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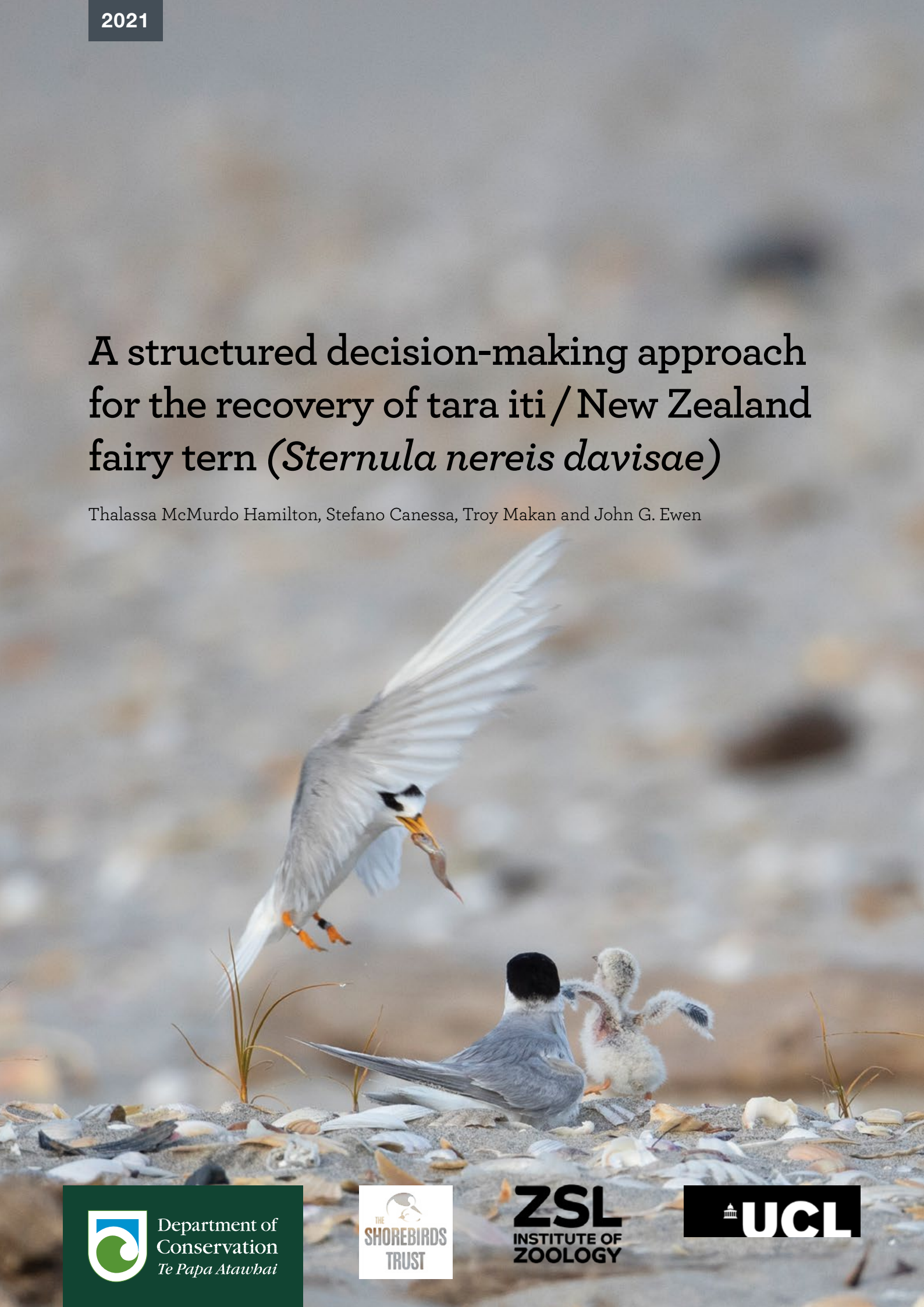
A structured decision-making approach for the recovery of tara iti / New Zealand fairy tern *(Sternula nereis davisae)*

Thalassa McMurdo Hamilton, Stefano Canessa, Troy Makan and John G. Ewen



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Thalassa McMurdo Hamilton[1,2,3], Stefano Canessa[4], Troy Makan[5] and John G. Ewen[6]

[1] Doctoral student, Institute of Zoology, Zoological Society of London, Regent's Park, London, NW1 4RY, UK

[2] Biodiversity Consultant, Centre for Biodiversity and Environment Research (CBER), University College London, Gower 10 Street, London, WC1E 6BT, UK

[3] Present address: Biodiversify, 6 Great North Road, Cromwell, Newark, Nottinghamshire, NG23 6JE, UK

[4] Research Fellow, Division of Conservation Biology, Institute for Ecology and Evolution, Bern University, 3012 Bern, Switzerland

[5] Technical Advisor, Department of Conservation, 99 Sala Street, Rotorua. Email: tmakan@doc.govt.nz

[6] Senior Research Fellow, Institute of Zoology, Zoological Society of London

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Cover: Tara iti chick being fed at Mangawhai. *Photo: Ian Southey.*

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Ko koe ki tēnā, ko ahau ki tēnai kīwai o te kete
You at that, and I at this handle of the basket

CONTENTS

Executive summary

Tara iti / New Zealand fairy tern (*Sternula nereis davisae*) is Aotearoa New Zealand's rarest indigenous bird, with only 12 known breeding pairs in 2020 and a conservation status of Threatened – Nationally Critical. Its range is restricted to northern Aotearoa New Zealand and breeding is confined to only four sites in the Auckland and Northland regions.

A scientific review of the tara iti management programme in 2017 produced a series of key management recommendations and identified some critical issues within the programme. However, there was a lack of clarity and support for how these issues should be addressed. Therefore, the Department of Conservation (DOC) initiated a structured decision-making (SDM) process that involved a facilitated working group of stakeholders (including DOC, iwi, non-government organisations, Auckland Zoo, New Zealand Defence Force, universities and the community) as the first step towards developing a collaborative and inclusive plan for tara iti recovery. The scientific review also highlighted an urgent need for reformation of the tara iti recovery group, which was re-established soon after the SDM process got underway.

The SDM framework enabled a range of management options to be identified and assessed against multiple objectives that are fundamentally important to tara iti recovery, including increasing the viability of the wild population, the integration of mātauranga Māori / traditional knowledge, wider ecosystem benefits, and the awareness and respect for tara iti amongst communities in Aotearoa New Zealand; and reducing the cost of management. Management options were later assembled by the authors, in consultation with members of the working group, into eight potential recovery strategies for further consideration. Options included a mix of intensive predator management, nesting shell patch creation and protection, pair management, egg supplementation, reinforcement of the wild population through the harvest of wild eggs and captive rearing of young, and creation of new breeding sites. The outcomes of the different recovery strategies were then predicted by analysing the available information both quantitatively and qualitatively.

The analysis showed that five of the management strategy alternatives had a high probability (≥ 0.94) of population persistence over the next 50 years, three of which were acceptable to the tara iti community (as judged by the tara iti recovery group). Among the acceptable strategies, two would also provide the opportunity to develop techniques for establishing additional populations in the future (not assessed in this report) and included a captive breeding component, but the strategy that was predicted to give the largest population size in 50 years is not currently aligned with mātauranga Māori. The predicted annualised cost over 50 years of implementing a strategy that includes captive breeding is NZ$940,000.

The recovery group agreed that the most workable solution would be to implement component actions building up from a set of *in situ* actions that are common to all five strategies that had a high probability of persistence and population size increase. A logical progression would be to immediately implement these *in situ* actions and then expand these to include new sites as quickly as possible (at predicted annualised costs over 50 years of $410,000 and $640,000, respectively). Meanwhile, work should continue with iwi and other stakeholders to refine a captive rearing component that maximises persistence and population size, can be resourced, and is acceptable to all stakeholders.

It is also recommended that partnership options for tara iti management are explored between DOC, the tara iti stakeholder group and wider community to allow the resources that are needed to fully fund a management programme to be identified and secured.

1. Background

Tara iti / New Zealand fairy tern (*Sternula nereis davisae*) is Aotearoa New Zealand's rarest indigenous bird and has a conservation status of Threatened – Nationally Critical (Robertson et al. 2016). Tara iti currently breed at four sites in the Auckland and Northland regions and occur within the rohe/territories of 11 iwi – Patuharakeke Te Iwi, Ngāi Tai ki Tāmaki, Ngāti Manuhiri, Ngāti Maru, Ngāti Tamaterā, Ngāti Te Ata, Ngātiwai, Ngāti Whanaunga, Ngāti Whātua o Kaipara, Te Kawerau a Maki and Te Uri o Hau. In 2020, there were only 12 known breeding pairs of tara iti, despite conservation efforts by the Department of Conservation (DOC) and the tara iti community.

Between 2006 and 2016, there was no active recovery group or recovery plan for tara iti, resulting in no changes being made to the management strategy. In 2017, four scientists undertook a DOC-led review of the tara iti management programme and reported communication difficulties and divergent opinions within the tara iti community (Maloney et al. 2017). They also urged that the recovery group was reformed as soon as possible and made a series of field management recommendations. However, the community showed little support for some of the recommendations due to the divergence of opinions and limited consultation. Therefore, DOC suggested that a structured decision-making (SDM) process was used to restart tara iti recovery planning and implementation.

2. Structured decision making and species recovery

Species recovery programmes have long been identified as ideal candidates for the application of decision-analytic methods (Maguire et al. 1987), as they typically involve multiple objectives, values and attitudes, a need or desire to implement novel techniques or intensive management (e.g. captive breeding and translocation), and considerable uncertainty. These attributes create risks and trade-offs, as managers are required to make decisions with little information (data) and limited resources, and poor decisions can mean the loss of populations or entire species. However, the implementation of decision analysis in real-world recovery programmes has only started to gain momentum in recent years (Moore & Runge 2012; Converse et al. 2013; Ewen et al. 2014; Canessa et al. 2020; Panfylova et al. 2019; Ferrière et al. 2021; McMurdo Hamilton et al. 2021).

SDM is a decision-analytic approach that helps individuals and groups to analyse environmental management and public policy problems in an organised way to reach decisions that achieve multiple objectives (Gregory et al. 2012). The SDM approach is values-focused, meaning it recognises that the optimal choice depends on the preferences and values of decision-makers and stakeholders. It is based on an iterative process whereby the values (or objectives) are identified first, and then alternative management strategies are developed with these in mind. The performance of each alternative strategy is then evaluated in terms of its expected outcomes, and trade-offs are solved while explicitly accounting for uncertainty (Fig. 1).

SDM can help address the issues raised by species recovery programmes both rationally and transparently by breaking the decision problem into its components: fundamental objectives, potential alternative management strategies (often made up of component actions), a model of the system to predict the performance of each management strategy against the objectives, a method to find a solution across objectives, and a proposed monitoring framework to track the outcomes of a given choice (Nichols & Armstrong 2012). The focus on value-led decision making is rational and enables effective working relationships between multiple stakeholder groups (Maguire & Boiney 1994; Redford et al. 2011).

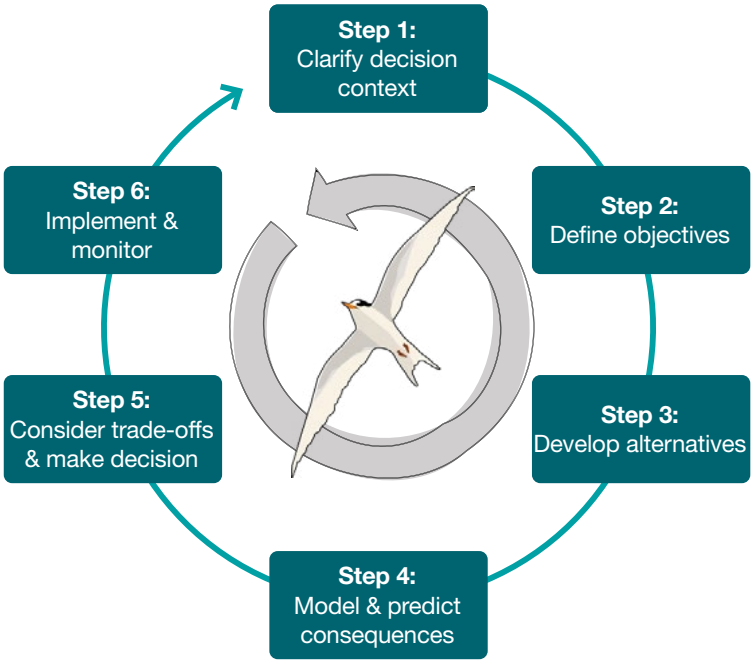

Figure 1. The six steps in the structured decision-making cycle (adapted from Gregory et al. 2012). The anticlockwise arrow indicates that steps may be repeated if required. Tara iti/New Zealand fairy tern (*Sternula nereis davisae*) illustration by J. Wold (University of Canterbury).

3. Methodology

In late 2017, DOC engaged a facilitation team to bring together a large stakeholder working group to identify management objectives, brainstorm alternative recovery actions and estimate the consequences of each alternative for tara iti recovery (see Fig. 2 & Appendix 1). During the same period, a tara iti recovery group (TRG) was reformed, comprising 11 members (all of whom were also part of the larger stakeholder working group). The TRG evaluated the final set of alternatives and developed a final recommendation. The SDM process involved two full working group meetings (attended by approximately 40 people), many smaller specialist working group meetings and one-on-one meetings, and frequent communication between the various groups and facilitators (in person and online).

The process taken and outcome of each of the six steps in the SDM process are detailed in the following sections, and a timeline for the entire process is presented in Fig. 3.

Figure 2. Some members of the tara iti/New Zealand fairy tern (*Sternula nereis davisae*) stakeholder group at the close of the 2018 workshop at Kaiwaka Sports Complex, Kaiwaka, Northland. Back row, L–R: H. Smith, I. Southey, C. Francescon, A. Auge, T. Harbrakan, T. Beauchamp, E. Henderson, R. Gibson, S. Oliver, E. Ashby, R. Maloney, T. Steeves, J.G. Ewen, K. Clark, P. Gleeson, T. Makan. Middle row, L–R: G. Pulham, R. Davies, H. Rogan, J. Vaughan, P. Seddon, K. Baird, T. Wilson, L. Judd, L. Edwards, T. McMurdo Hamilton, J. Snell. Front row, L–R: E. Lagnaz, L. Guzik, A. Wiles.

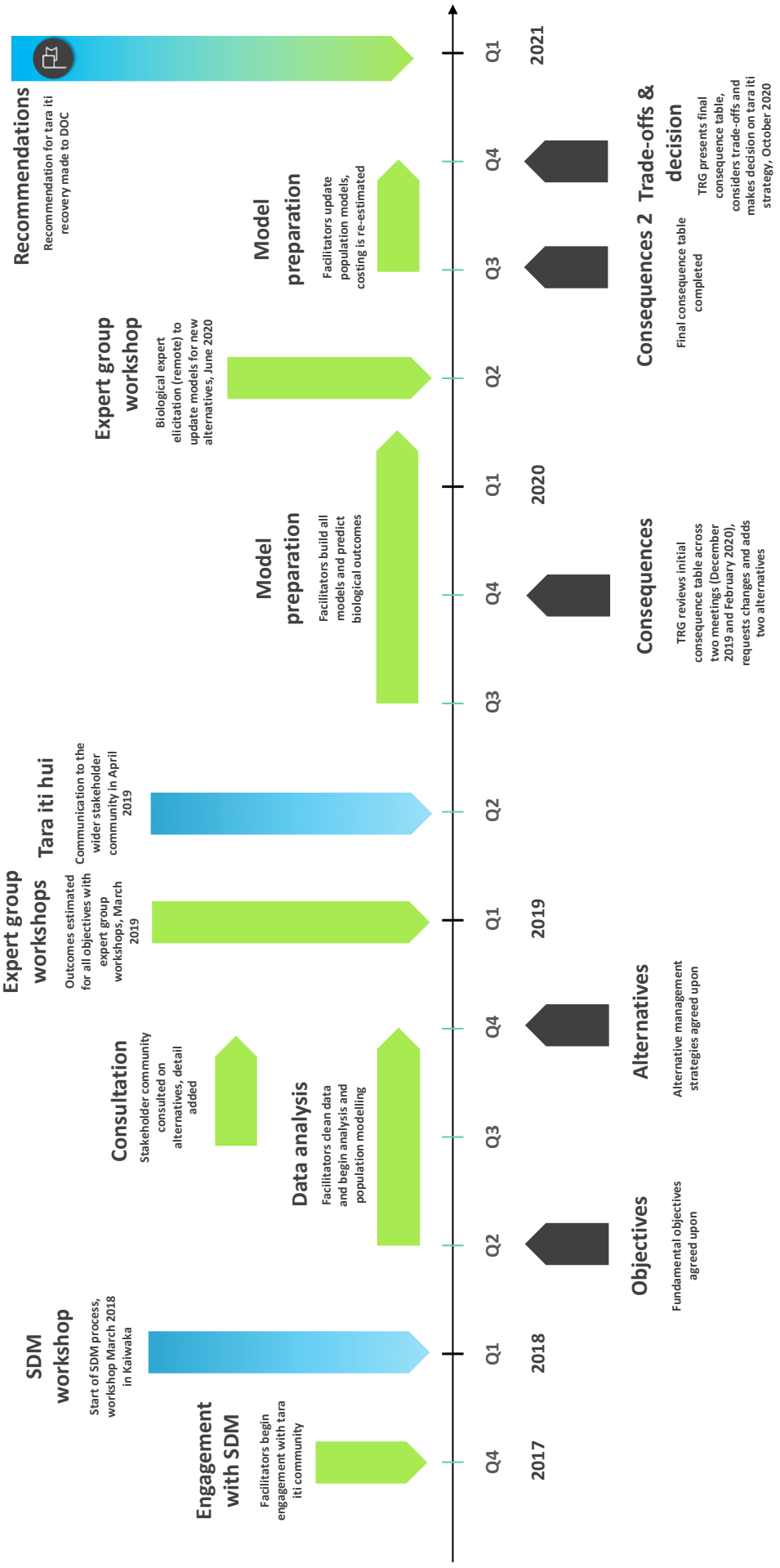

Figure 3. Timeline for the tara iti/New Zealand fairy tern (*Sternula nereis davisae*) stakeholder group meetings (blue arrows), other stages of work and smaller meetings (green arrows), and completion of the structured decision-making steps (black arrows). DOC = Department of Conservation; TRG = tara iti recovery group.

4. Conservation goal statement

Step 1 of the SDM process

The conservation goal statement highlights the focus and scope of the decision problem, describes why it has arisen, and identifies the decision-makers, as well as the time frame and legal framework within which a decision must be made. It may include up to seven core elements:

1. **Trigger**: Why does a decision need to be made? Why does it matter?
2. **Action**: What actions need to be taken?
3. **Constraints**: What are the constraints (legal, financial, political) on taking the stated action(s)? Are these perceived or real?
4. **Class or type of problem**: How many objectives are there? Do they conflict? What is the level of uncertainty?
5. **Decision-maker**: Who has the power to and will make a decision?
6. **Frequency and timing:** How often does a decision need to be made? Are other, related decisions needed?
7. **Scope**: How broad or complicated is the decision?

4.1 Process

The conservation goal statement was prepared by the facilitators after reading the 2017 tara iti management review and through discussion with TRG representatives. The resulting draft statement was discussed, amended and agreed upon during the first full stakeholder workshop and subsequently edited by the facilitators to clarify timelines with approval from the TRG.

4.2 Outcome

Tara iti is Aotearoa New Zealand's rarest indigenous bird species. Although its extinction risk has decreased since management began in 1983 and the number of individuals has grown to approximately 35, the viability of the population remains highly uncertain. Of major concern is that the number of breeding pairs has plateaued over the past 15 years at between 8 and 12 pairs.

DOC is committed to tara iti recovery and recently re-established the TRG to advise on how best to achieve this. In 2017, DOC commissioned a review of the tara iti management programme and recommended several conservation management actions, all of which focused on direct biological interventions and excluded wider regional development policy and legislation. A decision is needed as to which combinations of these, or other, actions should be applied to tara iti management.

This decision will have multiple objectives and the outcomes are expected to have high uncertainty due to the small size of the tara iti population and the proposal to use untested actions. The community that is involved in tara iti recovery is diverse and includes DOC, local iwi, and community conservation and non-government conservation groups. Therefore, any plan needs to be co-developed with these partners and the final recommendation should be made by the TRG, which represents them. This recommendation will then be passed to the ultimate decision-maker within DOC for formal approval. The targeted date of delivery of the plan to that decision-maker is late 2021.

5. Objectives

Step 2 of the SDM process

SDM recognises that the 'best' decision is that which best achieves the objectives of the decision-makers and stakeholders. Therefore, the 'best' strategy cannot be defined unless the objectives are clear. SDM recognises at least three important types of objectives:

1. **Fundamental**: These objectives reflect the group's core values or end goals and are useful for comparing and choosing between a range of possible management strategies.
2. **Means**: These objectives are important for highlighting ways of achieving the fundamental objectives.
3. **Process**: These objectives state the desired approach to the decision-making process.

Each objective should be expressed as a concise statement that consists of the thing that matters and a verb that indicates the desired direction of change (Gregory et al. 2012). It is critical to separate means objectives from fundamental objectives, as focusing on a means objective risks judging alternatives incorrectly (e.g. double counting a value), which can result in the misallocation of resources or suboptimal outcomes. Also, note that a single fundamental objective cannot be 'optimised', as optimisation (or efficiency) indicates that several fundamental objectives are being combined, which leads to hidden value judgments about what is 'optimal' – it is much better to separate the fundamental objectives and solve the decision rationally.

Each objective requires one or more performance measures to further clarify its meaning and provide a metric by which to predict and compare the expected outcomes of alternative strategies.

5.1 Process

During the initial stakeholder workshop, participants followed a systematic approach to develop their objectives, which involved:

- Individually listing their values (expressions of concern or aspirations) associated with tara iti conservation (e.g. 'to prevent the extinction of tara iti') along with objectives that would address these concerns (e.g. 'reduce the probability of extinction').
- Working in sub-groups to discuss and combine similar individual responses into a set of objectives that captured their sub-group's core values.
- Sub-groups reporting back to the entire working group and combining similar objectives until a final set of objectives was agreed on.
- Developing one or more performance measures for each fundamental objective.

5.2 Outcome

The group identified five fundamental objectives and associated performance measures for tara iti recovery planning (Table 1 & Fig. 4). Where relevant, the performance measures were forecast over 50 years based on DOC's strategic direction as set out in the Outcomes Model in DOC's Statement of Intent (DOC 2016; see section 8, 'Trade-offs').

Table 1. Fundamental objectives and their associated performance measures for tara iti/New Zealand fairy tern (*Sternula nereis davisae*) recovery planning.

FUNDAMENTAL OBJECTIVE	PERFORMANCE MEASURES
Increase the viability of the wild tara iti population	Probability of persistence after 50 years Tara iti population size in the wild after 50 years
Increase the integration of mātauranga Māori	Level of integration and, therefore, acceptability (i.e. 'not acceptable', 'acceptable')
Increase wider ecosystem benefits of tara iti management	Percentage change in the number of breeding pairs of: • Tūturiwhatu/northern New Zealand dotterel (*Charadrius obscurus aquilonius*) • Tōrea pango/variable oystercatcher (*Haematopus unicolor*)
Reduce the cost of management	Average cost in NZ$ per annum of implementing the strategies over 50 years
Increase the awareness and respect of tara iti amongst communities in Aotearoa New Zealand	For example, the number of media stories

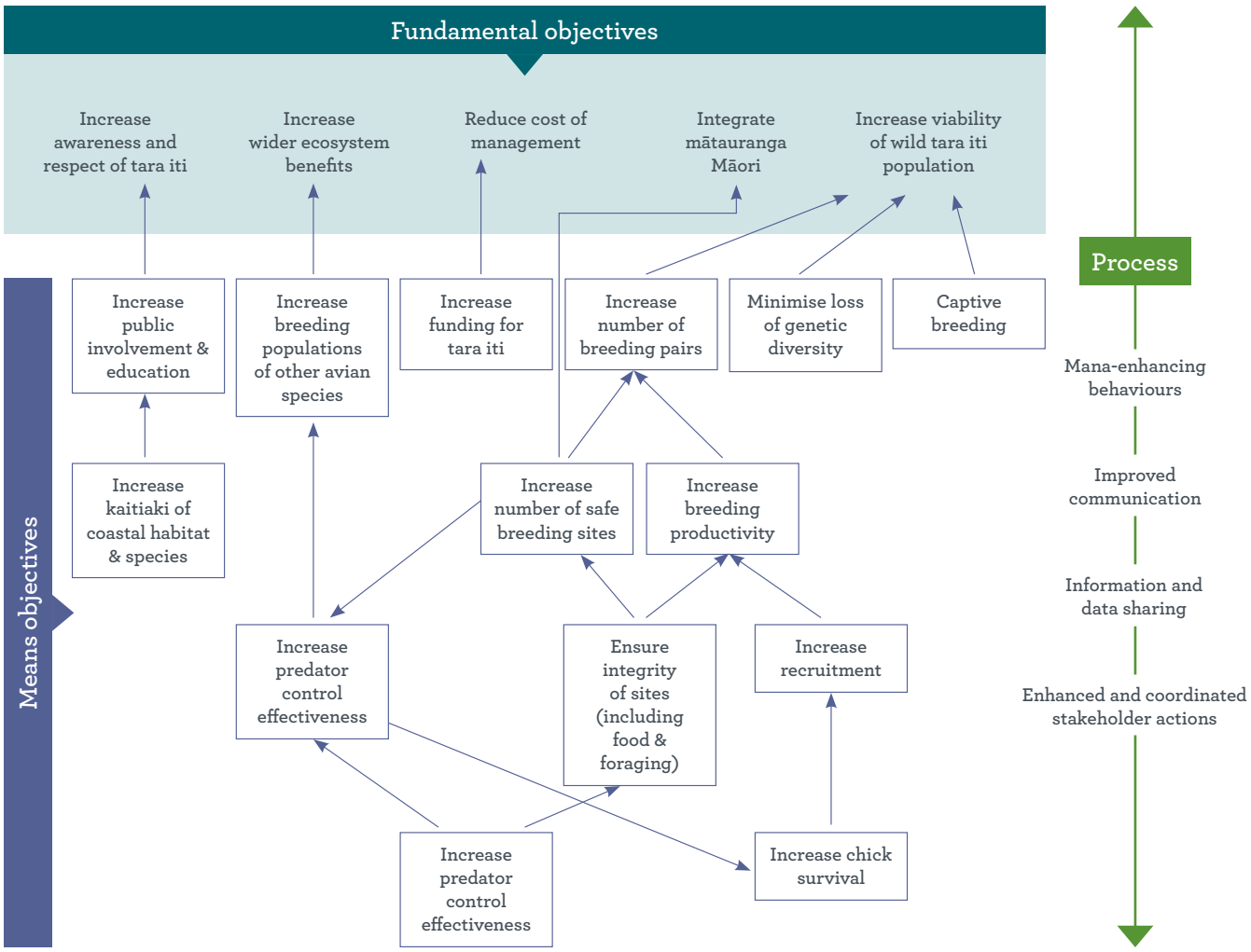

Figure 4. Diagram showing the five fundamental objectives agreed on by the tara iti/New Zealand fairy tern (*Sternula nereis davisae*) stakeholder working group and the related means objectives (i.e. the methods of meeting the fundamental objectives) and process objectives (i.e. the way the group wants to work while working towards achieving all of the objectives).

6. Alternative management strategies

Step 3 of the SDM process

Once the fundamental objectives have been clearly established, it is possible to define and evaluate alternative management strategies that could achieve these. This step often includes the identification of threats to populations of threatened species. Given the biological and non-biological complexity of most species recovery programmes, these alternative strategies will typically involve combinations of actions. The same actions can appear as components of more than one alternative.

6.1 Process

The alternative management strategies were identified using the following process:

1. The full stakeholder working group brainstormed possible actions using an influence diagram showing the key relationships between threats and management (see Appendix 2, Fig. A2.1).
2. Participants were then separated into five working groups and asked to produce their management vision for tara iti. Groups could bring forward new ideas and categories or discuss other actions they deemed to be important. Actions were identified under the following themes: predator control (breeding and non-breeding); nest protection; habitat management (breeding and non-breeding); foster pairs; captive management; and advocacy.
3. In the few months after the first full stakeholder workshop, the results of this group work were condensed by facilitators into six distinct alternative management strategies.
4. Facilitators consulted on these six alternative strategies with all members of the TRG, field staff and other DOC staff during October–December 2018. This was achieved through face-to-face meetings to ensure that everyone understood all of the elements and were satisfied that the ideas were feasible and captured appropriately.
5. Full, detailed descriptions of each alternative were then circulated and edited until the entire stakeholder working group agreed on them.
6. A second iteration of the SDM cycle was undertaken in December 2019, during which the TRG added two alternatives, bringing the total number of alternative strategies to eight.

6.2 Outcome

The eight alternative management strategies proposed for tara iti recovery are summarised in Table 2 and fully described in Appendix 3, Table A3.1.

Table 2. Summary of the alternative management strategies for tara iti/New Zealand fairy tern (*Sternula nereis davisae*) recovery indicating key differences in their component actions and a comparison with the status quo. 'Y' indicates application of the action; 'C' indicates current application of the action in 2021 (including the same elements but at a lower intensity than envisaged in the other alternative strategies). A full description of each strategy is provided in Appendix 3. OZFT = Australian fairy tern (*S. n. nereis*).

ALTERNATIVE STRATEGY	PREDATOR MANAGEMENT			NEST PROTECTION			HABITAT MANAGEMENT			CAPTIVE MANAGEMENT AND MANIPULATION		NEW SITES AND RELEASES	
	Breeding grounds, non-native	**Breeding grounds, native**	**Wintering grounds/winter management**	**Deterrents at poor nesting locations**	**Mobile or raised nests**	**Storm egg & chick care**	**Shell patches**	**Vegetation management**	**Foraging habitat management**	**Infertile males**	**Multi-clutching & harvesting***	**Releases**	**New site creation**
Status quo	C	C					C	C					
Field 1	Y	Y		Y	Y	Y	Y	Y					
Field 2	Y	Y	Y	Y	Y	Y	Y	Y	Y				
Field 1 + Captive 1†	Y	Y		Y	Y	Y	Y	Y			x 1	Y	
Field 1 + Captive 2†	Y	Y		Y	Y	Y	Y	Y		Remove	x 1	Y	
Field 2 + Captive 3†	Y	Y	Y	Y	Y	Y	Y	Y		Remove	x 2	Y	Y
Field 2 + Captive 3† + keep infertile males‡	Y	Y	Y	Y	Y	Y	Y	Y			x 2	Y	Y
Field 2 + OZFT supplement	Y	Y	Y	Y	Y	Y	Y	Y	Y		Add OZFT eggs		
Field 2 + new sites‡	Y	Y	Y	Y	Y	Y	Y	Y	Y				Y

* Number of harvests indicated in table cells.

† Incorporates a 50% reduction in captive rearing success for the first 3 years to accommodate an initial learning period.

‡ Alternatives added in the second iteration of development.

7. Consequences

Step 4 of the SDM process

Alternative strategies can be compared according to their expected outcomes (or consequences) for the different objectives, which are in turn quantified using performance measures. These outcomes can be estimated from a model of the system, which is informed by available empirical data (e.g. from previous monitoring), data from similar systems as a surrogate or expert judgement. When expert judgement is required, assessments should be obtained using best-practice protocols that include uncertainty (Martin et al. 2012; Hemming et al. 2018).

7.1 Process

To estimate the outcomes (consequences) of each alternative strategy for each objective, stakeholders worked in five expert groups: tara iti biology, wider ecosystem, mātauranga Māori,[1] costings and advocacy (see Appendix 1). The facilitators then combined the different sources of data and knowledge to derive predicted consequences. For example, the stage-based tara iti population model that informed the consequences for population viability included data from both population monitoring and expert judgement on how population vital rates would change under the proposed management. The steps taken to estimate the consequences for each of the five fundamental objectives are detailed below.

7.1.1 Population viability

1. Monitoring data and vital rates such as survival and productivity were extracted from DOC databases (1997–2017) to obtain predictions for population viability (Appendix 4, Tables A4.1 & A4.2).
2. The empirical data were then used to develop a stage-based, female-only post-breeding population model in R (R Core Team 2020; Appendix 2, Fig. A2.2) and to project growth under status quo management over a 50-year period, aligning with DOC's management strategy.
3. The status quo projections were informed by expert judgement to address the fact that some members of the tara iti biological expert group were concerned that adult survival rates may have deteriorated from 2017 onwards and would not be captured by the data-driven analyses.
4. A 1-day workshop was held by the tara iti biological working group, during which facilitators elicited expert judgements of tara iti population vital rates under each alternative strategy.
5. Experts estimated a total of 33 survival and productivity rates and carrying capacities (defined as the total number of territories that could fit into the sites and thus the maximum number of females that were able to breed in the population) (Appendix 4, Tables A4.1 & A4.2).

[1] Mātauranga Māori is defined as the body of knowledge originating from Māori ancestors, including the Māori world view and perspectives, Māori creativity and cultural practices (Māori Dictionary Online: https://maoridictionary.co.nz).

6. A modified model was built for each alternative strategy, parameterised with estimates derived from data analysis and expert judgement, and population growth was projected over a 50-year period. The models were built on the assumptions that harvests for captive rearing and Australian fairy tern (*S. n. nereis*) supplements would occur only during the initial 10-year period of operation. Additionally, at the TRG's request, all alternative strategies incorporating captive-rearing actions were modelled to accommodate a learning period over the first 3 years of operation, adjusting the effectiveness of captive-rearing productivity down to half of that predicted.
7. Demographic stochasticity, temporal variation and parametric uncertainty were incorporated into the models, with parametric uncertainty being propagated by randomly drawing values in each simulation run (n = 10 000) (McGowan et al. 2011).

7.1.2 Wider ecosystem benefits of tara iti management

1. Facilitators conducted a 1-day elicitation workshop with the wider ecosystem working group to estimate the wider ecosystem benefits of each alternative management strategy. Experts provided their judgements on changes in the numbers of pairs of two key indicator species (tūturiwhatu / northern New Zealand dotterel (*Charadrius obscurus aquilonius*) and tōrea pango / variable oystercatcher (*Haematopus unicolor*)) over a 50-year time frame at each site.
2. These estimates were later summarised as the mean percentage change across all sites.

7.1.3 Integration with mātauranga Māori

1. Iwi representatives provided a summary of te ao Māori / the Māori world view for tara iti (Table 3) at the full stakeholder workshop, which was subsequently used to inform the development of the alternative strategies and explore how they performed.
2. In November 2018, facilitators met with Ngāti Whātua o Kaipara representatives from the mātauranga Māori expert group at their office in Helensville, Auckland, to resolve linguistic and biological uncertainties. They discussed whether the summary of te ao Māori for tara iti had been captured appropriately and whether they understood all elements of the proposed alternative strategies. They also briefly explored how individual conservation actions might relate to mātauranga Māori.
3. In April 2019, iwi representatives from Te Uri o Hau, Ngāti Whātua o Kaipara and Ngāti Manuhiri hosted a mātauranga Māori meeting at the Ngāti Whātua o Kaipara office with the facilitators. During this meeting, iwi representatives explained and discussed in more detail how they saw each alternative strategy affecting mātauranga Māori. A scale of acceptability was agreed on and used to assess and ultimately classify each alternative strategy as either acceptable or unacceptable.

A comprehensive description of the methods applied for integrating mātauranga Māori in the tara iti SDM process is given in McMurdo Hamilton et al. (2021).

Table 3. Descriptions of the mātauranga Māori view for tara iti/New Zealand fairy tern (*Sternula nereis davisae*), defined by Te Uri o Hau, Ngāti Whātua o Kaipara and Ngāti Manuhiri participants at the first tara iti recovery planning workshop.

TE AO MĀORI	THE HOLISTIC MĀORI WORLD VIEW
Mauri	The binding force (essence) that holds together the physical and spiritual components of a being or thing. The mauri of tara iti is diminished and needs to be rebalanced.
Whakapapa	The spiritual connections, lineage, genealogy and direction. This represents the connection between humans and the natural world, ecosystems, all flora and fauna, etc. We are part of the system, not separate from it. Everything has whakapapa – our world is built on it. Everything comes from somewhere. It is holistic and integrated and applied to many aspects of life.
Kotahitanga	The oneness and unity of relationships. For tara iti, this means the support and connection with the community, schools and conservation groups (planned activities). It is collaborating to achieve objectives.
Kaitiakitanga	A combination of kaitiaki/guardians and tikanga/customs and the processes and practices of protecting and looking after the natural environment, the taonga/treasure. It involves a set of obligations and responsibilities to those who came before you and those who come after. Kaitiaki are the guardians and the caregivers – everyone has the role of kaitiaki.
Maramataka	The restoration of systems and knowledge of agricultural productivity, marine and forest gathering, resource management, health, healing, and daily practices that provide sustenance for wellbeing.
Rāhui	A form of tapu/sacredness, this is the practice of protecting or applying restrictions to an area to let resources recover.
Ako	A two-way learning relationship; the transmission of knowledge. Combining science and education with mātauranga Māori (knowledge of both the tangible and intangible). Emerging ideas are shared; both learning and teaching for the benefit of tara iti.
Taha wairua taha tangata	Bringing both worlds together to achieve the objective, the survival of tara iti.
Urutau	The Earth is shifting, things are changing (i.e. climate change), and we must change with it. Evolving the practice – creating new karakia/prayers for tara iti with the new unity, upgrades and changes within our time. Acknowledging our relationship with tara iti.

7.1.4 Cost of management

1. The costings expert group (including experts who were familiar with budgeting for species recovery programmes) used a mixture of data sharing and discussion to generate predicted outcomes.
2. Costs were collated by Richard Maloney (Principal Technical Advisor Systems Development, DOC) and discussed by the group. The performance measure was changed from 'millions of NZ dollars per annum' to 'average annual cost over 50 years'. This change improved the ability to compare the alternatives, as some had high one-off costs but lower tail-end costs, while others had low setup costs but significantly higher costs over time.
3. Estimations were made on the assumption that captive rearing work and supplementation with Australian fairy tern eggs would only happen during the initial 10-year period.
4. Cost estimates were completed using an 'indicative business case' approach and therefore are not full economic costings (e.g. they do not include inflation adjustment, contingency, depreciation capital charges or indirect costs). This was done to allow quick but robust costings to be estimated at this stage of the process and has enabled comparisons to be made of the relative differences between the alternative strategies. Full economic costings can be made once the number of alternatives has been narrowed down and a clear direction for recovery has been identified.

7.1.5 Increase awareness and respect of tara iti amongst communities in Aotearoa New Zealand (advocacy)

1. The advocacy/respect working group met with the facilitators for a 1-day workshop to discuss actions for this objective.
2. Given that the same set of advocacy actions applied across all alternative strategies, and therefore the estimated consequences would be the same, the group decided that this objective was not suitable for helping select the best strategy. Further details around useful awareness-raising actions are included in Appendix 5, with a view to developing these for future implementation.

7.2 Outcome

A comparison of the consequences for each of the alternative strategies is provided in Table 4.

Table 4. Full consequence table for the eight alternative management strategies developed for tara iti/New Zealand fairy tern (*Sternula nereis davisae*) recovery and the status quo. The columns and rows indicate the fundamental objectives and alternative management strategies, respectively, identified by the group. Each cell indicates the predicted outcome of a given strategy for a given objective, including uncertainty where applicable. The rows highlighted in green show the final options, while the row highlighted in yellow is an additional option for future consideration (see section 8.2). For details on how the predictions were obtained, see section 7.1.

ALTERNATIVE STRATEGY*	OBJECTIVES					
	VIABILITY OF WILD TARA ITI POPULATION		WIDER ECOSYSTEM BENEFITS OF TARA ITI MANAGEMENT†		INTEGRATION OF MĀTAURANGA MĀORI	COST OF MANAGEMENT
	Probability of persistence (> 3 adult females) in 50 years	**Mean adult female abundance in 50 years (2.5th to 97.5th percentile)**	**% change in number of breeding pairs of tūturiwhatu (lower to upper estimate)**	**% change in number of breeding pairs of tōrea pango (lower to upper estimate)**	**Scale of acceptability**	**Annualised 50-year cost (NZ$)‡**
Status quo§	0.60	10 (0–36)	N/A	N/A	N/A	90,000
Field 1	0.70	12 (0–34)	+15 (10–22)	+6 (–1 to 9)	Acceptable	350,000
Field 2	0.95	23 (1–47)	+27 (10–39)	+7 (–4 to 20)	Acceptable	410,000
Field 1 + Captive 1	0.74	12 (0–34)	+15 (10–22)	+6 (–1 to 9)	Acceptable	500,000
Field 1 + Captive 2	0.88	20 (0–45)	+15 (10–22)	+6 (–1 to 9)	Not acceptable	600,000
Field 2 + Captive 3	0.99	42 (12–77)	+36 (12–46)	+16 (–1 to 24)	Not acceptable	940,000
Field 2 + Captive 3 + keep infertile males	0.95	30 (2–60)	+36 (12–46)	+16 (–1 to 24)	Acceptable	940,000
Field 2 + OZFT	0.99	24 (3–49)	+27 (10–39)	+7 (–4 to 20)	Not acceptable	410,000
Field 2 + new sites	0.94	29 (1–59)	+36 (12–46)	+16 (–1 to 24)	Acceptable	640,000

* See Table 2 and Appendix 3 for details of the alternative strategies.

† Wider ecosystem benefits were considered in terms of changes in the populations of tūturiwhatu/northern New Zealand dotterel (*Charadrius obscurus aquilonius*) and tōrea pango/variable oystercatcher (*Haematopus unicolor*).

‡ Costs were calculated in 2020.

§ Status quo includes Field 1 elicited estimates of survival.

8. Trade-offs

Step 5 of the SDM process

The best strategy is the one that is believed to be the most likely to achieve the objectives. For single-objective decisions, it is easy to choose the strategy that provides the best outcome. However, when faced with multiple objectives, it is important that all of the alternatives are carefully considered, particularly when there are conflicting objectives and trade-offs are required. The final selection of a management strategy may be affected by the uncertainty that surrounds the estimated outcomes of the candidate strategies. SDM provides several tools to account for uncertainty and trade-offs, which can improve transparency and provide decision-makers with a more complete assessment of the problem.

8.1 Process

The TRG explored the decision by using simplifications of the consequence table (Table 4) and examining trade-offs between population viability, population size, cost of management and acceptability to mātauranga Māori. Since an available budget for tara iti recovery was not available, an exact trade-off could not be calculated. Instead, the TRG discussed the balance of multiple objectives using general thresholds and qualitative methods, knowing that cost would be a constraint.

This involved exploring the consequence table by fitting critical considerations as constraints:

1. The probability of persistence is equal to or higher than 0.95. This constraint is underpinned by DOCs strategic direction as set out in Intermediate Outcome Objective 1.2 of its Outcomes Model, 'Nationally threatened species are conserved to ensure persistence' (DOC 2016). Under this objective, long-term persistence is defined as 'where there is a 95% probability of species persistence within the next 50 years or three generations (whichever is longer), given that all human-induced threats likely to occur over the longer term (e.g. 300 years) are adequately mitigated'.
2. The number of adult females had the potential to increase to 50 in the 50-year time frame. This was used to address concern about 50 years being a considerable amount of time to continue to expose the population to a high level of extinction risk. Only considering those strategies that had the potential to reach 50 adult females in the 50-year time frame meant that only strategies with faster potential growth rates were chosen.
3. Alternatives must align with mātauranga Māori.

8.2 Outcome

Applying the constraints on persistence, population size and mātauranga Māori indicated that only two alternatives were viable: Field 2 + new sites (although this had a persistence just outside the threshold) and Field 2 + Captive 3 + keep infertile males. Both alternatives had similar probabilities of persistence (0.94 vs. 0.95, respectively) and mean population sizes (29 (1–59) vs. 30 (2–60), respectively), with the latter being slightly higher. Therefore, the main difference between them lay in their costs.

Regardless of the constraints, no single alternative performed best for all objectives, so reaching a resolution required a value-based balancing act between the competing objectives. After group deliberation of the consequence table (Table 4) and supporting figures examining the trade-off

between cost and the biological benefits to tara iti (Fig. 5), the TRG, with nine members present, agreed that the most workable solution was to implement component actions building up from Field 2, which includes a set of *in situ* actions that are common to all five strategies that had a high probability of persistence and population size increase. A logical progression would be to immediately implement Field 2 and then grow this as quickly as possible to include Field 2 + new sites (at predicted annualised costs over 50 years of $410,000 and $640,000, respectively). Meanwhile, a captive-rearing component that achieves the highest possible persistence and population size that can be resourced and is acceptable should be determined in discussion with iwi and other stakeholders. If a captive breeding-based strategy is considered acceptable, it is likely to provide the best future for tara iti (predicted persistence = 0.99; number of females = 42 (range = 12–77)).

If Field 2 and Field 2 + new sites are adopted initially, then Field 2 + Captive 3 should become the focus of continued discussion within the TRG and across the wider stakeholder group. After seeing the final product of the SDM process, the iwi representatives on the TRG said that iwi might be willing to further discuss removing infertile males from the population. Therefore, discussion with iwi about removing infertile males should be prioritised. If agreeable, the additional resources needed to implement Field 2 + Captive 3 should then be sought.

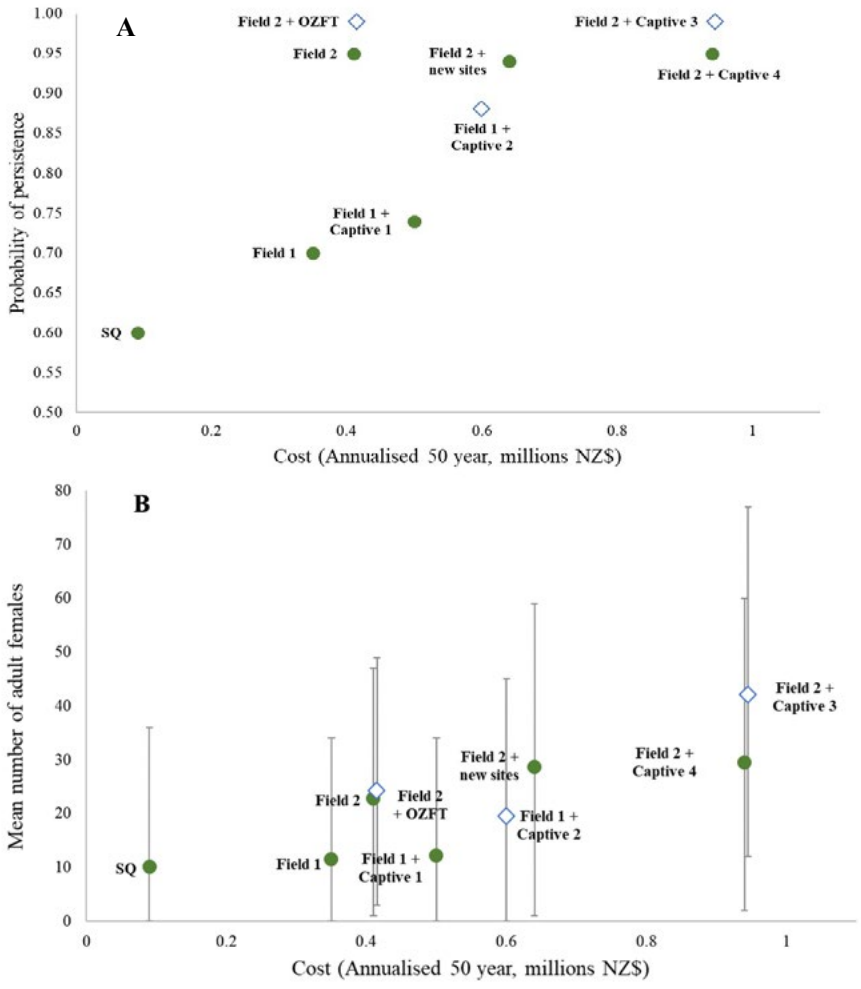

Figure 5. Relationships between the predicted cost and A. the probability of persistence after 50 years and B. the mean estimated population size after 50 years for the eight alternative management strategies. In A, the *y*-axis indicates the mean number of adult females in year 50 over 10 000 simulation runs and the bars indicate the 2.5th to 97.5th percentile uncertainty ranges. Note that the data points for Field 2 + Captive 3 and Field 2 + Captive 4 have been deliberately staggered along the *x*-axis to view them more clearly but have the same predicted cost (see Table 4). In B, the probability of persistence indicates the proportion of 10 000 simulation runs that result in tara iti extinction (less than three adult females). For both charts, 'SQ' denotes status quo productivity and Field 1 survival. Filled circles (acceptable) and open diamonds (not acceptable) indicate the alignment of each alternative with mātauranga Māori.

9. Implementation

Step 6 of the SDM process

The last step in SDM is to identify mechanisms for ongoing monitoring to ensure accountability with respect to on-the-ground results, research to improve the information base for future decisions, and review so that new information can be incorporated into future decisions.

A multi-stage management programme as discussed above would include the following steps (see Appendix 3 for a full description of the component actions):

1. **Improve management of occupied sites**: Increase predator management to the maximum practical effort for all predator species during the tara iti breeding season; extend management into winter months at breeding and wintering grounds; manage nests intensively in the field to reduce the number of eggs needing artificial incubation; maximise the number of constructed shell patches; and improve vegetation management.
2. **Continue to improve communication and co-management**: Many members of the tara iti stakeholder group expressed that they would like to continue working in this mana-enhancing way, working transparently, sharing knowledge and learning together.
3. **Seek financial investment to fulfil the actions for Field 2 + new sites**: Explore partnership options for tara iti management between DOC and the tara iti stakeholder group to identify and seek the resources needed to fully fund the restoration and management of new breeding sites.
4. **Establish and manage new (currently unoccupied) sites within the existing range of tara iti as soon as resources allow**: Restore and manage at least one former and one new breeding site, as per Field 1.
5. **Consultation**: Undertake further discussion with iwi to understand whether they might be more comfortable with the option of removing infertile males from the tara iti population.
6. **Contingent on the results of further iwi consultation, seek financial investment to fulfil Field 2 + Captive 3**: Explore partnership options for tara iti management between DOC and the tara iti stakeholder group and wider community to identify and seek the resources needed to fully fund the establishment of a captive facility and programme.

The next step is to develop a full recovery plan for tara iti along with an operational implementation plan based on the management direction recommended here. The SDM process included many of the necessary steps and components of a recovery plan, including objectives/goals and the actions needed to address these. The SDM process has also been very inclusive, directly involving many of the parties who would normally be consulted during the development of a recovery plan. The development of an operational implementation plan will also include the full economic costing of the strategy that is selected for ongoing tara iti management.

10. Acknowledgements

The authors would like to deeply thank all members of the tara iti community who contributed their precious time and knowledge to this effort with patience and kindness. Thanks also to Catherine Beard (DOC) for providing fresh eyes and useful edits to this report.

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This work is dedicated to Katie Clark, who was a wonderful person and a passionate, valued member of the tara iti community.

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Appendix 1

Process participants

Table A1.1. Participants in the tara iti structured decision-making process and working group membership, if applicable. All of those listed attended the initial workshop, unless otherwise indicated. DOC = Department of Conservation; IOZ = Institute of Zoology, Zoological Society of London; NZFT Trust = New Zealand Fairy Tern Charitable Trust.

NAME	AFFILIATION	WORKING GROUP MEMBERSHIP
Abigail Monteith*	DOC	Advocacy working group
Alex Wilson*	DOC	Wider ecosystem working group
Amelie Auge	DOC	Wider ecosystem working group
Ayla Wiles	DOC	Biological and wider ecosystem working groups
Ben de Thierry	Te Uri o Hau	
Catherine Francescon	Auckland Zoo	Biological and costings working groups
Edward Ashby	Te Uri o Hau	
Eliane Lagnaz	DOC	
Ewen Henderson	The Shorebirds Trust	
Fiona McKenzie*	Ngāti Manuhiri	Mātauranga Māori working group
Gwenda Pulham	Birds New Zealand	Biological and wider ecosystem working groups
Graeme Taylor*	DOC	Biological working group
Heather Rogan	NZFT Trust	Advocacy working group
Helen Smith	DOC	
Ian Southey	Birds New Zealand	Biological working group
Jane Vaughan	Mangawhai About Tern	
Janet Snell	NZFT Trust	Advocacy working group
Jenny Price	NZFT Trust	Costings working group
John G. Ewen	IOZ	Facilitator, supervisor to TMH
Karen Baird	Forest and Bird	Wider ecosystem working group
Katie Clark†	Te Uri o Hau	Mātauranga Māori and advocacy working groups
Kirsty Prior	DOC	
Leigh Bull	Boffa Miskell	Wider ecosystem working group
Les Judd	DOC	
Linda Guzik	The Shorebirds Trust	Advocacy working group
Louisa Gritt	DOC	
Lucy Edwards	NZ Defence Force	
Luke Connelly	Iwi representative	
Pani Gleeson	Ngāti Whatua o Kaipara	Mātauranga Māori working group
Peter Wilson	The Shorebirds Trust	Costings working group
Phil Seddon	University of Otago	
Reg Whale	Mangawhai About Tern	
Richard Gibson	Auckland Zoo	Biological working group
Richard Maloney	DOC	Biological and costings working groups
Robyn Davies	Waipu About Tern	Advocacy working group
Shannon Patterson	DOC	
Shona Oliver	Ngāti Whatua o Kaipara	Mātauranga Māori working group
Sioux Plowman	NZFT Trust	Biological working group
Stefano Canessa*	IOZ	Facilitator, supervisor to TMH
Tammy Steeves	University of Canterbury	
Thalassa McMurdo Hamilton	IOZ	Facilitator, PhD researcher

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Table A1.1 continued

NAME	AFFILIATION	WORKING GROUP MEMBERSHIP
Thelma Wilson	DOC	Wider ecosystem working group
Tony Beauchamp	DOC	Biological and wider ecosystem working groups
Tony Habraken	Birds New Zealand	Biological working group
Troy Makan	DOC	Facilitator, wider ecosystem working group

* Participant did not attend the initial workshop.

† Deceased.

Appendix 2

Influence and life cycle diagrams for tara iti / New Zealand fairy tern (*Sternula nereis davisae*)

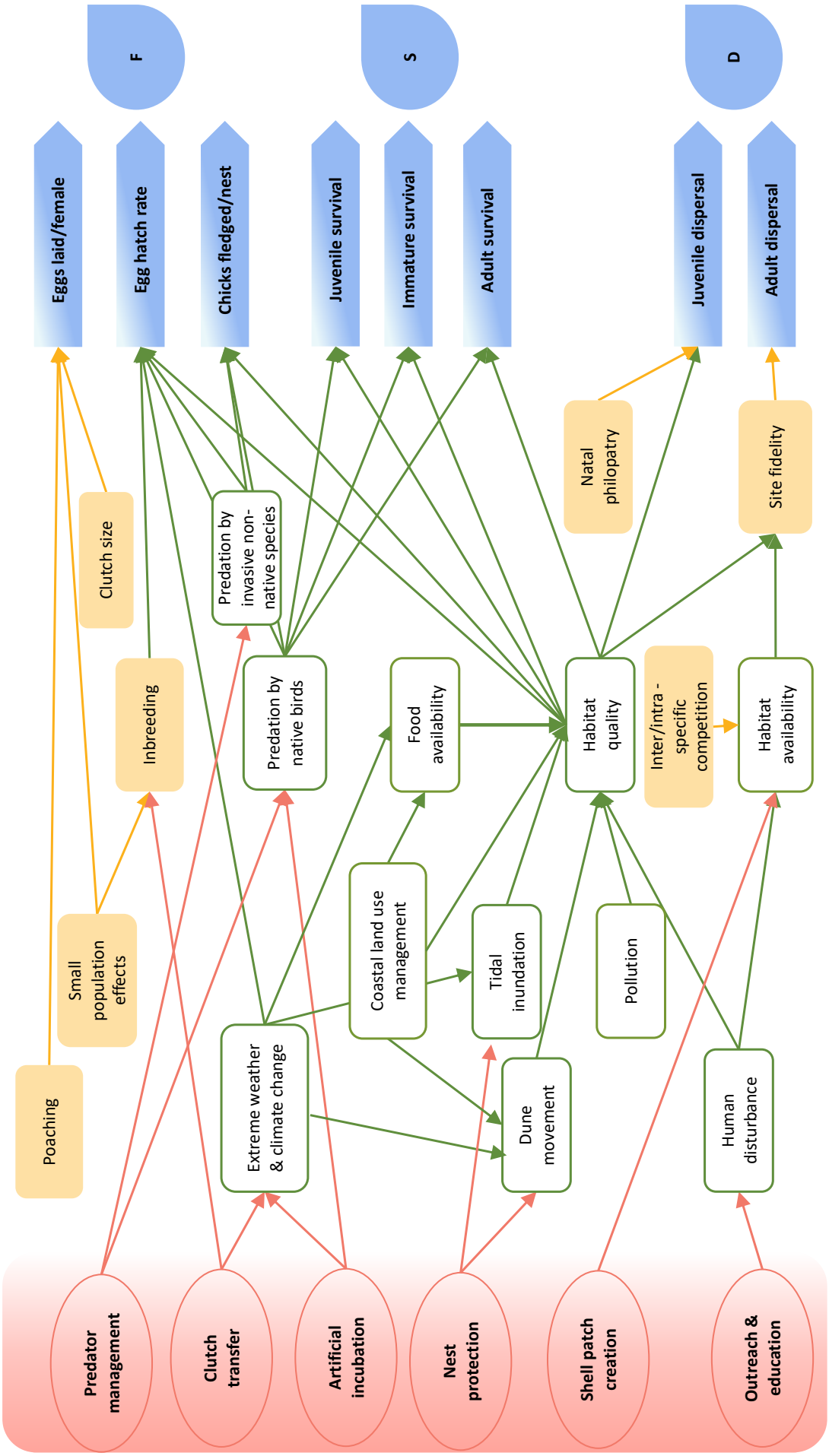
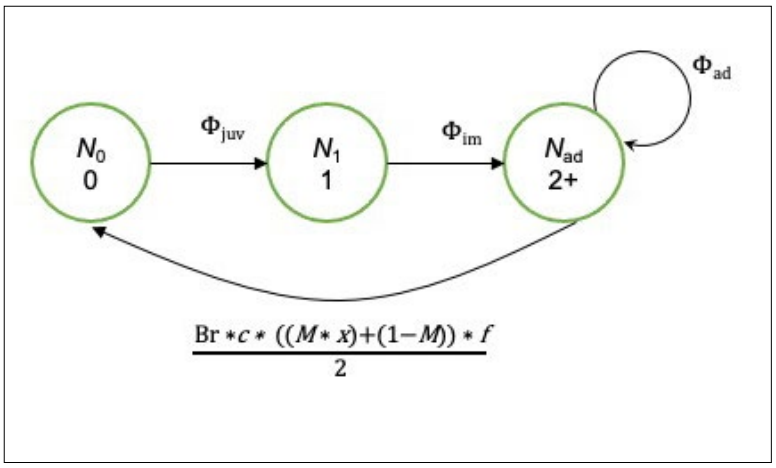


Figure A2.1. Influence diagram showing the presumed causal relationships between the status quo tara iti/New Zealand fairy tern (*Sternula nereis davisae*) management (red bubbles), extrinsic (green boxes) and intrinsic (yellow boxes) threats, and tara iti population rates (blue boxes; F = fecundity, S = survival and D = dispersal). Note that this is not a comprehensive depiction of this complex system and will necessarily have omissions.



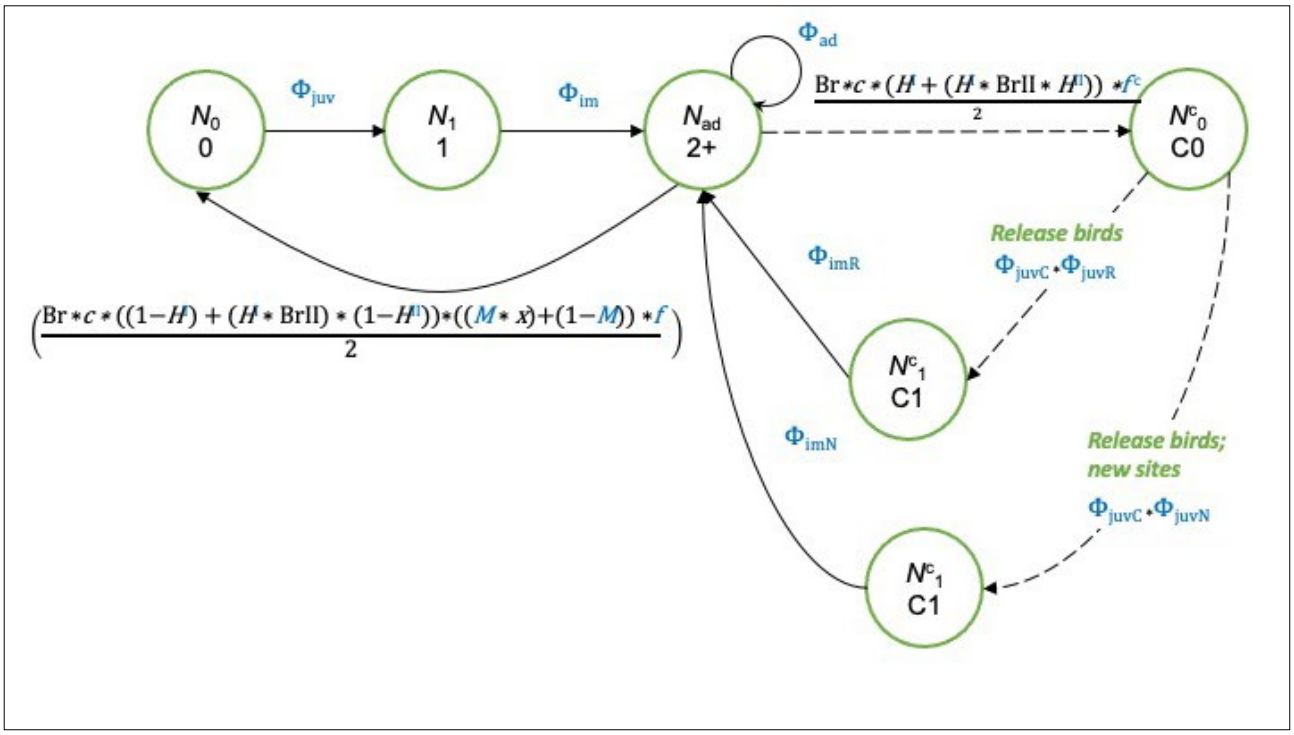


Figure A2.2. Life cycle models of the tara iti/New Zealand fairy tern (*Sternula nereis davisae*) population under A. status quo management and B. Field 2 + Captive 3 management. The models are based on females and consider a post-breeding census. See Table A2.1 for explanations of the symbols.

Table A2.1. Explanations of the symbols used in Fig. A2.2.

SYMBOL	PARAMETER
N_0	Number of fledged juveniles
N_1	Number of immatures aged 1
N_{ad}	Number of adults aged 2+
N^c_0	Number of fledged juveniles released
N^c_1	Number of immatures aged 1 released
Φ_{juv}	Survival of fledged juveniles to age 1 (immatures)
Φ_{im}	Survival of immatures to maturity at age 2
Φ_{ad}	Adult survival
Φ_{juvC}	Survival of fledged juveniles in captivity
Φ_{juvR}	Survival of released fledged juveniles to age 1 (immatures)
Φ_{imR}	Survival of released immatures to maturity at age 2
f	Fledging success (in the wild, unmanaged clutches)
f^c	Fledging success in captivity
K^I	Proportion of females laying first clutch
K^{II}	Proportion of females laying second clutch (multi-clutching)
c	Mean clutch size (fertile eggs)
M	Proportion of managed nests
x	Proportional reduction in productivity of managed eggs
Br	Proportion of females attempting to breed during first attempt
Br^{II}	Proportion of females attempting to breed during second attempt
H^I	Proportion of nests harvested during first harvest
H^{II}	Proportion of nests harvested during second harvest

Appendix 3

Alternative management strategies for tara iti / New Zealand fairy tern (*Sternula nereis davisae*)

Table A3.1. Full description of status quo management and eight alternative management strategies for tara iti/New Zealand fairy tern (*Sternula nereis davisae*). NZFT = tara iti/New Zealand fairy tern; OZFT = Australian fairy tern (*S. n nereis*); RBG = red-billed gull (*Larus novaehollandiae*); SBB = southern black-backed gull (*L. dominicanus*).

	PREDATOR MANAGEMENT			NEST PROTECTION			HABITAT MANAGEMENT			CAPTIVE MANAGEMENT AND MANIPULATION		NEW SITES AND RELEASES	
	Breeding grounds – non-native	**Breeding grounds – native**	**Wintering grounds/winter management**	**Deterrents at poor nesting locations**	**Mobile or raised nests**	**Storm egg & chick care**	**Shell patches**	**Vegetation management**	**Foraging habitat manipulation**	**Infertile males**	**Multi-clutching and harvesting**	**Release**	**New site creation**
Status quo	Trapping grids in the immediate vicinity (Waipu, Pakiri) and with a modest buffer zone (Mangawhai, Papakanui)	Targeted kāhu/swamp harrier (*Circus approximans*) control with leghold traps at all sites (high intensity); intermittent gull control with egg removal and egg pricking at Mangawhai	Nil to intermittent pindone poison control for rabbits (*Oryctolagus cuniculus*), and rats (*Rattus* spp.) as a secondary target, at Waipu and Mangawhai (low intensity); small-scale winter trapping grid in the immediate vicinity (Waipu, Pakiri), with nominal effort (Papakanui) and with a buffer zone (Mangawhai)	Intermittent use of deterrents	Raised nest trials only (Papakanui); movement of at-risk nests away from the incoming tide	Eggs incubated in flasks or taken to the zoo for incubation during storm periods	Intermittent, small patches built (Mangawhai uses dredge spoils)	Intermittent to regular spraying of shell patches and hand pulling of vegetation over winter	Intermittent pulling of mangrove seedlings; Pakiri Stream dug out if it becomes blocked	Managed as foster pairs	None	N/A	Bird Island: attempt to attract breeding birds with shell patch creation, vegetation management, decoys and playbacks, plus low-level predator control

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Table A3.1 continued

	PREDATOR MANAGEMENT			NEST PROTECTION			HABITAT MANAGEMENT			CAPTIVE MANAGEMENT AND MANIPULATION		NEW SITES AND RELEASES	
	Breeding grounds – non-native	**Breeding grounds – native**	**Wintering grounds / winter management**	**Deterrents at poor nesting locations**	**Mobile or raised nests**	**Storm egg & chick care**	**Shell patches**	**Vegetation management**	**Foraging habitat manipulation**	**Infertile males**	**Multi-clutching and harvesting**	**Release**	**New site creation**
Field 1	Maximum practical effort: all traps serviced annually, buffer zone maximised, trapping grid checked weekly throughout the breeding season (September–February); access to staff member with conservation dog for checks and treatment of any incidents	Maximum practical effort: control kāhu with leghold traps; eradicate the SBB colony at Mangawhai and the local SBB colony near Papakanui; eradicate RBG colonies at problem sites	As per status quo	Before the breeding season starts, manage all low-lying nesting locations: entirely remove shell and spread driftwood and debris over the site to make it unsuitable; if birds are prospecting in low-lying sites, disable the sites immediately before egg laying begins using the above management; at Pakiri, prioritise shell patch creation over disabling sites	If a nest is found at a high-risk location after the time that rangers are able to disable the site, immediately raise it onto a platform and photograph the original nest layout and surrounding area; place the eggs in a deep wooden square filled with sand that has carpeted, sloping sides and something inside to bind the sand; recreate the nest exactly as it appeared on the top of the platform using the photograph as a guide; at Pakiri, prioritise shell patch creation and then disable low-quality sites	**Eggs**: In a prolonged storm, place the eggs in an incubator on site (not a flask) and replace with dummy eggs **Chicks**: One extra staff member is needed if monitoring overnight; observe the feeding rates of the chicks and if they are below what is expected: • 1st level intensity: place out trays of fresh fish where chicks are sheltering • 2nd level intensity: place chicks in a sterilised incubator at the correct temperature and feed fresh fish for a maximum holding time of 4–8 hours; chicks are then returned to the original place, under shelter; hold the chicks until they are calm to lower the risk that they will run away	Maximise the number of higher quality, stable shell patches of an appropriate size (including at Mangawhai): • Small patches = 2 tonnes of shell; medium patches = 3–4 tonnes of shell • Small/ medium patches = 10 m x 5 m or 10 m x 10 m; large patches = 100 m long Source external shell and cover with local shell; have a minimum of 3 small patches at Pakiri; 9 medium patches at Waipu; and 15 medium or large patches (or equivalent area) at Papakanui	**All sites**: Spray / hand pull weeds and maintain shell patches annually **Waipu**: Manage revegetation of the spit so that the maximum number of shell patches can be created **Mangawhai**: Cease the planting of pīngao (*Desmoschoenus spiralis*); reduce planting of spinifex (*Spinifex sericeus*) to solely outside breeding areas; remove vegetation from the southern part of the spit where it is providing cover to predators **Pakiri**: Manage pīngao mounds **Papakanui**: Add vegetation for stabilisation where needed	As per status quo	As per status quo	As per status quo	N/A	As per status quo

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Table A3.1 continued

	PREDATOR MANAGEMENT			NEST PROTECTION			HABITAT MANAGEMENT			CAPTIVE MANAGEMENT AND MANIPULATION		NEW SITES AND RELEASES	
	Breeding grounds – non-native	**Breeding grounds – native**	**Wintering grounds/winter management**	**Deterrents at poor nesting locations**	**Mobile or raised nests**	**Storm egg & chick care**	**Shell patches**	**Vegetation management**	**Foraging habitat manipulation**	**Infertile males**	**Multi-clutching and harvesting**	**Release**	**New site creation**
Field 2	As per Field 1	As per Field 1	Control rabbits with poisoning (pindone) and shooting at Waipu and Mangawhai; continue to monitor trapping grids at all breeding sites every 3 weeks through winter; control predators at two major winter roosting sites at Kaipara with a trapping grid every 3 weeks	As per Field 1	As per Field 1	As per Field 1	As per Field 1	As per Field 1 + heavily manage all pīngao during pindone use	Hand pull mangrove seedlings (Pakiri, Mangawhai, Waipu, Waionui Inlet, Papakanui); undertake riparian planting on the west side of Waipu estuary, Pakiri and Mangawhai	As per status quo	As per status quo	N/A	As per status quo
Field 1 + Captive 1	As per Field 1	As per Field 1	As per status quo (+ control around aviary)	As per Field 1	As per Field 1	As per Field 1	As per Field 1	As per Field 1	As per Field 1	As per status quo	Harvest the first clutch from good pairs (minimum five clutches per season) at between 6 and 18 days incubation; put the lifted eggs in an incubator and transport to a purpose-built aviary with fulltime staff; hatch and give access to the aviary; move into the flight aviary with behavioural training	Release birds from the flight aviary as a cohort at 3–9 months; provide supplementary food at the aviary until it is no longer being taken; continue annually for 10 years	As per status quo

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Table A3.1 continued

	PREDATOR MANAGEMENT			NEST PROTECTION			HABITAT MANAGEMENT			CAPTIVE MANAGEMENT AND MANIPULATION		NEW SITES AND RELEASES	
	Breeding grounds – non-native	**Breeding grounds – native**	**Wintering grounds/winter management**	**Deterrents at poor nesting locations**	**Mobile or raised nests**	**Storm egg & chick care**	**Shell patches**	**Vegetation management**	**Foraging habitat manipulation**	**Infertile males**	**Multi-clutching and harvesting**	**Release**	**New site creation**
Field 1 + Captive 2	As per Field 1	As per Field 1	As per status quo	As per Field 1	As per Field 1	As per Field 1	As per Field 1	As per Field 1	As per Field 1	Capture all infertile males when appropriate and bring them into captivity to live in a purpose-built flight aviary	As per Captive 1	As per Captive 1	As per status quo
Field 2 + Captive 3	As per Field 2	As per Field 2	As per Field 2	As per Field 2	As per Field 2	As per Field 2	As per Field 2	As per Field 2	As per Field 2	As per Captive 2	As per Captive 1 + harvest the second clutch from selected pairs (1–2 pairs per season?)	As per Captive 1 + relocate all birds in the aviary/flight aviary to a new site and release from there once new sites have been restored (5 years); provide supplementary feeding as before; annual for 5 years	Restore one former breeding site (e.g. Ruakaka) and create one new breeding site (e.g. Great Barrier Island (Aotea Island)) over 5 years; add predator management and habitat management as per Field 1, plus staff
Field 2 + new sites	As per Field 1	As per Field 1	As per Field 2	As per Field 1	As per Field 1	As per Field 1	As per Field 1	As per Field 1 + heavily manage all pīngao during pindone use	As per Field 2	As per status quo	As per status quo	N/A	Restore one former breeding site (e.g. Ruakaka) and create one new breeding site (e.g. Great Barrier Island (Aotea Island)) over 5 years; add predator management and habitat management as per Field 1, plus staff

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Table A3.1 continued

	PREDATOR MANAGEMENT			NEST PROTECTION			HABITAT MANAGEMENT			CAPTIVE MANAGEMENT AND MANIPULATION		NEW SITES AND RELEASES	
	Breeding grounds – non-native	**Breeding grounds – native**	**Wintering grounds / winter management**	**Deterrents at poor nesting locations**	**Mobile or raised nests**	**Storm egg & chick care**	**Shell patches**	**Vegetation management**	**Foraging habitat manipulation**	**Infertile males**	**Multi-clutching and harvesting**	**Release**	**New site creation**
Field 2 + Captive 3 + keep infertile males	As per Field 2	As per Field 2	As per Field 2	As per Field 2	As per Field 2	As per Field 2	As per Field 2	As per Field 2	As per Field 2	As per status quo	As per Captive 1+ harvest a second clutch from selected pairs (1–2 pairs per season?)	As per Captive 1 + relocate all birds in the aviary / flight aviary to a new site and release from there once new sites are restored (5 years); provide supplementary feeding as before; annual for 5 years	Restore one former breeding site (e.g. Ruakaka) and create one new breeding site (e.g. Great Barrier Island (Aotea Island)) over 5 years; add predator management and habitat management as per Field 1, plus staff
Field 2 + OZFT supp.	As per Field 2	As per Field 2	As per Field 2	As per Field 2	As per Field 2	As per Field 2	As per Field 2	As per Field 2	As per Field 2	As per status quo + give foster pairs without NZFT eggs to foster two OZFT eggs instead	Candle clutches and swap any infertile eggs with OZFT eggs, bringing the clutch size to two (viable) eggs; supplement single-egg clutches with one OZFT egg	N/A	As per status quo

Appendix 4

Parameter tables for tara iti / New Zealand fairy tern (*Sternula nereis davisae*) population models

Table A4.1. Parameters used in the population models derived from empirical data. CI = confidence interval.

PARAMETER/STATISTIC	LOWER 95% CI	ESTIMATE	UPPER 95% CI
Annual juvenile survival (age 0–1 years)	0.55	0.81	0.93
Annual immature survival (age 1–2 years)	0.68	0.93	0.99
Annual adult survival (age 2+ years)	0.86	0.92	0.95
Probability of an unmanaged egg hatching	0.68	0.81	0.89
Probability of a managed egg hatching	0.45	0.60	0.74
Probability of an unmanaged (as egg) chick fledging	0.52	0.70	0.84
Probability of a managed (as egg) chick fledging	0.23	0.44	0.64
Mean clutch size (all breeding attempts)	1.68	1.73	1.78
Proportion of females aged 2+ attempting to breed* (2007–2017)	0.64	0.72	0.80
Proportion of nests managed† (2007–2017)	0.41	0.55	0.69
Egg fertility rate		0.68	
Proportion of females that lay again after the egg or chick in their first clutch failed		0.52	

* Attempting to breed is defined as laying eggs.

† Nest management is defined as shifting the nest, the use of dummy eggs, the artificial incubation of eggs or the transfer of eggs for fostering (i.e. any movement of the eggs).

Table A4.2. Elicited parameter values used in the population models. Mean estimates are the means of individual estimates from ten biological experts. Abbreviation: OZFT, Australian fairy tern (*Sternula nereis nereis*).

PARAMETER	MEAN OF INDIVIDUAL MINIMUM ESTIMATE	MEAN MOST LIKELY ESTIMATE	MEAN MAXIMUM ESTIMATE
Annual juvenile survival			
Field 1 (age 0–1 years)	0.53	0.82	0.94
Field 2	0.56	0.86	0.96
In captivity	0.67	0.87	0.95
Captive-reared birds released at new sites	0.30	0.53	0.76
Captive-reared birds released at occupied sites	0.36	0.63	0.86
OZFT	0.48	0.82	0.91
Immature survival			
Field 1	0.66	0.91	0.98
Field 2	0.64	0.93	0.98
Captive-reared birds released at new sites	0.47	0.73	0.84
Captive-reared birds released at occupied sites	0.47	0.71	0.81
Adult survival			
Field 1	0.83	0.91	0.95
Field 2	0.85	0.92	0.95

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Table A4.2 continued

PARAMETER	MEAN OF INDIVIDUAL MINIMUM ESTIMATE	MEAN MOST LIKELY ESTIMATE	MEAN MAXIMUM ESTIMATE
Probability of an unmanaged egg hatching			
Field 1	0.7	0.87	0.94
Field 2	0.71	0.89	0.96
Captive	0.73	0.89	0.95
OZFT egg	0.40	0.59	0.70
Probability of an unmanaged (as egg) chick fledging			
Field 1	0.63	0.8	0.90
Field 2	0.66	0.83	0.92
Probability of a chick fledging			
Captive	0.66	0.84	0.94
OZFT chick	0.53	0.66	0.73
Clutch size			
Field 2, all breeding attempts	1.70	1.79	1.89
Proportion of females aged 2+ attempting to breed*			
Field 1	0.64	0.74	0.78
Field 2	0.64	0.77	0.83
Field 2 + Captive 3	0.48	0.67	0.76
Proportion of nests managed†			
All alternatives	0.10	0.31	0.59
Number of territories in breeding sites			
Field 1	5.33	15.68	20.09
Field 2	6.27	16.32	21.77
Field 2 + two new sites	7.56	21.40	28.87
Probability that territories will be unlocked‡ inside the range§			
Adult dispersers without a territory	0.36	0.59	0.79
Wild/captive recruits released inside the range	0.34	0.56	0.74
Probability that territories will be unlocked outside the range¶			
Captive recruits released outside the range	0.1	0.39	0.6
Adult dispersers without a territory	0.04	0.2	0.37
Wild/captive recruits released inside the range	0.06	0.22	0.39

* Attempting to breed is defined as laying eggs.

† Nest management is defined as shifting the nest, the use of dummy eggs, the artificial incubation of eggs or the transfer of eggs for fostering (i.e. any movement of the eggs).

‡ Territory unlocking is defined as a bird pairing and breeding in an empty, previously unavailable territory.

§ Inside the range is defined as current breeding sites or new breeding sites in areas where birds in the living population have been seen but have not bred in the past 15 years.

¶ Outside the range is defined as new breeding sites in areas where birds in the living population have not been seen in the past 15 years.

Appendix 5

Advocacy working group notes

The following notes were taken during the tara iti / New Zealand fairy tern (*Sternula nereis davisae*) Advocacy Expert Working Group day on 9 April 2019 in Warkworth.

The facilitators decided to approach this over three stages:

1. **Summary of process:**

   The facilitators gave a quick summary of the structured decision-making (SDM) process so far, recapping the process, objectives, development of strategies and identification of working groups. This was followed by a description of what happens next and how the different futures (based on each strategy) would be compared to make the best possible decision. Finally, the advocacy objective was reviewed as currently worded.

2. **How to address the advocacy objective:**

   The facilitators first clarified whether advocacy was a fundamental and/or means objective. It was quickly agreed that the objective was fundamental although elements could also be treated as means (e.g. to generate money).

   Given it was fundamental, the facilitators then probed a little to understand whether there were competing alternatives that the group would need to decide between, or if there was a smorgasbord of options that would build into a single alternative that would not vary across the current tara-iti management strategies. The group was unanimous in deciding that there was only one advocacy alternative built from many component actions and that this would be the same across all alternative management strategies.

   To conclude, the advocacy expert working group recognised that advocacy was critically important but, in the context of this decision problem, would not weigh into the selection of a particular management strategy.

3. **Brainstorming ideas/thoughts:**

   The facilitators wanted to know more about expert views in this space and to get the experts to come together collaboratively to determine what an advocacy package would look like. This was fun and interesting, and the group bonded really well, with it quickly becoming clear that there were shared visions, target audiences and frustrations.

   The facilitators used a brainstorming tool to obtain people's thoughts. Participants first worked independently on paper and then the facilitators went around the room repeatedly until all ideas were exhausted. This represented a first attempt at generating information that a working group could use to build an advocacy package for tara iti.

   The areas that were brainstormed included:

   i) Tools

      a) Volunteers

      b) Website / social media / traditional media (good and bad narratives)

      c) Tara iti rangers

      d) Bird of the Year

      e) Compliance, signage and court action when habitat is threatened

      f) Education (school, community and local groups (e.g. Zonta?))

g) Web cameras (current), live feeds and videos (desired)

h) Business support and sponsorship (Bennett's, key industries, Endangered Species Foundation)

i) Trust activities (website, Facebook, newsletter, Mangawhai Museum, calendar)

j) Ambassadors, celebrities and television (desired)

k) Teaching packs, posters and resources for schools/libraries (desired)

l) Pop-up event kits, A&P show stands, competitions, tara iti costume for parades, national day (desired)

ii) Audiences

a) Children (and their parents)

b) Local residents using the beaches and those who are affected by the areas they are not allowed to access

c) Bird lovers and bird watchers

d) General New Zealand public and New Zealanders who visit the beaches as tourists from elsewhere

e) Teachers

f) Tourists/trampers/walkers

g) International tourists

h) Conservationists (e.g. Forest & Bird, conservation-minded people)

i) Boaties / surfers / kite surfers

j) Government agencies and politicians who can influence activity in areas adjacent to breeding and wintering sites

k) Iwi

l) Volunteers / Trusts / Department of Conservation (DOC)

m) House buyers

n) Youth (teenagers?)

o) Tourism industry

iii) Messages

a) We are confident we can save tara iti

b) We can all do a little to make a huge difference in the survival of the subspecies; no one must make a huge sacrifice – putting yourself out a tiny bit will make a big contribution to tara iti; we are part of the problem and the solution

c) Helping tara iti will help protect other endangered shorebirds too

d) Tara iti is Aotearoa New Zealand's most endangered bird (numbers/locations)

e) Biology (e.g. interesting sex life, chicks, parental care, diet, appearance, fun facts)

f) Distinctiveness of tara iti

g) Tara iti are great, nurturing parents

h) Tara iti are reliant on an abundant fish supply in the local harbour and oceans (and clean water); females and chicks need a lot of feeding at key points (e.g. laying)

i) Status and updates

j) Science-based evidence, population biology

k) Why tara iti is so endangered (e.g. predators, vulnerability to disturbance, storms)

l) Climate change impacts / vulnerability

m) Why eggs get moved / shell patches / trapping programmes (including avian predators)

n) Tara iti ranger and volunteer information, monitoring, what they do to help protect nests

o) What we are doing to help / approved strategies / how each initiative helps

p) How you can help / what resources are needed and why

q) Successes (project?) (e.g. recovery group in place)

r) How the wildlife reserve (?) protection helps

s) Use of the slogan 'It's our tern'

iv) Constraints and sensitivities

a) Population size – nervous to share numbers without certainty

b) Genetics of the population and its impacts (e.g. level of inbreeding – feel unqualified to talk about it)

c) Existing bad attitudes towards tara iti and reserves because locals cannot use them as they want (e.g. exercising dogs, kite boarding, drones, helicopters); necessary restrictions irk residents

d) Some locals have the attitude that there are 'already so few birds so it is a waste of time and money'

e) So many species are becoming endangered/extinct that it just seems like 'one more'; people do not feel that it is important because they are 'punch drunk'

f) Nest locations

g) Information coming back from sites freely, lack of information from DOC, facts incorrect

h) Lack of a plan

i) Science or technical spokesperson (needed?)

j) Lack of images and video

k) Sensitivity about nest control (e.g. harriers (*Circus approximans*), cats (*Felis catus*))

l) Mangrove removal is popular with locals; they do not believe it will affect tara iti survival

m) Communication and collaboration on key issues by all (stakeholder?) groups

A few general thoughts also came through in general discussion:

- **Audience**: In general, the audience was grouped as local, national and global. However, Linda Guzik (The Shorebirds Trust) raised a good point that this should also include internal, as work is needed to improve communication and messaging within DOC and among the tara iti partners.
- **Package**: In developing a package, it would be good to draw on other DOC examples. These can be collated and shared.

- **Compliance**: While compliance was mentioned, it was not delved into beyond court appearances being part of the audiences engaged with and concern about other beach users being unfriendly in response to compliance-related information.
- **Position statements**: These may be needed/requested on some issues where tara iti can be brought into environmental arguments. One example is mangrove management. A recovery group recommendation on position would help to unify and clarify the latest evidence for any relationship with tara iti. Position statements could be very useful going forward.
- **Limited information**: Limited access to knowledge and uncertainty around the ability to share it lead to concern about the accuracy of information. This was strongly felt from within DOC and among the external partners. Therefore, having a big push on good collaboration, knowledge sharing and understanding of sensitivities would be a huge step forward. Everybody was keen and ready and there was not a single disagreement expressed in the room. In fact, perhaps the opposite – there was a sense of things happening and moving in the right direction.
- **Giving people a voice**: To ramp up tara iti recovery, all the partners need a voice, as accurate information as possible to share and clarity on the ground rules that allow them to confidently do this. These groups have some major capacity to be able to do this, which is rarely the case for threatened species.