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If at First You Don't Eradicate: Remediating Rat Eradication Failure on Wake Atoll

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ABSTRACT: Island rodent eradication operations have been remarkably successful at eliminating damages caused by these harmful vertebrate pests. As efforts increase in scale and complexity, so does risk of eradication failure. In this paper we present the example of a partially successful rodent eradication project to highlight how best practices and lessons learned are being integrated to reduce risk of failure during a second attempt. In 2012 the U.S. Air Force (USAF) commissioned an attempted eradication of two rat species from Wake Atoll in the Western Pacific. Asian house rats were successfully eradicated, but it was soon confirmed that some Polynesian rats survived; population numbers have since soared. A panel of outside experts was asked to review the project and identify factors that may have contributed to failure. The USAF and Wildlife Services National Wildlife Research Center (NWRC) have used this report as a road map for further studies addressing issues including bait delivery strategies, bait application rates, and alternate bait formulations. A subsequent data gap analysis conducted by USAF, NWRC, and Island Conservation documented technical advances in the intervening years that address risk factors identified in the original review, and highlighted remaining needs including development of a community outreach component and refinement of baiting strategies for inhabited areas and abandoned structures. This exchange of knowledge and expertise among cooperating organizations is helping to refine feasibility assessments and address lingering knowledge gaps. These efforts include a review of other failed rodent eradications that were redone successfully. Ongoing studies continue to resolve areas of uncertainty, and results are being integrated into operational planning for a subsequent eradication effort on Wake Atoll. This process highlights the importance of ongoing refinement of best practices, incorporation of lessons learned, and transfer of knowledge to the wider eradication community.

KEY WORDS: best practices, ecological restoration, eradication failure, gap analysis, human dimensions, knowledge transfer, lessons learned, rodent eradication, rodenticide, tropical island

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INTRODUCTION

Eradication of invasive rodents is an important management tool for island ecosystem restoration (Russell et al. 2015), with proven conservation benefits (Jones et al. 2016, Russell and Broome 2016). The formalization of eradication principles (Cromarty et al. 2002) and on-going improvements in eradication methodology (e.g., use of helicopters to deliver bait, use of GPS to ensure comprehensive bait coverage) coupled with the continued refinement of best practice recommendations for aerial baiting (Broome et al. 2017), hand broadcast (Broome et al. 2011a), and bait stations (Broome et al. 2011b) have seen rodent eradications grow rapidly in both scale and complexity (Towns et al. 2013, Russell and Broome 2016). Despite the heightened risk of failure associated with increasingly large and complex eradication projects, overall rates of success have been very high (85%; Keitt et al. 2015). This is likely due to the commitment of the international community of eradication practitioners to thoroughly review and communicate lessons learned from their experiences, particularly those learned from failed eradication attempts (Amos et al. 2016, Kappes et al. 2019). As a result, best practice guidelines have been continually refined and eradication methodology improved. This paper presents a partially successful rodent eradication project to illustrate how best practices and lessons learned are being integrated to prepare for a subsequent rat eradication attempt. With these preparation actions, we anticipate reduced risk of failure for a proposed second attempt.

BACKGROUND

In 2012 the U.S. Air Force (USAF), in collaboration with the U.S. Fish and Wildlife Service (USFWS) and Island Conservation (IC), attempted to eradicate Asian house rats (*Rattus tanezumi*) and Polynesian rats (*R. exulans*) from Wake Atoll (19.2796° N, 166.6499° E), an unincorporated U.S. territory in the Western Pacific (Figure 1), using Brodifacoum-25W Conservation rodenticide (B-25W; Bell Laboratories, Madison, WI). Comprising three low-lying islands (Peale, Wilkes, and Wake) totaling approximately 740 ha and with maximum elevation of 6 m, Wake Atoll does not represent a topographically challenging eradication project. However, the combination of a multi-species eradication on an inhabited, tropical island with on-going military operations that restricted eradication operations, made the Wake Atoll eradication one of the most complex eradications that had been attempted at the time (Brown et al. 2013). Due to the complex nature of regulations limiting where various

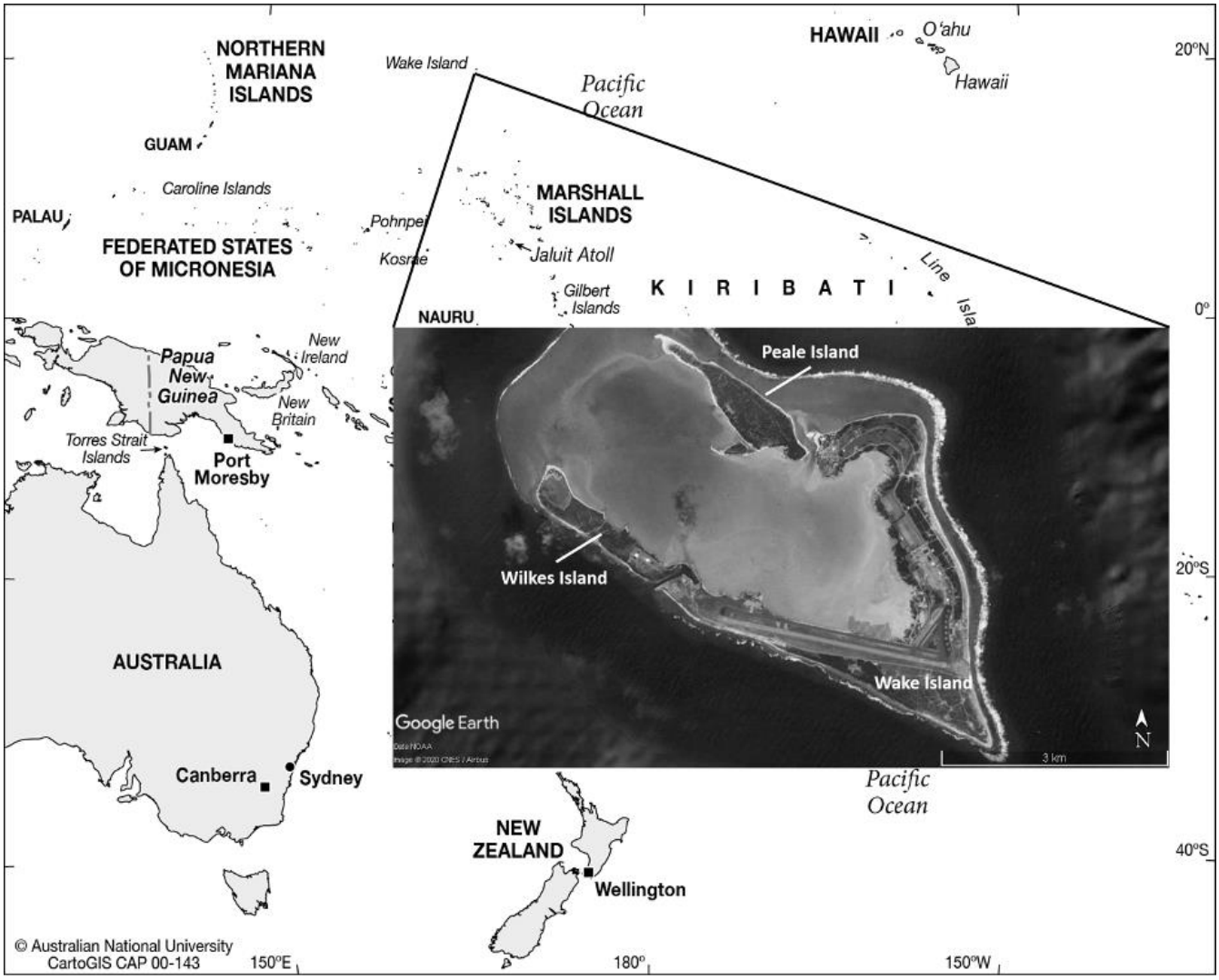

Figure 1. Location and map of the three islands comprising Wake Atoll.

application techniques could be used, the project relied on a patchwork combination of aerial baiting, bait stations, and hand broadcasting to establish comprehensive bait coverage.

Asian house rats were successfully eradicated from all three islands. Polynesian rats were also successfully eradicated on Peale Island. Despite the close proximity to Wake Island, Peale Island continues to be apparently rat-free. However, the eradication attempt failed to kill all of the Polynesian rats on Wake and/or Wilkes Islands. DNA analysis indicated that the eradication failed to eradicate the initial population, as opposed to re-invasion following eradication (Hanson et al. 2020). Polynesian rat population numbers have since recovered on these two islands and again pose a risk to ecosystem processes, island infrastructure, and mission readiness for the USAF.

Following confirmation that the eradication attempt was only partially successful, an outside panel of experts was commissioned to review the project with following two objectives: 1) identify what factors may have contributed to the failure; and 2) detail the lessons that could be learned and applied to a future eradication attempt on Wake Atoll, including identifying any additional research needs (see Brown et al. 2013 for full review and discussion). Since its completion in 2013, this review document has served as a research priority roadmap for the USAF, who has partnered with the Wildlife Services National Wildlife Research Center (NWRC) to address the risk factors and research needs identified in the review. In 2019, the USAF and NWRC partnered with IC to perform a gap analysis to assess the technical and methodological advances that have occurred in the intervening years that address risk factors and research needs identified in the Brown et al. (2013) review. The analysis identified any remaining research needs and recommendations for the feasibility of a future eradication attempt on Wake Atoll (Hanson et al. 2020).

RESULTS AND DISCUSSION

Due to the complexity of the Wake eradication project it was impossible for Brown et al. (2013) to identify any single risk factor responsible for the failure. Instead, they

concluded that failure to eradicate Polynesian rats "could have derived from a single factor or a 'perfect storm' of several overlapping issues." These risk factors, like those for any failure, can be assigned to one or both of the following fundamental scenarios:

1) All rats **could not** eat a lethal dose of bait (or lethal dose via secondary consumption of other bait consumers).
2) All rats **would not** eat a lethal dose.

Each of these scenarios can be further broken down into sub-categories, each of which are thoroughly reviewed and discussed in Brown et al. (2013), but several of which were considered particularly important in contributing to the failure to eradicate Polynesian rats (see Tables 1 and 2). In addition to identifying these important risk factors, Brown et al. (2013) also made an important call to the eradication community regarding the formulation of best practice guidelines for tropical rat eradications. Confirmation of Wake's failure coincided with several other projects that failed to eradicate rats from tropical islands (Enderbury, Henderson, and Desecheo) and there was a growing appreciation within the eradication community that best practice guidelines developed in temperate systems needed to be modified for tropical systems (Keitt et al. 2015, Griffiths 2019). In the intervening years not only has the eradication community produced best practice guidelines for rat eradications on tropical islands (Keitt et al. 2015), but also developed a standardized approach for measuring bait availability (Pott et al. 2015). Standardization informs the selection of appropriate bait application rates, facilitating comparisons among projects and islands, which can lead to greater insights and understanding on bait availability during eradication projects. Another knowledge gap identified by Brown et al. (2013) was how reproduction, widely considered a risk factor, and associated breeding behaviors (e.g., female ranging behaviors and dietary preferences, pup emergence behavior) might contribute to risk of failure. A recent study specifically addressed several of the knowledge gaps for this risk factor by attempting to eradicate an active breeding population of Polynesian rats from Reiono Island, Tetiaroa Atoll, French Polynesia (Samaniego et al. 2020a) and found no evidence that breeding or diet specialization compromised the success of eradication, even though they purposely used low bait application rates. Samaniego et al. (2020a) concluded that the reproduction risk factor can be addressed by ensuring comprehensive bait coverage and, while not always easily achievable, is something practitioners can actively control and represents a much better way to address this risk factor.

Table 1. Risk factors identified in the review process that could have caused failure because rats could not eat enough bait, recommendations and research conducted to address those concerns or knowledge gaps, and reference(s) addressing recommendation or indication if work has been completed to address recommendation.

Risk Factor	Recommendation	Reference or Technical or Methodological Advance
Insufficient Bait	Supplemental label(s) to increase bait application above maximum	Keitt et al. 2015
	Supplemental label to increase 2nd application a robust as initial application	Keitt et al. 2015
	Supplemental label to increase number of applications	Keitt et al. 2015
	Extend interval between applications for breeding behaviors • Focus on comprehensive bait coverage	Keitt et al. 2015 • Samaniego et al. 2020a
	Stratify application rates to specific areas: • Describe treatment locations • Accurately identify boundaries • Determine appropriate bait application rates • Solid waste aggregation area study	Niebuhr et al. 2018: • Keitt et al. 2015 • Keitt et al. 2015 • Keitt et al. 2015; Pott et al. 2015 • Scheduled 2020 (NWRC)
Gaps in coverage: Complex baiting strategy	Pre-determine and verify application technique for each zone	Hanson et al. 2020
	Reduce the number of exclusion zones for aerial baiting	Hanson et al. 2020
	Lift restrictions that reduce baiting efficiency	Hanson et al. 2020
Gaps in coverage: Tidally inundated habitat	Tested variety of delivery methods and proposed bait application strategies	Siers et al. 2018
Gaps in coverage: Structures poorly known	Update structure data base with all above and below ground structures	Completed 2019 (NWRC unpubl. data)
	Geo-reference all above and below ground structures into digital database	Completed 2019 (NWRC unpubl. data)
	Assess if bait can be delivered for rodents utilizing subterranean habitat	Completed 2019 (NWRC unpubl. data)

NWRC = USDA Wildlife Services National Wildlife Research Center

Table 2. Risk factors identified in the review process that could have caused failure because rats would not eat enough bait, research conducted to address those concerns or knowledge gaps, reference(s) addressing recommendation or indication if work has been completed to address recommendation. All bait trials used Bell Laboratories (Madison, WI) Brodifacoum 25W Conservation bait (hard) as the rodenticide. Soft bait in 2019 trials was Bell Laboratories FINAL Soft Bait with Lumitrack®.

Risk Factor	Research	Outcome	Research/Reference
Aversion/palatability issues: Preference for natural food items	2-choice trial between toxic bait and natural food items	Preferred bait	Shiels et al. 2015
Aversion/palatability issues: Localized dietary preferences	2-choice trial between soft and hard formulations of toxic bait with rats from commensal, bush, and solid waste aggregation locations	No soft bait consumed; 27% of rats (mostly from commensal and bush locations) consumed no bait	Completed 2019 (NWRC unpubl. data)
Tolerance to bait	No-choice efficacy trial	100% mortality	Shiels et al. 2015
	No-choice efficacy trial	Hard bait: 100% mortality Soft bait: 80% mortality	Completed 2019 (NWRC unpubl. data)

NWRC = USDA Wildlife Services National Wildlife Research Center

In combination, these contributions from the wider community of eradication practitioners and directed studies by the USAF and NWRC have addressed most of the important risk factors identified by Brown et al. (2013; see Tables 1 and 2). However, there are still several risk factors that need to be addressed (Hanson et al. 2020). Both Brown et al. (2013) and (Hanson et al. 2020) have noted that community understanding and buy-in during the previous attempt was not sufficient. Prior to another eradication attempt, a robust community outreach program will need to be developed. Emphasis should include educating the Wake community about eradication fundamentals and facilitating community buy-in by involving them in the planning process and implementation of a zero waste program. The zero waste program addresses the risk factor that rats could have access to alternative anthropogenic food sources and will require community participation and commitment to be successful. While the majority of previous eradication projects have been conducted on uninhabited islands, community buy-in has been an essential component of eradications on inhabited islands. Lessons learned from eradications on inhabited islands, such as the Lord Howe Island (Harper 2020) and Ascension Island (Ratcliffe et al. 2009), include the development of a robust outreach program. To be most effective these programs should be administered by a professional social scientist and have proven to require a substantial commitment of time and resources that are easy to underestimate (Harper 2020).

Future efforts will continue to resolve areas of uncertainty, particularly regarding how aspects presenting a risk to eradication efficacy are addressed. For example, rather than estimating appropriate bait rates for Wake Island's solid waste aggregation area, it would be ideal to remove the condition which necessitates an adjustment. Previous studies have been unable to meet best practice guidelines for bait persistence outlined in Pott et al. (2015) due to rapid and complete consumption by a hyper-abundance of rats in this area. Other work underway includes a review of other rat eradications that failed but were redone successfully. Practitioners undertaking a future effort on Wake Atoll should also seek to maintain continuity of staff within key roles and avoid including a high proportion of inexperienced participants (Brown et al. 2013, Hanson et al. 2019; Samaniego et al. 2020b). In particular, it will be important to ensure that the operation is managed by an experienced project leader who has spent substantial time working with the island residents and has a thorough understanding of the environmental and on-island social conditions under which the eradication will occur. The continuity of having this individual in place, with well-established relationships to both the island and military command structure, will allow them to minimize compromises to best practices and give them the authority to postpone the project if substantial concerns are raised throughout the planning process and/or if critical pre-operational conditions are not met (Brown et al. 2013). These efforts and recommendations are being incorporated into operational planning for a future eradication attempt on Wake Atoll.

CONCLUSIONS

Eradicating invasive rats from islands is important for protecting global biodiversity and island ecosystems. Each success spurs more research and technically and logistically challenging attempts in a positive feedback cycle (Simberloff 2001). Although failures may not seem like a part of that cycle, we often learn more from failures than we do from successes (Madsen and Desai 2010). The failure to eradicate Polynesian rats from Wake Atoll in 2012 illustrates that this is indeed true (e.g., Griffiths et al. 2014). The commitment of the eradication community to learn from this failure and others, to communicate lessons learned, and to identify knowledge gaps has led to the development of new best practice guidelines for rat eradications on all tropical islands, transfer of knowledge to the wider eradication community, and comprehensive recommendations for the success of a future eradication on Wake Atoll. This process highlights that "failures" can be remediated and learning from them can play an important role in future successes.

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DISCLAIMER

Reference herein to any specific commercial products, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government.

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