Biological Conservation 185 (2015) 27–35

Contents lists available at ScienceDirect

Biological Conservation

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

Special Issue Article: Tropical rat eradication

Improving the odds: Assessing bait availability before rodent eradications to aid in selecting bait application rates

Madeleine Pott [a,*], Alexander S. Wegmann [a], Richard Griffiths [a], Araceli Samaniego-Herrera [b,c], Richard J. Cuthbert [d,1], M. de L. Brooke [e], William C. Pitt [f,2], Are R. Berentsen [g], Nick D. Holmes [a], Gregg R. Howald [a], Karina Ramos-Rendón [b], James C. Russell [c]

[a] Island Conservation, 2161 Delaware Avenue, Suite A, Santa Cruz, CA 95060, USA
[b] Grupo de Ecología y Conservación de Islas, Ensenada, Baja California, Mexico
[c] School of Biological Sciences and Department of Statistics, University of Auckland, Private Bag 92019, Auckland, New Zealand
[d] Royal Society for the Protection of Birds, The Lodge, Sandy, Bedfordshire, United Kingdom
[e] Department of Zoology, University of Cambridge, Downing Street, Cambridge CB2 3EJ, UK
[f] USDA APHIS WS, National Wildlife Research Center, Hawaii Field Station, P.O. Box 10880, Hilo, HI 96721, USA
[g] USDA APHIS WS, National Wildlife Research Center, 4101 LaPorte Ave., Fort Collins, CO 80521-2154, USA

ARTICLE INFO

Article history:
Received 30 April 2014
Received in revised form 17 September 2014
Accepted 27 September 2014
Available online 6 November 2014

Keywords:
Rodent
Island
Conservation
Crab
Tropical
Eradication

ABSTRACT

Rodent eradications undertaken on tropical islands are more likely to fail than eradications undertaken at higher latitudes. We report on 12 independent rodent eradication projects undertaken on tropical islands that utilized the results of an in situ bait availability study prior to eradication to inform, a priori, the bait application rate selected for the eradication. These projects also monitored bait availability during the eradication. The results from our analysis verified the utility of bait availability studies to future rodent eradication campaigns and confirmed the influence of two environmental factors that can affect bait availability over time: precipitation prior to the study and the abundance of land crabs at the study site. Our findings should encourage eradication teams to conduct in-depth assessments of the targeted island prior to project implementation. However, we acknowledge the limitations of such studies (two of the projects we reviewed failed and one removed only one of two rodent species present) and provide guidance on how to interpret the results from a bait availability study in planning an eradication. Study design was inconsistent among the twelve cases we reviewed which limited our analysis. We recommend a more standardized approach for measuring bait availability prior to eradication to provide more robust predictions of the rate at which bait availability will decrease during the eradication and to facilitate future comparisons among projects and islands.

1. Introduction

Despite adopting some of the most up-to-date and accepted eradication methods, rodent eradications undertaken on tropical islands are more likely to fail than eradications undertaken at higher latitudes (Russell and Holmes, 2015; Varnham, 2010). The more than twofold difference in failure rate (Russell and Holmes, 2015) suggests that the methods and strategies developed and used in temperate ecosystems may not be wholly applicable to tropical environments (Keitt et al., 2015; Wegmann et al., 2011). The higher and more consistent year-round temperatures found on tropical islands contrast with conditions on temperate islands and will influence the perceived main factors that affect eradication success, such as rodent breeding behavior, the availability of natural food for rats, and non-target bait consumers (Samaniego-Herrera et al., 2014; Wegmann et al., 2011).

One response to the added complexity of tropical island rodent eradications has been the development and use of pre-eradication "bait availability" studies in situ. Using non-toxic versions of the rodent bait selected for the eradication, such studies test the proposed baiting strategy and assess the minimum amount of bait needed to achieve success (Brooke et al., 2010; Wanless et al., 2008). Bait availability is a measure of the density (kg/ha) of rodent

* Corresponding author. Tel.: +1 (831) 359 4787.
E-mail address: madeleine.pott@islandconservation.org (M. Pott).
[1] Wildlife Conservation Society, Goroka, Eastern Highlands Province, Papua New Guinea.
[2] Smithsonian Conservation Biology Institute, National Zoological Park, 1500 Remount Road, Front Royal, VA 22630, USA.

http://dx.doi.org/10.1016/j.biocon.2014.09.049
0006-3207/

bait available to rodents at a point in time or over a period of time. It has been common practice to aim for four days of bait availability (Keitt et al., 2015), a recommendation stemming partially from the U.S. Environmental Protection Agency requirement for second generation anticoagulants to achieve 90% efficacy within three days (Schneider, 1982).

The first published bait availability study occurred in 2004 on Little Barrier Island, New Zealand (Greene and Dilks, 2004). Henceforward, bait availability studies have been incorporated into the planning and implementation of several rodent eradication projects on tropical, temperate, subarctic, and sub-Antarctic islands. The Palmyra Atoll bait availability study (Buckelew et al., 2005) and a similar study conducted on Isabel Island, Mexico (Samaniego-Herrera et al., 2010) were undertaken because previous attempts to eradicate rats from these islands failed. In both cases, competition for bait by land crabs (Griffiths et al., 2011; Wegmann, 2008) and other factors unique to tropical islands were believed to have influenced the outcome. Subsequent campaigns were successful in eradicating rats from both of these sites, using baiting strategies developed through the use of preparatory bait availability studies. Other rodent eradication projects (both tropical and temperate) have employed similar studies to both shape the development of bait application strategies and to guide bait application rates during the implementation of eradication projects.

We report on 12 independent rodent eradication projects undertaken in the tropics that utilized the results of an in situ bait availability study prior to eradication to determine, a priori, the bait application rate selected for the eradication. All of these projects also monitored bait availability during the eradication, allowing us to assess how well such studies predict bait availability during an eradication campaign. The studies we examined were of varied design and execution. By comparing these results, we verify the utility of bait availability studies to future rodent eradication campaigns and investigate factors associated with bait availability over time. We also provide guidelines for the planning and standardization of future bait availability studies to assist with the interpretation of results and to facilitate future meta-analyses to improve the practice of eradicating invasive rodents from islands.

2. Methods

To verify the utility and generality of bait availability studies, we compared 12 rodent eradication projects for which: (1) a study conducted prior to the eradication was used to determine the final bait application rate used in the eradication attempt, (2) high quality raw data were available, and (3) practitioners were available for comment. These projects are presented in Table 1 along with key elements of the study designs used. Rodents (three species of rats: *Rattus exulans*, *R. rattus*, *R. tanezumi*, and one species of mouse: *Mus musculus*) were successfully eradicated in eight of the 12 projects; three projects were unsuccessful and the outcome for one has not been confirmed (Table 1). Eradications during which mice and rats were targeted were treated separately as there is evidence to suggest that fundamental differences in mouse and rat behavior may require different baiting strategies for individuals of each genus (MacKay et al., 2007).

Pre-eradication studies were conducted in an effort to identify the minimum application rate required to ensure that bait would remain available to the targeted rodent population for sufficient time, thus maximizing the chance of eradication success. In comparison, studies undertaken during the eradication aimed to document how long bait was available to the targeted population of rodents and to assess the accuracy (on-the-ground application rate and uniformity) of the bait application (Engeman et al., 2013). A non-toxic version of the rodenticide proposed for each eradication was used during pre-eradication studies. For the purposes of determining bait exposure in animals, all non-toxic versions also contained a biomarker (pyranine or Rhodamine B) detectable under ultraviolet light. There is, however, some evidence that biomarkers in baits can affect palatability in both mice and rats (Pitt, 2015; Weerakoon and Banks, 2011).

In most cases, the islands were too large to be baited in their entirety during the pre-eradication studies and smaller study sites were established. In the cases of Palmyra Atoll and Dekehtik Island, one or more small islets (<3 ha) were used as study sites and were baited entirely during the studies. Study sites on larger islands were situated in parts of the island that were readily accessible to personnel and, where necessary, were replicated in order to sample representative habitat types, as in the case of Wake Atoll (IC, 2013b; Wegmann et al., 2009) and Isabel Island (Samaniego-Herrera et al., 2010). The baited areas of study sites ranged from 0.26–20 ha. Fixed plots within study areas at Palmyra Atoll, Wake Atoll, Isabel Island, and Henderson Island were stratified by habitat type and randomly located (Berentsen et al., 2014; Cuthbert et al., 2012; Samaniego-Herrera et al., 2010; Wegmann et al., 2009). Plots were randomly located with no differentiation by habitat at the other study sites.

All bait applied to the pre-eradication study sites was broadcast by hand and bait application rates were based on knowledge of the environmental factors present at the site, e.g. the presence of land crabs, and information from other rodent eradications previously completed in similar environments. In the case of eradications, the aerial distribution of bait containing a rodenticide (Howald et al., 2007) was the primary method of bait application at all sites except Pohnpei (Wegmann et al., 2007), Pérez Island, Pájaros Island, Muertos Island (GECI, 2013), and Allen Cay (Alifano et al., 2012) where bait was applied by hand.

Following the application of bait to the study area, bait availability was measured in two ways: either counting the number of pellets remaining within plots or weighing pellets remaining within plots. Studies variously used fixed transect-lines, transect-plots (1 m wide), or square-plots, where individual bait pellets applied at the target application rate were marked within a designated area and the presence of each pellet was noted daily throughout the study period. Bait pellets were marked with pin flags or chalk circles depending on the substrate at the study site. Other studies used fixed or randomly located circular plots in which pellets within a set distance from a central point were recorded daily throughout the study period. The random circle plots employed during the pre-eradication study at Palmyra consisted of large circles (radius 3 m) centered on random points on the island which changed daily. The fixed circle plots used during the Palmyra eradication consisted of a PVC hoop (radius 0.68 m) into which pellets were added or removed from the plot as needed to reflect the prescribed bait application rate (Berentsen et al., 2014). Bait availability within fixed circle plots (radius 3 m for both pre- and during-eradication studies) at Isabel, Muertos, Pájaros, Pérez, and Cayo Norte Mayor was assessed by collecting, weighing and returning all pellets to the corresponding plots.

The wide range of study designs employed by the 12 projects (Table 1) made it challenging to complete an analysis of the results. In several cases, the methods used to assess bait availability differed between the pre-eradication bait availability study and the study executed during project implementation. Several projects also measured bait availability during the eradication at sites that were different to those used in the pre-eradication study. Because the same sample days (days after bait was applied to the study area) and the number of sample days during which bait availability was measured were not consistent across the projects considered here, we were only able to compare measures of bait availability collected on sample days 1 and 3.