Conservation Biology

Diversity

Restoring islands and identifying source populations for introductions

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Introduction

Conservation introductions, the intentional movement of species' outside their natural range to achieve a conservation goal (Seddon et al. 2014), are becoming an increasingly relevant strategy to help restore, maintain, and protect biodiversity in a changing world. Most conservation introductions focus on a target species, often at risk of extinction, and identify habitat for introduction. We consider a novel, inverse scenario in which a species endemic to an island has gone extinct, and the drivers of its extinction has been removed, creating habitat into which a population of a closely related species could be introduced. Island species are among the most threatened taxa globally, and this proactive conservation approach may not only benefit the island's ecosystems and values, but also provide an additional insurance population for the source species.

Where an extinct species has multiple closely related extant species, a decision must be made about which source population to consider for a conservation introduction. We undertook a structured decision-making process to identify an optimal source population.

Case Study

Macquarie Island, a sub-Antarctic World Heritage Site and UNESCO Biosphere Reserve, has recently undergone a major conservation restoration. Invasion by several vertebrates, including rats, Weka (*Gallirallus australis*), mice, rabbits, and cats, has caused devastating ecological impacts and triggered extinctions, vegetation degradation, and predation on native species (Copson & Whinam 2001). Cat eradication was declared a success in 2002 (Robinson & Copson 2014). An AU$24.8 million program was implemented to eradicate rabbits, rats, and mice (Springer 2016) and declared successful in 2014. The island is now officially free of invasive mammals.

Introduced vertebrate pests drove 2 native species to extinction: the Macquarie Island Red-crowned Parakeet (*Cyanoramphus (novaezelandiae) erythrotis*) and the Macquarie Island Buff-banded Rail (*Gallirallus philippensis macquariensis*). The only extant native terrestrial vertebrate remaining on the island is a migratory duck (*Anas superciliosa*), which is restricted to coastal marshes. Very little is known about the extinct rail and its relatedness to other species, but more is known about the parakeet. It was "plentiful all over the island" in the late 1800s (Hamilton 1894), providing an abundant food source for stranded sailors (Thomson 1912), and much is known about the molecular systematics of the genus *Cyanoramphus* (Boon et al. 2001).

Given the success of vertebrate pest eradication on Macquarie Island, management discussions are focusing on further restoration projects, including bringing one of the extant parakeet species to Macquarie Island. There have been at least 10 successful reintroductions and several introductions of Red-crowned Parakeets in New Zealand (Ortiz-Catedral & Brunton 2009, 2010; Miskelly & Powlesland 2013). Natural recolonization is unlikely to happen on Macquarie Island in the foreseeable future given its extreme isolation and that there have been no records of vagrant parakeets since the extinction of the Macquarie birds (Copson & Brothers 2008).

We considered which of the extant island populations of Red-crowned Parakeet would be best suited to a conservation introduction to Macquarie Island, and

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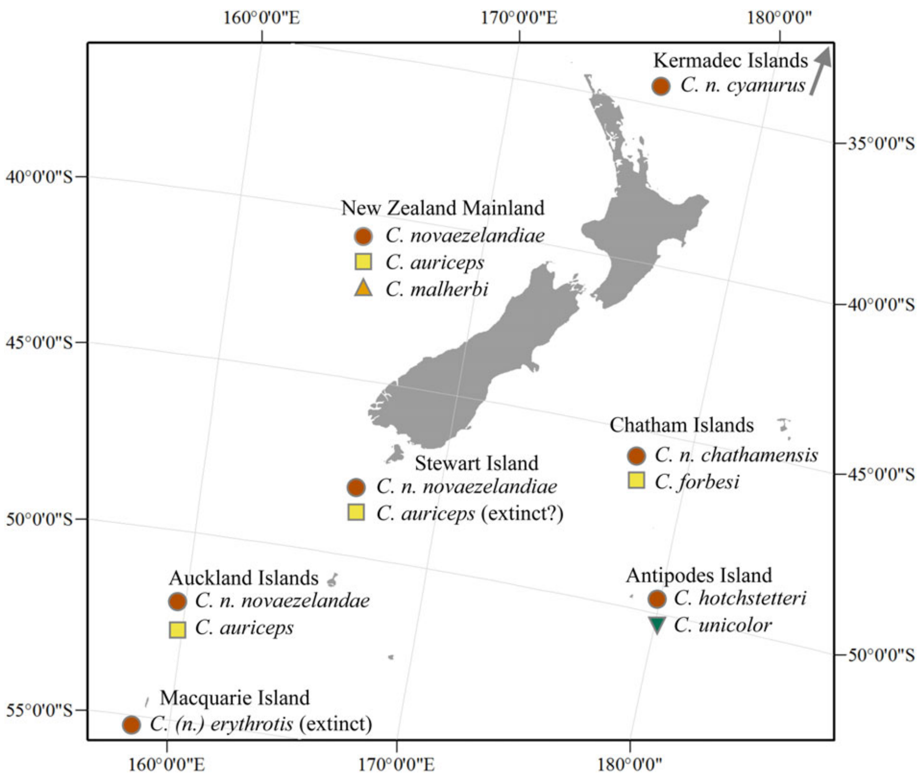

Figure 1. New Zealand and surrounding islands showing populations and clades of Cyanoramphus *parakeets (circle, Red-crowned, type species* C. novaezelandiae*; square, Yellow-crowned, type species* C. auriceps*; triangle, Orange-fronted [*C. malherbi*]; inverted triangle, Antipodes Parakeet [*C. unicolor*]). The Kermadec Islands are approximately 1000 km northeast of New Zealand.*

undertook structured decision making to identify a source population. Decision support frameworks are becoming widely used in conservation (Possingham et al. 2001; Rout et al. 2013). We used a systematic 4-step process: 1, identified the suite of potential source populations; 2, identified attributes that can be used to choose among the possible source populations; 3, weighted these attributes according to which are likely to be the most important to source population survival; and 4, ranked the suitability of the sources by summing the attribute values by the attribute weights for each. We used a modified analytic hierarchy process (Saaty 1977) to conduct weighting and ranking. Full mathematical details of our methods and a step-by-step example are given in Supporting Information.

Most suitable indicates which source is most suitable relative to the others. This then allows management to focus on a single species for further assessment of diet, physiological constraints, habitat, behavioral requirements, and impact to source population and recipient ecosystem (IUCN/SSC 2013).

Identifying Potential Source Populations

Cyanoramphus parakeets are naturally distributed throughout New Zealand and on many offshore and sub-Antarctic islands (Fig. 1). They are separated into clades based on crown color, and the extinct Macquarie Island Parakeet belongs to the Red-crowned clade (type species *C. novaezelandiae*). Although once abundant, multiple pressures have led to the presumed extinction of *C. novaezelandiae* from mainland New Zealand. The remaining populations persisting on offshore islands are near threatened and declining (BirdLife International 2014) (Fig. 1, circles). Four of these populations occur on islands that are geographically close or environmentally similar to Macquarie Island: *C. novaezelandiae chathamensis* on the Chatham Islands, *C. n. novaezelandiae* on the Auckland Islands and Stewart Island, and *C. hochstetteri* (Reischek's Parakeet) on Antipodes Island. All 4 are range restricted, globally threatened, or both.

Identifying and Weighting Attributes

We assessed 6 attributes (Fig. 2 & Supporting Information) that compare the habitat of each source species to Macquarie Island, based on data that were available. To weight the relative importance of attributes, we ran 6 analysis iterations. In each, we chose one attribute, weighted it as x times more important than the others, combined attribute values with these weights, and determined which source population was most suitable. We then repeated the process for values of x of 2, 4, 6, and 8.

Ranking Populations

Regardless of which attribute was heavily weighted, Reischek's Parakeet from Antipodes Island consistently outperformed the others in almost all cases (Fig. 2),

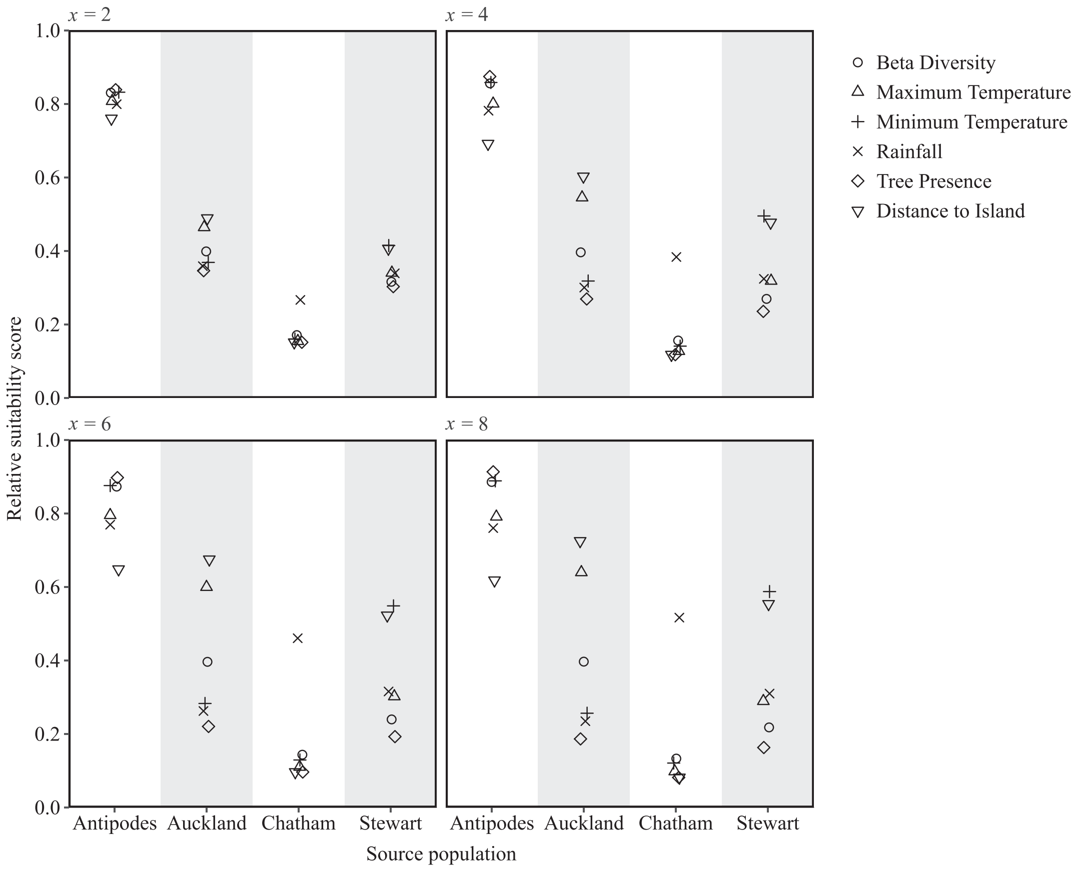

Figure 2. Relative suitability scores of 4 potential source populations of Cyanoramphus *spp. parakeets being considered for a conservation introduction to Macquarie Island. The higher the score, the greater the suitability for translocation between that source and Macquarie Island, relative to the other sources. Symbols indicate which attribute was weighted as x times (2, 4, 6, or 8) more important in that iteration.*

suggesting that it is the best source population to consider for a conservation introduction to Macquarie Island. Only when distance to island was weighted as ≥6 times more important than other attributes did the Auckland Island Parakeet outperform it.

Potential Conservation Benefits

Antipodes Island is very small (22 km^2, cf. Macquarie Island, 127.8 km^2), as such Reischek's Parakeet is particularly vulnerable to stochastic effects or accidental introduction of a predator and could benefit from the establishment of an insurance population. And while the exact functional role of the extinct Macquarie Island Parakeet cannot now be properly understood, Red-crowned Parakeets forage on seeds and berries (Elliott et al. 2015) and may contribute to plant propagule dispersal, especially in the light of recent research indicating that the role of parrots as seed dispersers has been widely overlooked (Young et al. 2012; Tella et al. 2015).

It could be argued a difference in selection pressures could drive the introduced population of parakeets to become genetically differentiated from their source, undermining the extent to which the conservation introduction is creating a genuine insurance population. Yet we believe the benefit of creating a new self-sustaining wild population, rather than a captive one, outweighs this risk because it enhances the retention of wild behaviors. Using empty islands to protect vulnerable species is not without precedent (e.g., Morrison et al. 2011; Freifeld et al. 2016), and given the changing state of Earth's climate and biodiversity loss, such proactive management is key to future conservation efforts (Thomas 2011).

Reischek's Parakeet survived well in captivity during the recent mouse eradication, and the immediate impact on the source population of keeping these captive individuals did not appear to be severe (Elliott et al. 2015). It is important to consider the impact of harvesting on source birds and the structure of the founder group; fortunately, there are many precedents and established protocols for this (e.g., Ortiz-Catedral & Brunton 2010; Collen et al. 2014). Most plant species consumed by Reischek's Parakeets (Greene 1999; Elliott et al. 2015) are also present on Macquarie Island (Shaw et al. 2010), and given

Red-crowned Parakeets are adaptable with a varied diet (Higgins 1999), their dietary needs are likely to be met.

Our simple structured decision framework for the initial evaluation of a source population for a conservation introduction following extinction is a precursor to an intensive analysis of suitability. It allows one to narrow down how to choose a species for an introduction to an island where a closely related species has gone extinct. As eradication of invasive species on islands increase worldwide, opportunities for proactive, restorative conservation are going to become increasingly commonplace, and our method provides structure and guidance to the first step in the process.

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Supporting Information

A detailed description of methods (Appendix S1) and the analytic hierarchy process, including a step-by-step example (Appendix S2), are available online. The authors are solely responsible for the content and functionality of these materials. Queries (other than absence of the material) should be directed to the corresponding author.

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