Biological Conservation xxx (2014) xxx–xxx

Contents lists available at ScienceDirect

Biological Conservation

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

Special Issue Article: Tropical rat eradication

# The next generation of rodent eradications: Innovative technologies and tools to improve species specificity and increase their feasibility on islands

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ARTICLE INFO

*Article history:*
Received 29 April 2014
Received in revised form 1 September 2014
Accepted 10 October 2014
Available online xxxx

*Keywords:*
*Rattus*
*Mus musculus*
Control methods
Pest eradication
Island restoration

ABSTRACT

Rodents remain one of the most widespread and damaging invasive alien species on islands globally. The current toolbox for insular rodent eradications is reliant on the application of sufficient anticoagulant toxicant into every potential rodent territory across an island. Despite significant advances in the use of these toxicants over recent decades, numerous situations remain where eradication is challenging or not yet feasible. These include islands with significant human populations, unreceptive stakeholder communities, co-occurrence of livestock and domestic animals, or vulnerability of native species. Developments in diverse branches of science, particularly the medical, pharmaceutical, invertebrate pest control, social science, technology and defense fields offer potential insights into the next generation of tools to eradicate rodents from islands. Horizon scanning is a structured process whereby current problems are assessed against potential future solutions. We undertook such an exercise to identify the most promising technologies, techniques and approaches that might be applied to rodent eradications from islands. We highlight a *Rattus*-specific toxicant, RNA interference as species-specific toxicants, rodenticide research, crab deterrent in baits, prophylactic treatment for protection of non-target species, transgenic rodents, virus vectored immunocontraception, drones, self-resetting traps and toxicant applicators, detection probability models and improved stakeholder community engagement methods. We present a brief description of each method, and discuss its application to rodent eradication on islands, knowledge gaps, challenges, whether it is incremental or transformative in nature and provide a potential timeline for availability. We outline how a combination of new tools may render previously intractable rodent eradication problems feasible.



## 1. Introduction

Invasive mammal eradications are powerful conservation tools to protect biodiversity and prevent extinctions on islands (Aguirre-Muñoz et al., 2008; Bellingham et al., 2010; Campbell et al., 2011). The opportunity to scale up existing eradication techniques is being realized, with larger and more challenging projects being undertaken (Phillips, 2010; Sutherland et al., 2014). Yet

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http://dx.doi.org/10.1016/j.biocon.2014.10.016
0006-3207/

despite these advances it is clear there are limits to what can be achieved and there is an urgent need to overcome these barriers. For example, approximately 50% of IUCN critically endangered and endangered insular tetrapods occur on islands with invasive rodents and human populations greater than 10,000 people, highlighting the challenge and need for innovative tools that abate the threat of invasive species (TIB Partners, 2012).

Three *Rattus* species (*R. rattus*, *R. norvegicus*, *R. exulans*) and house mice (*Mus musculus*) are the most common rodents introduced to islands worldwide (Atkinson, 1985). They cause population declines and extinctions of insular flora and fauna and interrupt ecosystem processes with negative cascading effects (Fukami et al., 2006; Jones et al., 2008; Kurle et al., 2008; Steadman, 2006; Towns et al., 2006). Invasive rodents negatively impact stored foods, crops, and infrastructure and can carry zoonotic diseases that can impact the health of people and their livestock (Banks and Hughes, 2012; Meerburg et al., 2009; Stenseth et al., 2003). To recover endangered species and restore ecosystem processes, invasive rodents on islands are increasingly targeted for eradication, with at least 474 successful rodent eradications to-date (DIISE, 2014). Other larger, more complex and expensive campaigns, some of which are on inhabited islands, are underway or being planned (Sutherland et al., 2014).

Today, rodent eradications on any island larger than 5 ha rely exclusively on the use of anticoagulant toxicants (DIISE, 2014). Toxicants are incorporated into cereal or wax baits applied to every rodent territory via bait stations, or broadcast by hand or from a modified agricultural spreader bucket suspended below a helicopter. Of the anticoagulants, brodifacoum is the most commonly used and has had the highest success rate (Howald et al., 2007; Parkes et al., 2011). Desirable characteristics of brodifacoum include: its high oral toxicity to rodents, likely lethal effects from a single feed, can be combined with bait that is highly palatable to rodents, delayed symptoms of toxicosis, low water solubility (Broome et al., 2013; Empson and Miskelly, 1999), is relatively economic to manufacture and incorporate into a bait matrix, and it is currently registered for use in many countries. Disadvantages include brodifacoum's broad-spectrum toxicity to vertebrates, moderate duration of persistence, ability to biomagnify (i.e. process whereby the tissue concentrations of a contaminant increase as it passes up the food chain), mode of death and negative public perception (Broome et al., 2013; Eason et al., 2002; Fitzgerald, 2009). In the planning phases of campaigns, impacts to non-target wildlife are predicted using risk assessments, and actions to avoid, minimize or mitigate risk (e.g. operational timing or captive holding) can then be taken to safeguard at-risk populations where required (e.g. Howald et al., 2009). Eradication projects have costs spread over time, leading to an implementation phase that involves a high percentage of total project costs, often over only a few weeks.

Rodent eradication on islands is currently limited by a lack of species-specific methods, animal welfare issues, high fixed costs, and socio-political opposition. Eradication projects may invoke controversy if they are perceived to be unlikely to succeed, costly, inhumane, or cause substantial collateral damage (Cowan and Warburton, 2011; Simberloff, 2002). In addition, implementing rodent eradications on inhabited islands with pets, livestock and non-target wildlife (all of which require management actions to eliminate or reduce risks from toxicants), have the potential to be highly controversial and will require innovative social approaches (Glen et al., 2013; Oppel et al., 2011) to secure sufficient consensus. The current reliance on a single pesticide for any large project may be perceived as inflexibility to consider other approaches.

Horizon scanning is the systematic search for nascent trends, opportunities and risks that may affect the probability of achieving management goals and objectives, and is being applied in medical, defense and conservation fields (Sutherland et al., 2012, 2010). For the vertebrate pest eradication industry, this exercise can aid prioritization of research, strategic planning and policy development with an overall goal of identifying the next generation of tools to eradicate rodents from islands. We undertook a horizon scanning exercise across relevant medical, pharmaceutical, invertebrate pest control, social science, technology and defense fields and highlight here some of the most promising emerging or potential future technologies and tools for advancing rodent eradications on islands. Potential innovations include increasing the species specificity of rodent eradication methods, improving animal welfare, reducing cost of applying bait, detecting low-density rodent populations, protecting non-target species from existing rodent eradication methods, and increasing the socio-political acceptance of restoration projects. We classify innovations as incremental or transformative, identify next steps and challenges, and the projected timeframe of commercial availability.

## 2. Horizon scanning and identification of innovative approaches

Island Conservation staff (KC, JB, NH, GH, AW) searched for opportunities for innovation in eradicating invasive rodent populations on islands. We requested innovation ideas from other Island Conservation staff, interviewed eradication practitioners and researchers in a wide range of fields, conducted literature searches and used a variety of creative-thinking techniques (Michalko, 2006). Potential innovations were listed, reviewed and those most promising were selected by a four-person panel (KC, JB, NH, GH). We classified innovation ideas as incremental or transformative. Incremental innovations provide supplemental improvements to existing tools to tackle rodent eradications with greater efficacy on islands where eradication is currently deemed possible, while transformative innovations provide tools that will allow the eradication industry to undertake rodent eradication projects on islands currently considered unfeasible. Ideas selected in the first process were investigated, articulated in more detail in a concept paper then subjected to another round of review and scoring against specific criteria including the ability to increase the feasibility of eradications, likelihood of success, potential payoff, and the relative investment required. The first and second processes were conducted twice between March 2010 and October 2012, and the resulting projects identified several incremental innovations (e.g. vitamin K1 implants), but few transformative innovations.

Between June and December 2011, in an attempt to identify additional transformative innovations, we identified the current barriers to eradications, listed the characteristics of methods that could overcome those barriers and reinitiated a search of the literature. We identified many of the ideas presented in this paper, identified specialists in those fields and held workshops (e.g. daughterless mice) or attended training sessions (e.g. conflict transformation) to develop the ideas further and evaluate their potential. These forums were rich in the exchange of ideas and discussion, often leading to the identification of additional innovation ideas. For example, ribonucleic acid interference (RNAi) had not been identified during our process, but was identified during discussions at a workshop. We had prior knowledge of other projects through exchanges with peers (e.g. norbormide, self-resetting traps and toxicant delivery devices).

## 3. Technologies and tools

Ten innovative technologies, techniques and approaches were identified that in the future might be applied to rodent eradications from islands (Table 1). The following order of technologies,

Please cite this article in press as: Campbell, K.J., et al. The next generation of rodent eradications: Innovative technologies and tools to improve species specificity and increase their feasibility on islands. Biol. Conserv. (2014), http://dx.doi.org/10.1016/j.biocon.2014.10.016