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Restoring islands while protecting species: identifying source populations for conservation introductions

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Abstract:	

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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. Here, we present a novel, inverse scenario where an island-endemic species has gone extinct, and the drivers of extinction have now been removed, creating available 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 might benefit not only 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. Here we undertake 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 a number of vertebrates including rats, weka, mice, rabbits, and cats has caused devastating ecological impacts, triggering extinctions, degrading vegetation, and predating on native species (Copson & Whinam 2001). Cat eradication was declared a success in 2002 (Robinson & Copson 2014) and in recent years, an AUD$24.8 million program was implemented to eradicate rabbits, rats and mice (Springer 2016). These efforts were declared successful in 2014 and the island is now officially free of invasive mammals.

Introduced vertebrate pests drove two 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*) 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 (Scott, in 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 ten successful reintroductions and several introductions of red-crowned parakeets in New Zealand (Ortiz-Catedral & Bunton 2009; 2010; Miskelly & Powlesland 2013). Natural recolonisation is unlikely to happen on Macquarie Island in the foreseeable future given its extreme isolation and there have been no records of vagrant parakeets since the extinction of the Macquarie birds (Copson & Brothers 2008).

Here we consider which of the extant island populations of red-crowned parakeet would be best suited to a conservation introduction to Macquarie Island, and undertake structured decision-making to identify a source population. Decision support frameworks are becoming widely used in conservation biology (Possingham et al. 2001; Rout et al. 2013) to tackle conservation problems. Here we present a systematic four-step process: 1) identify the suite of potential source populations; 2) identify attributes that can be used to choose among the possible source populations; 3) weight these attributes according to which are likely to be most important to source population survival; and 4) rank 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, see supplementary methods for full mathematical details and a step by step example.

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

Step 1: Identify Potential Source Populations

Cyanoramphus parakeets are naturally distributed throughout New Zealand and on many offshore and sub-Antarctic islands (Fig. 1). They are distinguished into clades based on crown colour, 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, and the remaining populations persisting on offshore islands are listed as Near Threatened and declining (BirdLife International 2014). Four of these taxa are geographically close to Macquarie Island (red points, Fig 1, excepting the Kermadec Islands). These are *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 four are range-restricted and/or globally threatened.

Steps 2 and 3: Identify and weight attributes

We assessed six attributes (see Fig. 2 & supplementary methods) considering the habitat similarity of each source to Macquarie Island, chosen by using key ecological attributes for which data were available. To weight the relative importance of attributes, we ran six 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.

Step 4: Rank Populations

Regardless of which attribute was heavily weighted, Reischek's parakeet *Cyanoramphus hochstetteri* from Antipodes Island consistently outperformed the others in almost all cases (Fig 2), suggesting it is the best source population to consider for a conservation introduction to Macquarie Island. Indeed, Reischek's parakeet was identified as a sister taxon to the Macquarie Island parakeet by Boon et al. (2001). Only when distance to island was weighted as six or more times more important than other attributes did the Auckland Islands outperform it.

Potential conservation benefits

Antipodes Island is very small (22km^2, cf. Macquarie Island, 127.8km^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 might possibly contribute to plant propagule dispersal, especially in the light of recent research indicating the role of parrots as seed dispersers has been widely overlooked (Tella et al. 2015; Young et al. 2012).

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, enhancing the retention of wild behaviours. Using 'empty' islands to protect vulnerable species is not without precedent (Morrison et al. 2011; Freifeld et al. 2016) and given the changing state of the 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 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 & Bunton 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.

We have presented a simple structured decision framework for initial evaluation of a source population for conservation introductions. Our analysis provides a first step at informing management by narrowing down how to choose a species for conservation introduction following extinction, as a precursor to an intensive analysis of suitability. As island eradications increase worldwide, such opportunities for proactive, restorative conservation are going to become increasingly commonplace, and this paper gives structure and guidance to the first step in the process.

Supporting Information

A detailed description of methods and the Analytic Hierarchy Process, including a step by step example, 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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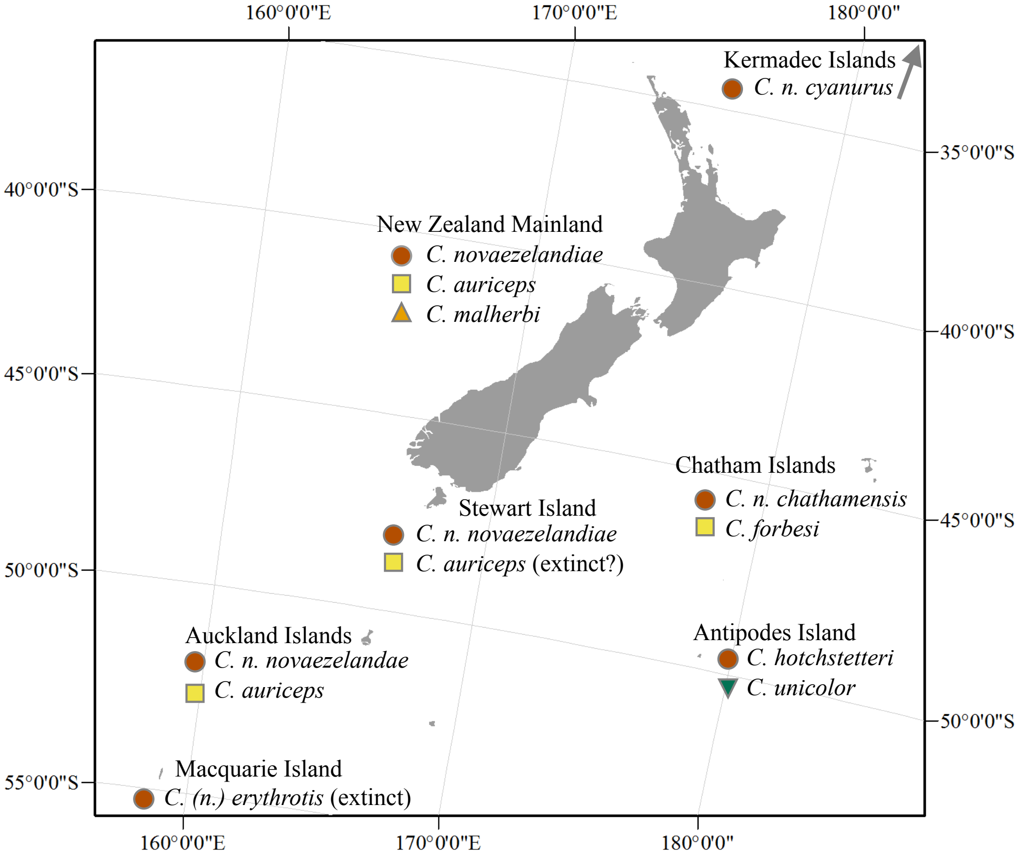
Figure Captions:

Figure 1. Map of New Zealand and surrounding islands, with populations and clades of *Cyanoramphus* parakeets. Symbols indicate which *Cyanoramphus* clade the species belongs to: circle = red-crowned, type species: *C. novaezelandiae*; square = yellow-crowned, type species: *C. auriceps*; triangle = orange-fronted, *C. malherbi*; and inverted triangle = Antipodes Parakeet, *C. unicolor*. The Kermadec Islands are ~1000km NE of New Zealand.

Figure 2. Relative suitability scores of four potential source populations of *Cyanoramphus spp.* parakeets being considered for a conservation introduction to Macquarie Island. A higher score indicates greater suitability of translocation between that source and Macquarie Island, relative to the other sources. Shape of the point indicates which attribute was weighted as *x* times more important in that iteration. Shown for four values of *x*: 2, 4, 6 and 8.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New Zealand Mainland
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C. auriceps
C. malherbi
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Chatham Islands
C. n. chathamensis
C. forbesi
Stewart Island
C. n. novaezelandiae
C. auriceps (extinct?)
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Auckland Islands
C. n. novaezelandae
C. auriceps
Antipodes Island
C. hotchstetteri
C. unicolor
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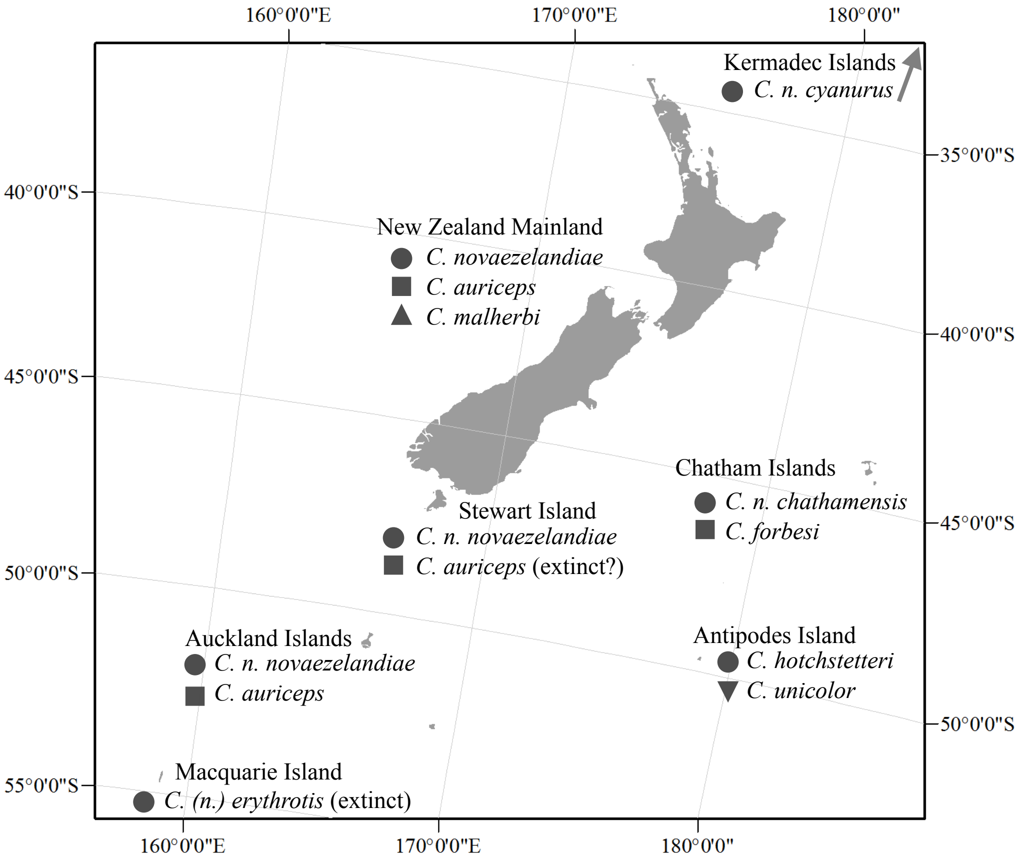
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Stewart Island
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Auckland Islands
C. n. novaezelandiae
C. auriceps
Antipodes Island
C. hotchstetteri
C. unicolor
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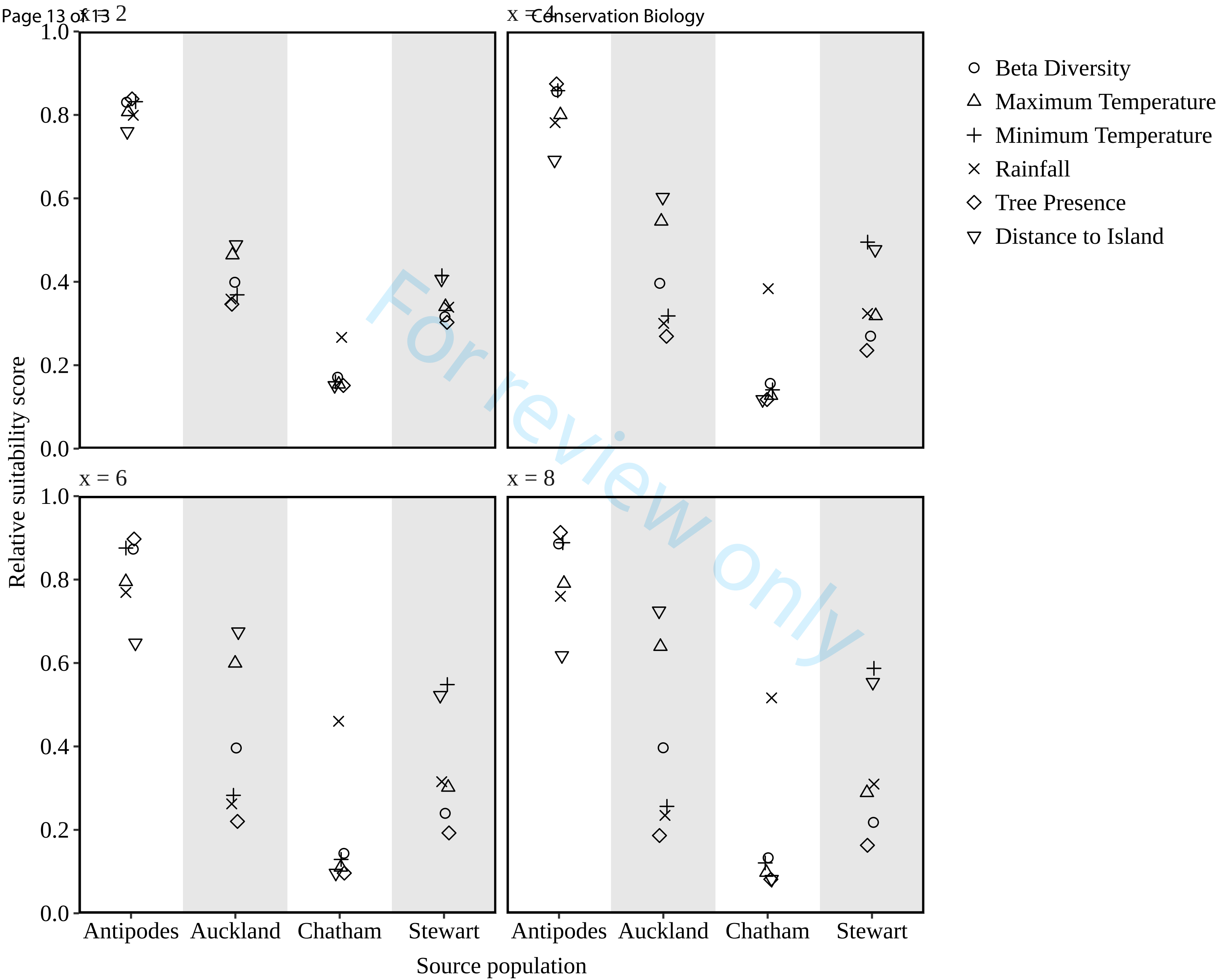
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Relative suitability score
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0.4
0.6
0.8
1.0
Antipodes
Auckland
Chatham
Stewart
Source population
Beta Diversity
Maximum Temperature
Minimum Temperature
Rainfall
Tree Presence
Distance to Island