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Using radio-tracking data to predict post-release establishment in reintroductions to habitat fragments

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ABSTRACT

Dispersal from release areas is a critical problem for reintroductions. Reliable methods are therefore needed for analysing post-release monitoring data to guide further releases. Radio tracking can greatly improve data quality by distinguishing dispersal from mortality. However, fates of animals continue to be uncertain if transmitters have short battery life and detection range, as is typically the case with small animals. We present an approach for simultaneously modelling probabilities of fidelity (remaining in release area), survival, detection and transmitter failure from post-release monitoring data, and illustrate how it was applied to translocations of North Island robins (*Petroica longipes*) to 17 forest fragments (5–56 ha) over 5 years. The modelling showed that fidelity probability depended on the sex (higher in females) and translocation date (higher in winter than autumn), and that variation among fragments was well explained by the "cost distance to nearest neighbour" (an index reflecting the amount of pasture and shrubland needing to be crossed to reach another forest area) and the area of the release fragment (higher in larger fragments). Combined with survival, the estimated probability of a bird remaining in its release fragment the next breeding season ranged from 0.02 to 0.39. As these estimates were refined, they could be used to assess suitability of fragments for further releases and numbers of each sex needing to be released to compensate for dispersal. The Bayesian framework underlying the approach potentially allows application to any amount of data by using informative priors derived from previous translocations or expert opinion.

1. Introduction

The most fundamental tenets of reintroduction are that the habitat must be restored so it is suitable for the species, and that there must be sufficient habitat to support a viable population (IUCN, 1998). However, post-release dispersal is also emerging as a critical issue, where dispersal refers to animals leaving the "release area" where it is hoped a population will form (Armstrong and Seddon, 2008; Le Gouar et al., 2012; Osborne and Seddon, 2012). Dispersal may be desirable if the surrounding landscape has habitat suitable for the species, but more commonly results in animals being lost to unsuitable habitat. Although reintroduction has traditionally focused on returning species to large habitat areas or offshore islands, there is an increasing trend for species to be reintroduced to small managed sanctuaries, often as part of community-led ecological restoration projects (Soorae, 2011; IUCN/SSC, 2013). Post-release dispersal is a key factor affecting the success of these projects.

Risk of failure due to post-release dispersal can potentially be reduced by managing dispersal, by translocating more animals to compensate for dispersal, or by avoiding release areas that will be prone to dispersal. Dispersal can be prevented by perimeter fences around reintroduction areas, but such fences are only effective for flightless species, and may be undesirable for financial, ecological, or philosophical reasons (Somers and Hayward, 2012). Dispersal can potentially be reduced to some extent through the choice of individuals released, the timing of translocation, or through strategies such as temporarily penning animals or providing food, but such methods are often ineffective (Le Gouar et al., 2012; Bradley et al., 2012a). Therefore, the most effective tool for managing post-released dispersal would be accurate prediction of dispersal rates based on the research area's connectivity, allowing sensible decisions to be made about site suitability and the numbers that should be released.

Connectivity is an important issue in conservation biology in general, as it affects the risk of invasion by exotic species (Hulme,

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2009) as well as gene flow and metapopulation dynamics of indigenous species (Hanski, 1999). However, it is also an elusive concept. Connectivity is a complex interaction between the species of interest and the landscape, and needs to be modelled based on the behaviour of the species (Tischendorf and Fahrig, 2000). Many recent studies have modelled connectivity using a "cost distance" approach, whereby the cost of moving from one habitat area to another is calculated based on the distances of different substrates that need to be crossed and relative "resistance" values assigned to those substrates (Adriaensen et al., 2003). Regardless of how connectivity is conceptualised, the ability make accurate predictions for conservation management requires fitting models to monitoring data.

Radio tracking can greatly improve monitoring by allowing animals to be reliably located and their fates to be known (Millspaugh and Marzluff, 2001). It is possible to make useful interpretations solely from return rates following translocation, i.e. proportions of individuals found in release areas at some point in the future (Parlato and Armstrong, 2013). However, return rates confound dispersal and mortality, limiting the power to understand the factors affecting both processes (Dickens et al., 2009; Le Gouar et al., 2012). Radio tracking may not only allow dispersal to be distinguished from mortality, but also give precise information on the timing of these events (e.g. Hardman and Moro, 2006; Bradley et al., 2012b; Lawes et al., 2013). However, even with radio tracking, such clear inferences may be impossible with small animals due to limitations of the packages they can carry (Castellón and Sieving, 2006; Becker et al., 2010; Bradley et al., 2012a).

Small transmitters necessarily have short battery life and limited detection range. Consequently, with small transmitters it is often be unclear whether a translocated animal cannot be detected because its transmitter has failed or because it has left the release area. This problem can potentially be avoided by limiting the monitoring period so there is negligible chance of transmitter failure, but this approach may restrict inferences and be wasteful of data. The better approach is to model the probability of transmitter failure over time for individuals known to stay in the release area, and use this information to resolve probabilities of dispersal versus transmitter failure for undetected individuals.

Here we present an integrated approach for modelling probabilities of fidelity (remaining in the release area), survival, detection and transmitter failure from post-release monitoring, and for combining these post-release data with subsequent search data collected at the start of the next breeding season. We apply the approach to translocations of a small New Zealand forest bird, the North Island robin (Petroica longipes), to 17 forest fragments. The integrated approach allowed us to obtain unbiased estimates of fidelity probability in each fragment, and therefore to assess how fidelity was affected by the fragment's size and connectivity, which was measured in terms of cost distance. The overall approach allowed us to estimate the probability of a translocated bird establishing in any release fragment, therefore guiding subsequent decisions about numbers released.

2. Methods

2.1. Species and system

The North Island robin is a 26–32 g insectivorous passerine endemic to New Zealand (Higgins and Peter, 2002). They typically undergo a juvenile dispersal phase, but establish a permanent territory within a few months of fledging. They begin breeding in their first year, and form monogamous pairs that usually last until one partner dies. The breeding season is from about September to February. They were originally found throughout forested areas of the North Island, as well as some offshore islands, but are gone from >90% of this original range due to forest clearance and predation from exotic mammals.

Excluding the present study, North Island robins have been reintroduced to at least 15 mainland forest areas ranging from 30 to 1100 ha (Parlato and Armstrong, 2012, 2013). Robins are usually the first species reintroduced to New Zealand restoration sites because they are less threatened than other locally extinct species. They are also friendly and charismatic birds that are relatively easy to catch, translocate and monitor, and are therefore particularly attractive to community groups. Consequently, there is strong interest in reintroducing robins to small forest fragments as part of community projects.

We translocated robins to 17 native forest fragments ranging from 5 to 56 ha in a pastoral landscape near the town of Benneydale in the central North Island (Fig. 1; 175°220′E, 38°320′S) as part of a larger study on metapopulation dynamics and conservation management. Most (14) of these translocations were reintroductions to fragments where robins were known to have been absent for at least three years, whereas the other three translocations were conducted to supplement existing subpopulations. The rationale for reintroduction was an occupancy analysis suggesting that the 14 fragments had suitable habitat for robins, and that their absence was attributable to lack of recolonisation as a result of isolation (Richard and Armstrong, 2010a). The robins were sourced from exotic pine (*Pinus radiata*) plantations that were ready for harvesting, so an additional rationale for the translocations was that the source populations were going to lose their habitat.

2.2. Capture, translocation and transmitter attachment

We translocated 220 robins over five years (2005–2009). The total number released per fragment ranging from 3 to 30, with a minimum of 5 in previously unoccupied fragments. Translocation dates ranged from 6 February (end of breeding season) to 11 June, so the time to the next breeding season (September) ranged from 3 to 7 months. Robins were captured using hand operated clap traps baited with mealworms. They were then banded, measured (wing length and tarsus) for preliminary sexing, and if necessary had feathers collected for genetic sexing using Norris-Caneda and Elliot's (1998) method (sexes of adult males could be identified by plumage). Most (146) robins were fitted with transmitters using a Rappole harness around the legs (Rappole and Tipton, 1991), and the harness was always checked to ensure no restriction of birds' movements. We used 1.05 g BD-2 transmitters (Holohil Systems Ltd., Canada) that had an expected life of 6 weeks. After processing, robins were moved to individual cardboard transport boxes containing food and water (the latter was removed during transport). They were driven to the release fragment (5–20 km from capture site) by mid-afternoon on the day of capture, and released immediately. Transmitters were removed from robins at the end of their post-release monitoring periods if they could be re-captured. All procedures were approved by the Massey University Animal Ethics Committee (Protocols 05/06 and 07/08) and the New Zealand Department of Conservation (Wildlife Act permit WK-20863-FAU).

2.3. Monitoring protocol

Radio-tagged robins were always checked the day after release, then at varying intervals depending on logistic constraints. The median interval between checks was 3 days, and most (95%) intervals were $\leqslant$10 days. We usually continued to check robins until they left the release fragment, died, could not be found, or the transmitter failed or dropped off the robin, giving a maximum post-release monitoring period of 59 days. Each check was carried out by one person using a Telonics TR4 receiver, yagi antenna, and