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Temporary captive population and rapid population recovery of an endemic flightless rail after a rodent eradication operation using aerially distributed poison bait

Steffen Oppel [a,*], Alexander L. Bond [b], Michael de L. Brooke [c], Gavin Harrison [d,1], Juliet A. Vickery [a], Richard J. Cuthbert [b,2]

[a] RSPB Centre for Conservation Science, Royal Society for the Protection of Birds, David Attenborough Building, Pembroke Street, Cambridge CB2 3EZ, United Kingdom
[b] RSPB Centre for Conservation Science, Royal Society for the Protection of Birds, The Lodge, Sandy, Bedfordshire SG19 2DL, United Kingdom
[c] Department of Zoology, University of Cambridge, Downing Street, Cambridge CB2 3EJ, United Kingdom
[d] Royal Zoological Society of Scotland, Edinburgh Zoo, 134 Corstorphine Road, Edinburgh EH12 6TS, United Kingdom

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ABSTRACT

Operations to eradicate non-native invasive predators from islands generally have large conservation benefits, but may put native species at risk where poison bait is used for eradication. Whether the risk of unintentionally poisoning native species can be effectively reduced or mitigated is a critical determinant in deciding the potential utility of an eradication operation. Here, we describe the mitigation measures adopted for an endemic flightless rail species, the Henderson Crake (*Zapornia atra*), during a rodent eradication operation on Henderson Island, South Pacific, where aerially applied brodifacoum bait was used in 2011. We established a secure temporary in situ captive population of 108 birds, of which 22 individuals died due to initial complications in accepting artificial food. We used point counts and radio-tracking to estimate the effects of the eradication operation on the wild population of Henderson Crakes, and found the expected high mortality (83–97%) due to primary poisoning. Despite this mortality, the Henderson Crake population recovered from very low levels in 2011 (9 birds at 25 point count locations) to 2015 numbers similar to those in the 1980s and 1990s (228 birds at 25 point count locations), despite the eradication operation failing to remove all rats from Henderson Island. The recovery of the natural population was supplemented by 89 individuals released from temporary captivity 2–3 months after the eradication attempt. We conclude that, despite the high mortality of Henderson Crakes during the eradication attempt, the mitigation measures taken to safeguard this endemic species were effective and contributed to the rapid recovery of the species following the eradication operation.

1. Introduction

Introduced rodents, and rats (*Rattus* spp.) in particular, cause significant damage to island ecosystems through direct predation, competition with indigenous species, and alteration of ecosystem energetic pathways (Croll et al., 2005; Harper and Bunbury, 2015; Jones et al., 2008). Conservation efforts on hundreds of islands globally have therefore focused on eradicating introduced rodents as part of island restoration programs (Howald et al., 2007; McClelland, 2011; Towns and Broome, 2003). Such successful efforts often result in the restoration of ecosystems, and in particular, avian communities, in a relatively short time (Jones et al., 2016; Lavers et al., 2010; Russell and Holmes, 2015).

Since the early 1990s, rodent eradications on large islands (>100 ha) have been typically performed using the aerial distribution of an anticoagulant rodenticide in cereal pellets, which is both palatable and toxic to rodents. This approach ensures rapid coverage of the entire island with a sufficient density of bait to expose all individuals of the introduced rodent species to a lethal dose, and this technique is therefore highly successful (Keitt et al., 2015; Towns and Broome, 2003). However, aerial bait applications are not without risks, as non-target species may consume the bait directly, resulting in primary poisoning, or scavenge on dead rodents or other non-target species, causing secondary poisoning (Eason et al., 2002; Pitt et al., 2015; Wanless et al., 2010). The ultimate success of island restoration programs to safeguard native species therefore depends critically on appropriate actions to reduce or mitigate non-target mortality, while at the same time ensuring that the eradication operation will be successful. Typical measures to reduce non-target mortality include operational decisions on the distribution, type, and size of cereal bait pellets used (Parkes et al., 2011), the timing of

* Corresponding author.
E-mail address: steffen.oppel@rspb.org.uk (S. Oppel).
[1] Present address: National Trust, Waddesdon Manor, Waddesdon, Buckinghamshire HP18 0JH, United Kingdom.
[2] Present address: Conservation Solutions, 9 Prospect Drive, Belper, Derbyshire DE56 1UY, United Kingdom.

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eradication operations (Howald et al., 2007), or the establishment of a captive population of potentially vulnerable non-target species (Empson and Miskelly, 1999). Maintaining a temporary captive population of a wild native species can, however, be a formidable challenge. To our knowledge there has been no thoroughly documented case study about the establishment, maintenance, and subsequent release of a captive population of a wild native species in association with a rodent eradication operation using aerial bait application. Here, we describe a case study of a globally threatened bird species vulnerable to non-target mortality; we report the pre-operational planning, mitigation measures implemented, and post-operational monitoring to demonstrate that appropriate mitigation resulted in no negative long-term population-level effects of an aerial bait application.

Henderson Island (24° 20′ S, 128° 20′ W) is a 43 km^2 raised coral atoll in the Pitcairn Islands of the South Pacific Ocean where non-native Pacific rats (*Rattus exulans*) were introduced during Polynesian occupation, and have negative effects on native biodiversity (Brooke, 1995a, 1995b; Brooke et al., 2010b; Jones et al., 1995). Rat eradication on Henderson Island is a high priority to safeguard globally important biodiversity (Dawson et al., 2015), and an aerial baiting eradication operation was carried out in 2011 (though subsequently found to be unsuccessful; Amos et al., 2016). The island supports four endemic land bird species (Graves, 1992), an endemic petrel (Brooke and Rowe, 1996), 18 endemic invertebrate and nine endemic plant species (Benton and Lehtinen, 1995; Churchyard et al., 2016; Florence et al., 1995). The petrels and three volant species of land birds were unlikely to suffer non-target mortality during an eradication operation due to their ecology and diet (Brooke and Hartley, 1995; Brooke and Jones, 1995; Graves, 1992; Trevelyan, 1995). However, one flightless bird species – the Henderson Crake (*Zapornia atra*) – is a ground-foraging generalist (Jones et al., 1995) and such species may be susceptible to primary and secondary poisoning: populations of the closely-related Weka (*Gallirallus australis*), Buff-banded Rail (*G. philippensis*), and Pukeko (*Porphyrio porphyrio*) decreased considerably when populations had access to brodifacoum bait (Dowding et al., 1999; Eason and Wickstrom, 2001; Empson and Miskelly, 1999; Fisher et al., 2011). Consequently, careful measures to reduce non-target mortality were necessary to ensure the survival of Henderson Crakes during an eradication operation.

We developed and implemented mitigation strategies to minimize negative effects of an aerial baiting rodent eradication operation on Henderson Crakes. We then evaluated the effects of these mitigation steps on the Henderson Crake population both during the rat eradication operation and for four years following the operation using systematic point count surveys.

2. Methods

2.1. Estimation of minimum captive population size

The entire Henderson Crake population was potentially at risk of primary (ingesting bait directly) or secondary poisoning (ingesting poisoned rats, or invertebrates) (Brooke et al., 2013; Brooke et al., 2011). The general guideline for preserving the genetic diversity of populations in the short term (5 generations, or 14 years for Henderson Crake; Birdlife International, 2016; Frankham et al., 2014) is an effective population size (N_e) ≥ 50 (Franklin, 1980), though this has recently been revised to N_e ≥ 100 (Frankham et al., 2014). To allow for operational complications and logistical complexities our minimum target for maintaining short-term genetic diversity was a temporary captive population of 100–120 individuals during the eradication operation.

2.2. Establishment and maintenance of a captive crake population

Extensive work during a preliminary field expedition in August–September 2009 was necessary to determine the techniques required for the successful capture and maintenance of captive Henderson Crakes (Brooke et al., 2010a). The developed techniques were implemented and refined in preparation for the eradication operation in 2011. Between 16 July and 26 August 2011, we captured Henderson Crakes using water traps and mist nets positioned along a ~7 km network of trails (Fig. 1). Traps consisted of a 60 × 40 cm wooden base with an inset plastic water bowl and a spring-powered flip-net that was triggered when a bird bathed in the bowl. Mist nets were set at ground level along paths and birds were guided into the nets through a combination of tape-luring or through herding individuals. Mist nets were used due to higher than expected rainfall in the initial stages of the capture period, which reduced the efficacy of water traps.

Captured crakes were weighed upon capture to the nearest 1 g using an electronic balance, and sex determined by using the colouration of their bill and legs (Jones et al., 1995). When we captured both members of a breeding pair from a territory, they were housed together, otherwise birds were caged individually. Crakes were housed in 1.5 × 3.0 × 0.8 m cages, with side walls comprising a 10 m length of 90 cm wide wire mesh dug about 10 cm into the ground. The four corners were supported by 1.2 m metal reinforcing rods hammered into the ground. Cages were roofed with bird netting sewn onto the wire sides, and supported by a central wooden post. Roofs had a small opening with a sliding bolt to allow access for providing food and water. All cages were shaded by natural vegetation, or fronds from coconut (*Cocos nucifera*) trees. We placed natural vegetation inside each enclosure, including small logs and rocks, as shelters for birds. Crakes were also provided with two plastic bowls 17 cm in diameter and 3 cm deep for water and food that could be covered during heavy rain.

Each morning, crakes were fed with 15 g of Wombaroo Insectivore Rearing Mix (Wombaroo Food Products, Glen Osmond, Australia; 52% protein, 18% carbohydrate, 12% lipid, maximum 5% fibre, 2% calcium, 500 mg/kg taurine, 500 mg/kg carotenoids; metabolisable energy 15 MJ/kg) mixed with water to form a firm paste, and combined with dried raisins; food was replenished at midday if the bowl was empty. A calcium supplement (Vetark Nutrobal, Vetark Professional, Winchester, UK) was added every 3–4 days. Crakes were provided water ad libitum, which was replenished through the day, and an avian probiotic and a critical care formula (Vetark Avipro plus, and Vetark CCF, Vetark Professional, Winchester, UK) were added to the water for the first few days of captivity to combat the effects of stress. These served to replenish vitamins and minerals, gut flora, maltodextrins and included a protein concentrate to aid birds that were reluctant to consume food. Food and water bowls were removed at night to avoid attracting rats and crabs into aviaries; water bowls were scrubbed each morning before refilling with water, and food bowls were cleaned with detergent every evening and allowed to air dry to reduce the risk of bacterial build up and contamination to food in the warm humid conditions. To ensure food recognition and acceptance in the days immediately following capture, we provided live sphingid moth caterpillars (*Gnathothlibus erotus*) or small hermit crabs with shells removed together with the Wombaroo Insectivore Rearing Mix until we observed crakes eating the mix directly. Similarly, we provided live prey to chicks hatched in captivity (see Results) to aid their development and assist natural instincts and prey recognition.

On 15–17 August 2011, cereal bait pellets (Pestoff 20R, Animal Control Products, Whanganui, New Zealand) with 20 μg/g (ppm) brodifacoum and a mean mass of ~2 g were spread aerially using helicopters across the island at a density of 10 kg/ha on inland areas, and 40–60 kg/ha in beach areas with high densities of hermit crabs *Coenobita* spp. The second bait drop of 6 kg/ha followed on 21–22 August 2011. During the aerial application of rodenticide pellets, all aviaries were covered with heavy transparent plastic sheets to exclude all pellets from the inside of aviaries and ensure that captive birds had no access to poison baits. Cages were thoroughly checked after each bait drop to ensure that no bait pellets had entered the cage, and in the following days to ensure any bait falling into the cage after being lodged in

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