Going to scale: reviewing where we've been and where we need to go in invasive vertebrate eradications

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Abstract We are on the edge of the sixth mass extinction on Earth. Islands represent ca. 5% of the earth's land area yet are home to 61% of extinctions in the past 500 years, and currently support 39% of critically endangered species. Invasive species are a leading cause of extinction and endangerment on islands. Invasive vertebrates, particularly mammals, are among some of the most damaging invasive species on islands. Eradicating invasive mammals is an increasingly utilised conservation tool. Nevertheless, conservation intervention needs greatly outstrip the island restoration community's capacity. There are thousands of islands where invasive vertebrates are driving species toward extinction. So, how can the effort be matched to the scale of the problem? One approach is to improve outreach and communications to increase the resources available for projects. There are great stories; but these need to be told compellingly and repeatedly. Increasing social acceptance and support for invasive species eradications will reduce project costs associated with stakeholder engagement. Broadening the funding base can be accomplished by building stronger cost benefit valuations as well as engaging funders of climate change, marine conservation, human wellbeing, and food security. Furthermore, it is important to build upon existing partnerships to create or grow coalitions that can access these resources as part of broader, holistic efforts to address multiple conservation issues.

Keywords: communications, eradication, funding, invasive species, stakeholder engagement

INTRODUCTION

Multiple lines of evidence demonstrate that we are facing a significant global extinction crisis through the loss of biodiversity (Dirzo, 2003; Barnosky, et al., 2011). At a global scale, the response to this crisis includes the 2011–2020 strategic plan for biodiversity, highlighted in 20 targets to reduce pressures on the environment and to curb biodiversity loss (CBD, 2011). Islands are a logical place to focus conservation efforts because they offer a disproportionately higher rate of biodiversity and threatened species per unit area. Islands represent only ca. 5% of the earth's land area yet support ca. 39% of critically endangered species on the IUCN Red List (Tershy, et al., 2015), and an endemic richness of plants and vertebrates that is 8–9 times that on mainlands (Kier, et al., 2009).

Invasive alien species have been implicated as a leading cause of extinctions and endangerment for native plants and animals on islands (Tershy, et al., 2015). In particular, invasive mammals pose a significant risk (Doherty, et al., 2016). The development of tools and techniques to completely remove invasive mammal populations from islands has been a valuable intervention strategy for island managers to overcome this threat (Veitch & Clout, 2002; Veitch, et al., 2011). To date there have been more than 1,200 vertebrate eradication attempts on more than 700 islands with an 85% success rate (DIISE, 2014), and the pace and scale of eradications on islands is increasing (Simberloff, et al., 2018). Following successful eradications, demonstrable biodiversity conservation gains have accrued. A recent literature review found 596 populations of 236 native insular species benefited from 251 invasive mammal eradications on 181 islands (Jones, et al., 2016). Benefits included resident population recovery, recolonisation and unassisted colonisation, plus the enabling of reintroductions and conservation introductions. Similarly, Brooke, et al. (2017) investigated population growth rates in seabirds following invasive mammal eradications on islands and found a median population growth rate of 1.119 based on 181 populations of 69 seabird species.

NOTABLE ADVANCES AND INNOVATIONS

Several key innovations were critical to increasing the rate at which eradications of invasive mammals on islands have occurred. For rodents, New Zealand based programmes that researched the effectiveness of bait station approaches led to a series of successful implementations on small islands (Howald, et al., 2007). The advancement of aerial application techniques, including the use of satellite navigation systems, enabled efforts on larger islands and increased the number of islands treated, including >11,000 ha Campbell Island (Towns & Broome, 2003). These techniques have been exported internationally, with Macquarie Island at >12,000 ha recently declared successful, and implementation units recently treated within the South Georgia eradication reaching almost 30,000 ha. Likewise, for invasive ungulates, the advent of aerial hunting, extensive near real-time data management combined with mapping technology to coordinate large teams and different eradication methods, and the use of Judas goats enabled similar increases in number and size of islands treated (Campbell & Donlan, 2005) whereas aerial application, toxicant development and remote trap monitoring allowed continued increases in island size, efficiency and efficacy to be obtained on cat eradications (Campbell, et al., 2011), including the currently on-going treatment of ca. 65,000 ha Dirk Harthog Island in Australia.

The cumulative impact of numerous existing and on-going innovations is expected to increase the scope and scale of eradications on islands. Models to confirm eradication success (Ramsey, et al., 2009; Ramsey, et al., 2011) provide significant opportunities to reduce costs, particularly for large projects using hunting and/or trapping techniques, by increasing the efficiency of determining when a project is complete. Increased use of these tools, and associated real time, digital data collection and analysis tools, is recommended to increase efficacy, reduce costs and provide more information to enable post project review and analysis for future improvements (Will, et al., 2015).

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Efforts are ongoing to reduce reliance on second generation anti-coagulants for rodent eradications, whose efficacy comes with a trade-off of greater risk to nontarget species (Howald, et al., 2007). These include expanding the use of first generation anticoagulants that pose less risk to non-target species (Poncet, et al., 2011), investigating alternative compounds, such as Norbamide, and investigating new bait recipes that could increase efficacy, such as crab deterrents (Campbell, et al., 2015). Self-resetting traps, a relatively new tool, that have been deployed successfully for eradication on small islands in Puerto Rico and New Zealand, present another alternative on small islands where rodenticide use may not be possible (Carter, et al., 2016). These self-resetting traps present significant potential for biosecurity management and can provide long term protection where reinvasion risk from swimming rodents is high.

New strategies have been developed to overcome the higher failure rate in rodent eradications in the tropics. After a series of high profile rodent eradication failures on tropical islands, a workshop of practitioners, The Tropical Rodent Eradication Review, was convened to evaluate reasons for these failures and develop recommendations to increase success rates in the future. These guidelines were published in 2015 (Keitt, et al., 2015) and several projects implemented since have followed the spirit of these guidelines. It remains to be seen whether efficacy rates will increase as a result, though the second attempt on Desecheo, which followed the guidelines, was declared successful (Will, et al., 2019).

Another promising approach is genetic tools that can lead to eradication of rodent populations (Campbell, et al., 2015, Campbell et al., 2019). Genetically modifying rodents to produce sterile offspring or only males and using gene drives to push for near 100% inheritance of this trait, could lead to eradication at large scales, including on inhabited islands where eradication is not currently feasible. This technology is in the early stages of development for house mice and it is unlikely that it would be available for field trials sooner than a decade from now; longer for commensal rat species. However, there has been significant concern raised about the safety and ethics of pursuing this line of conservation, particularly around the potential for a gene drive to run through an entire species and lead to extinction (National Academies of Sciences, Engineering, and Medicine, 2016). If this technology can be proven safe and gain the appropriate social and political approvals, it could have wide ranging impact on the conservation of large inhabited islands while also providing significant benefit to humans through reduced disease transmission and reduction in agricultural loss.

LOOKING TO THE FUTURE

These efforts have made significant contributions to global progress in protecting biodiversity. However, there remains much to be done, and the conservation need is high. Jones, et al (2016) predicted that 107 highly threatened insular terrestrial vertebrates (229 populations) have benefitted in some way from invasive mammal eradications on islands, however this represents just 12% of all 860 highly threatened terrestrial vertebrates occurring on islands. The picture is brighter for seabirds, where 47% of critically endangered and 74% of endangered species were predicted to have benefitted from invasive mammal eradications to date. Considering the future, McCreless, et al. (2016) found that efforts to control or eradicate relevant invasive species could prevent 41–75% of future predicted extirpations of populations of threatened vertebrate species. Almost half of these extirpations reflect species with a single population (endemic) and thus extirpation is the same as extinction.

The number of islands targeted for eradication are few compared to the number of islands worldwide. Invasive rodents are widespread, with estimates of 80% of the world's island groups being invaded (Atkinson, 1985). Recent estimates suggest there are > 400,000 islands in the world > 10 ha (UNEP-WCMC, 2013) yet only ca. 450 have been the focus of rodent eradications (DIISE, 2014). Thus, the need to increase the scope and scale of efforts to eradicate invasive vertebrates is known (Philips, 2010). A considerable number of these invaded islands are outside the boundaries of what is considered feasible for invasive species eradications today, and innovative approaches will need to be established to realise these opportunities (Campbell, et al., 2015). These include use of some of the innovations mentioned above as well as ones yet to be envisioned. Two additional focal areas for development include the social acceptability of these projects and increased funding to implement projects.

CONSERVING SPECIES ON INHABITED ISLANDS – UNDERSTANDING THE SOCIAL CONTEXT

Due to the overlap of human settlements and biodiversity there has been an increasing interest in eradication projects on inhabited islands (Oppel, et al., 2011). Simberloff, et al. (2018) reported 194 eradication attempts on 94 inhabited islands, and a "sharp uptick" in numbers of attempts on inhabited islands for all species except rodents in 1960 and for rodents in 1990. Notable projects under consideration include Lord Howe Island, Robinson Crusoe, Great Barrier Island and Floreana Island. Glen, et al. (2013) make the case that inhabited islands often support a suite of invasive species and thus restoration efforts can require multi-species eradications that must take into account the ecological impacts of improper sequencing of removals and potential negative consequences of allowing some invaders to remain. Combining this challenge with that of gaining social license to achieve eradication, inhabited islands have been hailed as a next great challenge for conservation (Glen, et al., 2013).

It is likely that most land managers attempting to implement invasive vertebrate eradications on islands would prefer to do so in the relatively accommodating social environment of New Zealand, where signs in tourism shops proudly report on their efforts to control invasive species. Understanding the underlying reasons for social acceptance, or lack thereof, for eradication projects, is an important aspect of planning an appropriate process to achieve stakeholder support and approval for a project. As an example, the New Zealand conservation movement arguably began with efforts to protect its endemic birds, including the national bird, the kiwi (genus *Apteryx*) (Stoltzenberg, 2011). Given that invasive species currently are their greatest threat, it is natural that control and eradication enjoy broad support within the country. Contrast this with the United States, where some suggest the environmental movement can be traced back to Rachel Carson's Silent Spring (1962), which highlighted the imminent extinction of the US national symbol, the bald eagle, (*Haliaeetus leucocephalus*) from pesticide exposure. It is exactly these kinds of underlying human conditions that can impact attitudes about invasive species and the tools to control and eradicate them. Island restoration projects have typically applied significant rigor to the biological science necessary to understand invasive mammal eradication projects. As projects face more complex human dimensions, it will be necessary to apply the same rigor to the social sciences in order to achieve the necessary project support to proceed.

INCREASING FINANCIAL AND STAKEHOLDER SUPPORT

To expand funding opportunities for island restoration projects it is important to expand project justifications beyond biodiversity conservation to include human health and livelihoods, and ecosystem services. This will require new research to document and communicate the non-biodiversity impacts of these projects. For example, the Lord Howe Island rat eradication project underwent a comprehensive Cost Benefit Analysis that demonstrated there would be a benefit cost ratio of 17.0, i.e. 17 dollars in benefits for every dollar spent on the project (Gillespie, 2016). A similar approach was completed for the Cabritos Island donkey eradication in the Dominican Republic (Rijo, 2014). This analysis showed a benefit cost ratio of between 2.0 and 4.2 depending on the methods used to remove all of the donkeys and resulting cost of the work. Additional efforts to highlight the value of vertebrate eradications on islands to humans, including human health (de Wit, et al., 2017), ecosystem services (Peh, et al., 2014), and agriculture will be key to securing the necessary support, both financial and stakeholder, to meet the challenge.

Making a strong link between island restoration and marine conservation is important for maximising available resources. Islands serve an important function in marine ecosystems (Gove, et al., 2016), including providing key breeding habitat for species that are dependent on marine resources. Most seabirds, sea turtles and marine mammals are dependent on islands to reproduce yet are key members of marine ecosystems. Making this case to marine funders and incorporating goals to protect and maintain populations of top level native predators in the management plans of these reserves is a good place to start.

Climate change is projected to have a significant impact on islands and island species and there are significant global financial resources available for addressing climate change impacts. Tershy, et al. (2015) argue that some of the same attributes that make island species vulnerable to invasive species, primarily smaller ranges and population sizes and less genetic diversity, also make them vulnerable to climate change. For many island ecosystems, invasive mammal eradications, in combination with other restoration actions, can increase resilience to projected climate change impacts, and provide refugia for species whose habitat is projected to be lost. However, proposed island restorations on low elevation islands should consider future sea level rise projections (Courchamp, et al., 2014) and include this in the project cost/benefit analysis.

Partnerships are not new to conservation, yet as island restoration projects expand in size and scope, diverse partnerships become more important to their success. Non-governmental organisations and governments working collaboratively together are becoming more commonplace. For example, the United States Fish and Wildlife Service has established a national level Memorandum of Understanding with other government agencies and US based NGOs to facilitate invasive species work and move from a project focus to a more programmatic one. Collaboration between NGOs internationally is also becoming more commonplace in the implementation of eradication projects. An example is the partnership between Island Conservation and Birdlife International on the multi-island, multi-species eradication in the Acteon and Gambier archipelagos, a project led by the local Tahitian NGO, and Birdlife Partner, SOP Manu. There are opportunities to expand these types of governmental and non-governmental partnerships, to enhance the capacity for conservation actions worldwide. Much is written about how to create successful partnerships, and common tenets to these types of partnerships are working to clarify shared values, programme goals, respective responsibilities and definitions of success.

Perhaps one of the greatest opportunities to grow support for island conservation work in this increasingly connected and wired planet is through communication and outreach. Effective communication requires sharing the right information with the right audience at the right time. Story-telling is a communication approach that can make difficult to understand ideas, such as the need to kill non-native species to conserve native ones, more accessible. Having island residents and stakeholders tell their stories or presenting a project from the viewpoint of the native species that will benefit, can resonate far more than statistics and summaries of what has happened somewhere else. The Goodman Center (<www.thegoodmancenter.com>) is a resource that can help train how to develop and tell compelling stories. For island restoration, the audiences are varied – funders, stakeholders, island communities and practitioners. This requires creating story arcs that reflect the values of key decision-makers and involve rigorous and defensible research to create story content. The recovery associated with removing invasive species from islands is often exceptional, providing compelling and dramatic messages that can be shared to generate interest in projects. Investing in the monitoring to document these stories is often under-valued, yet the link to funding future projects is clear. The platform for telling stories and reaching some audiences is evolving quickly alongside technology, thus these social media platforms require constant innovation and novel approaches to reach audiences. Conversely, many island communities communicate the same way they did decades or even a century ago, with shared experiences and face-to-face time as the key medium. Effective and thoughtful planning of communications will continue to evolve as necessary components of island restoration.

CONCLUSION

There are few conservation approaches that can match the return on investment of invasive mammal eradications on islands. As the earth continues to lose biodiversity at a rapid pace, with islands disproportionately affected, it is urgent to increase the rate at which islands are restored. Innovation has played a key role in past increases in eradication efficacy and efficiency (Keitt, et al., 2011) and new innovations are primed to do the same (Campbell, et al., 2015). However, these innovations must expand beyond the technical aspect of how to eradicate invasives and include ways to increase funding and stakeholder engagement and support. With greater buy in for island restoration projects they will become easier to implement.

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