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## BIODIVERSITY AND ECOSYSTEM RESTORATION

# INCREASING THE SCALE OF SUCCESSFUL INVASIVE RODENT ERADICATIONS IN THE GALAPGAOS ISLANDS

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*The* ***Galapagos National Park Service*** *has its headquarters in Puerto Ayora, Santa Cruz Island, Galapagos and is the Ecuadorian governmental institution responsible for the administration and management of the protected areas of Galapagos.*

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***Galapagos Conservancy****, based in Fairfax, Virginia USA, is the only US non-profit organization focused exclusively on the long-term protection of the Galapagos Archipelago.*

Julia Ponder with the twentieth Galapagos hawk placed in temporary captivity.

Photograph: ©Rory Stansbury, Island Conservation

# Increasing the scale of successful invasive rodent eradications in the Galapagos Islands

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## Background

Introduced rodents are major drivers of extinctions on islands, impact agricultural production, consume and spoil stored foods, and spread diseases that impact human health (Towns *et al.*, 2006; Varnham, 2010). Introduced rodents impact the reproduction of native vegetation through seedling and seed predation, and prey on invertebrates, land and seabirds, and reptiles (Towns *et al.*, 2006). In Galapagos, introduced rodents have negatively impacted natural ecosystems by contributing to the extinction of endemic rice rats, declines in giant tortoise populations, and declines and extirpations of land and seabirds and other fauna (Cruz & Cruz, 1987; Dowler *et al.*, 2000; MacFarland *et al.*, 1974; Steadman & Stafford, 1991). By consuming seeds and seedlings they impede regeneration and alter forest dynamics, affecting entire ecosystems (Clark, 1981). Impacts on invertebrates have not been quantified in the Galapagos but likely occur based on impacts elsewhere (Towns *et al.*, 2006).

The eradication of invasive rodents is possible; over 360 rodent eradications on islands worldwide have been successful to date. Anticoagulant rodenticides have made these eradications possible, using aerial bait application methods on large islands and those with rough terrain. Rodent eradications on islands as large as 11,300 ha (Campbell Island, New Zealand with *Rattus norvegicus*) have been successful. Success of a recent eradication attempt on the even larger Macquarie Island, Australia (12,870 ha), with both mice (*Mus musculus*) and black rats (*Rattus rattus*) is awaiting confirmation. Rodent eradication allows extant plant and animal populations to recover, creates additional habitat for extirpated species, which can then recolonize or be reintroduced, and provides rodent-free habitat for conservation introductions to occur (Bellingham *et al.*, 2010).

In 2007, a roadmap for a programmatic step-by-step approach to introduced rodent eradications in Galapagos was developed to prevent imminent extinctions (FCD / SPNG 2007). Each step builds local capacity and knowledge, and each subsequent step involves progressively larger and more complex eradications. In late 2007, a hand-baiting rat eradication on North Seymour Island (184 ha) was successful. We report here on the second step, in 2011, involving the aerial broadcast of bait to target three introduced rodent species on Rábida, Bartolomé, Sombrero Chino, and nine smaller islands.

## Methods and results

Since the North Seymour rat eradication was completed in 2007, more than two years of planning, trials and groundwork were required to prepare for aerial

Photograph: Rory Stansbury, Island Conservation

baiting operations. Bait color choice trials with finches determined that blue baits were least preferred by finches, and baits in this color would therefore minimize risk to finches (Carrión Bonilla, 2009). Blue non-toxic bait uptake trials with mockingbirds, finches, other land birds, lava lizards and tortoises were conducted. A toxic bait trial using Conservation 25D (Bell Laboratories, Wisconsin), a cereal bait with 25 ppm brodifacoum formulated for dry conditions with a pyranine biomarker, was conducted with before and after monitoring on Plaza Norte, allowing for the potential population level impacts of baiting to be determined (IC / CDF, 2010). A non-target risk assessment was conducted for all vertebrate species present on Pinzón, Rábida and other islands proposed for rodent eradication (Table 1). The assessment determined likely low risk, with high uncertainty, for island endemic Pinzón tortoises and Pinzón lava lizards. This high level of uncertainty was considered unacceptable for these island endemics and it was recommended to delay implementation on Pinzón and conduct additional trials for these species. Mitigation actions proposed for Plaza Sur land iguanas, which have unique genetics (Tzika *et al.*, 2008), also delayed the proposed eradication of mice from that island. The non-target risk assessment identified Galapagos Hawks to be at high risk and this was considered unacceptable on Pinzón due to their conservation status and the unique genetics of the Pinzón population (Bollmer *et al.*, 2006). Hawks were also present on other islands to be targeted - Rábida, Bainbridge #3, and Bartolomé, all of which form part of the Santiago Hawk population. To build capacity in hawk mitigation measures leading up to Pinzón it was decided to capture and temporarily hold hawks from these islands in captivity until the risk to hawks from eating toxic rodent carcasses and other prey was minimal.

An implementation plan was produced that detailed logistics, roles and responsibilities of personnel, baiting rates, and methods, among other details. The operation was to be timed during the dry season when natural foods for rodents are most limited. The operation was to occur in November 2010, but delays in the contracting of the helicopter caused the operation to occur in January 2011. The Technical Council of the Galapagos National Park Service (GNPS) reviewed and validated the non-target risk assessment, implementation and hawk mitigation plans. In accordance with the implementation plan, bait buckets were calibrated on the abandoned airstrip on Baltra with non-toxic bait to ensure buckets would disperse the precise amount of bait. Two aerially applied bait applications on the 12 target islands occurred on 7-8 and 14-15 January 2011. Bait was applied using a helicopter with a bait-spreader bucket flown along pre-designated GPS lines by a specialist pilot to accurately 'paint' the island in parallel swaths. The coast was flown

**Table 1.** Islands proposed for the initial aerial baiting campaign to eradicate rodents. Due to uncertainty of risks to island endemic reptiles and mitigation plans for land iguanas, eradications on Pinzón and Plaza Sur Islands were postponed.

| No. | Island | Area (ha) | Eradication target |
|---|---|---|---|
| 1 | Rábida | 499 | *Rattus norvegicus* |
| 2 | Bartolomé | 124 | *Rattus rattus* |
| 3 | Islote Gran Felipe | 0.4 | *Rattus rattus* |
| 4 | Plaza Norte | 8.8 | *Mus musculus* |
| 5 | Roca Beagle Oeste | 4.3 | *Rattus rattus* |
| 6 | Roca Beagle Sur | 8.7 | *Rattus rattus* |
| 7 | Roca Beagle Norte | 0.7 | *Rattus rattus* |
| 8 | Bainbridge #1 | 11.4 | *Rattus rattus* |
| 9 | Bainbridge #3 w/lagoon | 18.3 | *Rattus rattus* |
| 10 | Bainbridge #5 | 4.1 | *Rattus rattus* |
| 11 | Bainbridge #6 | 4.5 | *Rattus rattus* |
| 12 | Sombrero Chino | 20.9 | *Rattus rattus* |
| | **Total** | **705.1** | |
| | **Postponed Islands originally proposed** | | |
| | Pinzón | 1,815 | *Rattus rattus* |
| | Plaza Sur | 11.9 | *Mus musculus* |

with a directional bait bucket to minimize bait entering the marine environment. Each bait application across the 12 islands took two days, and applications were seven days apart. Total bait applications were 19-22 kg/ha for most coastal areas and 9-12 kg/ha for inland areas. Tourist sites (Rábida, Bartolomé, and Sombrero Chino) were temporarily closed during the bait application, with GNPS staff providing interpretation to boat passengers and crews. Informative warning signs were placed at landing sites. Local and national press attended the second application on Rábida, and press releases were distributed by the GNPS and project partners. Twenty hawks from Rábida, Bainbridge #3, and Bartolomé were captured prior to baiting and temporarily held in captivity in aviaries on Santiago for six weeks. All 20 hawks survived and were released with radiotelemetry transmitters in healthy condition.

A before-after-control-impact study was conducted to determine the potential risk of the bait application for populations of non-target species and to provide a baseline for post-eradication environmental monitoring. This study design incorporates a control, in this case an unbaited island, to account for seasonal fluctuations. Pinzón was used as a control and Rábida, Bartolomé, Bainbridge #3 and Beagle Sur as treatment islands (CDF / CCAL, 2011). There were no significant changes in the Galapagos Dove population due to baiting. Ground finches experienced a significant seasonal decrease on the control island and a minor increase on baited islands. Lava lizards experienced significant increases on baited islands, possibly due to a lack of predation and subsequent population recruitment. No species monitored underwent significant declines; however Short-eared Owls on the treatment islands were likely negatively impacted by secondary poisoning. However it is expected that populations on these islands will quickly recover due to immigration. After one year of monitoring, Galapagos Hawks have shown a mixed response (Ponder & Cunninghame, 2012). On Rábida, only one of the original seven hawks remains; three are confirmed dead, three are missing. However, at least five hawks that were not originally present have been sighted on the island since the eradication event. On Bainbridge #3, all hawks survived, with one male dispersing to Santiago, and two young being fledged in 2011. Sullivan Bay (Bartolomé) hawks are all still alive, with a juvenile having dispersed to the Santiago highlands. There appears to have been an adjustment in hawk carrying capacity on Rábida, perhaps as the result of short-term food availability or changes in behavior.

Two breeding seasons of monitoring is required before rodent eradication campaigns can be declared successful. This has now been completed and Rábida and nine other islets have been confirmed to be free of introduced rodents. However, rats have been detected on Sombrero Chino and Bartolomé and work is underway to compare genetic samples from before and after the eradication attempt to determine whether the attempts there failed or whether reinvasion has occurred. As both islands are within the known swimming distance of rats from Santiago, reinvasion is suspected. Reinvasion was thought likely and treating these islands allowed us to test the time until reinvasion.

Photograph: Rory Stansbury, Island Conservation

A suite of biodiversity benefits from the introduced rodent eradications are slowly being revealed and documented. On Rábida, a gecko was found during monitoring in late 2012. The only known geckos from Rábida were recorded from subfossils estimated at more than 5700 years old, which were only classified to genus (Steadman & Stafford, 1991). The species of gecko present is currently being identified. Live Rábida Island endemic land snails (*Bulimulus (Naesiotus) rabidensis*), not seen since collected over 100 years ago, were collected in late 2012 (C. Parent, pers. com.). A second species of land snail, potentially endemic but not yet identified, was also found on Rábida post rat eradication and is considered a new record for the island (C. Parent, pers. com.). Post eradication, several new records of plant species for Rábida have also been added to the island's inventory, including several threatened species (P. Jaramillo, pers. com.).

## Recommendations

We recommend that the process outlined here for Rábida and other islands be repeated for Pinzón and Plaza Sur with mitigation conducted for non-target species determined to be at unacceptable risk. Monitoring of short- and medium-term impacts should continue as this will allow non-target risk assessments to be refined and improve predictions of ecosystem response. Continuing to increase local capacity to conduct major restoration projects such as these will facilitate future successes. Lessons learned from this eradication will be applied to Pinzón and Plaza Sur, and later to rodent and cat eradication on Floreana. Planning for work on Floreana is underway and involves the local community. This is in line with the programmatic roadmap developed in 2007 (FCD / SPNG, 2007). Challenges on Floreana include the large scale (17,253 ha), livestock, pets, and working with the community to develop solutions from which they will genuinely benefit. With successful rodent eradication projects throughout the archipelago, imminent extinctions of native and endemic flora and fauna can be halted and ecosystems recover.

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