Biological Conservation 191 (2015) 274–281

Contents lists available at ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/bioc

Rattus management is essential for population persistence in a critically endangered passerine: Combining small-scale field experiments and population modelling

Gwen Maggs [a,b,*], Malcolm Nicoll [a], Nicolas Zuël [c], Patrick J.C. White [d], Edward Winfield [c], Sandra Poongavanan [c], Vikash Tatayah [c], Carl G. Jones [c,e], Ken Norris [a]

[a] Institute of Zoology, Zoological Society of London, Regent's Park, London NW1 4RY, United Kingdom
[b] Centre for Biodiversity and Environment Research, Department of Genetics, Evolution and Environment, University College London, Darwin Building, Gower Street, London WC1E 6BT, United Kingdom
[c] Mauritian Wildlife Foundation, Grannum Road, Vacoas, Mauritius
[d] Edinburgh Napier University, School of Life, Sport and Sciences, Sighthill Campus, Edinburgh EH11 4BN, United Kingdom
[e] Durrell Wildlife Conservation Trust, Les Augrès Manor, Trinity, Jersey JE3 5BP, Channel Islands, United Kingdom

ARTICLE INFO

Article history:
Received 24 November 2014
Received in revised form 11 June 2015
Accepted 26 June 2015
Available online xxxx

Keywords:
Passerine
Rattus
Predator control
Nesting success
Annual productivity
Population growth

ABSTRACT

Invasive species are a major threat for island biodiversity, causing species decline and extinction globally. Of all invasive mammals rats are one of the most detrimental and have been the target of numerous control and eradication programmes. In Mauritius rats have contributed to the extinction of 50% of the island's fauna and are thought to be the main threat to the endemic Mauritius olive white-eye (*Zosterops chloronothos*), a critically endangered passerine. Assessing the impact of rats and suitable control strategies is often problematic in such cases because of the lack of replicate populations for experiments. Here, we illustrate how to overcome this issue by combining a small-scale rat management experiment on olive white-eyes with demographic models that provide estimates of the potential effects of management on vital rates and population growth. We established poison and trapping grids within breeding territories, and show that rat management significantly decreased rat abundance and increased nesting success. An individual-based stochastic simulation model suggested that rat control could produce a 5–6 fold increase in the annual productivity of female olive white-eyes, which in turn would be sufficient to stabilise population growth. In the absence of rat management, our analysis suggests the olive white-eye population will decline by about 14% per annum. By combining low cost field experiments with widely available demographic models we highlight the value of targeted, effective rat management techniques for both short and long-term population management in threatened passerines.

1. Introduction

Since the 15th century invasive species have been partly or wholly responsible for the extinction of at least 65 bird species making them the greatest threat to avifauna, especially on islands where predation is a major cause of extinction (Atkinson, 1985; Birdlife International, 2004; King, 1985). Having reached around 90% of all islands rats have been identified as a 'massive' global threat under a new classification system based on the IUCN Global Invasive Species Database with *Rattus rattus* (ship or black rats) having the greatest detrimental effects on island bird populations (Atkinson, 1977, 1985, 1989; Blackburn et al., 2014; Towns et al., 2006).

The eradication of rats from islands is now a widely used conservation tool benefiting numerous taxa (Towns et al., 2006), with 344 successful eradications of ship rats and *Rattus norvegicus* (brown rats) from islands between 1951 and 2011 (Island Conservation, 2012). In contrast to rat eradications from unpopulated islands, the control of rats in areas on large populated islands remains challenging, however, the local extirpation of rats through the establishment of rat-free areas using poison and trapping is one possible solution. To date these have been implemented with varying degrees of success for many island passerine species threatened by rats where marooning on predator free islands is not an option but the creation of rat-free areas is a viable long-term solution e.g. Cook Islands, Hawaii, New Zealand, Seychelles and Tahiti (Blanvillain et al., 2003; Innes et al., 1999; Rocamora and Baquero, 2007; Robertson et al., 1994; Trent et al., 2008; Vanderwerf and Smith, 2002). However, one of the challenges faced by this approach is quantifying the degree (and duration) to which rat populations can be suppressed (or eradicated) and the apparent benefits of

* Corresponding author at: Institute of Zoology, Zoological Society of London, Regent's Park, London NW1 4RY, United Kingdom.
E-mail address: Gwen.Maggs@ioz.ac.uk (G. Maggs).

http://dx.doi.org/10.1016/j.biocon.2015.06.039
0006-3207/

this management to improve the viability of threatened bird populations in both the short and long-term (Innes et al., 1999; James and Clout, 1996; Moorhouse et al., 2003).

Identifying any measurable benefits of management is in itself challenging as it requires observing individuals through whole seasons and individual identification. For multi-brooded passerines this challenge is compounded due to their ecology and behaviour compromising our ability to collect annual individual-based data and accurately assess the benefits (Bottrill et al., 2008; Pease and Grzybowski, 1995). Here we deal with these challenges by combining a small scale field experiment, investigating the impact of rat management on nesting success, with an individual-based stochastic simulation model to predict annual productivity and a population matrix model to assess the population-level consequences of management. These techniques have been applied successfully for other threatened passerine species investigating species responses to management actions using field experiments spanning numerous years (Armstrong et al., 2006; Basse et al., 2003; Brook and Kikkawa, 1998; Fessl et al., 2010). However, here we investigate the impacts of small-scale, short-term management actions combined with demographic models to obtain quick results for species management; which for critically endangered populations is vital.

In the *Zosterops* genus ship rats are considered a threat to 70% of the endangered or critically endangered species all of which are situated on islands (Mauritius, Norfolk Islands, Northern Mariana Islands, Sangehi and Seychelles), they are also thought to be the main cause of the robust white-eye (*Zosterops strenuus*) extinction (Birdlife International, 2004, 2015; IUCN, 2014). The Mauritius olive white-eye (*Zosterops chloronothos*) (hereafter referred to as the olive white-eye) is one of the four white-eye species currently classed as critically endangered and is in the top 10% of the Evolutionary Distinct and Globally Endangered (EDGE) bird species list (IUCN, 2013; Jetz et al., 2014).

Within Mauritius the olive white-eye is the rarest of the remaining nine endemic land bird species, with a limited understanding of its basic ecology (Nichols et al., 2005; Safford, 1991; Safford and Hawkins, 2013; Staub, 1993). The species has experienced an island wide decline due to habitat loss, competition with introduced bird species and suspected nest predation (eggs and nestlings) by ship rats (Nichols et al., 2005; Safford, 1997a; Safford and Hawkins, 2013). Between 1975 and 2001 the population declined from 340–350 pairs to 93–148 and is now primarily restricted to an area less than 25 km^2 in the Black River Gorges National Park (Fig. 1) (Cheke, 1987; Nichols et al., 2004). In response to the population decline a recovery project was initiated in 2005, which involved the establishment of a sub-population on a rat-free island nature reserve (Ile aux Aigrettes, 20°42′S 57°7′E), the monitoring of a remnant sub-population in the National Park and the control of rats (Cole et al., 2007, 2008; Maggs et al., 2009, 2010).

The recovery project used rat control measures in the mainland population using rat snap-traps around individual nesting sites from 2006 to 2010. However, this sporadic management was unable to identify if rats are a major limiting factor for the breeding population or whether management could effectively control them. Here we examine, using an experimental framework, if rats are a threat to the mainland olive white-eye population and whether the management of rats through poisoning/trapping can reduce their impact by combining a small-scale field experiment with demographic models. Specifically, we examine if (i) the application of poison reduces rat abundance, (ii) the management of rats leads to an improvement in nesting success, (iii) an observed increase in nesting success can significantly improve annual productivity, and (iv) an increase in productivity can have a biological impact on the rate of population change and prevent population decline. Based on our findings we demonstrate how small-scale, short-term field experiments in conjunction with demographic models can provide an insight into the long-term benefits of controlling nest predators such as rats for threatened passerine populations.

2. Methods

2.1. Study site and species

The olive white-eye population has a very restricted range, and within this range, a very patchy distribution with low densities. Combo (20°46′S 57°51′E), the chosen study site, is an area of c.5 km^2 in the Black River Gorges National Park where the highest density of olive white-eye breeding pairs remain, estimated at 25–30 breeding pairs (Nichols et al., 2004; Fig. 1). Combo has a riparian upland forest habitat with degraded vegetation supporting populations of four other endemic bird species (Safford, 1997b).

The olive white-eye is part of an ancient Indian Ocean white-eye lineage with birds colonising from Asia prior to the subsequent evolution of the African species (Warren et al., 2006). Prior to 2001 little was known about the olive white-eye with only eight nesting episodes where eggs were laid, ever recorded; of which only one successfully fledged nestlings (Nichols et al., 2005; Safford, 1991; Staub, 1993). However, through the management and monitoring of the Combo population and the establishment of the Ile aux Aigrettes island sub-population the life-history of the species is now better documented (Cole et al., 2007, 2008; Maggs et al., 2009, 2010, 2011).

Olive white-eye pairs are monogamous and in the wild defend territories of c. 0.5 ha ($\pm$0.2, n = 21) which characteristically include running water sources, an area of canopy and open areas (Cole et al., 2008; Maggs et al., 2011; Nichols et al., 2005; Safford and Hawkins, 2013). The breeding season is in the austral summer, typically between August and March. They are a multi-brooded species and will breed continuously throughout the season, regardless of whether their nests

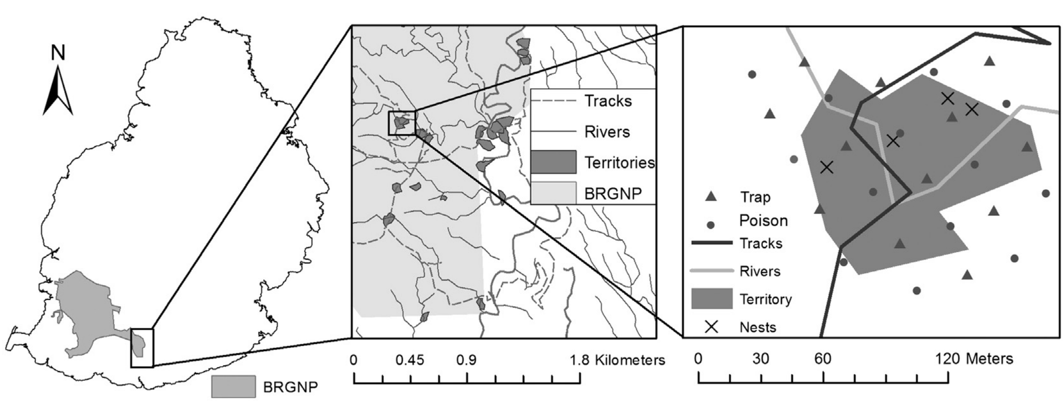

Fig. 1. The location of the Black River Gorges National Park (BRGNP) in Mauritius (left), Mauritius olive white-eye breeding territories in the Combo region in the South-west of the National Park (middle) and a schematic representation of a poison and trapping grid across an olive white-eye breeding territory (right).