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To translocate or not to translocate? Embedding population modelling in an inclusive structured decision-making process to overcome a conservation impasse

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Abstract

The need for effective conservation strategies to combat the ongoing biodiversity crisis is well recognised. Conservation translocations are an important and frequently used form of conservation management for species recovery. Despite this, the uncertainty prevalent throughout the translocation cycle often makes it challenging to determine whether translocations should be included in the suite of actions to achieve desired conservation outcomes. Further, the fundamental question of whether translocations should occur is seldom assessed as a formal decision. We applied a formal decision analysis for the conservation management of a highly threatened bird (karure | kakaruia | Chatham Island black robin | *Petroica traversi*) to evaluate whether translocation and/or other actions should be implemented for species recovery. The species' precarious status (<330 adults), combined with uncertainty about translocation outcomes, meant that for years, decision-makers were reluctant to act given the potentially severe consequences of translocation failure. We used structured decision-making in conjunction with population modelling to estimate the consequences of translocations and other actions across a range of objectives identified by Moriori and Ngāti Mutunga o Wharekauri (Indigenous Peoples of Rēkohu | Wharekauri | the Chatham Islands), the local community and government agencies. Structured decision-making facilitated an inclusive approach that ensured all participants were actively engaged in the decision-making process including the identification of the best management alternative while balancing multiple objectives. This process overcame the long-standing conservation impasse, resulting in rapid implementation of actions, including translocation, that would have otherwise been difficult to achieve. The preferred alternative across objectives involved multiple translocations, illustrating the vital role translocations have in the desired future management for the species. The methods used in our study can be readily applied in other species recovery programmes to help decision-makers navigate the complexities and uncertainties inherent in conservation decisions.

Introduction

In the face of the current biodiversity crisis, effective strategies for the conservation of threatened species are crucial (Taylor *et al.*, 2017). Conservation strategies typically involve a set of actions designed to achieve desired outcomes of invested parties (Martin *et al.*, 2023). However, deciding on the best strategy to implement is challenging for a range of reasons, including the need to make trade-offs between multiple, often conflicting, values or objectives (Converse *et al.*, 2013; Regan *et al.*, 2023), diversity of interested parties (e.g. Indigenous Peoples, western scientists, government departments, industry or local communities) (McMurdo Hamilton *et al.*, 2021), complex alternatives (Fischer *et al.*, 2023), limited resources (Ng *et al*., 2014), and ubiquitous uncertainty (Gee *et al*., 2023; Gerber *et al*., 2023).

Conservation decision-making becomes even more difficult when there are potentially catastrophic and irreversible consequences, such as species extinction (VanderWerf *et al*., 2006). Uncertain outcomes can be paralysing in these circumstances, particularly when decision-makers need to balance the potential for successful intervention with the risk that intervention could make the situation worse (Canessa *et al*., 2020). Given the repercussions of making the wrong decision, decision-makers tend to be risk-averse when dealing with highly threatened species and uncertain conservation outcomes (Tulloch *et al*., 2015). Consequently, they may choose to maintain the status quo even though this is not perceived as the best strategy, as the risk is considered too great to act under uncertainty (Canessa *et al*., 2020).

One of the most important causes of uncertainty is paucity of information (Freckleton, 2020). Accordingly, gaining information can reduce uncertainty and help in choosing management actions (Taylor *et al*., 2017). Further research can address uncertainty, but often a species' threat status means that immediate management action is required. In addition, more research sometimes serves to delay making crucial decisions. Alternatively, knowledge gaps can be filled using advanced analyses to extract as much information as possible out of the existing data (Freckleton, 2020). When empirical data is absent or lacking expert elicitation is increasingly being used to inform conservation decision making, including for responses of populations to management (Hemming *et al*., 2018; Leseberg *et al*., 2023). Modelling empirical and/or expert elicited data is a powerful tool for predicting the consequences of current and future management to inform decision-making (Fischer *et al*., 2023).

Modelling approaches that combine empirical and expert elicited data are increasingly being used to inform conservation translocations (e.g. Converse *et al*., 2017; Fischer *et al*., 2022). Conservation translocations (hereafter translocations) are an important and frequently used management intervention involving both risk and uncertainty, thus representing a decision problem as to whether they should be implemented (Pérez *et al*., 2012; Ewen *et al*., 2022). However, this fundamental question of whether a translocation should occur is rarely assessed as a formal decision (Keating *et al*., 2023). Translocation programmes have the potential to successfully recover imperilled species but they have a mixed record of successes and failures (Griffith *et al*., 1989; Bubac *et al*., 2019). Uncertainty is prevalent throughout many aspects of a translocation, including the level of threat at the release site relative to threats faced in other parts of the species' range, the survival and reproduction of translocated individuals, and the impacts of removing individuals from the source population (McCarthy, Armstrong, & Runge, 2012). Despite the promise of translocations for species recovery, the potential for negative consequences means it is often unclear whether translocation should form part of the suite of actions to achieve desired management outcomes (Pérez *et al*., 2012; Moehrenschlager *et al*., 2013).

This quandary was faced by decision-makers for the recovery of karure | kakaruia | Chatham Island black robin (*Petroica traversi*) (hereafter black robin; see Box 1). The black robin is a high-profile threatened species endemic to Aotearoa New Zealand that was saved from the brink of extinction in the late 1900s (Butler & Merton, 1992). There are now two extant populations, one small (~300) and stable and the other very small (~30) and declining. Despite general agreement that action was needed given the precarious and declining state of one population, decision-makers were reluctant to intervene because they were plagued with uncertainty around the consequences of different actions, including translocation. For example, there was particular concern about the translocation impact of removing individuals from one stable population to reduce the imminent extinction risk of the second population. In addition to urgency in the face of uncertainty, decision-makers were confronted with other challenges, including differing values and risk tolerance of passionate invested parties, scarce resources, and undefined potential actions to aid species recovery.

Box 1. Primacy of place and species names in this paper.

Primacy of naming of places and species on Rēkohu|Wharekauri|the Chatham Islands can be legitimately claimed by both Moriori and Ngāti Mutunga o Wharekauri. No satisfactory solution exists as to which language, ta rē Moriori, or te reo Māori, has primacy. Here, for consistency, ta re Moriori, te reo Māori and English names are presented on first mention, after which English names are used, based on the understanding that the order in which names are presented in no way reflects the priority given to each.

Here, we show how it was possible to navigate these commonly encountered complexities using an inclusive structured decision-making (SDM) process to frame the management problem (Hemming *et al*., 2022), in conjunction with population modelling to estimate the consequences of translocation and other actions using both empirical data and expert elicitation. SDM facilitates decision-making by breaking down complex problems transparently into their component parts, and has been successfully used in a wide range of conservation programmes (Ewen *et al*., 2022). This framework enabled decision-makers to identify the best management alternative while balancing multiple objectives, ultimately overcoming the conservation impasse and resulting in expedient implementation of actions that would have otherwise been difficult to achieve. We recommend using this combination of analytical and decision-support methods within an inclusive process to help navigate through the complexities that embody conservation decision-making and overcome decision paralysis.

Materials and methods

Study species

The black robin is a small (25 g), insectivorous, forest-dwelling passerine that once inhabited all five forested islands in the Rēkohu|Wharekauri|Chatham Islands (Tennyson & Millener, 1994). Black robins disappeared from four of the islands following human arrival, only persisting on 9 ha Tapuaenuku|Little Mangere Island (Butler & Merton, 1992). However, this one remaining population continued to decline and in 1976/77, the last seven birds were caught and translocated to Maung'Re|Mangere Island (113 ha, hereafter Mangere). By 1980 there were only five individuals remaining, including one effective breeding pair. The recovery of the species from the brink of extinction involved intensive management, including cross fostering and further translocation to Hokorereoro|Rangatira|South East Island (218 ha, hereafter South East). This recovery has been a tremendous conservation success and intensive management was halted in 1990. However, while the population on South East is stable at ~300 adult birds, the smaller Mangere population has been declining and currently numbers ~30 adult birds. The species therefore remains at risk of extinction, and the perilous state of the Mangere population highlighted the need for ongoing dedicated black robin management. Due to the remoteness of South East and Mangere, black robins are also essentially inaccessible to Moriori and Ngāti Mutunga o Wharekauri (Indigenous Peoples of the Chatham Islands), and the local Chatham Islands community, who are deeply connected to the species. This further highlights the need for ongoing, and expanded, management to re-establish lost connections.

Structured decision-making process

To identify a way forward for black robin recovery, we first formed a working group consisting of representatives (n = 15–20 depending on the day) from the Hokotehi Moriori Trust, Ngāti Mutunga o Wharekauri Trust, and the wider Chatham Island community (including main Chatham Island and Rangihaute|Rangiauria|Pitt Island, hereafter Pitt Island), the New Zealand Government (Department of Conservation Te Papa Atawhai; DOC), and local conservation organisations, such as the Chatham Island Land Restoration Group, the Chatham Island Taiko Trust, and Toroa Consulting Ltd., all of whom were invited to attend a SDM workshop on main Chatham Island. All parties participated in the workshop that was held 11–16 August 2021, except for Ngāti Mutunga o Wharekauri Trust for whom elements of the organisation of the workshop fell short of their expectations. However, Ngāti Mutunga o Wharekauri Trust provided input to the decision-making process after the workshop and they remain broadly supportive of the workshop outcomes. The workshop was held with an 'open door policy', so people beyond those invited initially were free to attend. The workshop, as well as engagement prior to and post-workshop, was structured around the seven stages of the formal structured decision-making process (Gregory *et al*., 2012; Fig. 1). The schedule for the workshop is provided in Appendix S1. This schedule provided an approximate timetable as SDM is a dynamic process and we were guided by the participants as to the time required for each stage. A report describing the SDM process and outcomes was produced following the workshop (Parker, Parlato, & Fischer, 2023).

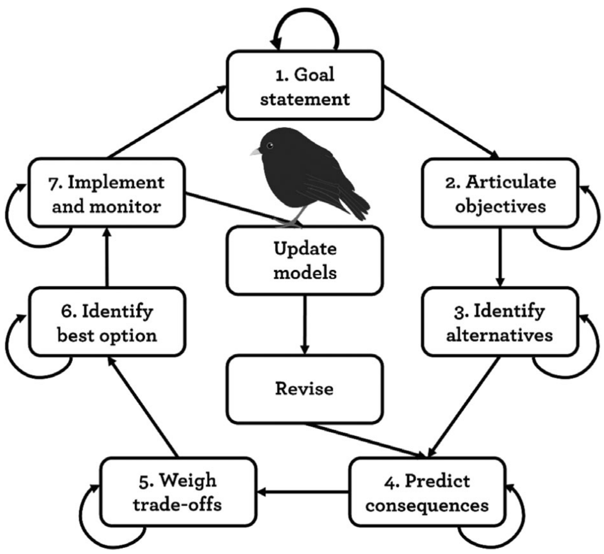

Figure 1 The structured decision-making cycle (adapted from Gregory *et al*., 2012).

Goal statement and objectives

We initially drafted the conservation goal statement based on responses gathered through an online questionnaire that was sent to all participants prior to the in-person workshop. The working group refined the goal statement during the workshop and the final goal statement was used as a benchmark and overarching decision frame to guide the decision-making process (see Appendix S1 for a link to the online questionnaire and Appendix S2 for the full goal statement).

The working group then identified seven fundamental objectives and associated performance measures (Table 1). First, each participant individually listed their aspirations and concerns for black robin recovery. Participants then formed sub-groups to refine and structure their deliberations and identify fundamentally important objectives (Gregory *et al*., 2012). Each sub-group then reported back to the entire working group and similar objectives were combined to form a final set of agreed fundamental objectives. The working group then jointly identified appropriate performance measures for each objective (Table 1).

Identifying alternatives

The working group articulated current management as 'Status Quo' and then formulated 11 additional potential management alternatives (Table 2). These alternatives had various combinations of conservation measures, including biosecurity, monitoring, nest box provision, habitat restoration, translocation, and post-release management (supplementary feeding). All alternatives included population monitoring, habitat restoration, and raising the appreciation of black robins, as these were part of the Status Quo, but the intensity of these actions varied among alternatives (Table 2). Biosecurity was consistently implemented across all

Table 1 Fundamental objectives and their associated performance measures for black robin recovery planning

Fundamental objective	Performance measures
Maximise the resilience of black robins	Total number of adult females in 2040 Number of adult females on Mangere in 2040 Number of adult females on South East in 2040 Total number of black robins in 2040
Minimise costs	Cost in NZ dollars over the first 5 years of implementation, that is 2021–2026
Maximise ecosystem gains	The number of populations of other species, or species groups, that benefit from black robin management
Maximise the sense of identity of local communities with black robins	The percentage of the Chatham Island community who have physical access to black robins
Maximise public appreciation	A qualitative scale of the wider outreach of black robin management
Ensure that Moriori principles and values are embodied in karure/black robin management	*'When Moriori migrated to Rēkohu/Rangihaute, the islands were forested and home to many bird species, including karure (black robin). Due to habitat loss, the introduction of pests and predators, and the conversion of much of the larger islands to pasture, humans have caused the significant decline of native species. Our vision is to see these birds thriving once more through the enhancement of biodiversity in their favourite forest environment. The foundation principles of unity, sharing and peacemaking that Moriori espouse form the core of our response to this report and subsequent plans. We believe that a collective, respectful approach that places biodiversity resilience at its heart will see beneficial results for this little bird. We believe that the whole island community has an interest in fostering the survival of karure and see bird recovery programmes in general as part of an "island identity". Moriori have a leadership role to play in supporting this work as the waina pono (first inhabitants), through exclusive Treaty settlement redress over the two nature reserves, through conservation settlement redress that offers engagement with species recovery programmes, and through our own conservation initiatives on land we either own or co-manage (for example, Caravan Bush/Ellen Elizabeth Preece Covenant).'*
Ensure that Ngāti Mutunga o Wharekauri are recognised as Te Tiriti o Waitangi[a] partners	Ngāti Mutunga o Wharekauri Trust are Te Tiriti o Waitangi partners in all decision-making for kakaruia/black robin management.

[a] Te Tiriti o Waitangi (The Treaty of Waitangi, 1840) is the founding document for governance in Aotearoa New Zealand between representatives of Māori (Indigenous People of Aotearoa New Zealand) and the British Crown.

alternatives due to its vital importance. To address knowledge gaps identified through this process, the working group also created a list of research priorities (Appendix S2).

Predicting consequences

The consequences of each alternative for each objective were estimated using a variety of methods, including population models, expert judgment, and formal expert elicitations. Expert elicitations followed the IDEA protocol, using four steps to improve the accuracy of expert judgement: (1) investigate, (2) discuss, (3) estimate, and (4) aggregate (Hemming *et al*., 2018). The methods used to estimate each consequence are outlined below.

Black robin resilience

Black robin banding and resighting data collected on Mangere and South East at the start (October) and end (March) of each breeding season between 2011 and 2021 were initially analysed using integrated population models (IPM) in the Bayesian modelling program OpenBUGS (Spiegelhalter *et al*., 2014). For each population, we estimated adult male and female survival, the number of juveniles produced per female (estimates were based on post-breeding surveys conducted in March), juvenile survival, and the population size and trajectory under the status quo. Survival was modelled using a state-space formulation of the Cormack-Jolly-Seber model (Kéry & Schaub, 2012), with survival and detection probabilities modelled with logit link functions and Bernoulli error distributions. We modelled juveniles per female using a generalised linear model with log link function and Poisson error distribution.

To predict how black robin populations would respond to the different alternatives, we conducted formal expert elicitations with black robin experts (n = 8) and used the responses, together with data transformations and IPM-generated estimates, in a female-only projection model. We first elicited mode, maximum, and minimum values (Burgman, 2015) specified at 100% confidence for adult female survival, juvenile survival, juveniles per female and carrying capacity (K) under three conservation management scenarios arising from the alternatives being considered: (1) provision of nest boxes, (2) provision of nest boxes and habitat restoration (assuming effects commence 10 years post-planting), and 3) provision of nest boxes, habitat restoration and post-release supplementary feeding. Initial Status Quo analysis using an IPM (see modelling section below) showed that the Mangere population was being constrained by low numbers of juveniles per female.

Table 2 Summary of alternative management strategies for black robin recovery planning indicating key differences in their component actions and a comparison with Status Quo

Alternative	Bio-security	Monitoring				Nest boxes				Habitat restoration				Reinforcement				Inter-island translocation		Post-release management				Identity/ appreciation
	All	SE	M	P	C	SE	M	P	C	SE	M	P	C	SE	M	P	C	SE	C	SE	M	P	C	
Status Quo	✓	✓	✓							✓	✓													✓
ConsMoni	✓	✓✓	✓✓				✓			✓	✓													✓
RestM	✓	✓✓	✓✓				✓			✓	✓✓													✓
RestBoth	✓	✓✓	✓✓				✓			✓✓	✓✓													✓
SQReinf	✓	✓	✓				✓			✓	✓				✓									✓
ReinfMoni	✓	✓✓	✓✓				✓			✓	✓				✓									✓
ReinfMoni+	✓	✓✓	✓✓				✓			✓✓	✓✓				✓						✓			✓
ReinfMoni+New	✓	✓✓	✓✓	✓	✓		✓	✓	✓	✓✓	✓✓	✓	✓		✓			✓	✓		✓	✓	✓	✓✓
TransPitt	✓	✓✓	✓✓	✓			✓	✓		✓✓	✓✓	✓			✓			✓			✓	✓		✓✓
TransCI	✓	✓✓	✓✓		✓		✓		✓	✓✓	✓✓		✓		✓				✓		✓		✓	✓✓
TransCI+	✓	✓✓	✓✓		✓		✓		✓	✓✓	✓✓		✓		✓				✓				✓	✓✓✓
MultiTrans	✓	✓✓	✓✓	✓	✓		✓	✓	✓	✓✓	✓✓	✓	✓		✓			✓	✓		✓	✓	✓	✓✓✓

The number of tick marks indicates increasing intensity of a component action. See Appendix S6 for a full description of each management strategy. SE, South East Island; M, Mangere Island; P, Pitt Island; C, Main Chatham Island.

Given that the Mangere population is small and isolated (Forsdick *et al*., 2017), it is likely that the population is suffering from the genetic consequences of small population size, including reduced reproductive and survival rates (e.g. Kennedy *et al*., 2014). As some alternatives to maximise the resilience of black robins involved the introduction of genetic diversity via translocation of 10 females from the larger South East population, we assumed this 'genetic rescue' action would improve reproductive and survival rates on Mangere. This is because genetic diversity is higher in the black robin population in South East when compared to Mangere, and because the two populations are genetically different from one another (Forsdick *et al*., 2017). In addition, reciprocal translocations between two genetically distinct inbred populations of the closely related South Island robin (*Petroica australis*) improved vital rates in resultant mixed-parentage offspring (Heber *et al*., 2013). Therefore, to account for this, the South East mode for juveniles per female was used for Mangere reinforcement scenarios.

We also elicited values for adult female survival, juvenile survival, juveniles per female and K at potential translocation sites. However, time constraints meant this elicitation could not be satisfactorily completed at the workshop. We therefore ran a subsequent expert elicitation following the same process and protocols (Hemming *et al*., 2018) as during the workshop to elicit values from experts (n = 7) on the basis of a hypothetical release site that would be broadly similar to those assessed at the workshop.

Population models were run during the workshop to project the number of adult females on Mangere and South East separately over 20 years (2021–2040) under Status Quo and the 11 alternative strategies. This involved generating beta-PERT distributions for each response using the average minimum, mode, and maximum values provided by the experts for population parameters (Vose, 1996). Status Quo values, the probability of a juvenile being female (*p.fem*) and initial population sizes (number of females) were based on estimates obtained from the IPMs detailed above. Eight of the management alternatives involved a translocation of 10 females from South East to Mangere, and five alternatives involved one or more translocations from South East to a new site or sites. Projections for these alternatives therefore required the impacts of Mangere reinforcement and South East harvest(s) to be estimated for the two populations, as well as predictions of population size for the new site(s). A description of the population modelling undertaken to make the projections is provided in Appendix S3. The model code and data used for these projections are provided in Appendix S4 and S5, respectively.

The total number of females across all populations over the 20-year period under each management alternative was estimated by summing the estimated annual number of females in each population.

Costs

Participants used existing costings for staff (i.e. full-time equivalents/FTEs), equipment (including pest fencing, aerial eradications, ongoing monitoring), transportation and logistics to estimate the cost of each management alternative. These costs were annualised and then presented as the total

5-year (2021–2026) cost for each alternative with a 10% contingency.

Ecosystem gains

To quantify ecosystem gains, participants identified, based on expert knowledge, which native threatened species could benefit from black robin management (for example, habitat restoration on Mangere and South East and at the new site(s) where restoration also involved mammalian predator eradication and exclusion). Experts recognised that there are unnamed mega-invertebrates, micro-invertebrates and threatened plants that might also benefit from black robin management; these were listed as three broad species groups. In addition to species and species groups native to the Chatham Islands, experts also considered ecological replacements (closely related replacements for extinct endemics, for example, Korimako|New Zealand bellbird|*Anthornis melanura* as a replacement for Chatham Island bellbird|*A. melanocephala*) (Atkinson, 1988) as potential benefactors from black robin management, when embedded in the context of ecological restoration. Ecological replacements were included as a single category. The number of additional populations of each species, or species group, benefiting from black robin management was then calculated as a range (lowest number of new populations to the highest number) for each management alternative.

Community sense of identity and public appreciation

The Chatham Island community is small with ~780 people, 95% of whom reside on main Chatham Island with the remainder on Pitt Island. Participants estimated the proportion of the local community that would have physical access to black robins under each management alternative, as physical access was considered strongly associated with the communities' sense of identity with the species. Meaningful engagement opportunities (for example, guided site visits) were also seen as an important contributor to public appreciation. Therefore, the degree to which each management alternative provided engagement opportunities was assigned a qualitative value of very low, low, medium or high.

Embedding with Moriori values

Hokotehi Moriori Trust representatives did not consider that a specific performance measure was required for their stated objective. Instead, they opted for a statement to ensure that their broad objectives for karure | black robins, and the decision-making process, were reflected throughout (Table 1).

Embedding with Ngāti Mutunga o Wharekauri values

As noted, Ngāti Mutunga o Wharekauri Trust representatives were not present at the workshop. However, in meetings after the workshop, Ngāti Mutunga o Wharekauri Trust representatives emphasised that non-attendance should not be perceived as disengagement. While elements of the organisation of the workshop, including location, timing, and the time commitment to attend, were unsatisfactory to Ngāti Mutunga o Wharekauri they are broadly supportive of the outcome for black robin recovery. Further, Ngāti Mutunga o Wharekauri are partners in all ongoing black robin decision-making under Te Tiriti o Waitangi (the Māori version of the Treaty of Waitangi, 1840), the founding document for governance in Aotearoa New Zealand.

Identifying the best option

Throughout the SDM process, we encouraged and fostered informed discussions about the alternatives under consideration and their respective performances. Predicted consequences for each alternative in relation to each objective were entered into a consequence table. While abundance estimates for the new site(s) were not available at the time of the workshop due to the aforementioned time constraints, the consensus of participants was that they were confident that habitat could be sufficiently restored at new sites for a translocated population (or populations) to grow. Consideration of the full range of options was therefore possible at the workshop on this basis. The working group then removed any alternatives that were outperformed (dominated) across all objectives by other scenarios from consideration to simplify the decision landscape. The working group also considered further approaches to simplify the consequence table, such as hard constraints or insensitive (irrelevant) objectives. Once the decision landscape could no longer be further simplified, participants anonymously ranked the remaining alternatives from most to least preferred. This ranking process reflected each participant's implicit weightings and trade-offs among objectives. The ranks were summed per alternative, with the most preferred alternative receiving the lowest score and the least preferred the highest score. The group reviewed these scores and used them as a base for further informed deliberations. In these deliberations, the group unanimously decided that the appropriate process would be to consider the top-ranked alternative as the best option for black robin conservation management.

Results

Consequences

Alternatives were predicted to perform differently when assessed against different objectives. The predicted consequences (and associated uncertainty) for each alternative and objective are provided in Table 3.

Black robin resilience

The vital rates and carrying capacities estimated for Mangere, South East and a new site are shown in Fig. 2a–d. These values informed the future trajectories of the black robin populations under each management alternative (Fig. 2e). Multi-Translocation resulted in the highest predicted number of female black robins in 2040 (194, 95% credible interval = 17–

Table 3 Consequence table for black robin management under each alternative

Objective	Performance measure	Alternative: Status Quo	Conservation Monitoring[a]	Restoration Mangere[a]	Restoration Both[a]	Status Quo Reinforcement	Reinforcement Monitoring	Reinforcement Monitoring Plus	Reinforcement Monitoring Plus New Population	Translocation Pitt	Translocation Chatham	Translocation Chatham Plus	Multi-Translocation
Maximise resilience	Total no. adult females (2040)	147 (16–215)	148 (16–220)	148 (16–222)	159 (32–248)	153 (14–219)	153 (14–219)	168 (30–254)	191 (24–335)	182 (12–302)	182 (12–302)	182 (12–302)	**194 (17–374)**
	No. adult females on Mangere Island (2040)	1 (0–24)	2 (0–29)	2 (0–31)	2 (0–31)	8 (0–29)	8 (0–29)	**13 (0–37)**	**13 (0–37)**	8 (0–29)	8 (0–29)	8 (0–29)	**13 (0–37)**
	No. adult females on South East (2040)	146 (16–191)	146 (16–191)	146 (16–191)	**157 (32 –217)**	145 (14–190)	145 (14–190)	155 (30–217)	146 (20–215)	142 (8–190)	142 (8–190)	142 (8–190)	130 (7–214)
	Number of populations	1–2	1–2	1–2	1–2	1–2	1–2	1–2	1–3	1–3	1–3	1–3	**1–4**
Minimise costs	NZ$ (2021–26)	**185 000**	230 000–460 000	480 000–710 000	630 000–860 000	197 000	242 000–472 000	872 000–1 102 000	4 359 000–4 589 000	3 959 000–4 189 000	3 959 000–4 189 000	4 259 000–4 489 000	7 651 000–7 881 000
Maximise ecosystem gains	No. populations of other species	0–2	0–2	0–2	0–2	0–2	0–2	0–2	7–18	8–18	7–17	7–17	**7–33**
Maximise the sense of identity of local communities with black robins	% of the Chatham Islands community with physical access to black robins	1%	5%	5%	5%	5%	5%	5%	30–90%	30–50%	90%	90%	**100%**
	Local engagement opportunities (qualitative scale)	Very Low	Low	Low	Low	Low	Low	Low	Medium	Medium	Medium	High	**High**
Maximise public appreciation	Wider outreach (qualitative scale)	Very low	Low	Low	Low	Low	Low	Low	Medium	Medium	Medium	High	**High**
Ensure that Moriori principles and values are embodied[b]													
Ensure that Ngāti Mutunga o Wharekauri are recognised as Te Tiriti o Waitangi partners[c]													

Uncertainty is represented by 95% credible intervals for total numbers of adult females; ranges are presented for the number of populations, costs, number of populations of other species and the percentage of the Chatham Islands community with physical access to black robins; and point estimates are provided for local engagement opportunities and outreach to the public. The best-performing alternative for each objective is in bold. The Hokotehi Moriori Trust ensured that all alternatives were consistent with their values during the workshop. Ngāti Mutunga o Wharekauri Trust representatives did not attend the workshop (see main text).

[a] Removed from the consequence table by the group during the trade-off phase (see main text).

[b] See the main text for an explanation of how Moriori principles and values were incorporated throughout the decision-making process.

[c] See the main text for an explanation of how Ngāti Mutunga o Wharekauri were recognised in this SDM process.

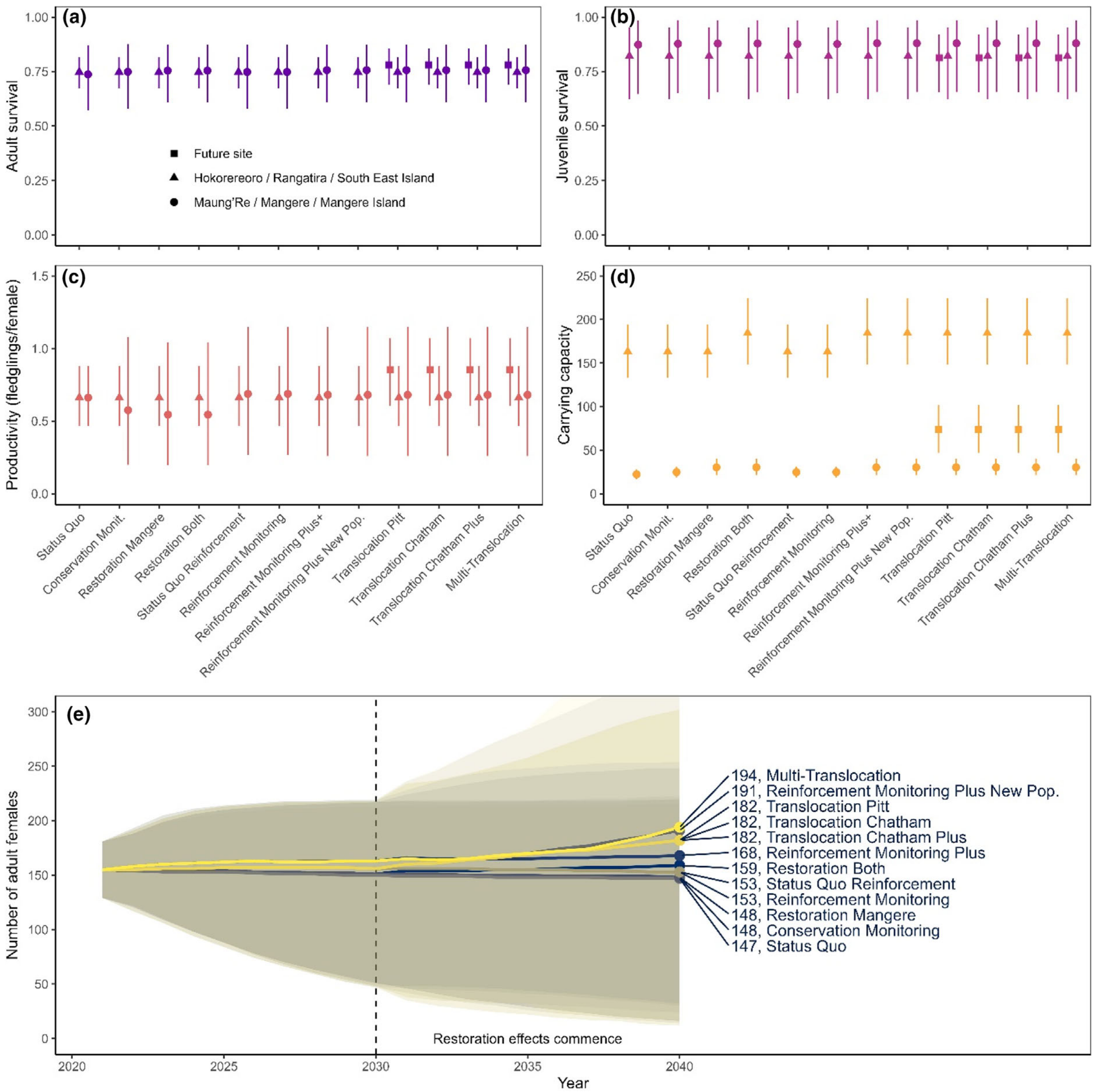

Figure 2 Estimated black robin vital rates (a–c), carrying capacity (d) and projected numbers of adult females (e) under different alternatives. Symbols represent medians and vertical lines represent 95% CIs (a–d). Trend lines represent median adult female numbers over time, with shaded areas representing 95% CIs (e).

374), while Status Quo resulted in the lowest (147, 16–215). Multi-Translocation also had the highest potential number of populations (4) compared to the alternatives involving translocation to one new site (3) or no new sites (2). Without intervention, the Mangere population was highly likely to decline to extinction (adult females in 2040 = 1, 0–24). However, the prospects for this population were predicted to improve with reinforcement of 10 females in 2021 (11 (0–29) or 13 (0–37) females in 2040, depending on the level of habitat restoration on Mangere; Table 3). In contrast, harvesting those 10 females had little influence on the South East population (145 (14–190) females in 2040, compared to 146 (16–191) females under Status Quo). Even the most intensive harvest regime (Multi-Translocation; 50 females removed for three different translocations) was predicted to have a relatively minor impact on the South East population, with an estimated 130 (7–214) females present in 2040.

Cost

Status Quo was predicted to be the least expensive alternative at NZ$185 000 over 5 years. Alternatives that involved restoration of new sites for black robin translocations, including the need for a predator-proof fence and eradication of

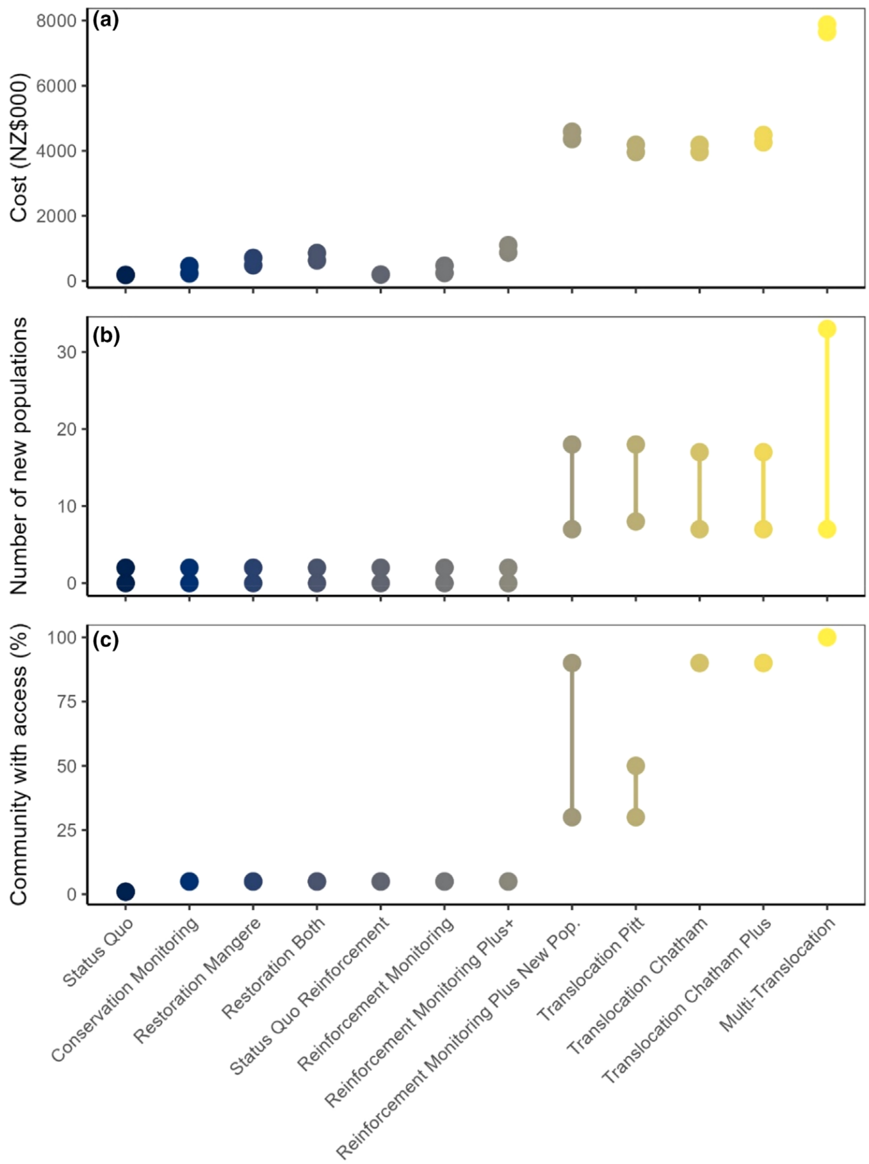

Figure 3 Estimated 5-year costs (a), number of new populations of threatened Chatham Island flora and fauna species (including ecological replacements) that could be created (b), and percentage of the Chatham Islands community that could gain physical access to black robins per management alternative (c). Dots show the minimum and maximum values estimated by workshop participants.

mammalian predators, including mice (*Mus musculus*), were perceived to be the most expensive, with Multi-Translocation being the most costly at NZ $7 651 000–$7 881 000 over 5 years (Fig. 3a; Table 3).

Ecosystem gains

Participants identified 13 bird, three plant, and one skink species, as well as three broad species groups (mega-invertebrates, micro-invertebrates and threatened plants) that would potentially benefit from black robin management, depending on the alternative. In addition, six bird species were identified as potential ecological replacements that may also benefit from habitat restoration at new black robin sites. Multi-Translocation provided the largest potential ecosystem gains (7–33 new populations of other species/groups), with alternatives that involved at least one new black robin site also benefitting numerous populations (Fig. 3b; Table 3). Alternatives without new black robin sites had the lowest predicted ecosystem gains (0–2 new populations; Fig. 3b; Table 3).

Community sense of identity and public appreciation

Alternatives that did not involve translocations of black robins to a new site also had the lowest capacity to provide the Chatham Islands community with opportunities for physical access (1–5%; Fig. 3c; Table 3). Establishment of a new population on Pitt Island was perceived to provide 30–50% of the community with physical access, as this island has a much lower human population and can only be reached by boat or charter plane, while a new population on main Chatham Island was perceived to provide access to 90%. Populations on both islands (Multi-Translocation) would provide 100% of the community with access the species (Fig. 3c; Table 3). Similarly, public appreciation of the species was predicted to be lowest for alternatives without translocation to Pitt and/or Chatham Island and highest for Multi-Translocation and Translocation Chatham Plus, under which black robins are accessible and a staff member (1 FTE) is employed to promote and facilitate public engagement with the species.

Embedding with Moriori and Ngāti Mutunga o Wharekauri values

As described above, the values of the Hokotehi Moriori Trust and the Ngāti Mutunga o Wharekauri Trust were encapsulated as two separate statements. Consequently, no specific predicted outcomes for either were expressed per alternative in the consequence table (Table 3). Instead, these statements guide the separate but ongoing integration of Moriori and Ngāti Mutunga o Wharekauri values in black robin recovery.

Identifying the best option

Translocations were an integral part of desired future management for black robins. The three alternatives other than Status Quo that did not involve translocation were removed from consideration during the trade-off phase as they were outperformed across all objectives (Table 3). Status Quo was considered unacceptable to all participants. Multi-Translocation was ranked as the best-performing alternative by nearly all (14/17; 82%) participants (Table 4). Consequently, this option was recommended by the working group as the preferred option for black robin management to the final decision-makers. The top five preferred alternatives all included a supplemental translocation of 10 females to Mangere Island, breeding season monitoring on Mangere Island and any new translocated population, at least one new translocated population on either Chatham Island or Pitt Island, and improving connections between black robins and the Chatham Islands community and the wider public through the provision of a 0.5–1 FTE engagement role (Table 4).

Implementation

An important outcome of the SDM process was that it resulted in rapid implementation of conservation measures. Intensive breeding season monitoring of the Mangere population commenced the following breeding season (2021/22) and has continued for the two subsequent seasons to date.

Crucially, in September 2022, ten female black robins were translocated from South East to Mangere. Nine of these birds were confirmed as present at the start of the breeding season in October 2022, with two successfully fledging young that season. Furthermore, an additional SDM process has been completed to identify the most suitable translocation sites on main Chatham Island and Pitt Island (Parker *et al*., 2023) and dedicated funds have been secured to build a predator-resistant fence at one of these sites, with work expected to proceed in 2024.

Discussion

Our case study species, the black robin, exemplifies the complex nature of conservation decisions. The species' precarious status, combined with uncertainty about whether translocation would have positive or negative outcomes, meant decision-makers were reluctant to act given the potentially severe consequences of translocation failure. In addition to risk and uncertainty, decision-makers were faced with other challenges including diverse interested parties representing a range of values, undefined, yet complex management alternatives, and limited resources. The SDM process facilitated an inclusive approach that ensured all participants

Table 4 Anonymised individual rankings of preferred management alternatives for black robin conservation management

Management alternative	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	Total	(P16)	(P17)
Multi-Translocation	1	1	5	1	1	1	1	1	1	1	1	6	1	1	2	25	*1*	*1*
Translocation Chatham Plus	2	2	3	4	2	3	2	3	2	2	2	3	3	2	3	38	*2*	
Translocation Pitt	3	5	2	3	3	2	5	2	4	4	5	2	3	4	5	52	*3*	*2*
Translocation Chatham	4	3	4	5	4	5	3	4	3	3	3	7	4	3	1	56	*4*	
Reinforcement Monitoring New Population	5	4	1	2	6	4	4	5	8	7	4	1	5	5	4	65		*3*
Reinforcement Monitoring Plus	7	6	6	6	5	7	6	7	5	8	8	4	6	6	8	95		
Status Quo Reinforcement	6	7	7	7	8	6	8	6	6	5	7	5	8	8	7	101		
Reinforcement Monitoring	8	8	8	8	7	8	7	8	7	6	6	8	7	7	6	109		
Status Quo	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	135		

The management alternatives are listed from the most preferred (Multi-Translocation, total score = 25) to least preferred (Status Quo, total score = 135). Participants 16 and 17 only ranked their top four and top three preferred alternatives, respectively, so their preferences are not included in the total scores. However, they are shown here in italics to illustrate the consistency of their preferred management alternatives with the rest of the working group.

were actively engaged in the decision-making process, enabling navigation of this complex decision landscape.

The preferred alternative was predicted to have the best conservation outcome for black robins. This alternative included ongoing biosecurity on Mangere and South East, breeding monitoring of the Mangere population plus *ad libitum* feeding and regular island searches, provision of nest boxes, restoration of Mangere Island and new sites on Pitt and Chatham Island, reinforcement translocation of 10 females from South East to Mangere as soon as possible, translocation of 40 birds to Pitt Island in 10 years' time and a further 40 birds to Chatham Island in 15 years' time, supplementary feeding and potentially cross-fostering at the new sites, and allocation of one FTE for community/public engagement with black robins. The multi-dimensional nature of this alternative highlights the richness of solutions developed through SDM (also see Fischer *et al*., 2023, McMurdo Hamilton *et al*., 2021, Paxton *et al*., 2022).

Translocations are a key component of desired future management for black robins. Given the prior conundrum of whether translocations were appropriate, this result clearly illustrates how gaining information can reduce uncertainty and aid decision-making (Taylor *et al*., 2017; Freckleton, 2020). Here, population modelling played a vital role in reducing uncertainty around the impact of removing individuals from South East for translocation to Mangere and new sites. Predicted recovery of the South East population post-harvest provided decision-makers with an acceptably low level of risk associated with translocation. This, in combination with the higher abundances predicted for alternatives that involved translocation(s), provided confidence that translocation would result in positive outcomes for the species.

Rarely is the question of whether translocation should occur at all formally addressed (Keating *et al*., 2023). Our study not only allowed this fundamental question to be assessed as a formal decision, but it also provided the platform to simultaneously consider translocations among a raft of other potential management actions. Given the limited resources for conservation, it is well recognised that recovery plans must consider how to allocate resources efficiently among actions (Ng *et al*., 2014; Martin *et al*., 2018). Our approach enabled us to explore the implications of translocation(s) among multiple other actions, whereby it emerged that translocations were a vital component of the optimal suite of actions to meet objectives.

Where population-specific data were lacking to estimate the consequences of management, we relied on data from other populations (genetic rescue effects), species (post-release effects), as well as expert judgement to predict outcomes. Although these are valid sources of information (Ewen *et al*., 2022), it is unknown how well they will reflect realised outcomes. For example, Hemming *et al*. (2018) note that while structured expert elicitation has been shown to produce relatively reliable judgements, it does not guarantee accurate estimates. A key step in the SDM cycle is implementation and monitoring (Step 7, Fig. 1). This iterative feedback loop allows for learning and assists adaptive management (McCarthy, Armstrong, & Runge, 2012; Canessa *et al*., 2016). Relevant research is underway to estimate genetic rescue effects in the Mangere population due to genetic augmentation from translocated South East birds. The intensive post-release monitoring following the release of South East birds on Mangere will allow post-release effects on translocated black robins to be estimated for the first time. Data collected following implementation of measures can be used to update the modelled predictions presented here and feed into future decision-making. The Bayesian modelling framework we have used is ideal for updating predictions, whereby existing information is represented as priors, and new information is used to update models or parameters (McCarthy & Possingham, 2007; Canessa *et al*., 2016).

We used a decision-analytic framework to identify values-based alternatives for threatened species recovery. SDM is not perfect, and it is ultimately a product of western science and ideas (Moehrenschlager, Soorae, & Steeves, 2023), whereas other processes have been suggested for translocation decision-making, especially when driven by indigenous values (Rayne *et al*., 2020). However, the inclusive approach described here encapsulated diverse values, generated solutions-focused collaboration and engendered group confidence in the decision. Critically, it also led to the rapid implementation of the preferred alternative for black robin recovery, including translocation. Integration of population modelling within the participatory decision framework bridged the space between research and implementation (Toomey, Knight, & Barlow, 2017; Dubois *et al*., 2020). Prior to the SDM process, decision-makers had defaulted to status quo for years, a situation common to many recovery programmes in the face of uncertainty (Canessa *et al*., 2020). However, through SDM it became clear that status quo was unacceptable to all parties. As such, this decision framework provided invaluable guidance on whether to act, as well as how to act (sensu Keating *et al*., 2023), overcoming the long-standing conservation impasse. Decision-making for animal conservation is complex and uncertain. Fortunately, these inherent challenges are surmountable with SDM. Future conservation decisions will therefore benefit greatly from the use of decision science, and the methods used in our study can be readily applied in other species conservation programmes to combat the global decline of biodiversity.

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Author contributions

KP led facilitation of the SDM workshop, alongside co-facilitator JF. JF carried out the expert elicitation. TS provided genetic advice to inform the population modelling. EP carried out the population modelling and led the writing of the paper following initial reporting by KP. HC, KG, EK, TM, EP, TT and JW provided crucial input to the SDM process. All authors contributed critically to the drafts and gave final approval for publication.

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Supporting information

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

Appendix S1. Workshop schedule and online questionnaire circulated prior to the structured decision-making workshop for karure/kakaruia/Chatham Island black robin (*Petroica traversi*) management.

Appendix S2. Goal statement and research priorities identified during the structured decision-making workshop for karure/kakaruia/Chatham Island black robin (*Petroica traversi*) management.

Appendix S3. Population modelling to predict black robin abundance under different management alternatives.

Appendix S4. OpenBUGS code for models predicting the outcomes (female numbers) of alternative management strategies for black robin populations on South East and Mangere Islands, as well as projections for a black robin population released at a new site. Status quo parameters for South East and Mangere are based on integrated population modelling of vital rate data collected for each population between 2011 and 2020.

Appendix S5. Data for models predicting the outcomes (female numbers) of alternative management strategies for black robin populations on South East and Mangere Islands, as well as projections for a black robin population released at a new site. Status quo vital rates, p.fem (probability of a juvenile being female) and female numbers at the start of projections for South East and Mangere are based on integrated population modelling of vital rate data collected for each population between 2011 and 2020.

Appendix S6. Fully specified management alternatives for karure/kakaruia/Chatham Island black robin (*Petroica traversi*) management.