), Scenario 5 (BCR = 0.39)—that is, 'Medium' intensity—was the highest-ranking alternative. The cost of joint-management increased almost linearly, from AU$4.03 million (Scenario 4) to AU$7.76 million (Scenario 6—'High' intensity). Scenario 4 ($W = 0.21$) had the lowest Impacts of the works–*W*, while Scenarios 5 and 6 were the same ($W = 0.61$). The socio-political risk ($p = 0.85$) did not vary across the three alternatives for joint-management; however, the Lag time (*L*) for Scenarios 5 and 6 ($L = 10$ years) were both considerably shorter than for Scenario 4 ($L = 30$ years).

Adoption of the proposed actions by private landholders and citizens (*A*) was described as *highly attractive* for fox-only management, and *neutral* for joint-management scenarios, so this parameter was set at 1, as none of the proposed actions require behavioural changes by local private landholders and citizens. The chance of private landholders or citizens *not* adopting adverse practices (*B*) was 0.95 in the scenarios that target fox-only management (Scenarios 1–3), and 0.7 for those scenarios that aimed at joint-management (Scenarios 4–6).

3.3 | Sensitivity analysis (SA)

We conducted a sensitivity analysis to determine the sensitivity of management recommendations to changes in three of the INFFER parameters: (a) Impact of works—*W*, (b) Socio-political risk—*P* (c) and Lag time—*L*. We chose these parameters because they demonstrated the greatest heterogeneity or were identified in the literature (Glen et al., 2013) as having a large impact on the success of invasive species management. We assessed changes in the three parameters across the *Best Performing Scenarios* (Scenarios 3 and 5), and calculated a Sensitivity Index (SI) (Alexander, 1989) for each parameter, as well as a *BCR Difference* (%) (see Table 4). A high SI score indicates a high sensitivity of the BCR to changes in that parameter. Across the three parameters, the BCR was most sensitive to changes in Socio-political risk—*P* (SI = 0.88 and 0.87 in Scenarios 3 and 5 respectively). After socio-political risk, Scenario 3 was more sensitive to changes in Impacts of the works—*W* (SI = 0.69), than to variation in Lag time—*L* (SI = 0.60), whereas Scenario 5 was more sensitive to changes in Lag time—*L* (SI = 0.77), than to changes in Impacts of the works–*W*.

4 | DISCUSSION

We assessed the BCR of six invasive species management scenarios on Minjerribah by including the perspectives of local government and community members into a cost-benefit analysis, INFFER. The analysis showed that fox-only control with 'high' intensity (Scenario 3) was the best strategy, as well as the only strategy under a conservative estimate of asset value ($V = 1$) that had a BCR greater than 1 (1.15), implying that the benefits of implementing this action exceeded the costs.

Among the fox-only Scenarios, Scenario 3 had a shorter time lag (3 years vs. 7). This result suggests that higher investment levels will lead to quicker outcomes, relative to lower investment levels. The dominance of this strategy can be explained by the perceived greater knowledge of red fox ecology among respondents, the current understanding of eradication measures and wider political and community support to control a species that is not considered a companion animal (like cats). Among the scenarios aimed at joint-management of feral cats and red foxes, Scenario 5 ('Medium' investment levels) had the highest BCR (BCR = 1.15). Invasive species managers on the island judged that Scenarios 5 and 6 (high investment levels) would have equivalent impact of works, socio-political risk and lag times. However, the higher cost of Scenario 6 resulted in a lower BCR relative to Scenario 5. It is important to note that Scenario 5 corresponds to current, recommended feral cat management strategies (Department of the Environment, 2015).

The perceived risk of management failure due to technical failure is low across all scenarios; this is consistent with the experience and on-ground expertise of Minjerribah's land managers who have already undertaken trial eradication campaigns over the last 4 years. At the same time, the risk of failure due to socio-political factors is considered low; this shows that the existing stakeholder network between government agencies, private organisations and community groups provides a suitable socio-political environment to develop and implement management actions aimed at these invasive species. However, on Minjerribah Island there is a risk that the local community could adopt adverse practices (*B*), for example, by not participating in identification or neutering programmes. This risk is evident in the value of *B*: 0.95 in the case of red foxes, and 0.7 for feral cats, as management works under all scenarios are expected to encounter some opposition from community groups, especially when it comes to island-wide baiting programmes and changes to companion animal legislation. Maintaining open communication between invasive species managers and local community members, particularly pet owners, is identified as an important requirement for all future invasive species management on the island (Crowley et al., 2016).

Overall, the impacts of feral cats on native species are well documented (Campbell et al., 2011; Denny & Dickman, 2010; Dickman, 1996; Doherty et al., 2015; Medina et al., 2011). What is not well understood is how to operationalise invasive management activities, such as baiting and banning companion animals on islands, without incurring significant community resistance. Existing management actions (i.e. hunting, trapping and baiting), which target feral cats are unlikely to be effective on inhabited islands in the long term, as pet cats can be a source for re-establishment of feral cat populations (Denny & Dickman, 2010). This is captured by the *Lag time* (*L*) for joint-management scenarios, which was 30 years (Scenario 4) compared to 10 years for Scenarios 5 and 6. In this project, none of the scenarios required behavioural changes (*A*) by the community—which we know is needed—which is why the perceived *Impacts of the Works—W* value for joint-management scenarios might not have been higher. Notwithstanding the lack of a standard procedure to tackle these species (Parkes, Fisher, Robinson, & Aguirre-Muñoz, 2014), management plans ought to be adapted to local environmental, socio-political conditions and use reporting protocols (Iacona

TABLE 4 Sensitivity analysis indices calculated for *initial*, *best* and *worst* values of INFFER parameters: Impacts of the works–*W*, Socio-political risk–*P* and Lag time–*L*. *Initial Benefit-cost ratio* (BCR) indicates the resulting BCR score when we use the *best* and *worst* values for each INFFER parameter (i.e. *W*, *P* and *L*)

Sensitivity analysis indices										
	Scenario 3					Scenario 5				
INFFER parameter	Value	BCRi	ΔBCR%	SI	SI rank	Value	BCRi	ΔBCR%	SI	SI rank
W—Impacts of the works										
Initial	0.61	1.15	n.c.			0.61	0.41	n.c.		
Best	1	1.88	63.48%	0.69	2nd	0.81	0.54	31.71%	0.61	3rd
Worst	0.31	0.58	−49.57%			0.31	0.21	−48.78%		
P—Socio-political risk										
Initial	0.85	1.15	n.c.			0.85	0.41	n.c.		
Best	0.97	1.31	13.91%	0.88	1st	0.97	0.47	14.63%	0.87	1st
Worst	0.12	0.16	−86.09%			0.12	0.06	−85.37%		
L—Lag time										
Initial	3	1.15	n.c.			10	0.41	n.c.		
Best	1	1.26	9.57%	0.60	3rd	1	0.64	56.10%	0.77	2nd
Worst	20	0.5	−56.52%			30	0.15	63.41%		

Note: *Difference in Benefit-cost ratio* (ΔBCR) shows the percentage change in the BCR once we recalculated it with the *best* and *worst* values for *W*, *P* and *L*. The *Sensitivity index* (SI) shows how much the BCR changes according to the *best* and *worst* values for the INFFER parameters, a higher SI value indicates greater sensitivity of the BCR to changes of *W*, *P* and *L*. The *Sensitivity Index Ranking* (SI rank) orders the *Sensitivity index* from 1st to 3rd, according to the SI values.
Abbreviation: n.c., not calculated.

et al., 2018). The implementation of complementary actions, such as: legislation that regulates existing and future companion animals, mandatory identification, control of the existing pet population by mandatory spay and neuter programmes, predation deterrents, cat curfews by night time and the prohibition—or control of—new pet cats are needed to secure long-term effects (Denny & Dickman, 2010; Nogales et al., 2013). These complementary actions can prevent—in the long term—the spillover of domestic pet cats to establish new feral populations, but as shown by Ratcliffe et al. (2010) it is possible to encounter public opposition and adoption of adverse practices (B = 0.7), reflected by lower values of the joint-management scenarios, despite the high adoption by private landholders and citizens (A = 1).

We would have expected a joint-management scenario to be the *Optimal Strategy*—as Ballari, Kuebbing, and Nuñez (2016) found, the removal of a single invasive species is not enough to have a positive, or even neutral effect on native species' performance or survival. The reasons joint-management was not the *Optimal Strategy* in our study were because of: (a) lower than expected values for Impacts of the work–W for joint-management scenarios, therefore resulting in lower BCR*s* for Scenarios 4, 5 and 6; (b) higher perceived uncertainty on the long-term benefits from the implementation of more expensive, combined actions; (c) longer expected Lag times (L) as management of feral cats requires the implementation of complementary actions and behavioural changes; and (d) the possibility of public opposition and adoption of adverse practices. Gaps in information will result in higher uncertainty and prevent robust comparison between proposed actions. We highly recommend further research on this topic. Methods such as *Ensemble Ecosystem Modelling* (Baker, Gordon, & Bode, 2016), *Optimal eradication schedules* (Bode, Baker, & Plein, 2015) and *Optimal surveillance* (Holden, Nyrop, & Ellner, 2016; Rout, Hauser, McCarthy, & Moore, 2017) have proven to be valuable techniques to identify potential ecosystem impacts from single-species management, and to optimise invasive species eradication.

Sensitivity analyses (Section 3.33.1 and Table 4) are a valuable tool to assess the sensitivity of management recommendations to changes in parameter values (Pannell, 1997). A sensitivity analysis showed that Scenarios 3 and 5 were highly sensitive to variation in Socio-political risk (P). This result highlights the need to account for local socio-political conditions and its possible variations between early planning stages and later implementation of the proposed actions. Moreover, it also emphasises the importance of facilitating the participation of multiple stakeholders to capture their perspectives, and the need for methods to evaluate local stakeholders' preferences, as new conditions could derail the future success of the proposed strategies. Scenario 3 is also sensitive to changes in the effectiveness of the proposed management strategy (Impacts of the works–W); if effectiveness were to decline, Scenario 3 would no longer be a viable management strategy (BCR < 1). Scenario 5, which was the best performing scenario within the 'joint-management' strategies, was also sensitive to changes in Lag time (L), followed by variations in effectiveness of the works (W). Even with a 'best' approach for these parameters (i.e. where all parameters are set to their most optimistic value, relative to project success), Scenario 5 does not have a BCR > 1, implying that the benefits of implementing this scenario would not exceed the costs. As previously suggested, information gaps could be affecting a proper assessment of joint-management strategies, as the removal of a single species has shown to be a suboptimal strategy when red foxes and feral cats coexist (Ballari et al., 2016).

Eliciting values for environmental goods is a difficult and complex process. Stakeholder valuation of local assets, like Minjerribah, can overestimate the intrinsic significance of the asset, and be sensitive to personal bias (Portney, 1994). The result is a high level of subjectivity and heterogeneity in provided answers (Marsh, Curatolo, Pannell, Park, & Roberts, 2010). Therefore, we suggest adopting a risk-adverse approach as a standard practice (McDonald-Madden, Baxter, & Possingham, 2008). In this study, we have demonstrated a structured approach to track the *change* in asset value as a result of management works. Nevertheless, we need approaches that account for cultural values, management preferences and contesting plans aimed at protecting biodiversity, to later compare them with alternatives that may adversely affect their future survival (Jakobsson & Dragun, 2001). Using INFFER allowed us to incorporate these perspectives and preferences explicitly to support a transparent decision-making process (Marsh et al., 2010).

This study outlined an approach to incorporate social, ecological and economic information into invasive species management design and evaluation. The key social and ecological benefits of this approach are: (a) maximising local participation, (b) providing an opportunity for local stakeholders to collaborate in the development of conservation management strategies, (c) improving the assessment of management strategies (i.e. by including project feasibility, costs and benefits) and thus (d) increasing the potential ecological benefits from management implementation. These characteristics make it a flexible and robust approach to deliver SMART and inclusive conservation management strategies by aligning conservation plans to local ecological, economic and social conditions (Berkes, 2007; Doyle-Capitman, Decker, & Jacobson, 2018).

The framework presented in this study is based on benefit-cost analysis (BCA), which is a preferred method to compare alternative strategies or set priorities (Marshall, McNeill, & Reeve, 2011). BCA is used to determine if a given project improves outcomes relative to initial conditions. These conditions are measured by estimating the benefits and costs of a proposed project (Marshall et al., 2011). One of the main concerns regarding BCA approaches is the difficulty assigning monetary value to environmental assets (Bateman et al., 2011; Marshall et al., 2011).

There are other approaches to making conservation investment decisions besides BCA, such as deliberative methods and multi-criteria analysis (MCA). Deliberative methods involve similar participatory approaches as BCA and MCA, however they do not use a formal organised model to calculate decision outcomes, which makes them a less reliable approach for decision making (Marshall et al., 2011). MCA methods allow for the inclusion of multiple strategies, multiple objectives and different criteria simultaneously (Marshall et al., 2011); but have been criticised for their complexity, vulnerability to abuse by special-interest groups and large information requirements, which can make implementation and interpretation by decision makers difficult (Dobes & Bennett, 2009; Marshall et al., 2011).

Local conditions and the requirements of different studies will determine which approach, for example, BCA, deliberative methods or MCA, is most appropriate. In our case study, INFFER was the most suitable approach as it can be easily implemented by decision makers, allows for a more collaborative approach, explicitly integrates local perspectives and technical components (i.e. feasibility, cost and benefits), and provides accountability over the decision process and its outcomes.

The environmental uniqueness of Minjerribah is a key determinant of the island's environmental and cultural significance. However, native species on the island are threatened by European red foxes and feral cats. Involving stakeholders in invasive species management is a critical but difficult aspect of management (Ford-Thompson et al., 2012). We have overcome barriers to incorporate local stakeholder knowledge into invasive species management by following a multi-stakeholder engagement process based on adaptive management principles (Holling, 1978) and INFFER (Pannell et al., 2012). Our approach allowed us to identify that a high level of investment targeting red foxes on Minjerribah would provide greater benefits relative to its costs. This result is a timely example of how invasive species management can be approached on inhabited islands but outlines the need for more research directed at feral cat management protocols.

We believe that provided the right pre-assessment, implementation and monitoring tools, Minjerribah is a suitable location to pursue eradication of feral cats and European red foxes. It is important to consider the existing socio-political environment, the technical experience of local natural resource managers, as well as community cohesiveness, engagement and overall support. Implementing these actions will ultimately protect the Island's unique biodiversity, future economic well-being and its unique cultural heritage.

RESEARCH ETHICAL APPROVAL

This research project complies with the requirements of the Human Research Ethics Committee (HREC) from the University of Queensland, approval number: 2016001001.

CONFLICT OF INTEREST

Nothing to declare.

ACKNOWLEDGEMENTS

We acknowledge the Traditional Custodians of the Islands, waters and seas surrounding Minjerribah and pay our respects to Elders, past, present and future and hope this work is of benefit to the aspirations of the Quandamooka People. We thank the support of everyone who gave their time to participate in the study, especially to the members of the Straddie Pest Management Group. This work was supported by the Australian Government's National Environmental Science Program, through the Threatened Species Recovery Hub, and the Chilean Doctoral Fellowship Programme: CONICYT PFCHA/Doctorado Becas Chile/2014 – 72150114, awarded to H.C.-E.

AUTHORS' CONTRIBUTIONS

H.C.-E., S.K., K.J.D. and H.P.P., conceived the idea and designed the methodologies; H.C.-E. and K.J.D. collected the data; H.C.-E., S.C.A. and K.J.D. analysed the data, H.C.-E. and K.J.D. led the writing of the manuscript. All authors contributed critically to the drafts and gave final approval for publication.

DATA ACCESSIBILITY

Raw data of the INFFER analysis and eSurvey associated with this paper are publicly available from the Dryad Digital Repository (https://doi.org/10.5061/dryad.kt647sq) (Caceres-Escobar, Kark, Atkinson, Possingham, & Davis, 2019).

ORCID

Hernan Caceres-Escobar https://orcid.org/0000-0003-0331-0891

Katrina J. Davis https://orcid.org/0000-0002-6982-9381

REFERENCES

Aguirre-Muñoz, A., Croll, D. A., Donlan, C. J., Henry, R. W., Hermosillo, M. A., Howald, G. R., … Wood, B. (2008). High-impact conservation: Invasive mammal eradications from the islands of western México. *Ambio*, *37*, 101–107. https://doi.org/10.1579/0044-7447(2008)37[101:HCIMEF]2.0.CO;2

Alexander, E. R. (1989). Sensitivity analysis in complex decision models. *Journal of the American Planning Association*, *55*, 323–333. https://doi.org/10.1080/01944368908975419

Atkinson, R., & Flint, J. (2004). Snowball sampling. In M. S. Lewis-Beck, A. Bryman, & T. F. Liao (Eds.), *SAGE Encycl. Soc. Sci. Res. Methods* (pp. 1044–1045). London, UK: Sage.

Auerbach, N. A., Tulloch, A. I. T., & Possingham, H. P. (2014). Informed actions: Where to cost effectively manage multiple threats to species to maximize return on investment. *Ecological Applications*, *24*, 1357–1373. https://doi.org/10.1890/13-0711.1

Baker, C. M., Gordon, A., & Bode, M. (2016). Ensemble ecosystem modeling for predicting ecosystem response to predator reintroduction. *Conservation Biology*, *31*, 376–384.

Ballari, S. A., Kuebbing, S. E., & Nuñez, M. A. (2016). Potential problems of removing one invasive species at a time: A meta-analysis of the interactions between invasive vertebrates and unexpected effects of removal programs. *PeerJ*, *4*, e2029. https://doi.org/10.7717/peerj.2029

Bardsley, D., & Edwards-Jones, G. (2006). Stakeholders' perceptions of the impacts of invasive exotic plant species in the Mediterranean region. *GeoJournal*, *65*, 199–210. https://doi.org/10.1007/s10708-005-2755-6

Barnosky, A. D., Matzke, N., Tomiya, S., Wogan, G. O. U., Swartz, B., Quental, T. B., … Ferrer, E. A. (2011). Has the Earth's sixth mass extinction already arrived? *Nature*, *471*, 51–57.

Barram, M., Carew, S. E., Hill, S., & Phillips, M. (2016). A nature guide to North Stradbroke Island - Minjerribah. Friends of Stradbroke Island Incorporated.

Bateman, I. J., Mace, G. M., Fezzi, C., Atkinson, G., & Turner, K. (2011). Economic analysis for ecosystem service assessments. *Environmental and Resource Economics*, *48*, 177–218. https://doi.org/10.1007/s10640-010-9418-x

Bellard, C., Genovesi, P., & Jeschke, J. M. (2016). Global patterns in threats to vertebrates by biological invasions. *Proceedings of the Royal Society B-Biological Sciences*, *283*, 20152454. https://doi.org/10.1098/rspb.2015.2454

Berkes, F. (2007). Community-based conservation in a globalized world. *Proceedings of the National Academy of Sciences of the United States of America*, *104*, 15188–15193. https://doi.org/10.1073/pnas.0702098104

Bode, M., Baker, C. M., & Plein, M. (2015). Eradicating down the food chain: Optimal multispecies eradication schedules for a commonly encountered invaded island ecosystem. *Journal of Applied Ecology*, *52*, 571–579. https://doi.org/10.1111/1365-2664.12429

Bottrill, M. C., Joseph, L. N., Carwardine, J., Bode, M., Cook, C., Game, E. T., … Possingham, H. P. (2008). Is conservation triage just smart decision making? *Trends in Ecology & Evolution*, *23*, 649–654.

Bower, S. D., Brownscombe, J. W., Birnie-Gauvin, K., Ford, M. I., Moraga, A. D., Pusiak, R. J. P. P., … Bennett, J. R. (2018). Making tough choices: Picking the appropriate conservation decision-making tool. *Conservation Letters*, *11*, e12418. https://doi.org/10.1111/conl.12418

Braysher, M. (2017). *Managing Australia's pest animals: A guide to strategic planning and effective management*. Clayton South, Vic.: Csiro Publishing.

Bremner, A., & Park, K. (2007). Public attitudes to the management of invasive non-native species in Scotland. *Biological Conservation*, *139*, 306–314. https://doi.org/10.1016/j.biocon.2007.07.005

Brooke, M. D. L., Hilton, G. M., & Martins, T. L. F. (2007). Prioritizing the world's islands for vertebrate-eradication programmes. *Animal Conservation*, *10*, 380–390. https://doi.org/10.1111/j.1469-1795.2007.00123.x

Caceres-Escobar, H., Kark, S., Atkinson, S. C., Possingham, H. P., & Davis, K. J. (2019). Data from: Integrating local knowledge to prioritise invasive species management. Dryad Digital Repository, https://doi.org/10.5061/dryad.kt647sq

Campbell, K., & Donlan, C. (2005). Feral goat eradications on islands. *Conservation Biology*, *19*, 1362–1374. https://doi.org/10.1111/j.1523-1739.2005.00228.x

Campbell, K. J., Harper, G., Algar, D., Hanson, C. C., Keitt, B. S., & Robinson, S. (2011). Review of feral cat eradications on islands. In: Veitch, C. R., Clout, M. N., Towns, D. R. (eds) Island invasives: eradication and management. *Proceedings of the international conference on island invasives* (pp. 37–46). Gland, Switzerland and Auckland, New Zealand: IUCN.

CBD (2019). Invasive Alien Species [WWW Document]. Retrieved from https://www.cbd.int/island/invasive.shtml

Clavero, M., & García-Berthou, E. (2005). Invasive species are a leading cause of animal extinctions. *Trends in Ecology and Evolution*, *20*, 110.

Courchamp, F., Chapuis, J.-L.-L., & Pascal, M. (2003). Mammal invaders on islands: Impact, control and control impact. *Biological Reviews of the Cambridge Philosophical Society*, *78*, 347–383.

Crowley, S. L., Hinchliffe, S., & McDonald, R. A. (2016). Invasive species management will benefit from social impact assessment. *Journal of Applied Ecology*, *54*, 351–357.

De Vos, J. M., Joppa, L. N., Gittleman, J. L., Stephens, P. R., & Pimm, S. L. (2015). Estimating the normal background rate of species extinction. *Conservation Biology*, *29*, 452–462. https://doi.org/10.1111/cobi.12380

Denny, E., & Dickman, C. (2010). *Review of cat ecology and management strategies in Australia*. Canberra, ACT: Invasive Anim. Coop. Res. Centre.

Department of the Environment (2015). Threat abatement plan for predation by feral cats. *Commonwealth of Australia*, *2015*, 1–50.

Dickman, C. R. (1996). Overview of the impacts of feral cats on Australian native fauna. *Wildlife Biology*, *2*, 1–195.

Dobes, L., & Bennett, J. (2009). Multi-criteria analysis: "Good Enough" for government work? *Agenda a J. Policy Anal. Reform*.

Doherty, T. S., Davis, R. A., van Etten, E. J. B., Algar, D., Collier, N., Dickman, C. R., … Robinson, S. (2015). A continental-scale analysis of feral cat diet in Australia. *Journal of Biogeography*, *42*, 964–975.

Doherty, T. S., Glen, A. S., Nimmo, D. G., Ritchie, E. G., & Dickman, C. R. (2016). Invasive predators and global biodiversity loss. *Proceedings of the National Academy of Sciences of the United States of America*, *113*, 11261–11265. https://doi.org/10.1073/pnas.1602480113

Doyle-Capitman, C. E., Decker, D. J., & Jacobson, C. A. (2018). Toward a model for local stakeholder participation in landscape-level wildlife conservation. *Human Dimensions of Wildlife*, *23*, 1–16. https://doi.org/10.1080/10871209.2018.1444215

Ecosure. (2009). Prioritisation of high conservation status of offshore islands. Report to the Australian Government Department of the Environment, Water, Heritage and the Arts. Cairns.

Estévez, R. A., Anderson, C. B., Pizarro, J. C., & Burgman, M. A. (2015). Clarifying values, risk perceptions, and attitudes to resolve or avoid social conflicts in invasive species management. *Conservation Biology*, *29*(1), 19–30. https://doi.org/10.1111/cobi.12359

Ford-Thompson, A. E. S., Snell, C., Saunders, G., & White, P. C. L. (2012). Stakeholder participation in management of invasive vertebrates. *Conservation Biology*, *26*, 345–356. https://doi.org/10.1111/j.1523-1739.2011.01819.x

Glen, A. S., Atkinson, R., Campbell, K. J., Hagen, E., Holmes, N. D., Keitt, B. S., … Torres, H. (2013). Eradicating multiple invasive species on inhabited islands: The next big step in island restoration? *Biological Invasions*, *15*, 2589–2603. https://doi.org/10.1007/s10530-013-0495-y

Glen, A. S., & Dickman, C. R. (2005). Complex interactions among mammalian carnivores in Australia, and their implications for wildlife management. *Biological Reviews of the Cambridge Philosophical Society*, *80*, 387–401. https://doi.org/10.1017/S1464793105006718

Gong, W., Sinden, J., Braysher, M., & Jones, R. (2009). *The economic impacts of vertebrate pests in Australia*. Canberra: Invasive Animals Cooperative Research Centre.

Gregory, R., Failing, L., Harstone, M., Long, G., McDaniels, T., & Ohlson, D. (2012). *Structured Decision Making: A Practical Guide to Environmental Management Choices*. Oxford, UK: Wiley-Blackwell.

Holden, M. H., Nyrop, J. P., & Ellner, S. P. (2016). The economic benefit of time-varying surveillance effort for invasive species management. *Journal of Applied Ecology*, *53*, 712–721. https://doi.org/10.1111/1365-2664.12617

Holling, C. S. (1978). *Adaptive environmental assessment and management*. Chichester, UK: John Wiley & Sons.

Holmes, N. D., Campbell, K. J., Keitt, B. S., Griffiths, R., Beek, J., Donlan, C. J., & Broome, K. G. (2015). Reporting costs for invasive vertebrate eradications. *Biological Invasions*, *17*, 2913–2925. https://doi.org/10.1007/s10530-015-0920-5

Holmes, N. D., Campbell, K. J., Keitt, B. S., Griffiths, R., Beek, J., Donlan, C. J., & Broome, K. G. (2016). Correction: Reporting costs for invasive vertebrate eradications. *Biological Invasions*, *17*, 2913–2925. https://doi.org/10.1007/s10530-015-0920-5

Iacona, G. D., Sutherland, W. J., Mappin, B., Adams, V., Armsworth, P. R., Coleshaw, T., … Possingham, H. P. (2018). Standardized reporting of the costs of management interventions for biodiversity conservation. *Conservation Biology*, *32*(5), 979–988. https://doi.org/10.1111/cobi.13195

Innes, J., & Saunders, A.. (2011). Eradicating multiple pests: an overview. In *Turn. tide Erad. invasive species. Proc. Int. Conf. Erad. Isl. Invasives*. Auckland, New Zealand: IUCN.

Jakobsson, K. M., & Dragun, A. K. (2001). The worth of a possum: Valuing species with the contingent valuation method. *Environmental & Resource Economics*, *19*, 211–227.

Jones, H. P., Holmes, N. D., Butchart, S. H. M., Tershy, B. R., Kappes, P. J., Corkery, I., … Croll, D. A. (2016). Invasive mammal eradication on islands results in substantial conservation gains. *Proceedings of the National Academy of Sciences of the United States of America*, *113*, 4033–4038. https://doi.org/10.1073/pnas.1521179113

Jones, R., Saunders, G. R., & Balogh, S. (2006). An Economic Evaluation of a Pest Management Control Program: 'Outfox the Fox'.

Kerr, N. Z., Baxter, P. W. J., Salguero-Gómez, R., Wardle, G. M., & Buckley, Y. M. (2016). Prioritizing management actions for invasive populations using cost, efficacy, demography and expert opinion for 14 plant species world-wide. *Journal of Applied Ecology*, *53*, 305–316. https://doi.org/10.1111/1365-2664.12592

Larson, D. L., Phillips-Mao, L., Quiram, G., Sharpe, L., Stark, R., Sugita, S., & Weiler, A. (2011). A framework for sustainable invasive species management: Environmental, social, and economic objectives. *Journal of Environmental Management*, *92*, 14–22. https://doi.org/10.1016/j.jenvman.2010.08.025

Laycock, J. (1978). North Stradbroke Island. Dep. Geol. Univ. Queensl., *8*, 89–96.

Legge, S., Murphy, B. P., McGregor, H., Woinarski, J. C. Z., Augusteyn, J., Ballard, G., … Zewe, F. (2016). The abundance of feral cats in Australia: Enumerating a continental-scale threat. *Biological Conservation*, *206*, 293–303.

Lowe, S., Browne, M., Boudjelas, S., & De Poorter, M. (2000). 100 of the world's worst invasive alien species. A selection from the Global Invasive Species Database. Invasive Species Spec. Gr. a Spec. Gr. Species Surviv. Comm. World Conserv. Union, 12.

Luyet, V., Schlaepfer, R., Parlange, M. B., & Buttler, A. (2012). A framework to implement Stakeholder participation in environmental projects. *Journal of Environmental Management*, *111*, 213–219. https://doi.org/10.1016/j.jenvman.2012.06.026

MacArthur, R. H., & Wilson, E. O. (1967). *The theory of island biogeography*. Princeton, NJ: Princeton Univ Press.

Marsh, S. P., Curatolo, A., Pannell, D. J., Park, G., & Roberts, A. M. (2010). Lessons from implementing INFFER with Regional Catchment Management Organisations. 54th Annu. Conf. Aust. Agric. Resour. Econ., Soc, 1–19.

Marshall, G. R., McNeill, J. M., & Reeve, I. J. (2011). *Economics for accountability in community-based environmental governance*. Armidale: Institute for Rural Futures, University of New England.

McDonald-Madden, E., Baxter, P. W. J., & Possingham, H. P. (2008). Making robust decisions for conservation with restricted money and knowledge. *Journal of Applied Ecology*, *45*, 1630–1638. https://doi.org/10.1111/j.1365-2664.2008.01553.x

Mcleod, L. J., & Saunders, G. R. (2010). Improved implementation of regional fox management programs.

Medina, F. M., Bonnaud, E., Vidal, E., Tershy, B. R., Zavaleta, E. S., Josh Donlan, C., … Nogales, M. (2011). A global review of the impacts of invasive cats on island endangered vertebrates. *Global Change Biology*, *17*, 3503–3510. https://doi.org/10.1111/j.1365-2486.2011.02464.x

Moser, D., Lenzner, B., Weigelt, P., Dawson, W., Kreft, H., Pergl, J., … Essl, F. (2018). Remoteness promotes biological invasions on islands worldwide. *Proceedings of the National Academy of Sciences of the United States of America*, *115*, 201804179. https://doi.org/10.1073/pnas.1804179115

Murphy, D. D., & Weiland, P. S. (2014). Science and structured decision making: Fulfilling the promise of adaptive management for imperiled species. *Journal of Environmental Studies and Sciences*, *4*, 200–207. https://doi.org/10.1007/s13412-014-0165-0

National Native Title Tribunal. (2011). Quandamooka People's native title determinations.

Nogales, M., Vidal, E., Medina, F. M., Bonnaud, E., Tershy, B. R., Campbell, K. J., & Zavaleta, E. S. (2013). Feral cats and biodiversity conservation: The urgent prioritization of island management. *BioScience*, *63*, 804–810. https://doi.org/10.1525/bio.2013.63.10.7

Novoa, A., Shackleton, R., Canavan, S., Cybèle, C., Davies, S. J., Dehnen-Schmutz, K., … Wilson, J. R. U. (2018). A framework for engaging stakeholders on the management of alien species. *Journal of Environmental Management*, *205*, 286–297. https://doi.org/10.1016/j.jenvman.2017.09.059

Oppel, S., Beaven, B. M., Bolton, M., Bodey, T. W., Geraldes, P., Oliveira, N., … Silva, C. (2011). Plans to eradicate invasive mammals on an island inhabited by humans and domestic animals (Corvo, Azores, Portugal). In *8th Eur. Vertebr. pest Manag. Conf. B. Abstr. Jul. Kühn- Inst. Berlin*, pp. 40–43.

Oppel, S., Beaven, B. M., Bolton, M., Vickery, J., & Bodey, T. W. (2011). Eradication of invasive mammals on islands inhabited by humans and domestic animals. *Conservation Biology*, *25*, 232–240.

Pannell, D. J. (1997). Sensitivity analysis of normative economic models: Theoretical framework and practical strategies. *Agricultural Economics*, *16*, 139–152.

Pannell, D. J., Roberts, A. M., Geoff, P., & Alexander, J. (2013). Designing a practical and rigorous framework for comprehensive evaluation and prioritisation of environmental projects. *Wildlife Research*, *40*(2), 126.

Pannell, D. J., Roberts, A. M., Park, G., Alexander, J., Curatolo, A., & Marsh, S. P. (2012). Integrated assessment of public investment in land-use change to protect environmental assets in Australia. *Land Use Policy*, *29*, 377–387. https://doi.org/10.1016/j.landusepol.2011.08.002

Parkes, J., Fisher, P., Robinson, S., & Aguirre-Muñoz, A. (2014). Eradication of feral cats from large islands: An assessment of the effort required for success. *New Zealand Journal of Ecology*, *38*, 307–314.

Portney, P. R. (1994). The contingent valuation debate: Why economists should care. *Journal of Economic Perspective*, *8*, 3–17. https://doi.org/10.1257/jep.8.4.3

Queensland Herbarium (2009). Regional Ecosystem Description Database (REDD). Version 6.0 b Updat. Novemb. 2009.

Ramsar Convention (1971). Convention on Wetlands of International Importance especially as Waterfowl Habitat. Ramsar (Iran), 2 February 1971. UN Treaty Series No. 14583. As amended by the Paris Protocol, 3 December 1982, and Regina Amendments, 28 May 1987.

Ratcliffe, N., Bell, M., Pelembe, T., Boyle, D., Benjamin, R., White, R., … Sanders, S. (2010). The eradication of feral cats from Ascension Island and its subsequent recolonization by seabirds. *Oryx*, *44*, 20–29. https://doi.org/10.1017/S003060530999069X

Reed, M. S. (2008). Stakeholder participation for environmental management: A literature review. *Biological Conservation*, *141*, 2417–2431. https://doi.org/10.1016/j.biocon.2008.07.014

Roberts, A. M., Pannell, D. J., Graeme, D., & Vigiak, O. (2012). Agricultural land management strategies to reduce phosphorus loads in the Gippsland Lakes. *Australia. Agricultural Systems*, *106*(1), 11–22.

Rout, T. M., Hauser, C. E., McCarthy, M. A., & Moore, J. L. (2017). Adaptive management improves decisions about where to search for invasive species. *Biological Conservation*, *212*, 249–255. https://doi.org/10.1016/j.biocon.2017.04.009

Rout, T. M., & Walshe, T. (2013). Accounting for Time Preference in Management Decisions: An Application to Invasive Species. *Journal of Multi-Criteria Decision Analysis*, *20*(3–4), 197–211.

Saunders, G. R., Coman, B., Kinnear, J., & Braysher, M. (1995). Managing vertebrate pests: foxes. *Aust. Gov. Publ. Serv. Canberra*, 12.

Saunders, G. R., Gentle, M. N., & Dickman, C. R. (2010). The impacts and management of foxes Vulpes vulpes in Australia. *Mammal Review*, *40*, 181–211. https://doi.org/10.1111/j.1365-2907.2010.00159.x

Simberloff, D. (1995). Why do introduced species appear to devastate islands more than mainland areas? *Pacific Science*, *49*, 87–97.

Simberloff, D. (2009). Invasion of introduced species. In *Encycl. Life Sci., Major Reference Works* (pp. 1–6). Chichester, UK: John Wiley & Sons Ltd.

Simberloff, D., Genovesi, P., Pyšek, P., & Campbell, K. (2011). Recognizing conservation success. *Science*, *332*(6028), 419. https://doi.org/10.1126/science.332.6028.419-a

Spatz, D. R., Zilliacus, K. M., Holmes, N. D., Butchart, S. H. M., Genovesi, P., Ceballos, G., … Croll, D. A. (2017). Globally threatened vertebrates on islands with invasive species. *Science Advances*, *3*, e1603080.

Tershy, B. R., Shen, K.-W., Newton, K. M., Holmes, N. D., & Croll, D. A. (2015). The importance of islands for the protection of biological and linguistic diversity. *BioScience*, *65*, 592–597. https://doi.org/10.1093/biosci/biv031

Threatened Island Biodiversity Database Partners. (2014). The Threatened Island Biodiversity Database: developed by Island Conservation, University of California Santa Cruz Coastal Conservation Action Lab, BirdLife International and IUCN Invasive Species Specialist Group. Version 2014.1 [WWW Document]. Retrieved from http://tib.islandconservation.org/

Toomey, A. H., Knight, A. T., & Barlow, J. (2017). Navigating the space between research and implementation in conservation. *Conservation Letters*, *10*, 619–625. https://doi.org/10.1111/conl.12315

USGS. (2019). Structured Decision Making [WWW Document]. Retrieved from https://www.usgs.gov/centers/pwrc/science/structured-decision-making?qt-science_center_objects=0#qt-science_center_objects

Vane, M., & Runhaar, H. A. C. (2016). Public support for invasive alien species eradication programs: Insights from the Netherlands. *Restoration Ecology*, *24*, 743–748. https://doi.org/10.1111/rec.12379

Williams, B. K. (2011). Adaptive management of natural resources-framework and issues. *Journal of Environmental Management*, *92*, 1346–1353. https://doi.org/10.1016/j.jenvman.2010.10.041

Wilson, H. B., Kendall, B. E., Fuller, R. A., Milton, D. A., & Possingham, H. P. (2011). Analyzing variability and the rate of decline of migratory shorebirds in Moreton Bay, Australia. *Conservation Biology*, *25*, 758–766. https://doi.org/10.1111/j.1523-1739.2011.01670.x

Wise, R. M., & Capon, T. R. (2016). Assessing costs and benefits of adaptation. CoastAdapt Inf. Man. 4, Natl. Clim., 52.

Zavaleta, E. S., Hobbs, R. J., & Mooney, H. A. (2001). Viewing invasive species removal in a whole-ecosystem context. *Trends in Ecology & Evolution*, *16*, 454–459. https://doi.org/10.1016/S0169-5347(01)02194-2

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

How to cite this article: Caceres-Escobar H, Kark S, Atkinson SC, Possingham HP, Davis KJ. Integrating local knowledge to prioritise invasive species management. *People Nat*. 2019;1:220–233. https://doi.org/10.1002/pan3.27