Vol. 54: 29–40, 2024
https://doi.org/10.3354/esr01321

ENDANGERED SPECIES RESEARCH
Endang Species Res

Published May 8

Contribution to the Theme Section 'Managing flatback turtles for the future'

Flatback futures — evaluating conservation interventions to reduce threats to an endemic Australian turtle

Alistair J. Hobday[1,2,*], E. Ingrid van Putten[1,2], Christopher Cvitanovic[3], Michael Dunlop[4], Sabrina Fossette[5], Sierra Ison[1,2], Shane A. Richards[6], Linda Thomas[1], Paris Tuohy[2], Ruby Annand-Jones[1,2], Tony Tucker[5], Scott Whiting[5]

[1]CSIRO Environment, Castray Esplanade, Hobart, Tasmania 7000, Australia
[2]Centre for Marine Socioecology, University of Tasmania, Hobart, Tasmania 7000, Australia
[3]School of Business, University of New South Wales, Canberra, ACT 2600, Australia
[4]CSIRO Environment, Black Mountain, Canberra, ACT 2601, Australia
[5]Biodiversity and Conservation Science, Department of Biodiversity, Conservation and Attractions, 17 Dick Perry Avenue, Kensington, Western Australia 6151, Australia
[6]School of Natural Sciences, University of Tasmania, Hobart, Tasmania 7000, Australia

ABSTRACT: Australia's endemic flatback turtle *Natator depressus* is the focus of a long-term conservation program aimed at securing the persistence of healthy populations in the northwest of Australia into the future. Primary threats to flatback turtles include (1) sea level rise, (2) predation from introduced species, (3) temperature increases, (4) onshore and nearshore light, (5) marine debris, and (6) modification to beaches. Population declines resulting from these threats have been reported or are anticipated, and a range of intervention options are possible that may limit their negative impact. Following methods previously developed and applied to iconic marine species and habitats, we generated a range of intervention options, and asked experts to prioritise those actions using an intervention prioritisation tool (IPT) and the public to prioritise based on social acceptability assessment (SAS). The IPT allows different conservation interventions to be assessed based on their economic cost, implementation feasibility, social acceptability, and perceived effectiveness in maintaining or increasing future turtle populations while simultaneously accounting for expert confidence in their assessment. Results generated by the IPT and SAS can be explored further to resolve uncertainty, a process that can help managers and experts alike in their decision-making process associated with flatback conservation. While this paper is focused on interventions relating to flatback turtles, we propose that our IPT can be applied in different settings to enable consideration of interventions for a range of threatened species and habitats to guide research and conservation investment decisions by managers.

KEY WORDS: Intervention · Climate change · *Natator depressus* · Social acceptability · Economic cost · Decision-support

1. INTRODUCTION

The threats to natural systems because of human activities are increasing in scope and diversity (IPBES 2019). Pollution, climate change, invasive species, coastal development, and habitat loss place species and habitats at risk around the world (e.g. Fuentes et al. 2020, Kearney et al. 2023). Traditional conservation measures, such as protected areas and pest eradication, can reduce some of the risks, but other

*Corresponding author: alistair.hobday@csiro.au

Publisher: Inter-Research · www.int-res.com

approaches may be required. Fortunately, over the last decade, a wide array of conservation options has been developed (e.g. Alderman & Hobday 2017, Bolam et al. 2021, Mason et al. 2021, Handler et al. 2022). This diversity of choice, combined with limited resources, uncertain implementation processes and outcomes, and increasing time pressures, means that prioritising immediate and future conservation interventions is often difficult. Uncertainties regarding the impact and time scales associated with many conservation threats, and insufficient information for many species and habitats that would help ascertain effective conservation interventions, means that decision-making must often proceed despite considerable uncertainty (Bolam et al. 2021). To wait until more information is gathered is not likely to lead to success for many imperiled species (e.g. Martin et al. 2012).

Implementing conservation actions may require considerable public and private financial resources (Narayan et al. 2016). This investment is not only taking place in the context of an uncertain future; other conservation and non-conservation uses also compete for this money (Gjertsen et al. 2014). Moreover, investment in conservation is complicated by the often long time frames for positive impacts to become apparent, and the potential for unexpected ecological responses to the conservation actions and uncertain outcomes. Long-term conservation outcomes and ecological uncertainties are not conducive to standard approaches to investment analyses (Iftekhar et al. 2017). As the costs are often more easily identifiable than the benefits of conservation actions, problems arise with using standard economic evaluation approaches (i.e. benefit-to-cost ratio) and methods such as cost effectiveness analysis (Shwiff et al. 2012).

Assessments of the cost and benefits that guide investment into conservation will also need to take account of the social acceptability of actions (Bennett 2016). After all, investment into actions that are not supported by stakeholders can fail or ultimately cost more than initially budgeted. If a conservation action is controversial, steps might be needed to build increased support, for example, via strategic outreach and engagement programs focused on building stakeholder awareness and knowledge on the issue. Alternatively, more acceptable actions may need to be implemented, even if they are more expensive or less effective (e.g. the use of humane pest control methods). The lead times for building social acceptability can be long and need to be considered, and engagement must be designed to include all stakeholders irrespective of their worldviews and beliefs (Cvitanovic et al. 2018, Tuohy et al. 2022). There are many stakeholders and stakeholder groups that are relevant to conservation, including: the public, indigenous people, managers, and scientists (Ison et al. 2021). The perceptions of what the right investment is for conservation of any species is likely to differ between stakeholders, and finding the best and most socially acceptable management approach can be tricky and contested (van Eeden et al. 2020).

Nevertheless, conservation managers and other decision-makers have a responsibility to make decisions about actions and their timing. To do so, they frequently rely on scientific information about the biological and ecological effectiveness of the action. Experts can provide estimates of implementation costs and risks to aid decision makers, as well as an assessment of social acceptability (cf. social licence[1]). This is not always easy, as it requires experts to prioritise interventions based on various aspects that they may not have complete knowledge on. Moreover, there is a human tendency to focus our attention on solutions that we already know about or that we have experience with (Wason 1968). There are multiple processes leading people to 'stick with' what they have and know; these influence everyone, including scientists. These processes include the transaction costs of assessing multiple available options at every decision point, heuristics for dealing with ever-present uncertainty (Gigerenzer & Todd 1999), ambiguity aversion (Ellsberg paradox), risk aversion, and cognitive bias (e.g. Mynatt et al. 1977). Therefore, experts need to be encouraged to think about and prioritise potential interventions that may not be so obvious, familiar, or well characterised.

Here, we describe an expert intervention prioritisation tool (IPT), following a process developed by Hobday et al. (2015), and modified from subsequent uses (e.g. Thresher et al. 2015, Alderman & Hobday 2017). We used the Australian north-west shelf flatback turtle *Natator depressus* as a case study to illustrate how the IPT can help reveal implementation risk and effectiveness for common and less usual conser-

[1]Social acceptability is considered distinct from social licence. Based on Brunson et al. (1996), social acceptability can be seen as the result of individual judgement where (1) reality (as perceived by the person/respondent) is compared with an alternative (i.e. the current state of turtle conservation with the potential state if interventions are implemented); and (2) a determination is made on which situation is more favourable. Social licence has been defined in many different ways (Raufflet et al. 2013), with the core component referring to 'less tangible elements that make the operations of a company acceptable or legitimate in an area by local communities and stakeholders' (p. 2224).

vation actions, and how it can help generate useful discussion on scoring differences and uncertainties, and potential social acceptability issues. We focused on a subset of actions, hereafter termed interventions, which directly target specific threats. Using the IPT, we assessed the intervention risk in terms of economic cost, implementation feasibility, and social acceptability. We also included measures of perceived effectiveness of the intervention and confidence in the effectiveness. Importantly, a community social acceptability survey (SAS) should be undertaken following evaluation with the IPT, as it allows expert assessment of social acceptability to be verified and contrasted with community perceptions (Tuohy et al. 2024). For potentially controversial management options, there may be low confidence and lack of consensus about risks. With the IPT, these uncertainties and the diversity of perspectives can be considered in decision-making.

2. METHODS

We focus on illustrating the usefulness of an intervention prioritisation tool (IPT) in prioritising management interventions for conservation programs as part of a 10-step process (Fig. 1). The expert-based IPT is developed in parallel with a community-based social acceptability survey (SAS) (see van Putten et al. 2023, Tuohy et al. 2024; both this Special). Both the IPT and SAS (Steps 4 and 5) rest on the same 3 preceding steps in the 10-step intervention prioritisation process (Fig. 1). Below, we illustrate the steps involved, using flatback turtle conservation as a case example, and highlight why consideration of the human dimensions (both expert and community perspectives) is essential to successful conservation program outcomes.

2.1. Problem definition

The first step involved in prioritising conservation management interventions is the problem definition, in which the threats to the conservation species of interest (flatback turtle) are identified (grey bar at the bottom of Fig. 1). This step assumes that scientific information on the species is available. For the north-west shelf flatback turtle, the extant threats to turtle populations have been listed in a variety of management agency documents (see https://flatbacks.dbca.wa.gov.au/publications/north-west-shelf-flatback-turtle-conservation-program-strategic-conservation-plan-2014) that were derived from peer-reviewed papers and expert elicitation. Six primary threats have been identified for flatback turtles: sea level rise, increasing temperature, modification to beaches, introduced animals, onshore and nearshore light, and marine debris.

2.2. Scope interventions

A series of management interventions were developed in Step 2 to address the threats identified in Step 1. These interventions were based on avail-

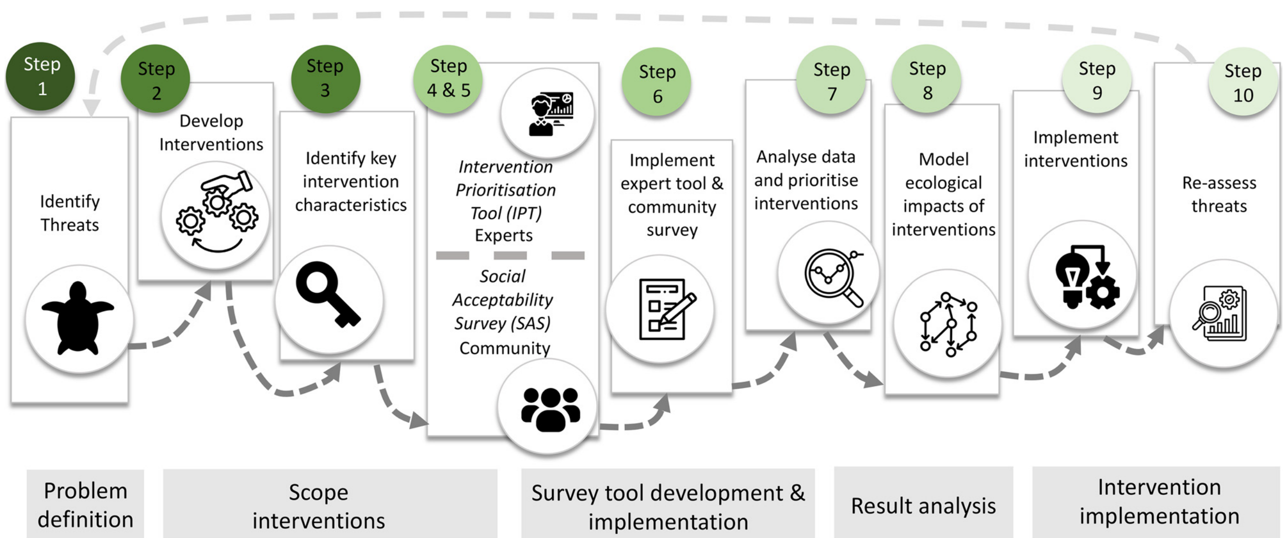


Fig. 1. Conceptual model of the 10 steps involved in prioritising interventions. These steps are part of 5 broader categories, illustrated in grey. Icons from Flaticon.com

able information from published papers (e.g. Heppell et al. 1996, Alderman & Hobday 2017), grey literature, and the experience of the co-authors. In developing the list, we sought to deliberately broaden the scope of possible management interventions, beyond those currently being considered. We included some interventions that had not previously been considered or were currently considered infeasible, unnecessary or undesirable. For inspiration, we drew on management of other marine fauna and our imagination. This was done as much to provoke consideration and deliberation about novel and more-interventionist actions (as might be needed to address climate impacts) as it was to consider those specific interventions.

Each intervention addressed a particular threat. For example, cooling of the nest using shade cloth was one possible management intervention to address the threat posed by temperature increases. In total, 29 potential management interventions covering all life stages were developed by the research team (A. J. Hobday, E. I. van Putten, C. Cvitanovic, M. Dunlop, S. Ison, S. A. Richards, L. Thomas, P. Tuohy, R. Annand-Jones) and reviewed by members of the North West Shelf Flatback Turtle Conservation Program (NWSFTCP; S. Whiting, S. Fossette, T. Tucker) (see Table S1 in the Supplement at www.int-res.com/articles/suppl/n054p029_supp.pdf for the list of interventions). The number of interventions used in the SAS was reduced to 24 because of the perceived ability of the public to distinguish between some similar interventions and to reduce the survey length.

To ensure a common understanding of the interventions, a short description of each was written, including a picture and references from the literature where available (Fig. 2). These were provided when

Boost egg survival - Exclude feral animals from nesting areas

Egg survival is threatened by the predation of several feral animals. In some locations predation by feral animals such as foxes, pigs and dogs can cause significant mortality. The control of pigs and foxes falls under the auspices of the relevant government department whereas the responsibility for dog predation lies largely with local residents. These feral animals (pigs and foxes) can be excluded from nesting sites by fences. Around 50 nests can be protected in this manner. The control of dogs will need a punitive system to be implemented where owners are fined when their dog is found roaming nesting beaches.

Agency responsible for action: NWSFTCP/Local group

On-ground action

Threat category – Introduced animals

Image source: https://www.abc.net.au/news/2017-03-01/feral-pig-proof-fence-could-save-40000-endangered-turtle-eggs/8313600

Fig. 2. Example description for one flatback turtle intervention, noting the spatial impact, the threat category, and the type of implementation agency and action

the IPT and SAS tools were being used by experts or the public. To enable more standardised ratings of the interventions in the IPT and SAS tools, in Step 3, each was characterised according to the expected spatial scale (geographic) impact, the likely implementing agency, and the type of activity that was required to implement the intervention.

The spatial scale of the potential interventions varied considerably, from one turtle nest, to 50 nests, to a whole beach. The entity that might be responsible for implementation included local councils, state and federal government departments, industry, local community groups, and academic researchers. The activities that would be were required to implement the interventions included regulation, education, or on-ground action.

In addition, information on 3 intervention-specific factors — demographic outcomes, vulnerability, and directness of the intervention — was considered when interpreting the IPT and SAS results. The demographic outcomes described what flatback turtle life stages the interventions were expected to impact. For example, excluding introduced animals (e.g. foxes) was expected to boost egg survival (because foxes eat eggs). The demographic aspects were incorporated into the modelling phase (Step 8) and reported in Richards et al. (2024; this Special). The interventions were also assessed for how they might reduce the different components of vulnerability of the flatback turtle population, specifially, exposure, sensitivity, and adaptive capacity (IPCC 2007). The interventions were also characterised by whether they required a change (or restriction) of human behaviour (e.g. not driving on the beach in nesting season) or whether they would be applied directly to the turtles without requirement for people to adjust their behaviour (i.e. shade netting of the turtle nests).

2.3. Survey tool development and implementation

In Step 4 of the intervention prioritisation process, criteria were developed for respondents to rate each intervention with the IPT (Table 1).

Table 1. Attributes of economic cost, implementation feasibility, and social acceptability with the scoring guidelines

Attribute	Low (1)	Medium (2)	High (3)
Economic cost			
Initial cost: What is the cost of implementing the action (training, equipment, salaries, communication)?	<\$100 000	\$100 000– \$1M	>\$1M
Persistence: How long would the action remain effective?	>20 yr	5–20 yr	<5 yr
Maintenance: How often will the intervention require maintenance or repair?	Not for 10 yr	Every few years	Every year
Development: How much time is needed until action can begin (proxy for research/engagement costs; institutional/technical development time lead time)?	<5 yr	5–20 yr	>20 yr
Scale: What is the scale at which the action is expected to benefit turtles?	Population (many colonies)	Colony	Individuals
Implementation feasibility			
What is the likelihood of action failing (negative impact) — wasted money?	<33%	33–66%	>66%
What is the likelihood of negative effect on some other action to assist flatbacks?	<33%	33–66%	>66%
What is the likelihood of adverse impacts to habitats or ecosystem?	<33%	33–66%	>66%
What is the likelihood that other native or iconic species will be negatively impacted by the action?	<33%	33–66%	>66%
Is the action reversible (qualitative)?	Completely reversible	Somewhat reversible	Low reversibility
Social acceptability			
When will we see benefits on the demographic parameter from action (e.g. benefit for future)?	<5 yr	5–20 yr	>20 yr
How likely is it that the action will restrict lifestyle or recreation (closures, cat ownership, dogs on beaches)	<33%	33–66%	>66%
How likely is it that the action will impact on economic activities (closures)?	<33%	33–66%	>66%
What is the level of public trust for the implementing individual/organisation? (specified in scenario)	High level of trust	Medium level of trust	Low level of trust (i.e. many conflicts)
What is the likelihood that local 'groups' will not engage with this proposed action? (likely speed that issues could evolve, implies connections and networks)	<33%	33–66%	>66%

When making a management decision (in this case a conservation intervention), managers generally need to assess the associated economic cost and implementation feasibility. In some cases, they may also consider the social acceptability aspects of the intervention (which we explicitly considered in the IPT).

Economic cost, implementation feasibility, and social acceptability were each associated with 5 distinct attributes, and expert respondents scored these attributes according to 3 levels that were given numeric values (low = 1, medium = 2, and high = 3) (Table 1). Scores were described in words for context. For example, a low initial cost was <$100,000, a medium cost was between $100,000 and $1 million, and a high cost was >$1 million. An overall risk score was calculated based on the average scores for economic cost, social acceptability, and implementation feasibility. In addition to these 15 risk attributes, the IPT seeks a rating of the potential overall effectiveness for each intervention (ability to increase the turtle population) and the level of confidence the expert respondent has in their assessment of overall effectiveness. The social acceptability criteria in Table 1 focus on individual factors that may influence how community members judge the potential interventions. The tool also elicits a rating of the overall social acceptability of each intervention to the expert respondent themselves and their expectation of the overall acceptability of each intervention to community members (see Tuohy et al. 2024). The SAS was developed to elicit ratings about the potential interventions from members of the community (Fig. 1, Step 5). The social acceptability of each of the conservation interventions was rated in both the IPT and the SAS, which allows comparisons of the acceptability of the interventions between experts and community members (see Tuohy et al. 2024).

Step 6 involves implementation of the IPT and the SAS. For the flatback turtle application, the IPT was implemented in an Excel spreadsheet, into which experts (researchers and managers) directly entered their scores for each management intervention (Fig. 1). The SAS was implemented using the online platform Survey Monkey™, which respondents accessed either via tablets provided by a researcher at a booth in a shopping centre or on their own devices via an invitation and link circulated by email and Facebook. Community surveys were conducted in May 2022 in 2 coastal communities (Port Hedland and Broome) in northwestern Australia, where flatback turtle nesting sites are found (van Putten et al. 2023).

2.4. Result analysis, interpretation, and ecological modelling

Several types of analyses can be undertaken based on the IPT and SAS survey data. Examples of the types of results that the SAS can provide for the flatback conservation example are presented in van Putten et al. (2023). Examples of how social acceptability ratings of community members (from SAS) and experts (from IPT) can be compared are presented in Tuohy et al. (2024). Here, we do not detail these results; instead, we provide a general overview of the type of information that can be obtained in Step 7. We also make a link to the modelling component (Step 8) that will help predict ecological outcomes (Richards et al. 2024).

3. RESULTS

3.1. Intervention scoring

To test and illustrate the use of the IPT, the 29 potential interventions (Table S1) were rated by 11 experts; these included 8 members of the research team (some of whom had little expertise in sea turtle conservation, but considerable expertise in adaptation science) and 3 members of the NWSFTCP. There were clear patterns in the overall implementation risk for each intervention, which was calculated based on the scoring of the 15 attributes of risks associated with economic cost, implementation feasibility, and social acceptability (Table 1). Statistical testing was not used in this project but could be included if required for decision-making. The overall implementation risk score can be grouped by the 6 threat categories (defined in Step 1), the demographic outcome, and the vulnerability aspect (see Step 3) that the interventions are most likely to affect (Fig. 3). In each of these, the risk score is the Euclidean distance from the origin based on the economic cost score (average of 5 attributes) and social acceptability (average of 5 attributes), following the approach used in Alderman & Hobday (2017), where risk = (average cost^2 + average acceptability^2)$^{0.5}$. These scores can range between 1.41 (all risks rated low = 1) and 4.24 (all risks rated high = 3) (Hobday et al. 2011).

In our case study, the overall average risk score was highest for those that involve beach modification (Fig. 3A), meaning experts tended to rate these interventions as having higher risks, which could lie in high economic costs, low implementation feasibility, or absence of (low) social acceptability. In contrast,

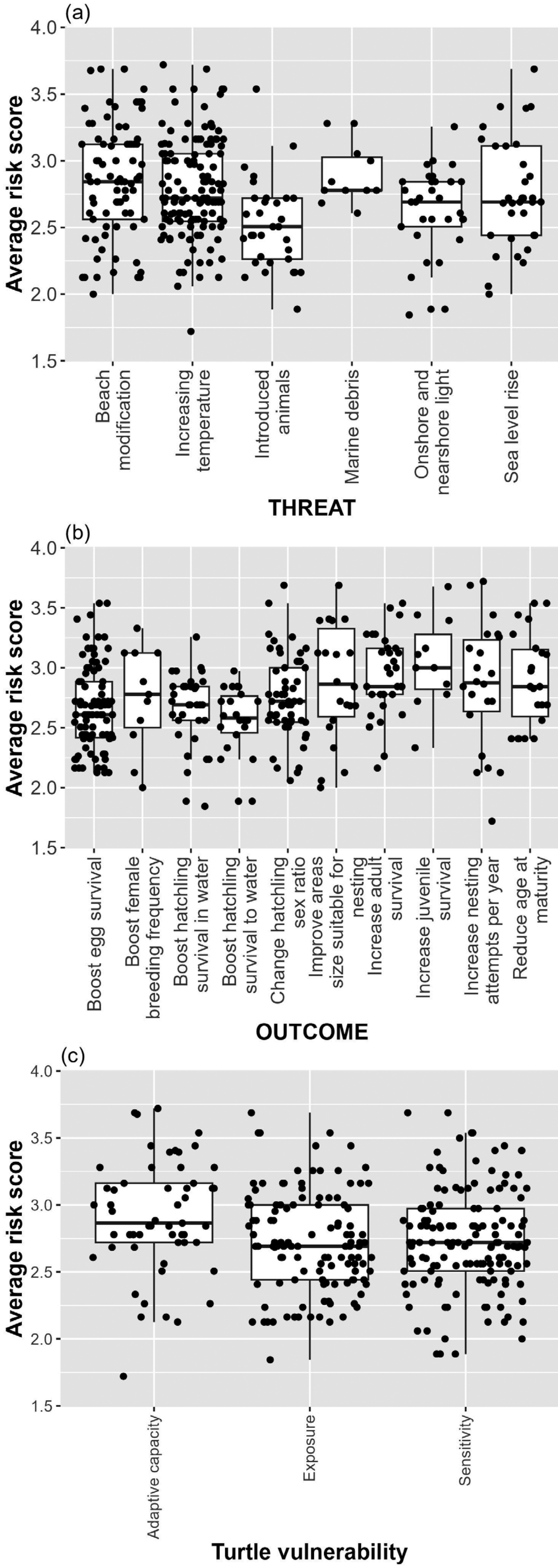


Fig. 3. Overall risk scores for conservation interventions grouped by (a) threat category, (b) demographic ecological outcome, and (c) vulnerability aspects for flatback turtles in Western Australia. Each dot represents one score from 11 experts rating each of 29 interventions. Dots are spaced horizontally in each group to avoid overlaying each other. Box and whiskers graphs show the means and upper and lower quartiles, and the feasible range is scores of 1.41–4.24

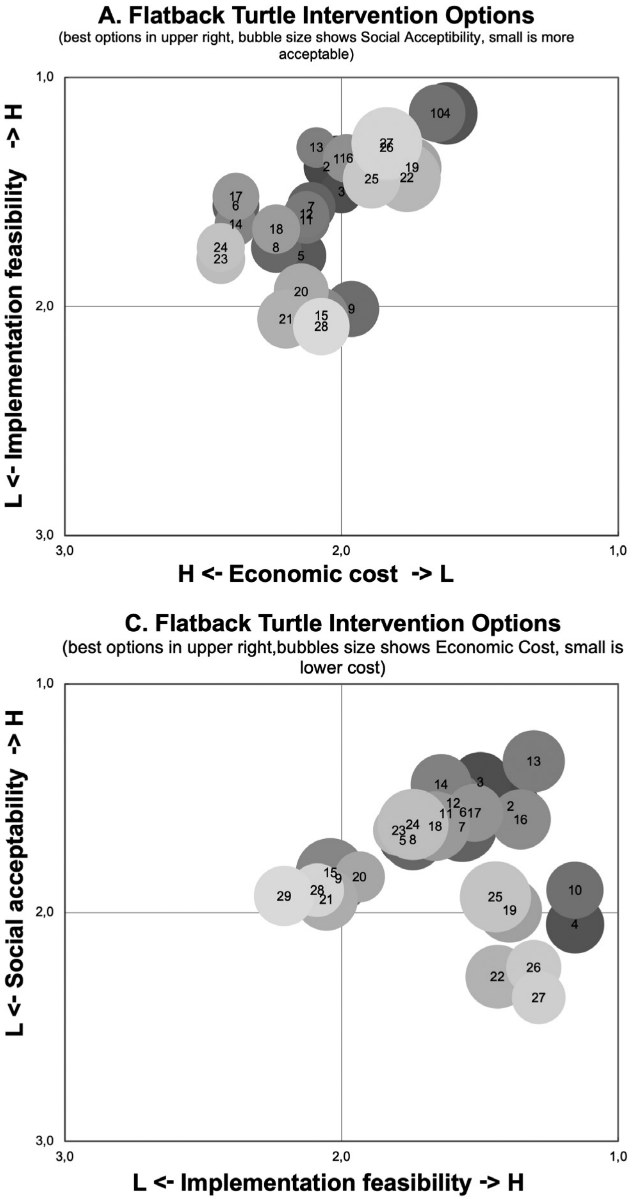
interventions that address introduced animals (e.g. shooting or exclusion fencing) were rated as having a lower risk and may therefore have higher implementation feasibility, lower cost, and higher social acceptability. In prioritising interventions, this level of analysis can be used to focus attention on threat categories where interventions might be most feasible.

Interventions that boosted hatchling survival before they entered the water had the highest overall implementation feasibility. Interventions that increased juvenile survival (once at sea) had the highest overall implementation risk, due to perceived technical difficulty and higher cost (Fig. 3B). These results show how this type of analysis can be used to prioritise single interventions. The interventions that address the adaptive capacity of turtles were rated as having higher implementation risks that those addressing exposure or sensitivity (Fig. 3C). For all 3 of these data summations, there was spread in the risk rating by the experts, which is explored further below.

3.2. Relationship between economic cost, implementation feasibility, and social acceptability

To gain an overview of which flatback turtle interventions are lowest risk (i.e. have low cost, high social acceptability, and high implementation feasibility), the average score for each intervention as scored by the experts (Table S2) can be mapped (Fig. 4 shows the 3 pairwise comparisons, with the third dimension as the symbol size). In general, interventions showed a range of social acceptability, implementation feasibility, and economic cost, and there was often a trade-off between these elements.

Most potential interventions were rated relatively high on implementation feasibility, and there was a generally lower cost for those that were most feasible (Fig. 4A). There was a slight negative relationship with high cost related to high social acceptability (Fig. 4B), while those options that had high implementation feasibility spanned a range of social



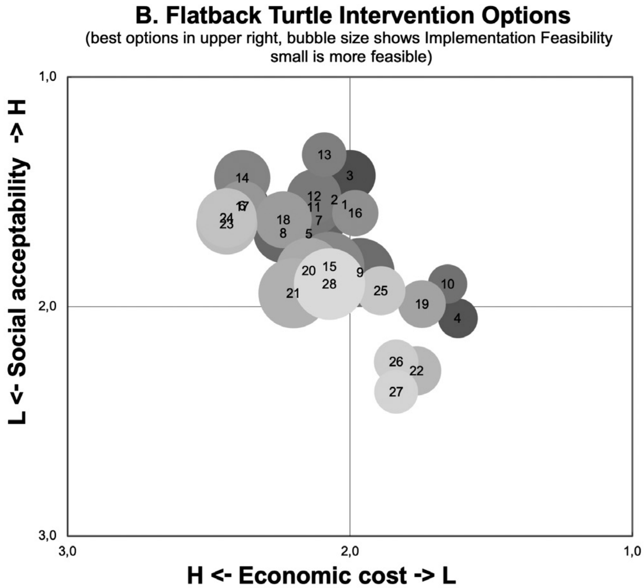


Fig. 4. The average scores for implementation feasibility, economic cost, and social acceptability of interventions for flatback turtles in Western Australia, as rated by 11 respondents using the intervention prioritisation tool. Best options are in the upper right quadrant of each plot. The size of each circle indicates the average score for the third element in each pairwise plot. Numbers correspond with interventions listed in Table S1 in the Supplement, and shading distinguishes different interventions. L: low, H: high. (A) Economic costs and implementation feasibility. Circle size shows social acceptability; small size indicates higher acceptability. (B) Social acceptability and economic cost. Circle size shows implementation feasibility; small size indicates higher feasibility. (C) Social acceptability and implementation feasibility. Circle size shows economic cost; small size indicates lower cost

acceptability (Fig. 4C). For example, the highest priority (upper right) based on the combination of implementation feasibility and social acceptability was nest guarding (#13), while the option to modify sand composition (#21, lower left) had low feasibility and low social acceptability.

The average economic cost, implementation feasibility, and social acceptability ratings provide a useful overview, but it is important in decision-making to consider how much experts agree on the rating of interventions. A high level of variability in the expert scoring can identify interventions that need additional discussion or investigation, for example to determine whether the differences are due to information asymmetries or true uncertainty. This can be revealed with consideration of the raw results of scoring (data not shown). In addition, if experts agree that implementation feasibility is high (for example) but the social acceptability is low, further discussion or investigation about the relevant interventions may be needed to develop a plan.

3.3. Intervention effectiveness and confidence

While scoring the 3 elements described in the previous section provided a transparent method to prioritise interventions, the confidence and overall effectiveness for the turtle population in each intervention (and not just the feasibility) also needs to be considered. The perceived effectiveness of the intervention, as well as the confidence in the respondents' own assessment of effectiveness, was elicited with the IPT. Respondents tended to be more confident in their ratings of potential interventions that they rated as likely to be more effective (Fig. 5). The interventions were classified according to the type of action required to implement or enable the intervention, predominantly policy/legislation change, on-ground action, and education (colours in Fig. 5). The interventions with highest perceived effectiveness and highest confidence in that rating typically required policy or legislation changes in order to be implemented (Fig. 5, top right).

Confidence in the effectiveness scoring was relatively high for interventions aimed at reducing the threat posed by introduced animals, which were also perceived to be the most effective interventions, and are actions currently being undertaken (Fig. 5). The potential intervention with the lowest perceived effectiveness, and lowest confidence in the effectiveness rating, was the genetic intervention. The overall scores were higher for the interventions that were implemented using policy and legislation (Fig. 5, blue dots towards upper right).

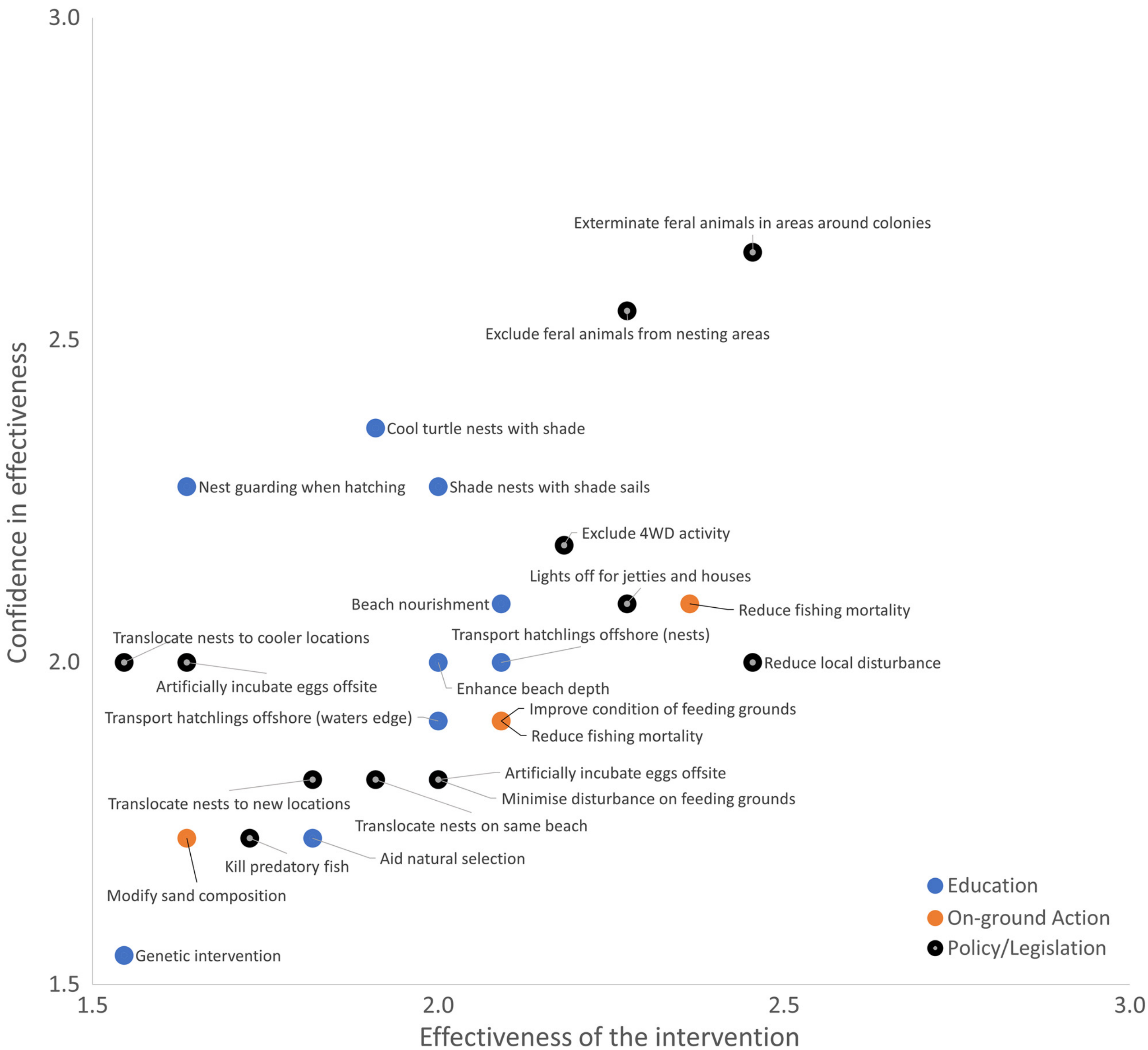


Fig. 5. The perceived effectiveness and confidence in the effectiveness rating of potential flatback turtle conservation interventions to address different threats in Western Australia. Colours indicate the nature of actions required to enable or implement the intervention, as described in Table S1 in the Supplement. Most interventions require more than one type of action, and here we indicate the first-step action to allow for general categorisation

4. DISCUSSION

It is widely agreed that long-term conservation of flora and fauna in the face of increasing threats may require management actions that are more interventionist than current actions (such as protecting habitat) (e.g. Martin et al. 2012, Bennett et al. 2023). Active intervention to conserve species is not straightforward as it often has high cost and low implementation feasibility, support and social acceptance by local communities or interest groups may be absent, and effectiveness may be unknown or lacking consensus (Abrahamse & Steg 2013). For example, interventions such as closing a beach to 4-wheel driving or dog walking have raised community protests in several locations (Zander et al. 2022). There may be significant differences of opinion about the acceptability and anticipated effectiveness of different proposed options among community members and among experts, and potentially between the community and experts. For example, experts may disagree about which interventions will achieve better ecological outcomes; they may also disagree on what outcomes should be sought (e.g. single species versus whole ecosystem outcomes). Nevertheless, conservation managers need to make decisions now and plan for future interventions to achieve the desired conservation objectives, and to make these decisions they rely on scientists, experts, and local communities. Managers can be assisted in their decision-making by an understanding of the economic costs, the implementation feasibility, and social acceptability of different interventions.

Here, we present the IPT, which was developed for and in consultation with conservation managers, to help compare a wide range of potential interventions, including novel options, that may assist with the long-term persistence of flatback turtle populations in northwestern Australia. The IPT helps elicit different aspects associated with potential interventions, and the results can be used to help prioritise conservation interventions or direct further deliberation or research about potential interventions. The data generated by the IPT can reveal the relationship between economic costs, implementation feasibility, and social acceptability for different interventions. Making transparent the trade-offs between the 3 aspects provides a useful rationale for choosing and implementing interventions (Hobday et al. 2015).

This approach may also limit a potential bias associated with familiarity with different interventions. For example, interventions that have been discussed for a long time may at first be favoured over new options. Here, the relatively new potential interventions to temperature increases are considered to have lower implementation feasibility than long-standing interventions that address other threats, such as managing introduced animals. In cases where additional information is needed, the high priority options (e.g. feasible, cheap, and socially acceptable) can be the focus of new experiments or studies. Interventions that may be novel in one area may have been tested elsewhere, which can further inform implementation for the focal organism. For example, nest shading (Clarke et al. 2021) and nest cooling (Smith et al. 2021) have been tested on other species, which can lend insight to a flatback turtle manager.

The effectiveness of conservation interventions can be expressed as the long-term persistence of healthy populations of the threatened species (Bottrill & Pressey 2012, Handler et al. 2022). The IPT was used to elicit ratings of the effectiveness of potential interventions to sustain turtle populations, along with ratings of the respondent's confidence in their ratings of effectiveness. In the present study, high effectiveness and certainty ratings were associated with interventions that protected the turtles from introduced animals and that reduced disturbance and destruction of nests. These types of interventions may require changes in policies and/or legislation to enable on-ground management action. These same interventions were also rated as relatively low-cost, with high implementation feasibility, but some had lower social acceptability. If these interventions are chosen for implementation, these results suggest that conservation managers may need to ensure that social acceptability issues are addressed prior to or alongside implementation, otherwise these beneficial interventions could be judged as a failure by the community or may need to be abandoned (Bennett 2016, Zander et al. 2022). Implementation of an SAS in relevant communities to assess the acceptability is recommended (see Tuohy et al. 2024).

Here, only 11 'experts', scientists, and managers involved in this study, were involved with using the IPT to test it and illustrate its utility. It is not unusual for expert-based studies to have a relatively low number of participants (Wilcox et al. 2018, Bennett et al. 2023). This is in part because there are often relatively few experts who have the appropriate expertise on a topic and/or who are willing to participate given the time needed to complete the process. Even amongst small groups of experts, there may be different perceptions of the costs and benefits of the interventions. These differences can be very informative if they are explored further with the expert group. For instance, subsequent discussion may be used to reveal elements that were not universally considered, and to gain a holistic understanding of costs and benefits for interventions. This can happen while retaining expert anonymity or in face-to-face forums such as workshops or focus groups.

There are many benefits of using our 10-step intervention prioritisation process and using the IPT with experts. We suggest the approach can be applied to a wide range of species, it is intuitive and easy to apply (compared to empirical testing), and the results are multi-dimensional. The cost and risk attributes and the semi-quantitative scoring rubric used here for flatback turtles can be tailored to other species and situations. For example, here, (i) initial set-up costs and (ii) infrastructure persistence were included amongst the 5 economic cost attributes, but other attributes might be relevant elsewhere. The rating scales can be similarly adjusted (i.e. we chose 3 levels [low, medium, and high], but a 1 to 10 Likert scale might be preferred where more information is available). Another advantage of semi-quantitative scoring systems is that they are relatively rapid (taking only a few hours to complete), which is an advantage when seeking expert input. The number of intervention options that can be rated is potentially unlimited; however, survey fatigue and time considerations are common to surveys (see van Putten et al. 2023, Tuohy et al. 2024), and restricting each participant to less than 30 options was deemed important for this flatback turtle example. With more options, random sets of options could be presented to each expert, potentially using balanced incomplete block designs (e.g. Fisher & Yates 1963).

The IPT makes an important link between the ecological and human dimensions of conservation and adds value to ecological models that predict outcomes in response to interventions (Heppell et al. 1999, Gerber & Heppell 2004). By explicitly considering the spatial and demographic impact of interventions on model parameters (e.g. in our example on flatback turtles: egg, juvenile, or mature turtle survival), impacts of interventions on long-term conservation success can be numerically investigated (e.g. Gammon et al. 2020). Using the framework presented here to identify interventions that have low risks associated with cost, feasibility, and social acceptability helps managers identify which options should be the focus of numerical ecological projections, field trials, or other empirical investigation. The combination of screening and prioritisation tools such as the IPT with ecological modelling can be used to build stakeholder awareness of the options and improve the allocation of resources to support interventions to improve species persistence and reduce threats. The IPT presented here provides a straightforward way for managers and stakeholders to rapidly consider a wide range of management interventions, including novel ones, to broaden the scope of management options for addressing accelerating and emerging conservation threats.

Acknowledgements. This research is co-funded by the North West Shelf Flatback Turtle Conservation Program (NWS FTCP) and CSIRO Environment. We appreciate the comments from the editor and three anonymous reviewers that improved the clarity of our paper.

LITERATURE CITED

Abrahamse W, Steg L (2013) Social influence approaches to encourage resource conservation: a meta-analysis. Glob Environ Change 23:1773−1785

Alderman R, Hobday AJ (2017) Developing a climate adaptation strategy for vulnerable seabirds based on prioritisation of intervention options. Deep Sea Res II 140: 290−297

Bennett NJ (2016) Using perceptions as evidence to improve conservation and environmental management. Conserv Biol 30:582−592

Bennett AF, Haslem A, White M, Hollings T, Thomson JR (2023) How expert are 'experts'? Comparing expert predictions and empirical data on the use of farmland restoration sites by birds. Biol Cons 282:110018

Bolam FC, Mair L, Angelico M, Brooks TM and others (2021) How many bird and mammal extinctions has recent conservation action prevented? Conserv Lett 14:e12762

Bottrill MC, Pressey RL (2012) The effectiveness and evaluation of conservation planning. Conserv Lett 5:407−420

Brunson MW, Kruger LE, Tyler CB, Schroeder SA (eds) (1996) Defining social acceptability in ecosystem management: a workshop proceedings. 23−25 June 1992, Kelso, WA, USA. Gen Tech Rep PNW-GTR369. US Department of Agriculture, Forest Service, Pacific Northwest Research Station Portland, OR

Clarke LJ, Elliot RL, Abella-Perez E, Jenkins SR, Marco A, Martins S, Hawkes LA (2021) Low-cost tools mitigate climate change during reproduction in an endangered marine ectotherm. J App Ecol 58:1466−0476

Cvitanovic C, van Putten EI, Hobday AJ, Mackay M and others (2018) Building trust among marine protected area managers and community members through scientific research: insights from the Ningaloo Marine Park, Australia. Mar Policy 93:195−206

Fisher RA, Yates F (1963) Statistical tables for biological, agricultural and medical research. Longman, Harlow

Fuentes MMPB, Allstadt AJ, Ceriani SA, Godfrey MH and others (2020) Potential adaptability of marine turtles to climate change may be hindered by coastal development in the USA. Reg Environ Change 20:140

Gammon M, Fossette S, McGrath G, Mitchell N (2020) A systematic review of metabolic heat in sea turtle nests and methods to model its impact on hatching success. Front Ecol Evol 8:556379

Gerber LR, Heppell SS (2004) The use of demographic sensitivity analysis in marine species conservation planning. Biol Conserv 120:121−128

Gigerenzer G, Todd PM (1999) Fast and frugal heuristics: the adaptive toolbox. In: Gigerenzer G, Todd PM, ABC Research Groups (eds) Simple heuristics that make us smart. Oxford University Press, Oxford, p 3–34

Gjertsen H, Squires D, Dutton PH, Eguchi T (2014) Cost-effectiveness of alternative conservation strategies with application to the Pacific leatherback turtle. Conserv Biol 28:140–149

Handler SD, Ledee OE, Hoving CL, Zuckerberg B, Swanston CW (2022) A menu of climate change adaptation actions for terrestrial wildlife management. Wildl Soc Bull 46: e1331

Heppell SS, Crowder LB, Crouse DT (1996) Models to evaluate headstarting as a management tool for long-lived turtles. Ecol Appl 6:556–565

Heppell SS, Crowder LB, Menzel TR (1999) Life table analysis of long-lived marine species with implications for conservation and management. Am Fish Soc Symp 23: 137–148

Hobday AJ, Smith ADM, Stobutzki I, Bulman C and others (2011) Ecological risk assessment for the effects of fishing. Fish Res 108:372–384

Hobday AJ, Chambers LE, Arnould JPY (2015) Prioritizing climate change adaptation options for iconic marine species. Biodivers Conserv 24:3449–3468

Iftekhar MS, Polyakov M, Ansell D, Gibson F, Kay GM (2017) How economics can further the success of ecological restoration. Conserv Biol 31:261–268

IPBES (2019) Global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. Brondizio ES, Settele J, Díaz S, Ngo HT (eds). IPBES secretariat, Bonn

IPCC (2007) Climate change 2007: impacts, adaptation and vulnerability. In: Parry ML, Canziani OF, Palutikof JP, van der Linden PF, Hanson CE (eds) Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate. Cambridge University Press, Cambridge

Ison S, Pecl GT, Hobday AJ, Cvitanovic C, van Putten I (2021) Stakeholder influence and relationships inform engagement strategies in marine conservation. Ecosyst People 17:320–341

Kearney SG, Watson JEM, Reside AE, Fisher DO and others (2023) Threat-abatement framework confirms habitat retention and invasive species management are critical to conserve Australia's threatened species. Biol Cons 277: 109833

Martin TG, Nally S, Burbridge AA, Arnall S and others (2012) Acting fast helps avoid extinction. Conserv Lett 5: 274–280

Mason C, Hobday AJ, Alderman R, Lea MA (2021) Climate adaptation interventions for iconic fauna. Conserv Sci Pract 3:e434

Mynatt CR, Doherty ME, Tweney RD (1977) Confirmation bias in a simulated research environment: an experimental study of scientific inference. Q J Exp Psychol 29: 85–95

Narayan S, Beck MW, Reguero BG, Losada IJ and others (2016) The effectiveness, costs and coastal protection benefits of natural and nature-based defences. PLOS ONE 11:e0154735

Raufflet E, Baba S, Perras C, Delannon N (2013) Social license. In: Idowu SO, Capaldi N, Zu, L, Gupta AD (eds) Encyclopedia of corporate social responsibility. Springer, Berlin, p 2223–2230

Richards SA, Hobday AJ, Cvitanovic C, Dunlop M and others (2024) Identifying impactful sea turtle conservation strategies: a mismatch between most influential and most readily manageable life-stages. Endang Species Res 54:15–27

Shwiff SA, Anderson A, Cullen R, White PCL, Shwiff SS (2012) Assignment of measurable costs and benefits to wildlife conservation projects. Wildl Res 40:134–141

Smith CE, Booth DT, Crosby A, Miller JD, Staines MN, Versace H, Madden-Hof CA (2021) Trialling seawater irrigation to combat the high nest temperature feminisation of green turtle *Chelonia mydas* hatchlings. Mar Ecol Prog Ser 667:177–190

Thresher RE, Guinotte JM, Matear RJ, Hobday AJ (2015) Options for managing impacts of climate change on a deep-sea community. Nat Clim Chang 5:635–639

Tuohy P, Cvitanovic C, Shellock RJ (2022) Understanding visitor awareness and knowledge of marine parks: insights from the Ningaloo Coast, Australia. Ocean Coast Manage 227:106282

Tuohy P, Richards S, Cvitanovic C, van Putten EI, Hobday AJ, Thomas L, Annand-Jones R (2024) Social acceptability of climate-management interventions for flatback turtles: comparing expert and public perceptions. Endang Species Res 53:1–12

van Eeden LM, Newsome TM, Crowther MS, Dickman CR, Bruskotter J (2020) Diverse public perceptions of species' status and management align with conflicting conservation frameworks. Biol Conserv 242:108416

van Putten EI, Cvitanovic C, Tuohy P, Annand-Jones R and others (2023) A focus on flatback turtles: the social acceptability of conservation interventions in two Australian case studies. Endang Species Res 52:189–201

Wason PC (1968) Reasoning about a rule. Q J Exp Psychol 20:273–281

Wilcox C, Hobday AJ, Chambers LE (2018) Expert elicitation of anticipated climate impacts on iconic Australian marine species. Ecol Indic 95:637–644

Zander KK, Burton M, Pandit R, Gunawardena A, Pannell D, Garnett ST (2022) How public values for threatened species are affected by conservation strategies. J Environ Manage 319:115659

Editorial responsibility: Mark Hamann, Townsville, Queensland, Australia
Reviewed by: A. R. Patricio and 2 anonymous referees

Submitted: September 25, 2023
Accepted: February 13, 2024
Proofs received from author(s): April 25, 2024