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Tropical Island Rodent Eradications: A Proposed Model to Improve Outcomes

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ABSTRACT: Recent failures of tropical island rat eradications have spurred a re-appraisal of the approach required to increase the success rate. A review of some failures implies that direct transfer of the temperate island eradication strategy to tropical islands, based on a 'seasonal vulnerability' model, may be erroneous, and particularly so for 'wet' tropical islands with year-round breeding by rodents. A new model based on intra-specific competition is proposed, with suggested research avenues to tease out aspects of rodent population dynamics that may make rodents vulnerable to eradication techniques in tropical islands.

KEY WORDS: climate, competition, eradication, intra-specific, islands, *Rattus*, resources, rodent, tropical, survivorship

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INTRODUCTION

Invasive rodent eradication on islands is a highly efficacious method for ecosystem restoration and safeguarding endangered species (Russell and Holmes 2015, Jones et al. 2016). In essence, the technique invariably involves delivery of toxic bait, usually a 2nd generation anticoagulant in pellet form, within every rodent territory in order to supply a fatal quantity to each individual (Broome et al. 2014). The technique has developed to the stage where larger islands and more complex operations are being conducted (Holmes et al. 2015, Harper et al. 2020). However, the success of eradications on temperate islands is not entirely reflected on tropical islands, where a higher failure rate is tied to novel environmental factors, such as the presence of coconuts; land crabs as competitors for bait; and consistently high primary productivity, resulting in high rodent abundance, especially on 'wet' tropical islands (Harper and Bunbury 2015, Holmes et al. 2015, Russell and Holmes 2015).

On temperate islands, seasonal declines in primary productivity drives rodent population dynamics and has been the main determinant in operational planning, leading to winter eradications being the norm, because rodent survivorship is low due to resource scarcity (Cromarty et al. 2002). In contrast, on tropical islands, primary productivity is function of water availability. On tropical islands with seasonal rainfall, food availability is restricted late in the dry season, rodent eradications generally take place then, which is analogous to winter eradications at temperate sites. In the case of tropical islands where sufficient rainfall is available year-round, no obvious seasonal 'window' is available to target rodent populations when they are most at risk (Figure d in Russell and Holmes 2015), which has confounded the past 10-20 years of operational planning based on the 'seasonal vulnerability' model.

To improve tropical island rodent eradication success there is a need to investigate rat population dynamics and their relationship with rainfall and primary productivity, in order to develop a modified model for improving eradication success on tropical islands. This paper will attempt the first steps to solve this conundrum.

BACKGROUND

Tropical island eradication failures are likely caused by two factors: rats not able to eat a lethal dose of toxic bait, or not consuming a lethal dose. The former would occur if there were gaps in bait coverage or not enough bait on the ground, whereas the latter would be due to unpalatable bait, more favoured alternative food, or reproductive activity resulting in altered behaviour in pregnant females or emergent pups (Holmes et al. 2015). Other alternative reasons, such as sub-toxic bait or toxin resistance have been discounted after innumerable post-operational appraisals have shown these as non-causal factors.

As the majority of rodent eradication operations are carried out at a high level of accuracy using GPS guided aerial bait application or ground application, gaps in bait coverage, although possible, is a unlikely reason for eradication failure, as is insufficient bait as most operations in the tropics have increased bait application rates, relative to temperate island operations. Similarly, the principal bait types used have a considerable record of success, suggesting the baits are highly palatable. Therefore, in order to tease out the possible causal factors we need to consider alternative food availability and palatability and rat population dynamics.

Rat population density is positively correlated with vegetation biomass in the tropics (Clark 1980), with a positive correlation between rainfall and breeding activity (Temme 1979). Certainly, seasonal aridity or droughts on 'wet' islands cause declines in rat population abundance with a concomitant increase in the populations after rainfall and a flush on new vegetative growth (Clark 1980, Harper and Bunbury 2015). This has probably been the principal causal factor in the failure of several tropical rodent eradications at Lehua (Hawai'i; Parkes and Fisher 2017), Enderbury Island (Phoenix Islands), Desecheo (Puerto Rico; Will et al. 2019), several Galapagos islands (Harper and Carrion 2011), and Henderson Island (Pitcairn; Griffiths 2017) where the eradication operation occurred during a wetter than average period on a usually arid island, or after a drought broke on a normally 'wet' island.

Unfortunately, little data on population dynamics are available for any of these islands before or after the eradications except Henderson Island, and this is largely anecdotal. A drought had occurred in the Pitcairn archipelago through the summer and early autumn of 2011 and broke in May. During the subsequently unsuccessful

July eradication operation an atypical and flourishing rat breeding season was occurring, with many juvenile rats recorded, along with heavy fruiting of several tree species. Similarly, breeding by the endemic dove was noted, which did not occur in other winters (Cuthbert 2011, Lavers et al. 2016). The eradication operation killed over 99% of the rat population but missed about 60-80 individuals (Amos et al. 2016). In a usual winter there is little or no rat breeding activity and rat survivorship is at its lowest ebb (Oppel et al. 2019), suggesting a restricted food supply. Similarly, on semi-arid Desecheo Island rat breeding was recorded immediately after the first unsuccessful eradication attempt in an unusually wet season, but not during the successful 2016 operation with a normal rainfall regime (Will et al. 2019). However, more bait was applied in the second operation, which confounds the result.

In summary, limited evidence suggests a flush of vegetative growth after a period of aridity on tropical islands can lead to a lagged but pronounced breeding response by rodents. As this situation can lead to eradication failure it suggests that an excess of food resources means at least a few rats are avoiding rodent bait that is normally favoured, judging by the success of the same baits in eradication operations elsewhere. Unfortunately, there is little or no monitoring of natural food availability and rodent bait avoidance during rodent eradications, and it would be difficult to assess if at least 99% of the rodents die from toxic bait consumption in any case. Examples of favoured food avoidance when alternative natural food is available in large amounts appear to be rare, but have been seen in other rodents, such as mice and voles in temperate sites (Selva et al. 2012).

A similar example comes from southern beech forest (*Fuscospora* spp.) in the South Island, New Zealand, where seasonal rodent (mainly *Rattus rattus* and *Mus musculus*) abundance is often monitored for research and management purposes, using tracking cards in tunnels. A tracking card, with ink in the centre, is placed in a tunnel and rodents will track on the card when they are attracted by the lure, often peanut butter. Southern beech mast-seeds every 2-5 years and produces huge numbers of seed, with an associated irruption in rodent numbers by late winter and spring. At Lake Rotoiti, monitoring is carried out on about 20 tracking tunnel transects of 10 tracking tunnels. In a 'normal' year, some 5-20% of tunnels are tracked and all peanut butter lure is consumed. In the 2013 beech mast, 9,000-18,000 seeds/m^2 were produced and winter tracking rates were about 50% (Harper et al. 2014, Long et al. 2015). However, during that winter, although tracking rates were high in many tunnels, peanut butter was not consumed in most tunnels that were tracked (G. Harper, pers. observ.), which suggested that super-abundant beech seed was favoured over a normally highly desirable lure. In spring, with sustained high rodent numbers, the peanut butter lure was once again eaten by rodents once the beech seed germinated and become unpalatable.

CONCLUSION

When an excess of food rapidly becomes available, a diminished rodent population will respond with an increase in breeding activity and for a while can select favoured food, likely high in fats and/or protein, with reduced intra-specific interactions. This is shown in Figure 1, where vegetative resources exceed rodent numbers immediately following a drought (hatched area), but with rodent numbers eventually increasing to reach equilibrium with the resources.

However, when the excess of favoured food becomes increasingly restricted, through consumption for example, intra-specific competition increases which is often expressed in increased fighting (Davis 1979, Harper 2005) and reduced reproductive output (Temme 1979), which demonstrates that when rodent populations are constrained by the available resources, intra-specific competition is acute. It would also lead to less favoured foods being consumed. This infers that tropical island rodent eradications should take place when intra-specific competition is at its most intense. Rather than using a 'seasonal vulnerability' model based on temperate eradications, an 'apex competition' model should be the basis for rodent eradication planning in the tropics. The high rat population density commonly found on tropical islands should be the situation eradication planners are aiming for, as it likely translates to intense competition for food.

There are a few recent successful tropical eradications that provide some support for this approach. Samaniego et al. (2020) carried out an experimental eradication of Pacific rats (*R. exulans*) in 2018 using a moderate bait application rate on a 22-ha wet tropical island with high rat population density and year-round breeding. Another recent eradication mirrored the events on the drought-affected eradications discussed earlier. Pacific rats were eradicated in 2017 on Teuaua, a 4-ha islet in the Marquesas, despite a recent flush of plant growth and the presence of nesting seabirds. In the case of the vegetation flush, it was less verdant during the second bait application, three weeks after the first. Unfortunately, rat abundance was not recorded but was likely to be high on this usually dry island (Zito and Withers 2017).

SUMMARY

The information presented offers a possible formula to improve the success of rodent eradications on tropical islands. In order to fine-tune the proposed 'apex competition' model, eradication operations in future should, where possible, incorporate well considered monitoring and

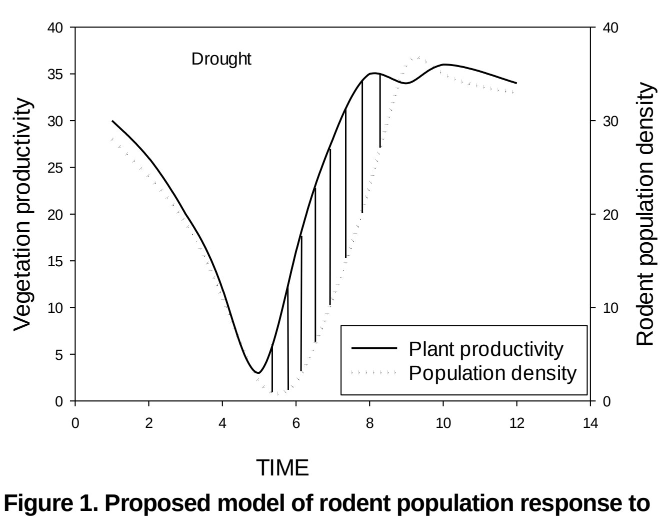

Figure 1. Proposed model of rodent population response to drought induced declines in vegetation productivity.

studies to tease out factors that make rodents vulnerable to eradication techniques on these islands. The most promising research would likely focus on resource competition in populations on 'wet' islands at maximum densities. Developing a measure of competitive interactions or monitoring a surrogate indicator such as reproductive success and/or survivorship may provide a metric for use in eradication planning. Tying these data to resource availability is also likely to be of use, but will require a more in-depth knowledge of the rodent diet and food preferences on each individual island. If the opportunity arises to carry out eradication trials concurrently on adjacent islands, this would improve the robustness of the research.

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