Floreana Island Ecological Restoration:

Rodent and Cat Eradication Feasibility Analysis

Author: Chad Hanson, Karl Campbell

Reviewers: Richard Griffiths, Erin Hagen, Victor Carrion, Alex Wegmann

Version History:

VERSION	DATE	AUTHOR	REASON FOR CHANGE
v1	7.16.2012	Hanson	Initial Draft
v2	1.2.2013	Hanson	Incorporated comments from K. Campbell review
v3	1.25.2013	Hanson	Incorporated comments from R. Griffiths, V. Carrion, E. Hagen
v4	5.29.2013	Hanson	Incorporated final comments from K. Campbell
v5	7.23.2013	Hanson	Incorporated comments from R. Griffiths and A. Wegmann
v6	10.19.2013	Hanson	Formatted for Spanish translation
v6.1	11.16.2013	Hanson	Final

Citation:

This report should be cited as:

Island Conservation (2013) Floreana Island Ecological Restoration: Rodent and Cat Eradication Feasibility Analysis version 6.0. Island Conservation, Santa Cruz, California. 85 pp.

TABLE OF CONTENTS

EXECUTIVE SUMMARY

The eradication of introduced vertebrates has become a widely accepted strategy for restoring island ecosystems. Based on an understanding of eradication methods and the Floreana Island project site, the feasibility of removing black rats, house mice, and feral cats is assessed within this document. Feasibility was assessed based on current techniques to safely remove rodents and feral cats from islands which have been used worldwide, including recent eradications within the Galápagos archipelago.

The goal of this project is to restore ecosystem function as well as enhance community well-being on Floreana Island. This would be achieved through the eradication of black rats, house mice and feral cats and by implementing effective biosecurity measures (e.g. preventing a rodent incursion and ensuring that domestic cats present on the island cannot act as a source population).

The most common technique used globally for removing rodents from islands is the application of bait containing a rodenticide. Cats are primarily targeted with poison, trapping, and hunting. Floreana is a large island (17,125 ha) compared to efforts undertaken elsewhere. If successful, it would be the second largest island to have had cats and rats removed and the largest to have had mice removed. Methods recommended for this multi-species eradication on Floreana Island are aerial- and ground-dispersed toxic baits (resulting in primary and secondary exposure of target populations), trapping, and hunting with and without dogs. To complement these actions, domestic cats must be sterilized and registered, euthanized, or removed from the island. Regulations must be implemented prior to the eradication to ensure that these actions can be applied to all domestic cats on the island, and that no cats can be imported to the island. Community buy-in and regulations will be required to allow access to all buildings and areas of the island, regardless of tenure. Additional recommendations are made regarding options for interisland biosecurity as well as legislation to regulate or prohibit importations of certain animals.

Factors such as a permanent community on island, tourism, and farmland/agriculture will complicate actions to eradicate rodents and cats. Although this is the case, all eradication principles can be met if the appropriate measures are taken during the planning, implementation, and confirmation phases. The technical removal of both rodents and cats is considered feasible with current eradication methods. Social, legal, and environmental acceptability has been assessed and is considered feasible within the region. Feasibility should be re-assessed periodically as results are received from processes to engage the community. A total cost of $10-12 million dollars is estimated for the planning and implementation of the recommended actions.

This document lays out a detailed description of the site and target species, recommended project approach, scope, and suggested stakeholder involvement needed to carry out a successful multi-species (mouse, rat, cat) eradication campaign on Floreana Island.

ISLAND CONSERVATION
Preventing Extinctions

PROJECT AND CLIENT

Island Conservation was requested by the Dirrecion del Parque Nacional Galápagos (MAE-PNG/DIR-2012-0820) and the Gobierno Parroquial Rural Isla Santa Maria (028-GPRISM-2012) to analyze the feasibility of eradicating invasive rodents and cats from Floreana Island, Galápagos. This work was funded by the Leona M. & Harry B. Helmsley Charitable Trust and the David and Lucile Packard Foundation as part of grants to Island Conservation.

INTRODUCTION

Worldwide, roughly 80% of all recent extinctions have been island species; more than half of these have been a direct result of invasive species such as feral cats. Furthermore, introduced rodents have caused 40-60% of all historic bird and reptile extinctions. Rats, in particular, are one of the most aggressive and destructive invasive species and are found on more than 85% of oceanic islands and archipelagos, including the Galápagos Islands. Land managers throughout the world are increasingly eradicating rodents and cats from islands to aid the restoration of island ecosystems.

Both rodents and cats currently exist on Floreana Island (Floreana). Floreana supports more than 18 species endemic to the archipelago, including a lava lizard, medium tree finch, and multiple species of land snails that are endemic to Floreana. Six vertebrate species present on Floreana are considered globally threatened by the IUCN (2 critically endangered, 2 endangered, 2 vulnerable). As a result, a team of eradication practitioners, in consultation with the primary land manager, selected the restoration of Floreana Island as a priority within the region (CDF/GNP 2007). The removal of invasive vertebrate species found on Floreana was determined to be the most beneficial action to facilitate the Island’s recovery.

In 2009, individuals from the Galápagos National Park (GNP), Island Conservation (IC), Western Australia Department of Environment and Conservation (WADEC), and other experts attended a site visit to Floreana to assess the feasibility of removing feral cats. In addition to feral cats, the island was also assessed for the presence of other introduced invasive vertebrate species. The presence of feral cats (*Felis catus*), rats (*Rattus rattus*), and mice (*Mus musculus*), were confirmed. Visits to Floreana also occurred in 2010, 2011, and 2012. Following the site visits, it was determined that a strategy to simultaneously remove mice, rats and cats would be the most effective and financially feasible approach.

The methods to achieve this goal and complicating factors, such as human habitation of Floreana, are assessed within this document.

Preceding Eradications

Table 1. The three largest island-wide eradications of *Felis catus*, *Rattus rattus*, and *Mus musculus* (DIISE, 2012).

Felis catus / feral cat	*Rattus rattus* / black rat	*Mus musculus* / house mouse
29,300 ha / Marion Island, South Africa	12,900 ha / Macquarie Island[1], Australia	12,900 ha / Macquarie Island[1], Australia
12,900 ha / Macquarie Island, Australia	3,800 ha / Rangitoto/Motutapu, New Zealand	3,800 ha / Rangitoto/Motutapu, New Zealand
11,400 ha / Tristan da Cunha, British Overseas Territory of Saint Helena, Ascension, and Tristan da Cunha	2,100 ha / Capraia, Italy	1,250 ha / Coal Island, New Zealand

[1] Awaiting confirmation

Worldwide, a total of 87 campaigns to eradicate cats from islands have been successful (Campbell et al. 2011). The eradication of cats from Floreana has been proceeded by three islands within the Galápagos; Baltra (2,771ha), Venecia (16ha) Las Bayas Grande (2.57ha) (DIISE 2013). Within Ecuador, one additional cat eradication occurred on Isla de la Plata (670ha). Both Baltra and Isla de la Plata cat eradications were implemented by staff currently employed by the Galápagos National Park and Island Conservation.

Both of the introduced rodents present on Floreana (Black/ship rat - *R. rattus* and mice - *M. musculus*) have been eradicated on islands elsewhere in the world (Howald et *al*. 2007, Griffiths et *al*. 2012). *M. musculus* have been removed from 50 islands while *R. rattus* have been removed from 217 islands worldwide (DIISE 2013). At present, the largest rodent eradication operation exceeds 68,000 hectares on South Georgia Island where brown rats (*R. norvegicus*) and pockets of mice (*M. musculus*) are being targeted. The operation is to be conducted in three seasons, with the first two seasons having been completed. This multi-year approach is only possible due to glaciers prohibiting rodent movements and creating distinct eradication units akin to separate islands. The final season is planned for 2015 (http://www.sght.org/Habitat-Restoration).

Previous black rat eradication projects conducted within the Galápagos archipelago include 21 Islands, the largest being Isla Pinzon (1789ha), and Isla Bartolomé (124ha). One brown rat (*R. norvegicus*) eradication has occurred on Rábida (499ha). Each of these eradications has been planned and implemented with scalable methodologies as a stepping stone to conduct a similar operation on larger islands; particularly Floreana (CDF/GNP 2007). Four failed black rat operations are known to have occurred within the region (DIISE 2013).

Three additional islands have had mouse eradication attempts; Isla Plaza Sur (14.8ha), Isla Plaza Norte (12.4ha), and Venecia (16ha). Plaza Sur is awaiting confirmation, while Plaza Norte has been confirmed mouse free. Venecia was a failed attempt, but the island is connected at low tide to Santa

Cruz Island so it is possible that the eradication succeeded yet the island was reinvaded by mice from Santa Cruz.

GOAL, OBJECTIVES and OUTCOMES

Goal

The goal of the proposed project is:

Contribute to the restoration of natural ecosystem function, native species recovery and community well-being on Floreana Island by eradicating cats, introduced invasive rats and mice.

Objectives and Outcomes

The objectives that this project will achieve and the outcomes that will be seen as a result of achieving these objectives are:

Objectives	Outcomes
1. Contribute to the ecological restoration of Floreana Island through the eradication of cats, rats, mice and the control of feral chickens.	1.1 Planning documents are prepared detailing the eradication of rodents and cats (feasibility plan, non-target risk assessment, project management plan, operational plan) and control of feral chickens (operational plan).
	1.2 Three damaging invasive species are removed permanently from Floreana Island.
	1.3 The feral chicken population is reduced or removed altogether.
	1.4 Produce mitigation plans for non-target native species, domestic animals and the community, and mitigate negative impacts.
	1.5 The recovery of native species, including the medium tree finch, Galápagos petrel, marine iguana, lava lizard, Galápagos martin, endemic snails and *Opuntia* cactus
	1.6 On-island conditions support successful reintroductions of extirpated species, including the Floreana mockingbird, Floreana giant tortoise, Galápagos hawk, Galápagos racer (a snake) and lava gull.

	1.7 Biosecurity measures are functional and effective. No livestock or pets are brought on-island without GBA permits and having undergone quarantine procedures, including disease checks for livestock and sterilization of pets.
	1.8 Detection measures continue in perpetuity and response measures are in place for dealing with any 'rodent spills' post eradication confirmation.
2. Participatory decision making process developed and is led by a steering committee, including Galapagos Biosecurity Agency (GBA), Galápagos National Park, Floreana Island Parish Council (FIPC), community members and Island Conservation representatives.	2.1 All domestic cats on Floreana Island are sterilized and registered. Regulations are in place and are being enforced for directing the management of pets. .
	2.2 Charter for steering committee approved by members
	2.3 Partners have a regular forum in which to share information (i.e. plans, census information, etc.), collaborate on planning, and coordinate future project components.
	2.4 Eradication methods and other project components are developed and implemented with the community's awareness and support.
	2.5 The Floreana community supports biosecurity
3. Improve livelihoods on Floreana Island.	3.1 Additional capacities are developed within the Galápagos that relate to the planning and implementation of complex large-scale conservation projects.
	3.2 The Floreana community is supportive of the project.
	3.3 Reduced risk of disease, bacteria and parasites for which cats and rodents are vectors, including toxoplasmosis, leptospirosis, cat scratch disease, cutaneous larva migrans, lymphocytic clorio-meningitis, plague, hantavirus and salmonellosis.
	3.4 Improved quality and quantity of horticultural production.

	3.5 Reduced damage to infrastructure, unprotected materials/supplies and food for people and livestock.
	3.6 Improved quality and quantity of livestock products. 3.6.1 Regulations regarding domestic livestock management requirements are in-effect. 3.6.2 Island is destocked of livestock prior to eradication. Actions for eradicating livestock diseases occur. Disease-free livestock of the most appropriate breeds free of specific diseases are imported post-eradication. 3.6.3 Livestock management avoids farmer-conservation conflicts.
	3.7 Costs associated with rodent control are eliminated
	3.8 Aesthetic values and visitor experience improved. Tourism-based economic benefits increase due to ecosystem recovery, presence of endemic species, and the type of visitors attracted to the island.
4. Each partner leverages existing capacities and builds new ones in-line with their missions.	4.1 Each partner in the partnership has a role and contributes to the project's larger goals accordingly, leading to success of the overall project.
	4.2 Each partner develops additional capacities that facilitate implementation of their mission in the future.
5. Prepare for reintroductions of extirpated threatened species	5.1 Plans developed for reintroductions of Floreana giant tortoise, Floreana mockingbird, Galapagos hawk, Galapagos racer, and lava gull.
	5.2 Knowledge gaps relating to conducting reintroductions are filled prior to completion of eradications. Researchers/re-introduction practitioners bring funding not available for eradication activities.
	5.3 Reintroductions of Floreana giant tortoise, Floreana mockingbird, Galapagos hawk, Galapagos racer, and lava gull are conducted within 3 years post-eradication.

Background

Biodiversity Value of Islands

Islands are rich in endemic species; they make up only 3% of the earth's surface but are home to between 15% and 20% of all plant, reptile, and bird species. Islands have also been disproportionately impacted by humans; approximately 70% of recent animal extinctions have occurred on islands and most of these extinctions, including more than half of all seabird extinctions, were caused by invasive species. Today, more than half of all IUCN Red List birds are threatened by introduced species (**Figure 1**). Feral cats and rodents are the most devastating introduced species to island ecosystems, where they frequently impact native species through direct predation, competition or changes in the food web. Rodents have been introduced onto more than 80% of islands worldwide, causing ecosystem-wide perturbations, including profound effects on the distribution and abundance of native flora and fauna (e.g. Atkinson 1985, Jones et al. 2008, Kurle et al. 2008, Towns et al. 2009). Island ecosystems, like that of Floreana are key areas for conservation because they are critical habitat for seabirds and reptiles that depend on islands for breeding.

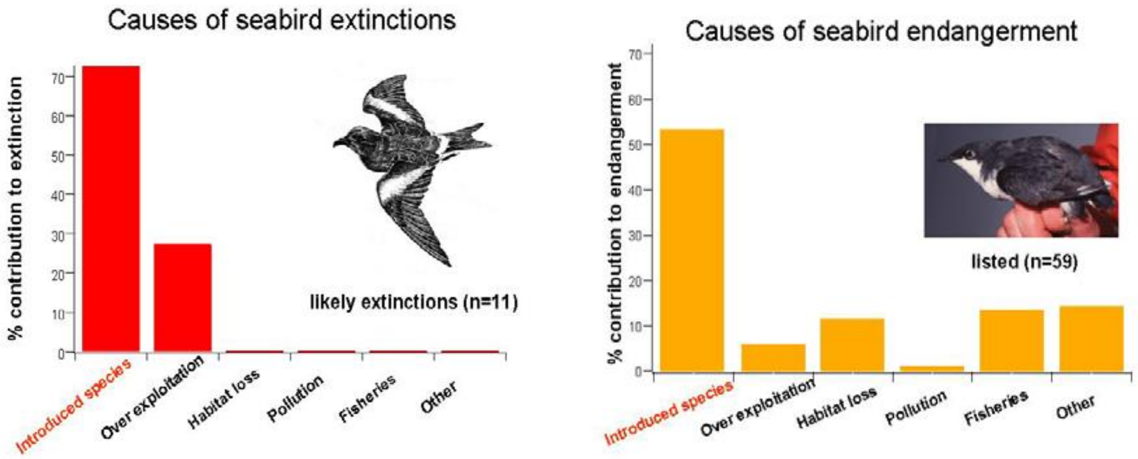


Figure 1. (Left) Causes of seabird extinction and (right) endangerment based on IUCN global red list data.

Floreana Island

Floreana Island is situated within the Galápagos archipelago lying roughly 1,000 km off the coast of Ecuador. All 128 islands and islets are within the Galápagos province of Ecuador. Floreana Island is the fourth largest of five inhabited islands and the sixth largest island within the Galápagos archipelago. It covers 17,125 ha, with a maximum elevation of 640 m at Cerro Pajas. Like all of the Galápagos Islands, Floreana is of recent volcanic origins. Two general habitat types make up the island; a dry arid lowland (12,654 ha), and a lush highland (4,471 ha), (**Figure 2**). The island has multiple ponds and lagoons, two drinking-water sources derived from springs that are present in the highlands, and an array of subterranean lava tubes lying underground. Sea cliffs of up to 30 m are present on the southern and eastern coastline.

Lying at 1.2 degrees south of the equator, Floreana Island experiences slight climatic variation; a dry season from Oct – mid-January delivering blue skies and little to no rain (and a declining or crashed rodent population); a wet (warm) season from mid-January – June with a near-tropical climate that includes daily precipitation and more consistent cloud cover; and a Garua season from July – September with dense marine air, routine fog presence, and precipitation in the form of fog (particularly heavy in the highlands). Air temperatures range from 21º - 30º Celsius while sea temperature remains between 21º – 25º Celsius and sea conditions are suitable for transit year-round. A climate shift to heavy and frequent rain can be expected during El Niño events while more arid drought conditions are present during La Niña events.

Floreana Island was previously known by several other names, the most common being Santa María and Charles (Woram 1989). The Galápagos National Park manages over 98% of the island, with an agricultural zone of 230 ha and the town of Puerto Velasco Ibarra (42 ha) filling the remaining 2%. The island was first settled in 1832, and has a well recorded history.

The primary use of Floreana Island includes agriculture, tourism, and fishing. Some resource extraction occurs (timber), though the quantity and frequency of export is limited by the high cost of transporting goods to neighbouring islands. Today, a community of roughly 140 people reside on island while tourism, primarily day-trips, results in dramatic, temporary increases in the number of people on the island. Infrastructure exists on island to accommodate tourists while safe moorage for tour cruises and recreational activities are found in the waters surrounding Floreana. Several farms make up the agricultural zone in the highlands.

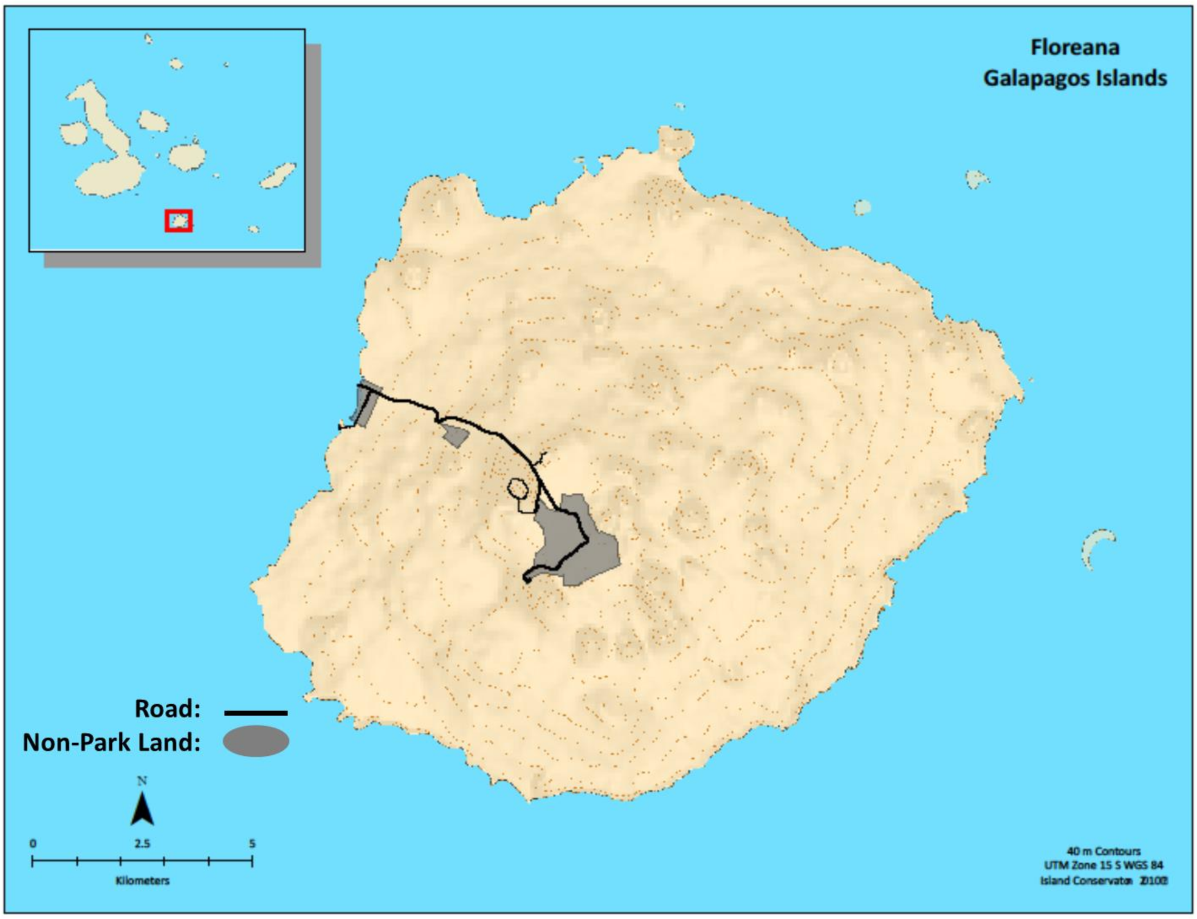


Figure 2. Floreana Island is round in shape and is approximately 16 km in diameter. The town of Puerto Velasco Ibarra is located in a bay on the western side of the island and a main road leads to the agricultural zone in the highlands.

Access to Floreana Island from other ports in the archipelago is generally achieved by boat. Puerto Velasco Ibarra is 62km (34 nautical miles) from Puerto Ayora on Santa Cruz Island (~1.5 hours by boat). The port can support small water craft and skiffs while offshore waters have no limiting factors that would restrict larger vessels. Airspace above Floreana Island is not restricted and potential helicopter landing zones are present across the landscape. No runway exists on island to accommodate fixed-wing aircraft. San Cristobal, Isabela, and Baltra Island each have a runway while Baltra (GPS) supports regular commercial flights daily and acts as the primary air conduit to the archipelago.

Floreana Island Fauna and Flora

Floreana Island is home to 54 IUCN threatened species (IUCN 2013) (**Table 1, 2, & 3)**. Eight vertebrate species present on Floreana are considered globally threatened by the IUCN (2 critically endangered, 4 endangered, 2 vulnerable) while four species have been extirpated (1 critically endangered, 3 vulnerable) (**Table 2**). Eleven seabird species nest on the island, including four species endemic to the archipelago, of which two are at risk of extinction (**Appendix A**): Galápagos petrels (critically endangered) and Galápagos penguins (endangered) (IUCN 2012). Floreana maintains the world's largest breeding colony of Galápagos petrels, with 63% of the population. This charismatic seabird nests on only four other islands. Lava gulls (vulnerable) were recently considered extirpated from Floreana after searches over the last few years failed to find any (GNP Floreana and Claudio Cruz pers. comm. 2012). Five resident shorebirds also nest on the island, including greater flamingos (*Phoenicopterus ruber*), while green turtles (*Chelonia mydas*) nest on the island's beaches. Several species extirpations and extinctions have occurred on Floreana (**Appendix A**). The reintroduction of critically endangered Floreana mockingbirds, Floreana giant tortoises and two or three other globally threatened species is pending the eradication of rodents and cats (**Appendix A**).

Floreana is home to 94 plan species that are endemic to the Galápagos of which six are endemic to Floreana; *Linum cratericola*, *Scalesia villosa*, *Lippia salicifolia*, *Alternanthera nesiotes*, *Psychotria angustata*, *Lecocarpus pinnatifidus*. Thirty-two plants species on the island were considered globally threatened by IUCN in 2006 (5 critically endangered, 8 endangered, 19 vulnerable), while two plants endemic to Floreana, *Sicyos villosa* and *Dellila inelegans* are considered to be extinct (Tye 2007) (**Table 3**).

Over 1500 terrestrial invertebrates are endemic to the Galápagos archipelago. In 2006, an evaluation of 103 invertebrate species with IUCN criteria resulted in two species being classed as extinct and 61 species as globally threatened. Of those, Floreana has at least 15 threatened terrestrial invertebrate species (Rogue-Albelo 2007; C. Parent pers. comm., 2013) (**Table 4**). As Floreana is one of the older islands in the archipelago, it has a higher rate of endemism than the younger islands to the west. Floreana is known to have at least 125 Galápagos invertebrate species endemic to the archipelago, but it is unknown how many of these are Floreana endemics (CDF database 2009).

Table 2. IUCN threatened vertebrates found on Floreana Island.

VERTEBRATES			
Common Name	***Species***	**Breeding Status**	**IUCN Status**
Galápagos petrel	*Pterodroma phaeopygia*	Present	Critically Endangered
Medium tree finch	*Camarhynchus pauper*	Present	Critically Endangered
Floreana mockingbird	*Mimus trifasciatus*	Extirpated	Critically Endangered
Green sea turtle	*Chelonia mydas*	Present	Endangered
Galápagos sea lion	*Zalophus wollebaeki*	Present	Endangered
Galápagos penguin	*Spheniscus mendiculus*	Present	Endangered
Galápagos martin	*Progne modesta*	Present	Endangered
Galápagos rail	*Laterallus spilonotus*	Present	Vulnerable
Marine iguana	*Amblyrhynchus cristatus*	Present	Vulnerable
Lava gull	*Larus fuliginosus*	Extirpated	Vulnerable
Galápagos hawk	*Buteo galapagoensis*	Extirpated	Vulnerable
Floreana giant tortoise	*Chelonoidis elephantopus*	Extirpated	Vulnerable

Table 3. IUCN threatened plants found on Floreana Island.

PLANTS			
Family	***Species***	**Subspecies**	**IUCN Status**
Asteraceae	*Lecocarpus pinnatifidus*		Critically Endangered
Linaceae	*Linum cratericola*		Critically Endangered
Verbenaceae	*Lippia salicifolia*		Critically Endangered
Amaranthaceae	*Lithophila subscaposa*		Critically Endangered

Rubiaceae	*Psychotria angustata*		Critically Endangered
Amaranthaceae	*Alternanthera nesiotes*		Endangered
Asteraceae	*Baccharis steetzii*		Endangered
Rubiaceae	*Galium galapagoense*		Endangered
Amaranthaceae	*Lithophila radicata*		Endangered
Cactaceae	*Opuntia megasperma*	var. megasperma	Endangered
Lamiaceae	*Salvia prostrata*		Endangered
Lamiaceae	*Salvia pseudoserotina*		Endangered
Asteraceae	*Scalesia pedunculata*		Endangered
Asteraceae	*Acmella darwinii*		Vulnerable
Amaranthaceae	*Alternanthera galapagensis*		Vulnerable
Rubiaceae	*Borreria dispersa*		Vulnerable
Euphorbiaceae	*Chamaesyce nummularia*	var. glabra	Vulnerable
Euphorbiaceae	*Chamaesyce nummularia*	var. nummularia	Vulnerable
Solanaceae	*Iochroma ellipticum*		Vulnerable
Cactaceae	*Jasminocereus thouarsii*	var. thouarsii	Vulnerable
Molluginaceae	*Mollugo flavescens*	ssp. insularis	Vulnerable
Molluginaceae	*Mollugo floriana*	ssp. floriana	Vulnerable
Nolanaceae	*Nolana galapagensis*		Vulnerable
Poaceae	*Paspalum redundans*		Vulnerable
Plantaginaceae	*Plantago galapagensis*		Vulnerable
Polygalaceae	*Polygala galapageia*	var. insularis	Vulnerable
Polygalaceae	*Polygala sancti-georgii*	var. sancti-georgii	Vulnerable

Myrtaceae	*Psidium galapageium*		Vulnerable
Rubiaceae	*Psychotria rufipes*		Vulnerable
Asteraceae	*Scalesia affinis*		Vulnerable
Asteraceae	*Scalesia villosa*		Vulnerable
Boraginaceae	*Tournefortia rufo-sericea*		Vulnerable

Table 4. IUCN threatened invertebrates found on Floreana Island.

INVERTEBRATES			
Common description	***Species***	**Class: Order**	**IUCN Status**
Nocturnal moth	*Eupithecia perryvriesi*	Insecta: Lepidoptera	Vulnerable
Nocturnal moth	*Tyrintheina umbrosa*	Insecta: Lepidoptera	Vulnerable
Land snail	*Naesiotus galapaganus*	Gastropoda: Stylommatophora	Critically endangered
Land snail	*Naesiotus eschariferus*	Gastropoda: Stylommatophora	Critically endangered
Land snail	*Naesiotus Jacobi*	Gastropoda: Stylommatophora	Critically endangered
Land snail	*Naesiotus cinerarius*	Gastropoda: Stylommatophora	Endangered
Land snail	*Naesiotus cucullinus*	Gastropoda: Stylommatophora	Endangered
Land snail	*Naesiotus nux*	Gastropoda: Stylommatophora	Endangered
Land snail	*Naesiotus perspectivus*	Gastropoda: Stylommatophora	Endangered
Land snail	*Naesiotus planospira*	Gastropoda: Stylommatophora	Endangered
Land snail	*Naesiotus rugulosus*	Gastropoda: Stylommatophora	Endangered

Land snail	*Naesiotus calvus*	Gastropoda: Stylommatophora	Vulnerable
Land snail	*Naesiotus unifasciatus*	Gastropoda: Stylommatophora	Vulnerable
Land snail	*Naesiotus ustulatus*	Gastropoda: Stylommatophora	Vulnerable

Most species of large invasive mammals have already been removed from Floreana Island. Feral pigs were eradicated in the 1980s, while feral cattle were eradicated in 2007. Feral goats and donkeys were targeted through 2010 with eradication confirmation occurring in 2011. Invasive cats, rats, mice and smooth-billed ani (*Crotophaga ani*) are present, as is an introduced gecko. Farms maintain populations of horses, cattle, pigs and a small number of donkeys and mules. Some cattle and donkeys have recently been reported grazing within the Park but are believed to be domestic stock. Dogs and chickens are kept by farmers and in town. According to a 2009 census, cats are only known to be kept by 4 households in town.

THE TARGET SPECIES, IMPACTS AND BENEFITS OF ERADICATION

Target Species

The species targeted for a multi-species eradication on Floreana includes black rats (*Rattus rattus*), house mice (*Mus musculus*), and the domestic cat (*Felis catus*).

Rodents

The impacts from invasive predatory mammals are one of the leading causes of species extinction on islands (Blackburn *et al.* 2004; Duncan and Blackburn 2007). Rodents living in close association, or commensally, with humans (Norway rat, *Rattus norvegicus*; black rat, *R. rattus*; and Polynesian rat, *R. exulans*) have been introduced to more than 80% of the world's islands and have a pronounced effect on island ecosystems (Towns et al. 2006). In addition, the extinction of many island species of mammal, bird, reptile, and invertebrate have been attributed to the impacts of invasive rats (Andrews 1909; Atkinson 1985; Daniel and Williams 1984; Hutton *et al.* 2007; Meads *et al.* 1984; Tomich 1986), with estimates of 40 – 60 percent of all recorded bird and reptile extinctions globally being directly attributable to invasive rodents (Atkinson 1985, Island Conservation analysis of World Conservation Monitoring Centre data).

Rodents can also have negative direct and indirect impacts on native species and ecosystem functions. For example, a comparison of rat-infested and rat-free islands, and pre- and post-rat eradication experiments have shown that rats depressed the population size and recruitment of birds (Campbell 1991; Jouventin *et al.* 2003; Thibault 1995), reptiles (Bullock 1986; Cree *et al.* 1995; Towns 1991; Whitaker 1973), plants (Pye et al. 1999), and terrestrial invertebrates (Bremner *et al.*

1984; Campbell *et al.* 1984) on invaded islands. In particular, rodents have significant impacts on seabirds, preying upon eggs, chicks, and adults and causing population declines, with the most severe impacts on burrow-nesting seabirds (Atkinson 1985; Jones *et al.* 2008; Towns *et al.* 2006). The introduction of rats on Midway Atoll during 1943 decreased seabird populations there and caused the extinction of the Laysan rail and Laysan finch (Fisher and Baldwin 1946).

In addition to preying on seabirds, introduced rodents feed opportunistically on plants, and alter the floral communities of island ecosystems (Campbell and Atkinson 2002); in some cases degrading the quality of nesting habitat for birds that depend on the vegetation (Wegmann 2009, Young et *al*. 2010). On Tiritiri Matangi Island, New Zealand, ripe fruits, seeds, and understory vegetation underwent significant increases after rodents were eradicated from the island, indicating the rats' previous impacts on vegetation (Graham and Veitch 2002).

Rodents are documented to affect the abundance and age structure of intertidal invertebrates directly (Navarrete and Castilla 1993), indirectly affect species richness and abundance of a range of invertebrates (Towns et al. 2009), and contribute to the decline of endemic land snails in Hawai`i (Hadfield et al. 1993), Japan (Chiba 2010), and American Samoa (Cowie 2001).

There is also increasing evidence that rats and mice alter key ecosystem processes. For example, total soil carbon, nitrogen, phosphorous, mineral nitrogen, marine-derived nitrogen, and pH are lower on rodent-invaded islands relative to rodent-free islands (Fukami et al. 2006). In rocky intertidal habitats, invasive rodents affected invertebrate and marine algal abundance, changing intertidal community structure from an algae-dominated system to an invertebrate dominated system (Kurle et al. 2008).

Where rodents co-exist with other predators (such as cats or predatory birds) the collective direct effect of introduced predators on seabirds is greater than the sum of the individual impacts because rats also act as a food resource to higher level predators when seabirds are absent from the islands (Atkinson 1985; Moors and Atkinson 1984).

Given the widespread successful colonization of rats on islands and their effect on native species, rats have been targeted as key species for eradication (Howald et al. 2007) by many managers of island wildlife.

Rodents on Floreana Island

Although the impacts of introduced rodents in the Galápagos, and specifically Floreana, have not all been identified, black rats are known to have curtailed the recruitment of tortoises into the population on Pinzón Island for at least a century. At present, the Floreana giant tortoise is extinct in the wild with rodent presence threatening the success of any future repatriation attempts.

Introduced rodents have managed to colonize just over half of the Galápagos Islands larger than 1000 ha (present on 7 out of 13) and 38% of the satellite islands and islets within 2 km of the infested islands. Rodent control programs of the last decades have helped to mitigate but not eliminate the effects of rodents on Floreana. The only long-term solution to the introduced rodent problem is total eradication supported by an on-going biosecurity program to prevent reinvasions.

Rodents, specifically black rats, were introduced to the Galápagos islands before Charles Darwin's visit in 1835 (Patton et al., 1975). On Floreana, rats and mice are established island-wide, and have impacted the Galápagos petrel populations as well as other ground-nesting birds, and possibly several reptile species as well. Many large-seeded plants are also likely affected by introduced rodents, including the *Opuntia* cactus, a keystone species in many arid Galápagos ecosystems. Rodent predation on adult *Opuntia* has been recorded on Floreana (**Image 1**). The continued consumption of cactus pads, branches, and stems weaken adult plants causing them to topple (Island Conservation, unpublished data). Five other extant endemic vascular plants and 20 land snails are present on Floreana; none of which evolved with endemic rodents (Steadman 1986).

Image 1. Rat predation and scat found near the top of an adult *Opuntia* cactus (top/bottom) and effects of prolonged predation resulting in toppling (right).

Further issues surrounding the introductions of rodents are apparent on seabird breeding colonies. The predation of eggs as well as chicks has been witnessed first-hand by Island Conservation personnel while in the archipelago and similar depradations are noted worldwide (Kepler, 1967).

It is presumed that rodents impact local seabirds, including the Galápagos shearwaters, petrels, blue-footed boobies, brown noddies and the brown pelican (Jones et *al*. 2008). Numerous terrestrial bird and reptile species are also likely affected by rodents. This is supported by sub-fossil evidence which indicates that several extirpations occurred after the introduction of invasive rodents and other species (Steadman 1986).

Benefits of rodent eradication

The conservation benefits of rodent eradications include increases in abundance and breeding success of a variety of taxa including seabirds, landbirds, reptiles, mammals, land snails, and plants. Owing to the well-documented impact of rodents on seabirds (Jones et al. 2008), significant benefits are predicted for existing seabird colonies and may promote recolonization by extirpated species such as lava gulls. In Western Mexico, the eradication of black rats from 5 islands resulted in the protection of 46 seabird populations (Aguirre-Muñoz et al. 2008). Direct benefits to breeding seabirds have also been reported, including an increase in nest site occupancy, nesting attempts, hatching success, and reduced nest depredation (Amaral *et al.* 2010; Jouventin *et al.* 2003; Smith *et al.* 2006; Whitworth *et al.* 2005). At Midway Atoll National Wildlife Refuge, Bonin petrel (*Pterodroma hypoleuca*) populations increased from fewer than 5,000 nesting pairs in the 1980s to over 135,000 pairs in 2008 after the eradication of rats in 1997 (FWS 2010; Pyle and Pyle 2009).

Change in productivity was the most commonly reported demographic response in bird populations after rodent eradication in a review by Lavers et al. (2010). They found that productivity increased by 25.3 percent in 112 studies of 87 species. Increases in abundance of native land birds after rat eradication have also been reported. The abundance of 4 species of native land birds increased between 10 and 178 percent during the 3 years after rat eradication within New Zealand (Graham and Veitch 2002), and endemic species have even recolonized islands after local extirpation by rats (Barker *et al.* 2005; Ortiz-Catedral *et al.* 2009); a potential result for the currently extirpated Floreana mockingbird, lava gull, Galápagos hawk and various small land bird species once present on Floreana. In addition to reintroduction opportunities, extant at-risk species including the Galápagos petrel, medium tree finch, Galápagos martin, and Galápagos penguin can be expected to benefit once non-native rodents are no longer present.

The restoration of endemic and native reptile populations can also be expected. This result has been targeted and achieved through rodent eradication. By 1998, rodents had been removed from 25 islands within New Zealand providing measurable or potential benefits for Tuatara (*Sphenodon* sp.), 8 species of geckos, and 12 species of skink (Cree *et al.* 1995; Towns 1994; Towns *et al.* 2007). At the ecosystem-level, indigenous forest restoration has been documented as a result of substantial increase in the number of shrub and tree seedlings after Norway rat eradication (Allen et al. 1994). Furthermore, the removal of rodents has been carried out to create rodent-free refuges for native and endemic fauna and flora that are at risk from rat and mouse impacts elsewhere in their range. By 2003, rodents had been eradicated from more than 90 offshore islands in New Zealand, allowing for the translocation of native birds, reptiles, amphibians, and invertebrates to these predator-free refuges (Towns and Broome 2003). Once Floreana's habitat is free from rodents, the reintroduction of extirpated species including the Floreana mocking bird, Floreana giant tortoise, Galápagos racers and other species are projected to be able to occur successfully.

Effects on Floreana's community well-being should be expected. Agricultural yields are likely to increase once rats and mice, each an omnivorous species, are eliminated and rodent foraging pressure is no longer present on farmed crops and gardens. Where infrastructure exists, rodents feed, chew holes, urinate, defecate and nest in areas where refuge can be sought; often in dwellings inhabited by humans. The presence of rodents in commensal areas can lead to an increased risk of disease including: toxoplasmosis, lymphocytic clorio-meningitis, Plague, leptospirosis, hantavirus and salmonellosis. Once rodents are removed from commensal areas, the hygiene of a building and its contents can be better managed. Ultimately, the removal of rats and mice eliminates a primary vector of such diseases and lessens the risk that this risk to human health will persist on Floreana.

Feral Cats

Since domestication from the African wildcat (*Felis silvestris libyca*), cats have travelled widely as human commensals, often establishing feral populations. Effects of predation on native species by feral cat populations are widespread, particularly on islands (Whittaker 1998). Cats prey on a wide range of species, including mammals, birds, reptiles, amphibians, and insects (Nogales *et al.* 2004). They impact ecosystems by causing extinctions and extirpations, or reducing species to population levels at which they no longer perform functional ecosystem roles (Nogales *et al.* 2004). Because of these impacts, cats are considered among the most damaging of introduced mammals and are included in the top 10 of the world's 100 worst invasive species (Lowe *et al.* 2000).

Feral cats on islands are responsible for at least 14% of the global bird, mammal, and reptile extinctions and are the principle threat to almost 8% of critically endangered birds, mammals, and reptiles (Medina et al. 2011). Even small numbers of cats can have dramatic impacts as demonstrated by the Steven's island wren (Traversii lyalli; New Zealand) which was driven to extinction by only one cat in 1894 (Fuller 2000). On the islands around the Baja California Mexico peninsula, cats have been responsible in part or wholly for the extinction of 11 mammal and 10 bird species, and the extirpation of 22 bird populations (Keitt *et al.* 2005; Wolf 2002). Feral cats are documented to have enormous impacts on insular seabird colonies, where, with abundant food, they can achieve large populations with high densities of animals. Researchers have estimated cat induced seabird mortality for Marion Island at 450,000 seabirds annually, (Van Aarde 1980), Macquarie Island at 47,000 Antarctic prions, *Pachyptila vittata*, and 110,000 white-headed petrels, *Pterodorma lessonii*, annually, (Jones 1977), and Kerguelen Island at 1.2 million seabirds annually (Pascal 1980).

Feral Cats on Floreana Island

Seabird populations on Floreana have been severely impacted by cats. In 1985, cats depredated nearly 50% of all nests in Floreana's Galápagos petrel colony at Cerro Pajas, even in the presence of measures to control cats (Cruz and Cruz 1987). On southern Isabela, Galápagos penguin colonies have been decimated by individual cats killing adult penguins (Steinfurth and Merlen 2005). Lava gull chicks cannot fly for the first few weeks after hatching and cats likely prey upon them on beaches where lava gulls nest and cats occur at high densities (Snow and Snow 1969). Lava gulls do not presently reside or breed on Floreana (GNP Floreana and Claudio Cruz pers. comm. 2012), a potential result of the presence of introduced cat and/or rodents. Additionally, while assessing impacts of cats on Floreana, the remains of red-billed tropic birds that had been consumed by cats were found above the southern coastal cliffs.

Marine iguanas are impacted heavily by feral cats which prey upon sub-adults and juveniles (Barnett 1986). Beach areas were inspected on Floreana for juvenile iguanas with limited to no evidence that recruitment was occurring; a stereotypical sign of cat predation (Campbell pers. comm. 2012). Galápagos giant tortoises, although the original Floreana species is no longer present on the island, are consumed by feral cats as hatchlings up to two years of age are vulnerable to cats (MacFarland *et al.* 1974). At present, the GNP proposes to reintroduce tortoises to Floreana; removing cats would benefit the goal of establishing a self-sustaining population. One researcher observed cats hunting the following animals, or found evidence of them in cats' scats on Santa Cruz and Isabela: lava lizards, frigate birds, pelicans, boobies, finches, mockingbirds, invertebrates and non-native rats (Konecny 1987a). The Floreana lava lizard and the medium tree finch are island endemics, while the Floreana mockingbird has been extirpated and is considered one of the world's rarest birds. The GNP also plans to re-introduce Floreana mockingbirds to the island. This re-introduction needs to be preceded by the eradication of feral cats and introduced rodents from the island.

Cats act as reservoirs and critical hosts of parasites and disease. Cats carry several diseases in the Galápagos which can infect both humans and wildlife (Levy *et al.* 2008), namely toxoplasmosis. Cats are the critical host for *Toxoplasma gondii*, which causes the disease toxoplasmosis. Most warm blooded animals are susceptible to toxoplasmosis infection. Symptoms of toxoplasmosis in native fauna include poor coordination, blindness, lethargy, respiratory and enteric distress, and often sudden death (Dickman 1996; Dreesen 1990; Dubey 2002). Research has demonstrated a high prevalence of *T. gondii* exposure in Galápagos penguins and flightless cormorants (*Phalacrocorax harrisi*, Deem *et al.* 2010). Although diseases of cats may be present in native wildlife it is difficult to ascertain the impact this may have at a population level. For some species like penguins with small, restricted populations, single threats can severely impact their populations and multiple threats, where they converge in time, could be catastrophic. For example, Galápagos penguin population declines of 65-77% can be experienced during strong El Niño events (Vargas *et al.* 2006). Surviving individuals are often left in poor condition and in that state are likely more susceptible to disease.

Additional indirect impacts can be experienced by plant communities via the extinction or near extinction of endemic vertebrates that play important roles in pollination, seed survival and dispersal, herbivory, soil disturbance, and nutrient distribution (Cushman 1995). For example, various species of Galápagos finch and the Floreana mockingbird are been responsible for seed dispersal across the Floreana landscape; predation from cats may alter this natural dispersal pathway. Furthermore, many islands including Floreana receive significant marine nutrient subsidies from seabirds that forage over thousands of kilometres of ocean and then return to their island nesting colonies (Keitt *et al.* 2005; Polis and Hurd 1995, Young et *al*. 2010). The elimination of seabirds by introduced mammalian predators has, in other parts of the world, significantly altered plant communities and thus altered entire insular ecosystems through decreased nutrient availability (Croll *et al.* 2005; Furness 1991; Maron *et al.* 2006).

Benefits of cat eradication

It is anticipated that the campaign to remove feral cats from Floreana Island will have both short-term and long-term impacts on the island. The overall anticipated effect is a net benefit to the island ecosystem. This prediction is based on documented cases of widespread damage, including numerous extinctions, caused by introduced feral cats on islands (Aquirre *et al*. 2008; Dowding and Murphy 2001; Iverson 1978; Jehl and Parks 1983; Keitt *et al*. 2005; Lever 1994; Mellink 1992, Mitchell *et al*. 2002; Nogales *et al*., 2004; Tershy *et al*., 2002; Veitch 2001) and follow-up studies that document the recovery of island species after cats have been removed (Keitt *et al*. 2002; Keitt and Tershy 2003; Nogales et al., 2004; Ratcliffe et al. 2010). The positive impacts expected on Floreana will primarily be the reduction in mortality of native and endemic island species including, but not limited to, the IUCN-listed Galápagos petrel, medium tree finch and Galápagos martin.

Contributors to this report believe that we have considered the ecosystem responses that can be anticipated with our current knowledge of the ecosystem, which is typically limited to bi-trophic responses (e.g. cats eat birds, removing cats will cause an increase in bird numbers) and some tri-trophic responses. There may be some unexpected responses that we are currently unable to predict (Zavaleta *et al.* 2001), which are most likely 3rd, 4th, and >4th level trophic responses.

A simplified theoretical example of a 4th level trophic response would be that removing cats increases bird numbers - increased bird numbers exert a greater predation pressure on insect Y - a decrease in the abundance of insect Y causes plant X to increase its distribution and abundance.

The ability to accurately predict responses is complicated by factors such as:

- Other management actions (re-introductions, eradications, control activities)
- Additional species may be introduced or colonize the island
- Floreana's vegetation is currently responding to introduced herbivore removal
- ENSO events often have over-riding effects on ecosystem components.

The gross impact to the ecosystem as a result of cat eradication is expected to be positive. Once feral cats have been removed, the interest to reintroduce previously extirpated species including the Floreana mockingbird and lava gull can be acted upon without threat of predation by feral cats; cat eradication will undoubtedly increase the likelihood of reintroduction success. Additionally, the removal of feral cats can benefit the well-being of island residents by removing a critical vector of toxoplasmosis, cat scratch disease, cutaneous larva migrans and other zoonotic diseases. The removal of the vector for such diseases (cats) will result in a reduced health risk to both humans and susceptible wildlife species on Floreana.

Benefits of rodent and cat eradication

In addition to seabirds, the diet of feral cats on islands is largely made up of small mammals and reptiles (Biro *et al.* 2005; Harper 2005; Konecny 1987a). However, cat diet changes with food availability and cats are known to take the most abundant available food source (Van Aarde 1980; Veitch 1985). On islands with seabirds, this means cats can consume seabirds when seasonally present and take different items at other times of the year. The dietary adaptability of cats increases their impact on island ecosystems by enabling them to maintain relatively high populations throughout the year even if a major food source, like seabirds, is present for only part of the year (Courchamp *et al.* 1999, 2000). By removing both cats and rodents, an elevated predatory pressure can be relieved. Removing cats and rodents simultaneously will reduce the likelihood of prey switching or meso-predator release that could place further pressure on endangered species populations (Griffiths 2011).

Although mice are often considered minor pests in relation to rats, they both have similar destructive potential. Mice are known to cause mortality of seabirds greater than 50x their own size (Cuthbert and Hilton 2004; Wanless et *al*. 2007; Woodward 1972). As seen on Gough Island, mice cause severe impacts as they will prey on seabirds as large as albatross chicks (Cuthbert and Hilton, 2004); an animal larger than any bird on Floreana. The simultaneous removal of both cats and rodents will alleviate any potential perverse outcomes that could potentially occur if only rodents or cats were removed.

Technical Feasibility

Technical Principles of Eradication

The basic technical principles to achieving successful eradication of an invasive mammal are:

• All individuals of the target species must be put at risk by the methods used.
• All target species must be removed at a rate faster than they can reproduce.
• Risk of reinvasion must be zero or able to be managed effectively.

The methods used should comply with the relevant local regulations or regulations changed to allow for their use. Multiple techniques are often needed, and rarely can one technique alone (with the exception of some rodent eradications) achieve eradication. Additional or modified techniques are often needed to remove the last few animals and to confirm that eradication is complete.

Proposed Methods

Multiple alternatives exist concerning the management of introduced rodents and cats on Floreana Island. Actions include:

- Eradicate rodents and cats
- Eradicate cats and do not target rodents
- Eradicate rodents and do not target cats
- Continue as-is with no further action aside from on-going control work of cats and rodents

If fewer than all three species are eradicated, the outcome of leaving cats, rats, and/or mice is unknown (Parkes, 2009). The relationship between cats, rodents and the Floreana environment is considered to be bottom-up, meaning rodent populations are regulated by the amount of food that is available rather than predation pressure from cats and other predators. As a result, the removal of rodents alone could be expected to result in a net positive effect on the ecosystem. Although this is the case, the remaining population of cats must substitute prey items as needed to survive in the absence of rodents. It has been shown for seabirds that the benefits of removing both cats and rodents are greater than the sum of the benefits from the removal of each individual species (Moors and Atkinson 1984, Atkinson 1985). In an effort to maximize conservation value it would be optimal to remove both cats and rodents simultaneously during the same campaign.

Multiple methods have been utilized in previous cat and rodent eradications to achieve successful results; some methods allow cats and rodents to be targeted simultaneously. Such methods are considered within this document and recommendations are made concerning the feasibility of a cat and rodent eradication on Floreana.

Recommended Techniques for Rodent Eradication

Strategy Overview for Rodents

1. Conduct bait application trials to inform the baiting strategy
2. Institute a public awareness program about the eradication project and community involvement
3. Conduct a detailed non-target risk assessment
4. Develop mitigation plans for species facing unacceptable risks
5. Initiate commensal area guidelines to ensure zero food availability to rodents
6. Collect baseline data with detection tools/methods
7. Conduct audits to assess community adherence to guidelines
8. Remove livestock from Floreana and address problematic crops
9. Bring into captivity temporarily any species identified as requiring this mitigation action in the non-target risk assessment and mitigation plans
10. Implement aerial baiting with cereal bait / utilize bait stations, snap traps, and glue boards as necessary
11. Assess bait availability and bait persistence
12. Reinstitute detection tools for monitoring purposes
13. Confirm the eradication outcome after at least two breeding cycles have passed

Background on Recommended Methodology

To date, successful rodent eradications have been achieved on at least 450 islands in over 40 countries/territories (DIISE 2013). The fundamental methodology that nearly all of these eradications used was the delivery of rodent bait containing a toxicant. Bait is distributed consistently across the island and during a time of year when rodents are relatively food deprived. In tropical environments this period is closely aligned with a characteristic dry season. Depending on island topography and size, climate, native species assemblages, operational logistics and other factors, successful eradication operations have applied bait using either bait stations or a broadcast method, or both.

All rodent eradications with the exception of two (</= 14ha) in size have utilized rodenticide delivered in a cereal-based bait. Rodenticides that present a low probability of bait shyness and where the target species has a high susceptibility (lower lethal dose) to the toxicant is preferred. The most widely used toxicant achieving these results are first and second-generation anticoagulants (Howald, 2007). The most commonly used toxicant in rodent eradications is brodifacoum; all large scale eradications, both planned and awaiting confirmation, are relying on aerially applied brodifacoum cereal-based bait (Howald, 2007; DIISE 2013).

Based on success rates, the eradication of mice is more challenging than the eradication of rats. Although multiple variables are responsible for this outcome, delivering an adequate amount of bait to each mouse of rat homerange is the most critical objective that must be achieved.

Rodenticides and bait products

The use of bait containing a rodenticide is the only known technique capable of achieving successful eradication on an island the size of Floreana. The choice of toxicant is important in achieving eradication success, but its use must be also evaluated against potential negative consequences, such as poisoning of non-target species.

From an eradication perspective, the rodenticide used must:

- contain an active ingredient that is known to be highly lethal to rodents,
- be palatable and demonstrate low or no bait shyness by rodents,
- be delivered into the territory of each rodent on the island,
- be consumed in sufficient amounts by every single rodent to receive a lethal dose.

From an efficacy standpoint, the rodenticide must contain a toxicant that has the ability to kill rodents and prevent the onset of bait avoidance before all individuals consume a lethal dose. In addition, the bait product must be legally available for use in Ecuador. There are three primary classes of rodenticides typically used for rodent eradications from islands; acute rodenticides, subacute rodenticides, and anticoagulants. About 58% of successful rodent eradications from islands have used a second-generation anticoagulant (e.g. brodifacoum, bromadiolone) (Howald et al. 2007, DIISE). Other rodenticides used have included acute toxicants (e.g. strychnine) and first-generation anticoagulants (e.g. diphacinone, pindone) the latter of which are less persistent in the environment which often makes them a preferred choice for operations where the goal is *control* rather than *eradication* (Eason and Ogilvie 2009). Acute toxicants are not recommended for eradication operations due to the much higher risk of failure (Parkes *et al.* 2011).

Preferred rodenticide

For successful rodent eradication from Floreana, brodifacoum is recommended as the preferred toxicant to achieve success with an aerial broadcast technique. Brodifacoum is a coumarin-based second-generation anticoagulant. It is a vertebrate toxicant that acts by interfering with the blood's ability to form clots, causing sites of even minor tissue damage to bleed continuously. Before the toxicant can have any measurable physiological effects, brodifacoum levels in the liver must reach a toxic threshold (which can vary widely between species). The relative threshold level for rats and mice to experience negative effects from brodifacoum exposure is very low, but can be higher in other vertebrate species. Brodifacoum is the primary rodenticide used in rodent eradications on islands (Howald et al. 2007). Detailed descriptions of brodifacoum and its effects on other native species or "non-targets" can be found in: Kaukeinen 1993; Eason and Spurr 1995; Eason et al. 2002; Erickson and Urban 2004; and Hoare and Hare 2006.

Bait formulation

Available bait products containing brodifacoum are typically formulated as a bait block or pellet that comprises the rodenticide locked within a grain-based matrix; the grain matrix is typically very palatable to rodents. When in pellet form, bait can be distributed from a mechanical spreader bucket which can be calibrated for specific application rates. The bait pellet formulation is designed to persist on the ground long enough for all rodents to be exposed, yet degrade quickly enough to minimize the risk of exposure to non-target species. To reduce the impact of brodifacoum to non-target species, the bait product can be formulated to be less attractive; typically bait blocks or bait pellets are dyed green or blue – colors which birds and reptiles tend to avoid (Tershy et al. 1992; Buckle 1994, H. Gellermen, unpubl. data). Cereal bait pellets are the recommended bait formulation. It is also recommended to utilize a formulation whose performance has been demonstrated as being effective as an eradication tool in conditions similar to those found on Floreana.

Bait Broadcast

Due to the size of Floreana, the rugged terrain, and inaccessible areas, the recommended strategy for rodent eradication is to apply rodent bait aerially using a spreader bucket suspended below a helicopter. In order to achieve success, an adequate amount of bait must be placed in every rat and mouse territory on the island. Areas with steep topography, loose substrate, caves, dense vegetation, and/or cliff faces are difficult to access, can often pose serious risk to personnel safety, and would exclude personnel from reaching every rodent territory on the island. Although bait station campaigns have been successful for both rats and mice, the largest bait station projects to date have been 3,100 ha for rats and 253 ha for mice. The sole use of bait stations and/or hand broadcasting bait on an island a large as Floreana would have a low to zero likelihood of success and these methods should be reserved for specific treatment areas.

Bait stations used within each individual rodent homerange will be valuable when treating areas not considered appropriate or feasible (i.e. within a structure) with an aerial broadcast. As the spacing between bait stations should be no greater than 20m x 20m, to include a typical mouse homerange, the logistical and financial impacts of utilizing bait stations should be considered during the planning process.

As with bait stations, a hand broadcast approach across the entire island, or even for large areas would risk the project's success. Like bait stations, hand broadcast will be useful in specific situations, such as exclusion zones around freshwater ponds, where precise bait placement is critical. All other areas (aside from the interiors of structures and caves can be treated by an aerial broadcast.

Further assessment and consultation will be required by all partners for the continued development of this approach. Issues that need to be considered include:

- Maximizing the probability of successfully eradicating rodents from the island.
- Minimizing the complexity of the eradication implementation
- Potential impacts to non-target vertebrates such as livestock, reptiles and birds, and particularly endemic and threatened species.
- Real and perceived risks to the community

• Complexities involving a commensal environment
• Access to all areas on the island

Bait application in commensal areas

A mixed method approach using aerial broadcast, hand broadcast and bait stations is recommended to target all rodent homeranges, including those within town and on farmland where covered structures exist. Extra attention must be given to areas where alternative food sources may exist.

If not removed from the island, pets should remain indoors and be monitored while being fed to ensure rodents are not utilizing pet feed or feces as an alternate food source. (Griffiths et al., 2012)

Interspecies competition is a noted risk to effectively targeting both species of rodent on Floreana. An early study (**Appendix B**) suggests that rats and mice do not segregate open habitat on Floreana. Although this is the case, the use of multiple methods including traps and glue boards, in addition to bait stations, are recommended to target both species rodents where bait cannot be openly broadcasted. Further trials will need to confirm that traps, glue boards, and bait stations intended for use do not exclude either species of rodent, and remain effective when used Floreana.

Bait application in agricultural/farmland area

It is proposed, and we recommend, that all livestock be removed from the island during implementation.

Crops will provide a source of natural food to rats and mice during the operation. As a result, it is recommended that an increased bait application rate be used in croplands to make the bait more attractive (less costly) to rodents by reducing search time. Having crops remain on island is a noted risk and additional information will need to be collected before determining what impact in-season crops will have on bait preference.

Early detection of survivors and response

Rodent eradications campaigns traditionally wait until two breeding seasons have elapsed before an effort is made to detect a remnant rodent population. The project is then declared successful or unsuccessful based on the absence or presence of rodents. Rodent eradication campaigns rely on one, two, or three bait applications across the entire island, typically without no follow-up work to mop-up surviving rodents. Based on the significant investment that will be needed to eradicate rodents from Floreana, it is recommended that trained rodent detection dogs and other detection devices are used systematically to provide an early detection of rodents and that response plans are contemplated within an operational plan to provide supplementary treatment of infestations. The island should be searched systematically with priority given to areas perceived to be at high risk of harbouring survivors (e.g. restaurants, inhabited buildings, agricultural areas). It should be recognized that this is an untested method. However, contributors to this report feel that the expense to employ this strategy is far outweighed by the costs that would be associated with an unsuccessful rodent eradication on Floreana.

Suggested Research to inform Rodent Operational Planning

Pre-eradication monitoring

It is recommended that studies to inform the rodent eradication operational plan are completed prior to eradication. The following data collection and trials are recommended:

• Baseline efficacy of methods employed to detect rodent – An indication of the efficacy of each method employed to detect rodents when they are present. This allows for the selection of the most efficient and effective methods for use during post-eradication monitoring and provides a baseline detection metric to which the post-eradication monitoring results can be compared. Rodent detection efforts should utilize as many detection methods as is practical. Typical rodent detection methods include: trail cameras, chew sticks/blocks, trapping, sign searching, and tracking boards. If no rodents are detected post-eradication using the techniques that were most successful in pre-eradication monitoring, there is a high probability that no rodents remain on the island.

• Bait availability trials - For an effective rodent eradication, bait must be available to rodents for at least 3 nights and possibly longer. An appropriate bait application rate (kg/ha) is required to ensure that sufficient bait is available to rodents for at least this period, but also to ensure that surplus bait does not remain on the ground beyond the desired exposure period; this would increase the exposure risk or exposing non-target species to rodenticide. To calculate the duration of bait availability, a maximum and mean bait consumption rate (referred to as “bait uptake rate”) over time is needed. Bait uptake can be measured with field trials (**Appendix B**) using placebo (non-toxic) or toxic bait and ideally should be measured at the same time of year and under the same climatic conditions as the proposed eradication.

• Bait exposure in rodents and non-targets – during bait application rate trials, the bait used can be impregnated at time of manufacture with a biomarker that fluoresces under ultraviolet light or is easily seen with the naked eye. Rodents would be captured during the trials and screened for the biomarker to monitor bait uptake. In addition, native and endemic species, such as reptiles, birds, and invertebrates, could be captured and screened for the biomarker to determine bait consumption and potential non-target impact in these species.

• Rodent DNA collection - Tissue samples from rodents should be collected and archived, according to standard protocols. If rodents are detected after the eradication, further samples can be collected, and DNA from pre- and post-eradication can be compared to determine if the presence of rodents is a result of a failed eradication (matching DNA signatures), or reintroduction (different DNA signatures). Rat and mouse DNA was collected in 2012.

• Interspecies competition – Verification of bait station, trap, and glue board effectiveness should be tested on Floreana’s commensal rodents.

Monitoring to Confirm Rodent Eradication

Field surveys to detect rodent presence should be undertaken after two rodent breeding seasons have elapsed since bait application. If no rats are detected, confirmation of a successful eradication can be declared. Specific attention should be given to methods that were utilized for baseline monitoring. Traps can include live traps and snap-traps that kill rodents; however kill traps are only recommended if they can be modified to exclude native and endemic reptiles and birds. In addition, rodent sign (faecal deposits, active nests, husking stations, and footprints) should be searched for.

Recommended Techniques for Cat Eradication

Strategy overview for Cats

- Placement of motion sensor IR trail cameras to provide baseline of cat abundance and activity (place inactive trap sites for later use if necessary)
- Survey island, select trap sites, document latrine sites
- Capture and GPS-collar cats to establish home-range data and utilize as an efficacy monitoring tool. Hold some cats in captivity
- Link data into Detection Probability Analysis
- Implement aerial baiting applications of cereal baits for rodent eradication
- Survey island and assess knockdown due to rodent bait applications
- Release second round of captive held cats with GPS collars
- Implement aerial baiting of sausage baits for cat eradication
- Survey island and assess knockdown due to cat bait application
- Activate trap network
- Monitor trap and camera activity, spot treat with sausage baits, and hunt with dogs to remove remnant animals
- Intensive monitoring (sign search, cameras, dogs)
- Confirm eradication based on Detection Probability Analysis

Population reduction during rat eradication

During rodent eradications using brodifacoum, cats have been eradicated or their numbers reduced in at least seven projects (**Table 5**). The goal of these projects was to eradicate both rodents and cats and secondary poisoning of cats with brodifacoum (by eating poisoned rodents) was specifically used as an eradication technique. On Tuhua Island, New Zealand, cats were successfully removed solely with this method (Towns and Broome 2003). In the other six projects, follow-up trapping and hunting was required to successfully remove all cats.

While cats have a relatively high tolerance to brodifacoum (LD50 25 mg/kg) compared to black rats (LD50 0.46 mg/kg), they can be poisoned through the consumption of rodents that have consumed rodenticide. Cats will prey on, or scavenge on rodents during and after the bait availability period associated with the rodent eradication phase of the project; as such, secondary poisoning is an effective tool for the eradication of feral cats in the presence of rodents. In addition, the eradication of rodents, typical prey items for cats, could make surviving cats more likely to take sausage bait intended for them. Predicting the effectiveness of secondary poisoning on Floreana is difficult, but reductions of 80% or more in cat populations have been observed when rats are targeted simultaneously with cats (Campbell et al. 2011). The effectiveness of secondary poisoning as a tool for eradicating cats is increased when the rodent population is targeted with a second generation anticoagulant as cats have a higher tolerance for first generation anticoagulants. It is recommended that direct methods to remove cats are employed only after aerial baiting for rodents has been completed and the window for secondary poisoning has passed.

Table 5. Broadcast baiting with brodifacoum for simultaneously eradicating rodents and providing a 'knockdown' or complete removal of the feral cat population.

Island Name	Country	Area (ha)	Year	Rodent baiting method	Reference
Rangitoto / Motutapu	New Zealand	3,854	2009	Aerial	{Griffiths, 2011 #6529}
Raoul	New Zealand	2,943	2005	Aerial	Broome, 2009
Tuhua	New Zealand	1,277	2000	Aerial	Towns and Broome, 2003
Pitcairn	UK Overseas Territory	500	1997	Ground	Nogales et al., 2004
Curieuse	Seychelles	286	2001	Aerial	Merton et al., 2002
Flat	Mauritius	253	1998	Ground	Bell, 2002
Isabela	Mexico	194	1996	Aerial	Rodriguez et al., 2006
Viwa	Fiji	60	2006	Ground	Campbell et al., 2011

Broadcast baiting

After the window for rodent mortality has passed and secondary poisoning of cats would have taken affect (~7-25 days) (Griffiths 2011; Weldon et al. 2011; R. Griffiths pers. comm. 2013), a follow-up application of sausage baits containing a toxicant specifically targeting cats should be broadcast at predetermined grid points as well as over terrain features frequented by cats.

Utilizing a helicopter for aerial bait dispersal is the recommended bait broadcast method for Floreana, and will have the advantage that it can be used for transporting personnel, equipment and supplies around the island (Wilcockson 2009). Parallel aerial baiting lines can be flown to provide grid coverage of the island. Spacing must provide coverage for any potential cat home range, and should be based on a known minimum of a 21 ha home range for an adult female cat in the Galápagos (Konecny 1987b). A circular 21 ha home range would have a diameter of 364 m. We suggest parallel baiting lines no further apart than 180 m, with baits applied at <180 m intervals. Additional aerial baiting of the coastline and features that cats frequent (e.g. cliff edges, trails, dry watercourses) should occur to compliment the parallel baiting lines. If dry conditions persist, additional baiting could occur to maximize the probability of exposing all cats to the sausage bait.

Western Australia Department of Environment and Conservation (WA DEC) sausage baits are suggested for use, though other bait mediums may be utilized if special circumstances necessitate a change. If imported from Australia, all sausages needed for the operation would need to be delivered to Floreana in a frozen goods container and kept onsite until used. Toxicant options, including PAPP (para-aminopropiophenone) and 1080 (sodium fluroacetate) will be analysed and the most appropriate toxicant will be recommended (refer to the non-target risk assessment and efficacy report to be prepared by Penny Fisher). Alternate toxicants could be assessed for efficacy and used if necessary.

Trapping

Trapping is the most frequently used method for feral cat removal and would serve as an important removal tool after baiting occurs. Typically, trapping would take place over several months. Effective traps for feral cats can include use of live leg-hold traps (e.g. Bridger #2 with four springs), live box or cage traps (e.g. Tomahawk), lethal traps (e.g. Conibear), and snares. Leg-hold traps have consistently shown a high level of efficacy, and are the recommended trap type for Floreana (**Image 2**). Skilled trappers should be engaged to prevent animals from becoming trap shy and to ensure that traps operate efficiently and effectively. Inexperienced trappers should be trained off-site, such as on Santa Cruz Island, until they have proven their trapping skills. Trapping feral cats would follow standard codes of practice and guidelines (Sharp and Saunders 2005a and 2005b, IAFWA 2006).

Image 2. Soft-jaw leg-hold live trap set for feral cats. Pictured here is a trail or walk-through set.

A trap monitoring system based on the system developed for the eradication of feral cats from San Nicolas Island (California) could be used to increase the efficiency of checking traps (Will et al. 2010, Hanson et al. 2010). The system is based upon radio telemetry transmitter units connected to traps. The transmitters emit a unique radio signal; when the trap is sprung the signal increases its pulse rate. Receivers can be checked manually or programmed to auto-scan all trap frequencies to continually monitor trap status island-wide. The trap monitoring system enables a rapid response time to sprung traps, reducing the time animals are left in traps and reducing risk to non-target species. The trap monitoring system also reduces the frequency with which traps are checked on-foot, which reduces damage to vegetation and disturbance to wildlife caused by regularly traversing the island. Trap monitors may also be utilized in areas where a rapid response is required, such as in areas where non-target species activity is expected to be high.

Hunting with dogs

Dogs are widely used in conservation programs and can be trained to perform specific tasks. Because of their well-developed sense of smell and ability to cover large areas of difficult terrain, dogs can greatly increase the ability to detect and locate feral cats. Hunting dogs can be trained to focus exclusively on feral cats and completely disregard other species including birds, marine mammals, rodents, and reptiles. As the substrate on Floreana reduces the ability to observe sign such as prints, other methods will be required to locate cats. Dogs are recommended for use on Floreana as a removal and detection tool.

Fumigants

Fumigants, primarily aluminium phosphide, are used to target cats seeking refuge within holes and burrows where a hunter cannot confidently place a gunshot. Cats are extremely susceptible to phosphine gas, which is produced by aluminium phosphide tablets mixed with water (Campbell et al. 2011). Holes and burrows showing signs of feral cat activity (scat, tracks, detected by dogs) should be marked, determined to be vacant of non-target vertebrates, and fumigated when found on Floreana.

Spotlight Hunting

Spotlight hunting can be very effective in the removal of cats due to the distinct and bright shine that is present from a felid's eye. Night hunting with spotlights is routinely utilized in cat control and cat eradication projects and has been utilized to remove the remaining cats when other methods were no longer effective (Hanson, 2011). Although this method can be very effective, it is very labor intensive and specific circumstances (i.e. clear and accessible terrain) must exist before success can be achieved. On Floreana, spotlight hunting may prove to be an important technique in special circumstances but would most often be combined with the use of dogs.

Monitoring techniques and tools to confirm eradication

Detection methods for feral cats typically include: trail cameras (including use of an olfactory or audio lure to attract cats); searches for cat sign (e.g. scat, paw prints); traps; and detection dogs. Once animals are no longer detected on the island, an operation would move into the confirmation monitoring phase.

All activities during the eradication operation should be recorded, including GPS location data for trap placement, date of cat capture, age and sex of animal, details of cat sign (e.g. type and age of sign, time of day), GPS location and photograph of cat sign, unintended mortality in traps, and unintended escapes. Small, rugged hand-held field computers with GPS capabilities (e.g. Archer PDA Juniper Systems, Logan, UT) can be used in the field to record all relevant data via drop-down menus (Fig. 11). This system allows for standardized data collection and when utilized with GIS, and allows for real time data analyses (Hanson et al. 2010). Data collected in this way provides managers with real-time information on the progress of the eradication operation, and assist in the making of critical decisions (Lavoie et al. 2007). A probability of detection model using data collected during the eradication operation can estimate the number of animals that may persist, as well as the amount of continued surveillance required to declare the eradication complete (Ramsey et al. 2011). For the detection probability model, managers would have to decide on the level of certainty (e.g. 99%) that if a cat existed, it would have been found. We suggest at least 99%. Two annual post-eradication monitoring surveys are recommended. Surveys would provide increased confidence in the eradication and ideally detect any cats that may be maliciously released. Surveys would utilize the detection methods described above, with the exception of dogs if they have departed Galápagos, and could coincide with field visits to confirm rodent eradication.

Combined Techniques

We believe that the combination of removal methods presented here address the four basic eradication principles discussed above. This conclusion is based on a review of analogous methods and logistics successfully implemented with eradication programs on other island islands; particularly islands within the Galápagos archipelago or islands that have similar characteristics to Floreana. Floreana has a climate that supports continuous breeding by rodents (Clark 1980, Jolley 2013-**Appendix B**), a stratified landscape, bi-seasonal climate (one wet and one dry season per year), inhabited, actively farmed and ranched, and is considered remotely located in terms of logistics. Islands referenced include, but are not limited to, rodent eradications from Palmyra Atoll, Rangitotu and Motutapu islands, Isla Pinzon and Rabida, Isla Plaza Sur and the lessons learnt from Henderson Island, Desecheo Island and Wake Atoll. Referenced cat eradications included successful campaigns on Rangitotu, Motutapu, San Nicolas, Faure, Ascension and Baltra Islands.

Environmental and Social Principals of Eradication

Environmental and social principles that are relevant to project acceptability:

• Environmental benefits of the project outweigh the costs imposed by project actions and outcomes
• The project is socially acceptable to stakeholders and the entire local community is supportive of the project

Impacts to Island Residents and Visitors Pertaining to Eradication Efforts

Human inhabitants are a variable that is not often present during invasive species eradication projects. As a result, there is not a long history of experience to draw from and special consideration must be given to mitigate for the established human presence.

Human Habitation

Due to Floreana having permanent residences and frequent tourists visiting the island, a thorough process to educate and inform the local community, other island residents, and particularly those conducting tourism operations to the island should be in place. Information will need to address real and perceived risks associated with an eradication being performed within a community as well as general information specifying the actions that are to be undertaken over the course of the eradication. Risks discussed should include both public health concerns as well as risks that could jeopardize the project's success. It will be important to provide distinct consideration to children and people with special needs who may not fully understand the implications of the proposed eradication methods (i.e. an island-wide broadcast of rodenticide). While the potential for negative impacts include serious harm or death, these risks can be greatly minimized or eliminated with appropriate planning and management (e.g. families taking a short-term vacation from the island) and ensuring that all actions are reviewed within a risk assessment with public safety as the first priority.

As the drinking water is derived from local springs on Floreana, and agriculture is occurring year-round, it should be expected that water quality and health risks from produce consumption will be raised as a public concern. This concern must be addressed regardless of the potential that surface or ground water contamination from brodifacoum is considered to be low or non-existent due to the chemical's lack of solubility in water and mobility within the soil column (US EPA 1998, DoC 2007, Fisher et *al*. 2011). As bait disintegrates, the chemical Brodifacoum remains in, and is absorbed by, organic compounds within the soil (World Health Organisation 1995) were it is degraded by micro-organisms including bacteria (DoC 2007). The low solubility of Brodifacoum in water means that plants are unlikely to absorb the chemical through osmosis (DoC 2007). Even in extreme cases, after approximately 18 tonnes of bait containing 360 g of Brodifacoum were inadvertently discharged into the environment, water solubility has been shown to be low and concentrations were below the minimum level of detection (<0.020 ppb) between 36 hours and 9 days (Primus et *al*. 2005). Furthermore, in what appears to be the most comprehensive report to date, 217 water samples from small open streams were taken after Brodifacoum was aerially broadcasted on Maungatautari, New Zealand, with no detectible residues. These results are consistent with another three islands where specific sampling for Brodifacoum occurred and determined that the binding of Brodifacoum to organic particles (sediment) would render it undetectable in water which could be utilized as a drinking source (Fisher et *al*. 2011).

In an effort to further reduce real or perceived risks, both drinking sources on island, Las Palmas and Asilo de la Paz, should be covered during the application of bait as well as have each site inspected for stray pellets under the cover after every bait application. A near shore fishing restriction is recommended while the consumption of any livestock present during implementation (including feral chickens) should not occur during or after implementation until samples taken demonstrate that flesh and organ residues are below the minimum level of detection.

In the event that rodenticide is inadvertently consumed, or symptoms similar to anticoagulant ingestion are shown, vitamin K1 is recognized as an effective treatment (DoD 2007).

Commensal Environment

A solid waste management program is in place on Floreana. The main objective of this effort is to improve the quality of life of the local inhabitants. Infrastructure has been put in place that provides storage bins and the collection of standard rubbish, recycling, perishable items, as well as garden debris and wood shavings. One individual is employed full-time to assist with the collection, sorting, and management of waste once it is placed in a receptacle outside of a home or business. Collections occur with a large truck and all material collected is deposited up the road from town in an open-air recycling center or burn pit (depending on the material). Food scraps are kept separate, then collected and taken to the farmlands where they are used to supplement the diet of domestic pigs and poultry. Collection of waste material occurs several times per week and may be subject to change depending on the availability of staff and if dates interfere with local holidays or island celebrations.

Once the eradication is confirmed a success, the solid waste management program will be able to continue according to the schedule and policies that were in place prior to the initiation of the eradication project. In the months leading up to, during, and shortly after the eradication project, various components of the waste management system will need to be altered to prevent rodents from accessing human-related or commensal sources of food. Particular areas of high risk include numerous residences on Floreana that serve as restaurants or storage locations for consumables, private kitchens and dining areas and an open-air dump site; all of these areas regularly contain food and/or food waste. Additional sites such as farm pens, grain storage areas and compost bins should also be considered a source of commensal products. These areas present a risk to the success of a rodent eradication if they are not managed appropriately. Relatively simple measures to prevent rodents from accessing commensal food sources should be developed with the lessons learned from previous rodent eradication campaigns in commensal areas, and in consultation with the local community to ensure long-term support for the alterations to the waste management.

It should be noted that this report was only able to address general aspects of the commensal environment on Floreana. As a result, it is recommended that during the planning phase for a rodent eradication, a more thorough assessment be completed concerning commensal rodents which further acknowledges and details these risks and provides measures for mitigation.

Pets and Livestock

Residents on Floreana have a number of pets and livestock including domestic cats and dogs, pigs and cattle, as well as chickens. The presence of these animals will complicate the eradication of cats and rodents from Floreana. Food provided to supplement domesticated animals' diets and animal feces are an alternative food source for rodents. Additionally, livestock will be at risk of exposure to the rodenticide and could interfere with baiting and trapping aimed at rodents and cats.

It is recommended and presently considered feasible that all livestock will either be harvested or removed off of island prior to the project's implementation. The logistics and community support for a "remove-and-replace" program will need to be assessed thoroughly and regularly revisited to ensure that full support exists on island. Win-win solutions should be developed in conjunction with livestock owners and one-on-one negotiations should occur to be able to customize solutions for each owner. Managers should engage community members early to ensure they are aware of the project goals as well as make project-related communication materials available to the whole community. Legally binding agreements should to be in place to ensure that livestock owners and the responsibilities of those with the authority over the livestock are clear and transparent. Other legislation and ministerial-level agreements should be developed to ensure that those with authority can act appropriately in the case of non-compliance with established regulations.

Project Approach in Regards to Risk

It is recommended that the eradication program adopts a critical-pathway approach to the project where specific crash points, or mitigation milestones (i.e. area of high risk to the project's success) are identified. If these milestones are not met, then a "crash" occurs and the project is temporarily, or permanently, postponed depending on the severity of the "crash." It should be understood by managers that the decision making process should be recorded in detail and that each risk should receive a thorough assessment. Based on this assessment, project progression should only continue after a risk has been appropriately mitigated.

If the project is initiated with a critical-pathway approach, the planning and implementation design should allow for the project to be "shelved" at various pre-determined states if a "crash" is identified.

Sustainability

Biosecurity to, and within the Galápagos

The Galápagos Biosecurity Agency has biosecurity protocols in place for people and materials travelling between the mainland and main ports in Galápagos, and between islands in the archipelago. As Floreana is only accessed by boat, the pathway of introduction is simplified resulting in a less complex strategy to enforce biosecurity. Galápagos Biosecurity Agency staff currently enforce the biosecurity guidelines, conduct inspections and provide interpretation when needed to ensure that rodents, cats, or other IAS are not brought to Floreana.

To protect the investment of eradicating rats and mice from Floreana, it is suggested that the ability to detect rodents in cargo would dramatically increase by incorporating specially trained detection dogs to work with inspectors while checking boats in Puerto Ayora (pre-departure for Floreana) and at the inspection point at the Floreana dock. Dogs may also be used for detecting and determining the extent of infestations and as part of the response to incursions if the initial biosecurity barrier is breeched. The inclusion of dogs to assist with biosecurity is currently contemplated within the Galápagos Biosecurity Agency's investment project.

Prior to the implementation of a rodent eradication, the robustness of biosecurity protocols should be assessed. Additionally, it is recommended that incursion response kits are developed so they are available on-hand and that on-site GBA staff are trained in their use. This will help protect the investment of eradication.

Table 6. Invasive Pathways

Species	Source of introduction	Pathway of introduction	Risk (low – high)	Prevention Strategy
Norway rat, black rat and house mouse	Within the Galápagos Islands, from mainland Ecuador, private international sailboat.	Accidental introduction with passenger boat / cruise ship / cargo ship due to the proximity of boat moorage. On building materials, on vehicles, in food stuffs or animal feeds.	MEDIUM – although biosecurity is in place, efforts are not thorough and an accidental introduction may occur.	Routine inspections of each vessel and gear brought aboard. Provide tools such as bait stations that can remain on-board each ship. Biosecurity needs to be improved to lower the risk – see section referring to utilizing dogs.
Domestic Cat and Dogs	Galápagos Islands, Mainland Ecuador, Private international sailboat.	Accidentally aboard any boat approaching close to, or mooring at Floreana. May also be from intentional release. Brought onto island as a pet.	LOW – Unlikely a cat will go unnoticed or will choose to abandon ship and swim to shore. All pets brought to the island will be required to have been spayed or neutered.	Routine inspections of each vessel and gear brought aboard. Any pets taken to Floreana will require authorization from the Galápagos Biosecurity Agency. Any authorized importations will only be of sterilized pets.

Socially acceptable

Invasive species eradication projects are perceived by communities in different ways depending upon the project's relevance to their own interests and livelihood. The community on Floreana has been both directly and indirectly impacted by the presence of rodents and feral cats. Many residents on Floreana rely on subsistence living as well as income generated by tourism. Tourism in the Galápagos is reliant on the natural environment, particularly numbers and variation of fauna and flora that are endemic to the Galápagos archipelago. Although not assessed, other groups within the Galápagos and internationally might be more concerned with wildlife protection, maintaining the biological integrity of the National Park, academic research, or animal welfare. The use of questionnaires may provide more insight on the local opinion of proposed conservation programs (Odgen and Gilbert, 2011). To ensure that this project is socially acceptable it has to address, or at the very least be aware of, the concerns of the various stakeholders (Varnham et *al*., 2011; Odgen and Gilbert, 2011; Griffiths et *al*. 2012).

The long-term sustainability of the project, i.e. ensuring that Floreana remains free of invasive mammals, is primarily dependent on the actions of the Floreana community; their support of the project is critical to the success of the project (Griffiths et *al*., 2012). It is anticipated that the local community will not express significant concern at the removal of rodents and feral cats; rodents are generally considered pests and feral cats provide no intrinsic benefit (aesthetically or ecologically) (Ruiz et *al*., 2010). The community promoted the idea of rodent and cat eradication as solutions to major invasive species issues that affect them in a community meeting in May 2012. However, the reaction to specific actions such as the need to adjust specific daily behaviors remains largely unknown. Community consultations, to make the public aware of the overall goals of the project and specific concerns have already occurred. The disruption to the current way of life that will occur during the eradication project may be disputed by members of the community; additional community engagement and transformation of conflict related to this project should be prioritised.

Outreach, including training, classes, informational materials, and/or seminars will likely be required for Galápagos National Park staff (primarily those not involved in eradication activities), who are tasked with the protection and management of Floreana and the other islands. Outreach will also be important to the wider public within the Galápagos and Ecuador, to improve awareness of the biodiversity importance of each island and the problem of invasive species in the Galápagos archipelago. This could be achieved through media releases (e.g. newspaper and magazine articles, radio, TV, signage) to the general public (Odgen and Gilbert, 2011; Griffiths et *al*., 2012).

The project provides the potential for local community members to be recruited for the operation, providing valuable employment opportunities. Bait loaders, trail cutters, non-target mitigation technicians, field workers, hunters and trappers can be sourced, trained and recruited to assist in the efforts to remove rodents and feral cats while working alongside experienced eradication practitioners. Presently, Floreana community members and other Galápagos residents have been participating in lead-up rodent eradication projects within the archipelago; these staff and their experience will be a valuable asset in the larger campaign on Floreana. Other opportunities to involve the community may relate to the support of field staff through the provisioning of housing and meals.

Logistical support, such as boats, boat captains and crew, vehicle operators, cooks and support and acquisition staff could be found within the local community. The eradication project will require a logistics base on Floreana, from which the operation will be managed; a house within town or another, locally owned facility in the highlands could be utilized. It is also anticipated that community outreach and consultation be conducted by local community members who already work in the area and are familiar with the community members and customs.

Table 7. Key stakeholders identified/suggested

Stakeholder	Representative	Potential involvement
Galápagos National Park Service	Christian Sevilla	Project co-owner, project management and implementation. Subsequent reintroductions of extirpated species.
Galápagos Biosecurity Agency	Marilyn Cruz, Director	Project co-owner, biosecurity between continent and islands, and between islands. Enforcement of livestock/pet regulations. Control of introduced animals in non-Park areas. Regulates importation of pesticides to Galápagos.
Ecuadorian Ministry of Environment	Walter Bustos	Project co-owner, oversees GNPS and Galápagos Biosecurity Agency in Galápagos. Reports on and secures annual funding allotments under the Invasive Species Investment Project and the annual plans of the GNPS and GBA
Junta Parroquial Isla Santa Maria	Max Friere, President	Project co-owner, inhabited area management, manage local regulations, representation for community
San Cristobal Municipal government	Maira Elena Flores (Unidad de Gestión Ambiental del Municipio)	Potential project co-owner, inhabited area management, refuse management, manage local regulations for pets
Island Conservation	Victor Carrion	Project co-owner. Technical assistance with invasive mammal eradications. Preventing extinctions.
Conservation NGOs in Galápagos, e.g. Conservacion y Desarollo, Charles Darwin Foundation, WWF, WildAid		Technical assistance with components of the GNPS invasive species investment fund (e.g. biocontrol), developing broader aspects related to project such as sustainable and environmentally responsible community-based tourism
Local Community	Max Freire as elected representative	Ultimate beneficiaries of project. Employment opportunities both direct and indirect. Improved quality of life.

Tourism sector	Claudio Cruz	Frequent movement of passengers and cargo inter-island. Major beneficiary of the project.
Health Department	Dr. Carlos Franco	Regulates use of pesticides in and around dwellings. Community health aspects.
Floreana Agricultural Association	Max Friere, President	Association representing Floreana's farmers. Affiliation is voluntary.
Commando Conjunto (Armed Forces)	Capitanía de Puerto Velasco Ibarra	Firearms permissions
Agrocalidad (National)	Ing. Rommel Betancourt (Director de Inocuidad Alimentaria)	Regulates importation of pesticides into Ecuador.

Politically & legally acceptable

Invasive species removal within the Galápagos Islands has been utilized frequently to restore ecosystems and many projects have served to provide new and innovative approaches to conservation efforts worldwide. In general, the legal standing of the GNP and its partners allows for efficient methods and new techniques to be utilized. With this understanding, the project must comply with government regulations, and ensure compliance with a number of laws relating to the use of firearms and toxicants, working in a protected area system, the use of helicopters and boats, and how domestic animals are dealt with. At present, legislation and government policies are being developed to support and mandate conservation actions within the Galápagos, and particularly on Floreana.

Although previous eradication projects that have occurred required similar compliance, there will be a need for consultation with government departments to understand all legal compliance requirements and processes, and a detailed list of all permits and other authorizations will be needed together with a description of the application processes and permit offices. Typically, this would include, but not be limited to, permits for use of firearms and their use within a protected area system, rodenticide application, importation permits, an assessment of the potential impact to Floreana as a result of the project, protection of threatened and native species, protection of natural resources such as air and water quality, and protection of any historic or cultural resources on the island.

Environmentally acceptable

A non-target risk assessment will be required to evaluate the potential harm to native and endemic species on Floreana from exposure to rodent and cat bait. An assessment should be compiled in 2013 detailing the expected impact that proposed toxicants could have on non-target species. Based on the results from this assessment, measures to reduce or mitigate potential non-target impacts will be incorporated where appropriate. Physical disturbances and trapping should also be evaluated although previous efforts within the Galápagos have shown positive net benefits with no long-term negative impacts from similar eradication actions.

Although incidental mortality of individual animals has occured during invasive species eradication operations in the Galápagos, populations of native and endemic wildlife have been not been critically impacted (GNP unpublished data). Species have shown rapid population growth or increased breeding success after invasive species have been removed, for example in seabirds (e.g. Howald et al. 2005, Whitworth et al. 2005, Smith et al. 2006, Regehr et al. 2007, Amarel et al. 2010), reptiles (e.g. Newman 1994, Daltry 2006, Towns et al. 2001, 2007), invertebrates (e.g. Sinclair et al. 2001, Towns et al. 2009, St Clair et al. 2010) and plants (e.g. Allen et al. 1994). In a non-target risk assessment, the benefits of long-term species recovery and protection should be considered, along with any potential short-term impacts through mortality of individuals as a result of eradication operations.

We have identified several species that should be given special consideration in the non-target risk assessment (**Table 8**). Mitigation actions can involve various methods, or combinations of methods designed to reduce the risk to individuals such as captive holding, hazing (scaring away from an area), reducing the likelihood of exposure to toxicants through other means such as aversion training, or antidotes. Mitigation actions are often expensive and increase the complexity of a project but may be required for biological, socio-political or cultural reasons.

Table 8. Tentative short-list of species that may require mitigation activities to avoid unacceptable risks.

Species	Reasoning
Medium tree finch (*Camarhynchus pauper*)	Island endemic with 100% of population on Floreana. Considered critically endangered by IUCN. Potential risk of primary or more likely secondary poisoning via invertebrates. May be difficult to keep in captivity. We recommend conducting captive holding trials in-situ prior to project implementation.
Galápagos rail (*Laterallus spilonotus*)	Galápagos endemic. Potential risk of primary and secondary poisoning via invertebrates. The Floreana population has undergone bottleneck events in recent past and based on its reduced dispersal abilities, the Floreana population may be genetically unique. Likely relatively easy to keep in captivity based on experience with similar rails elsewhere.
Short-eared owl (*Asio flammeus galapagoensis*)	Galápagos endemic subspecies, common across the archipelago. At risk of secondary poisoning. Difficult to acclimatize and keep alive in captivity. We recommend a genetic study to determine the genetic uniqueness of the population and gene-flow from nearby islands. The results of this study should guide whether mitigation actions should occur.
Common Gallinule or Moorhen (*Gallinula chloropus*) Paint-billed Crake (*Neocrex erythrops*)	Galápagos natives. Residents of freshwater lagoons. Potential risk of primary and secondary poisoning via invertebrates. Recolonization of the island may take considerable time. Farmers enjoy seeing these birds on their lagoons. Hazing likely to cause hiding behaviour rather than dispersal from island. Consider captive holding of set number of individuals on-island to repopulate Floreana.
White-cheeked Pintail (Galápagos) duck (*Anas bahamensis galapagensis*) American Flamingo (*Phoenicopterus ruber*)	Galápagos Pintail is Galápagos endemic subspecies. Greater Flamingo is Galápagos native with resident population. Risk of primary poisoning from baits in water, and for ducks possibly on-land. Hazing may disperse groups from the island. To avoid bait getting into lagoons, plastic floating sheets could be used to cover small lagoons while larger lagoons would require exclusion zones for aerial baiting with hand baiting around the shorelines.

Capacity

The project will require highly skilled and experienced individuals in key roles together with assistants who can be trained in the required skills. **Table 9** indicates the main skills needed in key personnel, but is not a complete list of personnel required. Island Conservation (IC) can provide personnel with many of the skills needed. Assistants and technicians will also be needed for field surveys, logistical support, boat crews, first aid and safety, helicopter support crew, rodent and cat baiting team, trapping, hunting, and GIS support among others. Personnel in lead roles will require prior experience and personnel with the desired skills will likely be sourced internationally or will already exist in the Galápagos, while many technicians and assistants can be recruited from the local community and will receive the appropriate training. A complete list of personnel, their roles, and skills needed should be provided in the Operational Plan.

Table 9. Key Skills needed to complete the project

ROLE / POSITION	PURPOSE	SOURCE TO OBTAIN SKILLS
Project Director	Initiate/manage project processes	GNP
Regional Manager	Liaison within region	IC
Project Management – Enabling Conditions Manager	Ensure conditions exist to facilitate the technical component of the project	IC and/or contract
Project Management – Technical Manager	Plan and Implement multispecies eradication	IC
Communications Manager	Develop and execute communications needs as necessary	GNP and IC
Eradication Specialists (mult.)	Field Team – Implement baiting actions, trapping, hunting, etc.	GNP, IC and contract
Logistics coordinator	Address logistics needs on island and in region	GNP or contract

PROJECT CONTINGENCIES

After assessing the feasibility of removing rodents and cats from Floreana, it was determined that the following contingencies should be met prior to initiating an eradication campaign:

- Legislation that supports actions proposed to eradicate rodents and rats
- Livestock are removed from the island prior to, and remain off-island through the eradication campaign
- Pet animals that have the potential to become invasive are sterilized or removed from the island
- All commensal requirements for both rodent and cat eradication are met and followed prior to, and throughout the eradication campaign.
- Biosecurity measures are in place prior to implementation and remain in place indefinitely
- The local community is in support of all facets of the eradication campaign

- The non-target species risk assessment suggests that the benefits from the project will outweigh the costs
- The governance structure put in place for the project is functional
- Enough funding is secured prior to implementation to complete the eradication of rodents and cats

FUNDING

Project	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Phase 6	Phase 7	Phase 8	Phase 9	hase 10	TOTAL
EXPENSES	TOTAL	TOTAL	TOTAL	TOTAL	TOTAL	TOTAL	TOTAL	TOTAL	TOTAL	TOTAL	TOTAL
Project Services	5,625	66,570	150	64,750	110,340	16,835	40,370	150	31,180	14,105	350,075
Field Work		209,173	13,540	111,252	508,093	35,700	46,450	7,540	22,350	300	954,398
Grants to Others											
Travel	2,304	55,798	13,255	46,574	50,678	99,312	136,946	19,255	27,474	11,664	463,260
General Management											
Personnel Costs	177,183	598,275	54,785	964,659	1,192,950	754,184	1,326,433	66,485	456,765	31,328	5,623,048
Professional Services	3,450	153,810	59,200	284,130	188,210	7,700	141,565	66,700	76,080	9,840	990,685
Occupancy Expense	13,859	34,229	1,035	64,856	69,346	41,601	81,925	1,435	46,122	3,030	357,436
SUBTOTAL PROGRAM EXPENSE	202,421	1,117,855	141,966	1,536,220	2,119,617	955,332	1,773,690	161,565	659,970	70,266	8,738,901
ALLOCATED G & A	31,142	171,978	21,841	236,342	326,095	146,974	272,875	24,856	101,534	10,810	1,344,446
TOTAL IC EXPENSES	233,562	1,289,833	163,806	1,772,562	2,445,712	1,102,306	2,046,565	186,421	761,504	81,076	**10,083,348**
PARTNER CONTRIBUTIONS											**4,194,990**
TOTAL PROJECT EXPENSES	233,562	1,289,833	163,806	1,772,562	6,202,801	1,474,656	2,112,115	186,421	761,504	81,076	**14,278,337**

CONCLUSION

Rodents

The feasibility of eradicating rodents from Floreana with an aerial broadcast approach is considered to be moderate. All requirements to successfully eradicate rats can be met with existing techniques though Floreana exhibits similarities to less-complicated rodent eradications that have been unsuccessful (e.g. Henderson Island, Wake Atoll, Desecheo Island). The reasons leading to the inability to remove all rodents are not fully understood and may be due any combination of factors including, but not limited to, a-seasonal breeding (Henderson, Wake Desecheo), island size (Henderson), human habitation (Wake Atoll), weather patterns (Henderson, Desecheo), application rates (Henderson, Wake Atoll, Desecheo), non-target bait consumption (Henderson, Wake Atoll, Desecheo), etc. Furthermore, mice will present a greater challenge due to their small homerange, higher tolerance to anticoagulant toxicants (relative to rats), and potential behavioural variation in the presence of rats. Special attention will need to be paid to ensure sufficient quantities of bait are planned for, and applied, and that the resolution of bait dispersal is appropriate to put every rodent on Floreana at risk (especially mice). Challenges (not considered insurmountable) may present themselves for this to occur in areas with non-target bait consumers, on cliffs, in caves, on offshore islets and rock stacks as well as all areas within the commensal environment. There is a risk that commensal guidelines and rodent biosecurity measures will not be effective or enforced, and that rodents may survive the eradication attempt or be re-introduced to Floreana; it will be important to develop an effective and realistic commensal and biosecurity plan for rodents.

Cats

The feasibility of eradicating feral cats from Floreana is high. Due to the size of Floreana and that there is a permanent community, a thoroughly planned campaign will need to be developed that addresses sustained eradication efforts and community engagement. There are precedents for the successful eradication of cats, including communities with pets, using the suite of techniques presented in this document. Combining cat and rodent eradication operations will increase the efficiency and probability of success of the cat eradication.

Table 10. Key issues reiterated:

Issue	Recommendation
Significantly larger than the largest mouse eradication to date.	Conduct thorough pre-eradication trials to increase confidence that all mouse homeranges can be confidently targeted for an effective duration of time. Over-engineer the bait application to reduce risk of failure, including using smaller bait pellets on secondary or tertiary bait application(s).
Project site supports a permanent human population.	The commensal environment will contribute greatly to the complexity of the eradication. Each compromise to optimal conditions will be associated with a risk to the success of the project for rats, mice, and cats.
Livestock and pets are at risk of brodifacoum poisoning through ingestion of bait.	Harvest or remove all livestock from the island prior to the implementation.
Project success within the short biological window will require key components to occur on time (i.e. bait and helicopter arrival).	Insure that full funding, permits, and all approvals are in hand prior to implementing time sensitive actions.
Contracts fall through	Ensure that redundancies exist to ensure critical project components are not at risk.

REFERENCES

Aguirre-Muñoz, A., Croll, D.A., Donlan, C.J., Henry, W., Hermosillo, M.A., Howald, G., Keitt, B., Luna Mendoza, L., Rodríguez-Malagón, M., Salas-Flores, L.M., Samaniego-Herrera, A., Sanchez-Pacheco, J.A., Sheppard, J., Tershy, B., Toro-Benito, J., Wolf, S., Wood, B., 2008. High-impact conservation: invasive mammal eradication from the Islands of Western Mexico. Ambio 37, 101-107.

Allen, R.B., Lee, W.G., Rance, B.D., 1994. Regeneration in indigenous forest after eradication of Norway rats, Breaksea Island, New Zealand. New Zealand Journal of Botany 32, 429-439.

Amaral, J., Almeida, S., Sequeria, M., Neves, V., 2010. Black rat *Rattus rattus* eradication by trapping allows recovery of breeding roseate tern *Sterna dougallii* and common tern *S. hirundo* populations on Feno Islet, the Azores, Portugal. Conservation Evidence 7, 16-20.

Andrews, C., 1909. On the fauna of Christmas Island. Proceedings of the Zoological Society of London, 101-103.

Atkinson, I., 1985. The spread of commensal species of *Rattus* to oceanic islands and their effects on island avifaunas, In Conservation of Island Birds. ed. P.J. Moors, pp. 35-81. International Council for Bird Preservation, Cambridge, UK.

Barker, D., Carroll, J.W.A., Edmonds, H.K., Fraser, J.R., Miskelly, C.M., 2005. Discovery of a previously unknown *Coenocorypha* snipe in the Campbell Island group, New Zealand, subantarctic. Notornis 52, 143-149.

Barnett, B.D., 1986. Eradication and control of feral and free-ranging dogs in the Galápagos Islands, In Proceedings of the Twelfth Vertebrate Pest Conference. pp. 359-368.

Biro, Z., Lanszki, J., Szemethy, L., Heltai, M., Randi, E., 2005. Feeding habits of feral domestic cats (Felis catus), wild cats (Felis silvestris) and their hybrids: trophic niche overlap among cat groups in Hungary. Journal of Zoology 266, 187-196.

Blackburn, T.M., Cassey, P., Duncan, R.P., Evans, K.L., Gaston, K.J., 2004. Avian extinction and mammalian introductions on oceanic islands. Science 305, 1955-1958.

Bremner, A., Butcher, C., Patterson, G., 1984. The density of indigenous invertebrates on three islands in Breaksea Sound, Fiordland, in relation to the distribution of introduced mammals. Journal of the Royal Society of New Zealand 14, 379-386.

Bullock, D., 1986. The ecology and conservation of reptiles on Round Island and Gunner's Quoin, Mauritius. Biological Conservation 37, 135-156.

Campbell, D., Atkinson, I., 2002. Depression of tree recruitment by the Pacific rat (*Rattus exulans* Peale) on New Zealand's northern offshore islands. Biological Conservation 107, 19-35.

Campbell, D., Moller, H., Ramsay, G.W., Watt, J., 1984. Observations on food of kiore (*Rattus exulans*) found in husking stations on northern offshore islands of New Zealand. New Zealand Journal of Ecology 7, 131-138.

Campbell, E., 1991. The effects of introduced roof rats on bird diversity of Antillean Cays. Journal of Field Ornithology 62, 343-348.

Chiba, S., 2010. Invasive rats alter assemblage characteristics of land snails in the Ogasawara Islands. Biological Conservation 143, 1558-1563.

Clark, David B., 1980. Poplulation ecology of Rattus rattus across a desert-montane forest gradient in the Galapagos Island. Ecology 61, 6, 1422-1433.

Courchamp, F., Langlais, M., Sugihara, G., 1999. Control of rabbits to protect island birds from cat predation. Biological Conservation 89, 219-225.

Courchamp, F., Langlais, M., Sugihara, G., 2000. Rabbits killing birds: Modelling the hyperpredation process. Journal of Animal Ecology 69, 154-164.

Cowie, R.H., 2001. Decline and homogenization of Pacific faunas: The land snails of American Samoa. Biological Conservation 99, 207-222.

Cree, A., Daughtery, C., Hay, J.M., 1995. Reproduction of a rare New Zealand reptile, the tuatara *Sphenodon punctatus* on rat-free and rat-inhabited islands. Conservation Biology 9, 373-383.

Croll, D., Maron, J.L., Estes, J.A., Danner, E.M., Byrd, G.V., 2005. Introduced predators transform subarctic islands from grassland to tundra. Science 307, 1959-1961.

Cruz, J.B., Cruz, F., 1987. Conservation of the dark-rumped petrel *Pterodroma phaeopygia* in the Galápagos Islands, Ecuador. Biological Conservation 42, 303-311.

Cushman, J.H., 1995. Ecosystem-level consequences of species additions and deletions on islands, In Islands: biological diversity and ecosystem function. eds P.M. Vitousek, L.L. Loope, H. Anderson, pp. 135-147. Springer-Verleg, Berlin, Germany.

Daniel, M., Williams, G., 1984. A survey of the distribution, seasonal activity and roost sites of New Zealand bats. New Zealand Journal of Ecology 7, 9-25.

Deem, S., Merkel, J., Ballweber, L., Vargas, F., Cruz, M., Parker, P., 2010. Exposure to *Toxoplasma gondii* in Galápagos Penguins (*Spheniscus mendiculus*) and Flightless Cormorants (*Phalacrocorax harrisi*) in the Galápagos Islands, Ecuador. Journal of Wildlife Diseases 46, 1005-1011.

Dickman, C.H., 1996. Overview of the impacts of feral cats on Australian native fauna. Australian Nature Conservation Agency.

Department of Conservation (DoC), 2007. Key facts about brodifacoum. < http://www.doc.govt.nz/Documents/conservation/threats-and-impacts/animal-pests/northland/brodifacoum-factsheet.pdf>

Dowding, J. E., and E. C. Murphy. 2001. The impact of predation by introduced mammals on endemic shorebirds in New Zealand: a conservation perspective. Biological Conservation 99:47-64

Dreesen, D.W., 1990. *Toxoplasma gondii* infections in wildlife. Journal of the American Veterinary Medical Association 196, 274-276.

Dubey, J.P., 2002. A review of toxoplasmosis in wild birds. Veterinary parasitology 106, 121-153.

Duncan, R., Blackburn, T., 2007. Causes of extinction in island birds. Animal Conservation 10, 149-150.

Fisher, H.I., Baldwin, P.H., 1946. War and the birds of Midway Atoll. The Condor 48, 3-15.

Fisher, P., Griffiths, R., Speedy, C., Broome, K., 2011. Environmental monitoring for brodifacoum residues after aerial application of baits for rodent eradication. In Veitch, C. R.; Clout, M.N. and Towns, D. R. (eds). Island invasives: eradication and management. IUCN Gland, Switzerland.

Fukami, T., Wardle, D., Bellingham, P., Mulder, C., Towns, D., Yeates, G., Bonner, K., Durrett, M., Grant-Hoffman, M., Williamson, W., 2006. Above- and below-ground impacts of introduced predators in seabird-dominated island ecosystems. Ecology Letters 9, 1299-1307.

Fuller, E., 2000. Extinct Birds, 2nd edition Oxford University Press, Oxford.

Furness, R.W., 1991. The occurrence of burrow nesting among birds and its effect on soil fertility and stability, In Proceedings of a Symposium held at the Zoological Society of London (No.63). eds P.S. Meadows, A. Meadows. Oxford University Press, London.

FWS, 2010. John Klavitter, Deputy Project Leader. Pers.comm. on Bonin Petrel nesting density at Sand Island, Midway Atoll NWR, Papahanaumokuakea Marine National Monument.

Graham, M., Veitch, C., 2002. Changes in bird numbers on Tiritiri Matangi Island, New Zealand, over the period of rat eradication, In Turning the tide: the eradication of invasive species. eds C. Veitch, M. Clout, pp. 120-123. IUCN SSC Invasive Species Specialist Group, Gland, Switzerland, and Cambridge, UK.

Grant, P.R., Grant, B.R., Petren, K., Keller, L.F., 2005. Extinction behind our backs: the possible fate of one of the Darwin's finch species on Isla Floreana, Galápagos. Biological Conservation 122, 499-503.

Griffiths, R. 2011. Targeting multiple species - a more efficient approach to pest eradication. In Veitch, C. R.; Clout, M.N. and Towns, D.R. (eds). Island invasives: eradication and management. IUCN Gland, Switzerland.

Griffiths, R., Buchanan, F., Broome, K., and B. Butland. 2012. Rangitoto and Motutapu - A starting point for future vertebrate pest eradications on inhabited islands. 25th Vertebrate Pest Conference. University of California, Davis. Pp. 22-27.

Hadfield, M., Miller, S., Carwile, A., 1993. The decimation of endemic Hawai'ian tree snails by alien predators. American Zoologist 33, 610-622.

Harper, G.A., 2005. Numerical and functional response of feral cats (Felis catus) to variations in abundance of primary prey on Stewart Island (Rakiura), New Zealand. Wildlife Research 32, 597-604.

Howald, G., Donlan, C.J., Galván, J.P., Russell, J., Parkes, J., Samaniego, A., Wang, Y., Veitch, D., Genovesi, P., Pascal, M., Saunders, A., Tershy, B., 2007. Invasive rodent eradication on islands. Conservation Biology 21, 1258-1268.

Hutton, I., Parkes, J., Sinclair, A., 2007. Reassembling island ecosystems: the case of Lord Howe Island. Animal Conservation 10, 22-29.

IUCN, 2008. 2008 IUCN Red List of Threatened Species. IUCN.

Iverson, J. B. 1978. The impact of feral cats and dogs on populations of the West Indian rock iguana, *Cyclura carinata*. Biological Conservation 14:63-73

Jehl, J. R., and K. C. Parks. 1983. 'Replacements' of landbird species on Socorro Island, Mexico. Auk 100:551-559.

Jiménez-Uzcátegui, G., Milstead, B., Márquez, C., Zabala, J., Buitrón, P., Llerena, A., Salazar, S., Fessl, B., 2007. Vertebrados de Galápagos: estado de amenaza y acciones de conservación, In Informe Galápagos 2006-2007. pp. 108-114. Parque Nacional Galápagos, Fundación Charles Darwin, Instituto Nacional Galápagos, Puerto Ayora, Galápagos.

Jones, H.P., Tershy, B.R., Zavaleta, E.S., Croll, D.A., Keitt, B.S., Finklestein, M.E., Howald, G.R., 2008. Severity of the effects of invasive rats on seabirds: A global review. Conservation Biology 22, 16-26.

Jones, E., 1977. Ecology of the feral cat, Felis catus (L.) (Carnivora: Felidae) on Macquarie Island. Australian Wildlife Research 4, 249-262.

Jones, H., Tershy, B., Zavaleta, E., Croll, D., Keitt, B., Finkelstein, M., Howald, G., 2008. Severity of the effects of invasive rats on seabirds: a global review. Conservation Biology 22, 16-26.

Jouventin, P., Bried, J., Micol, T., 2003. Insular bird populations can be saved from rats: a long-term experimental study of white-chinned petrels *Procellaria aequinoctialis* on Ile de la Possession (Crozet archipelago). Polar Biology 26, 371-378.

Keitt, B. and B. R. Tershy (2003). "Cat eradication significantly decreases shearwater mortality." Animal Conservation 6: 307-308.

Keitt, B. S., C. Wilcox, et al. (2002). "The effect of feral cats on the population viability of Black-vented Shearwaters (Puffinus opisthomelas) on Natividad Island, Mexico." Animal Conservation 5: 217–223.

Keitt, B., Henry, R.W., Munoz, A.A., Garcia, C., Mendoza, L.L., Hermosillo, M.A., B.Tershy, D.Croll, 2005. El Impacto de los gatos introducidos (*Felis catus*) en el ecosistema de Isla Guadalupe, In Isla Guadalupe Restauracion y Conservacion. eds K.S.d. Prado, E. Peters, pp. 219-230. Instituto Nacional de Ecologia, Mexico City.

Konecny, M.J., 1987a. Food habits and energetics of feral house cats in the Galápagos Islands Ecuador. Oikos 50, 24-32.

Konecny, M.J., 1987b. Home range and activity patterns of feral house cats in the Galápagos Islands, Ecuador. Oikos 50, 17-23.

Kurle, C.M., Croll, D.A., Tershy, B.R., 2008. Introduced rats indirectly change marine rocky intertidal communities from algae- to invertebrate-dominated. PNAS 105, 3800-3804.

Lavers, J., Wilcox, C., Donlan, C., 2010. Bird demographic responses to predator removal programs. Biological Invasions 12, 3839-3859.

Lever, C. 1994. Naturalized Animals. T & A.D. Poyser Natural History, London.

Lever, C., 1985. Naturalized mammals of the world. Longman, London; New York.

Levy, J.K., Crawford, P.C., Lappin, M.R., Dubovi, E.J., Levy, M.G., Alleman, R., Tucker, S.J., Clifford, E.L., 2008. Infectious diseases of dogs and cats on Isabela Island, Galápagos. Journal of Veterinary Internal Medicine 22, 60-65.

Lowe, S., Browne, M., Boudjelas, S., M., D.P., 2000. 100 of the world's worst invasive alien species. A selection from the global invasive species database. The Invasive Species Specialist Group (ISSG) a specialist group of the Species Survival Commission (SSC) of the World Conservation Union (IUCN), Auckland.

MacFarland, C.G., Villa, J., Toro, B., 1974. The Galápagos giant tortoises (*Geochelone elephantopus*) Part I: Status of the surviving populations. Biological Conservation 6, 118-133.

Maron, J.L., Estes, J.A., Croll, D.A., Banner, E.M., Elmendorf, S.C., Buckelew, S.L., 2006. An introduced predator alters Aleutian island plant communities by thwarting nutrient subsidies. Ecological Monographs 76, 3-24.

McChesney, G., Tershy, B., 1998. History and status of introduced mammals and impacts to breeding seabirds on the California Channel and northwestern Baja California Islands. Colonial Waterbirds 21, 335-347.

Meads, M.J., Walker, K.J., Elliot, G.P., 1984. Status, conservation, and management of the land snails of the genus Powelliphanta (Mollusca: Pulmonata). New Zealand Journal of Zoology 11, 277-306.

Medina, F.M., Bonnaud, E., Vidal, E., Tershy, B.R., Zavaleta, E.S., Josh Donlan, C., Keitt, B.S., Corre, M., Horwath, S.V., Nogales, M., 2011. A global review of the impacts of invasive cats on island endangered vertebrates. Global Change Biology 17, 3503-3510 + supplemental material.

Melink, E. 1992. The status of *Neotoma anthonyi* (Rodentia, Muridae, Cricentinae) of Todos Santos Islands, Baja California, Mexico. Bulletin of the Southern California Academy of Sciences 91:137-140.

Mitchell, N., R. Haeffner, V. Veer, M. Fulford-Gardner, W. Clerveaux, C. R. Veitch, and G. Mitchell. 2002. Cat eradication and the restoration of endangered inguanas (*Cyclura carinata*) on Long Cay, Caicos Bank, Turks and Caicos Islands, British West Indies. Pages 206-212 in C. R. Veitch and M. N.

Clout editors. Turning the tide: the eradication of invasive species. World Conservation union, Gland, Switzerland.

Moller, A.P., 1983. Damage by rats *Rattus norvegicus* to breeding birds on Danish islands. Biological Conservation 25, 5-18.

Moors, P., Atkinson, I., 1984. Predation on seabirds by introduced animals, and factors affecting its severity, In Conservation of Island Birds. ed. P.J. Moors, pp. 667-690.

Navarrete, S., Castilla, J., 1993. Predation by Norway rats in the intertidal zone of central Chile. Marine Ecology Progress Series 92, 187-199.

Nogales, M., Martin, A., Tershy, B.R., Donlan, C.J., Veitch, D., Puerta, N., Wood, B., Alonso, J., 2004. A review of feral cat eradication on islands. Conservation Biology 18, 310-319.

Ortiz-Catedral, L., Ismar, S.M.H., Baird, K., Brunton, D.H., Hauber, M.E., 2009. Recolonization of Raoul Island by Kermadec Red-crowned Parakeets *Cyanoramphus novaezelandiae cyanurus* after eradication of invasive predators, Kermadec Islands archipelago, New Zealand. Conservation Evidence 6, 26-30.

Parham, J.F., 2008. Rediscovery of an “extinct” Galápagos tortoise. Proceedings of the National Academy of Sciences 105, 15227-15228.

Parkes, J., Fisher, P., Forrester, G., 2011. Diagnosing the cause of failure to eradicate introduced rodents on islands: brodifacoum versus diphacinone and method of bait delivery. Conservation Evidence 8, 100-106.

Pascal, M., 1980. Structure et dynamique de la population de chats harets de l'archipel des Kerguelen. Mammalia 44, 161-182.

Patton, J. L., S. Y. Yang, P. Myers. 1975. Genetic and morphologic divergence among introduced rat populations (*Rattus rattus*) of the Galápagos Archipelago, Ecuador. Syst. Zool. 24:296-310.

Polis, G.A., Hurd, S.D., 1995. Extraordinarily high spider densities on islands: Flow of energy from the marine to terrestrial food webs and the absence of predation. Proceedings of the National Academy of Science 92, 4382-4386.

Primus, T., Wright, G., Fisher, P., 2005. Accidental discharge of brodifacoum baits in in a tidal marine envirnment: A case study. Bulletin of Envionrmental Contamination and Toxicology, 74:913-919

Pye, T., Swain, R., Seppelt, R., 1999. Distribution and habitat use of the feral black rat (*Rattus rattus*) on subantarctic Macquarie Island. Journal of Zoology 247, 429-438.

Pyle, R.L., Pyle, P., 2009. The Birds of the Hawaiian Islands: Occurrence, History, Distribution, and Status. B.P. Bishop Museum, Honolulu, HI, U.S.A.

Ratcliffe, N., Bell, M., Pelembe, T., Boyle, D., Bejamin, R., White, R., Goodley, B., Stevenson, J., and S. Sanders. 2010. The eradication of feral cats from Ascension Island and its subsequesnt recolonization by seabirds. Oryx, 44, pp 20-29.

Smith, J.E., Shaw, M., R, A., Edwards, Obura, D., Pantos, O., Sala, E., Sandin, S.A., Smirga, S., Hatay, M., Rohwer, F.L., 2006. Indirect effects of algae on coral: algae-mediated, microbe-induced coral mortality. Ecology Letters 9, 835-845.

Snow, B.K., Snow, D.W., 1969. Observations on the Lava Gull *Larus fuliginosus*. Ibis 111, 30-35.

Steadman, D.W., 1986. Holocene vertebrate fossils from Isla Floreana, Galápagos, Ecuador. Smithsonian Contributions to Zoology 413, 1-104. I-IV.

Steinfurth, A., and G. Merlen. 2005. Predacio´n de gatos salvajes (Felis catus) sobre el pingu˝ ino de

Gala´pagos (Spheniscus mendiculus) en Caleta Iguana, Isla Isabela. Report to the Charles Darwin Research Station and Galápagos National Park Service. Charles Darwin Research Station, Puerto Ayora, Isla Santa Cruz, Gala´pagos, pp. 1–8.

Tershy, B. R., C. J. Donlan, B. S. Keitt, D. A. Croll, J. A. Sanchez, B. Wood, M. A. Hermosillo, G. R. Howald, and N. Biavaschi. 2002. Island conservation in north-west Mexico: a conservation model integrating research, education and exotic mammal eradication. Pages 293-300 in C. R. Veitch and M. N. Clout, editors, Turning the Tide: the eradication of invasive species. World Conservation Union, Gland, Switzerland.

Thibault, J.-C., 1995. Effect of predation by the black rat *Rattus rattus* on the breeding success of Cory's Shearwater *Calonectris diomedea* in Corsica. Marine Ornithology 23, 1-10.

Tomich, P., 1986. Mammals in Hawai`i, 2nd edn. Bishop Museum Press, Honolulu, HI.

Towns, D., 1991. Response of lizard assemblages in the Mercury Islands, New Zealand, to removal of an introduced rodent, the kiore (*Rattus exulans*). Journal of the Royal Society of New Zealand 21, 119-136.

Towns, D., 1994. The role of ecological restoration in the conservation of Whitaker's skink (*Cyclodina whitakeri*), a rare New Zealand lizard (Lacertillia: Scincidae). New Zealand Journal of Zoology 21, 457-471.

Towns, D., Atkinson, I., Daugherty, C., 2006. Have the harmful effects of introduced rats on islands been exaggerated? Biological Invasions 8, 863-891.

Towns, D., Broome, K., 2003. From small Maria to massive Campbell: forty years of rat eradications from New Zealand islands. New Zealand Journal of Zoology 30, 377-398.

Towns, D., Parrish, G., Tyrell, C., Ussher, G., Cree, A., Newman, D., Whitaker, A., Westbrooke, I., 2007. Responses of Tuatara (*Sphenodon punctatus*) to removal of introduced Pacific rats from islands. Conservation Biology 21, 1021-1031.

Towns, D., Wardle, D., Mulder, C., Yeates, G., Fitzgerald, B., Parish, G., Bellingham, P., Bonner, K., 2009. Predation of seabirds by invasive rats: multiple indirect consequences for invertebrate communities. Oikos 118, 420-430.

Tye, A., 2007. La flora endémica de Galápagos: aumentan las especies amenazadas, In Informe Galápagos 2006-2007. pp. 101-107. Parque Nacional Galápagos, Fundación Charles Darwin, Instituto Nacional Galápagos, Puerto Ayora, Galápagos.

United States Envirnmental Protection Agency, 1998. Reregistration Eligibility Decision (RED) Rodenticide Cluster. Prevention, Pesticides and Toxic Substances (7508W). EPA 738-R-98-007

Van Aarde, R.J., 1980. The diet and feeding behaviour of feral cats, Felis catus at Marion Island. S. Afr. Tydskr. Natuurnav. 10, 123-127.

Vargas, F.H., Harrison, S., Rea, S., Macdonald, D.W., 2006. Biological effects of El Niño on the Galápagos penguin. Biological Conservation 127, 107-114.

Veitch, C. R. 2001. The eradication of feral cats (*Felis catus*) from Little Barrier Island, New Zealand. New Zealand Journal of Zoology 28:1-12

Veitch, C.R., 1985. Methods of eradicating feral cats from the offshore islands in New Zealand, In Conservation of island birds: case studies for the management of threatened island birds. ed. P.J. Moors, pp. 125-142. International Council for Bird Preservation, Cambridge.

Wegmann, A. S. 2009. Limitations to tree seedling recruitment at Palmyra Atoll. University of Hawaii, Honolulu.

Weldon, G., Fairweather, A., and P. Fisher. 2011. Brodifacoum pesticide infmation review. Department of Conservation, New Zealand DOCIM-25436

Whitaker, A.H., 1973. Lizard populations on islands with and without Polynesian rats *Rattus exulans* (Peale). Proceedings of the New Zealand Ecological Society 20, 121-130.

Whittaker, R.J., 1998. Island biogeography: ecology, evolution, and conservation. Oxford University Press, Oxford; New York.

Whitworth, D.L., Carter, H.R., Young, R.J., Koepke, J.S., Gress, F., Fangman, S., 2005. Initial recovery of Xantus's murrelets following rat eradication on Anacapa Island, California. Marine Ornithology 33, 131-137.

Wilcockson, R., 2009. Floreana Island feral cat eradication program; aerial baiting, technical report, p. 13. The Aeroplane Company, Western Australia, Perth.

World Health Organization, 1995. Anticoagulant rodenticides. Environmental Health Criteria 175, p.121. Geneva, Switzerland.

Wolf, S., 2002. The relative status and conservation of island breeding seabirds in California and Northwest Mexico, In Marine Sciences. p. 79. UCSC, Santa Cruz.

Woram, J.M., 1989. Galápagos island names. Noticias de Galápagos 48, 22-32.

Young, H., D. McCauley, R. Dunbar, and R. Dirzo. 2010. Plants cause ecosystem nutrient depletion via the interruption of bird derived spatial subsidies. Proceedings of the National Academy of Science **107**:2072-2077.

Zavaleta, E.S., Hobbs, R.J., Mooney, H.A., 2001. Viewing invasive species removal in a whole-ecosystem context. Trends in Ecology & Evolution 16, 454-459.

APPENDICES

Appendix A – Floreana Island Vertebrates

Table A. Seabirds nesting on Floreana Island. † indicates archipelago endemic.

Name	Name
Galápagos petrel, *Pterodroma phaeopygia* †	Blue-footed booby, *Sula nebouxii*
Galápagos penguin, *Spheniscus mendiculus* †	Nazca booby, *Sula granti*
Madeiran storm-petrel, *Oceanodroma castro*	Red-billed tropic bird, *Phaethon aethereus*
Galápagos shearwater, *Puffinus subalaris* †	Swallow-tailed gull, *Creagrus furcatus* †
Brown pelican, *Pelicanus occidentalis*	Brown noddy, *Anous stolidus*
Magnificent frigatebird, *Fregata magnificens*	

Table B. Extinctions and extirpations from Floreana Island. Once extinction drivers, such as cats and rodents are removed reintroductions could occur for eight or nine extirpated species, four or five of which are considered globally threatened.

Name	Status
Large-beaked ground finch, *Geospiza magnirostris*	Extirpated, archipelago endemic.
Large tree finch, *Camarhynchus psittacula*	Extirpated, archipelago endemic (S. Kleindorfer pers. comm., 2013)
Warbler finch, *Cirthidea olivacea*	Extirpated, archipelago endemic.
Lava gull, *Larus fuliginosus*	Extirpated, archipelago endemic.
Sharp-beaked finch, *Geospiza difficilis (nebulosa)*	Extirpated, archipelago endemic.
Floreana mockingbird, *Mimus trifasciatus*	Extirpated, Floreana and satellite islands endemic, survives on small satellite islands in small numbers.
Vermilion flycatcher, *Pyrocephalus rubinus*	Extirpated.
Galápagos barn owl, *Tyto alba punctatissima*	Extirpated, archipelago endemic sub-species.
Galápagos hawk, *Buteo galapagoensis*	Extirpated, archipelago endemic.

Galápagos racer, *Alsophis biserialis*	Extirpated, archipelago endemic.
Floreana giant tortoise, *Chelonoidis elephantopus*	Considered extinct until recently, island endemic. Genetics from Floreana tortoises have recently been found within the population of tortoises on Wolf volcano (Parham 2008) and in captivity on Santa Cruz Island (Wacho Tapia pers. comm.). Individuals are now reproducing in the breeding centre on Santa Cruz Island and hatchlings are being head-started in the facility there.
Sicyos villosa	Extinct, island endemic plant.
Dellila inelegans	Extinct, island endemic plant.

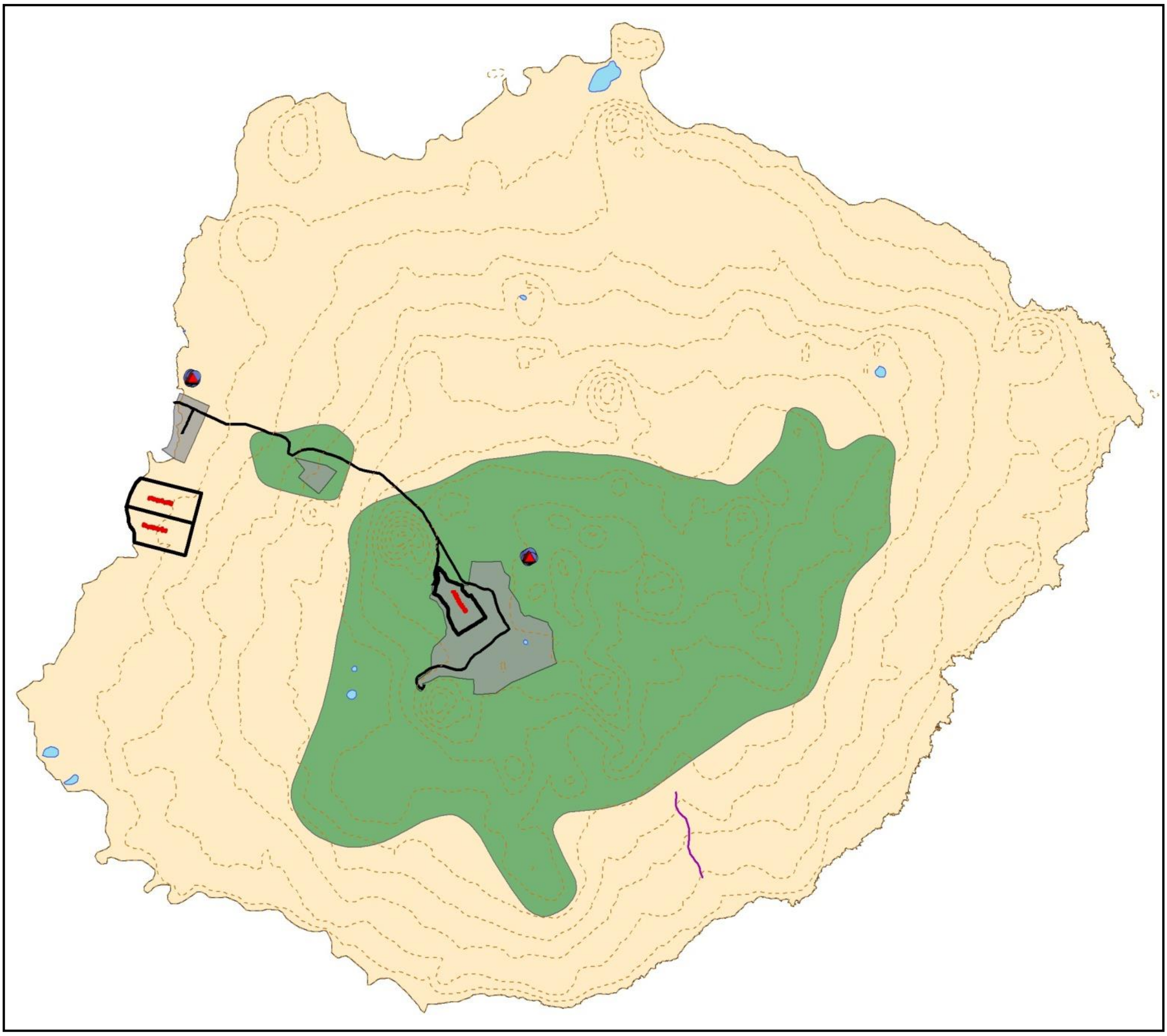
Source: (Grant *et al.* 2005; Steadman 1986; Tye 2007)

Appendix B – Floreana Bait Availability and Cat Trapping Trip Report

Trip Report: Floreana Island 2012

Wesley Jolley

Introduction



Island Conservation staff were on Floreana Island, The Galapagos, Ecuador from November 6 to December 19, 2012. The primary objective during this time was to assess the bait availability rates through time after an aerial broadcast of cereal bait pellets. This work is in preparation to eradicate rats, mice and feral cats from the island. Secondary objectives included trapping rats and mice inside and outside the baited areas, working alongside and training local hires, exploring the island and mapping trails with an eye towards future work, marking calibration points to create accurate maps, searching for the Galapagos rail, and trialing cat trapping methods.

Many single species rodent applications utilize two applications of bait by helicopter, spaced 7-14 days apart. The baiting rate is designed to have bait available for at least four nights after the first application. In eradications targeting rats and mice, a third application is often used. The trial on Floreana was designed to test a strategy of eradicating rats and mice using two applications of bait. Given Floreana's large size, the potential removal of a third areal broadcast and avoiding sowing bait at an unnecessarily high rate will amount to huge savings in the project budget.

We initially expected that mice would be undetectable in the presence of rats, and that we would see an increase in mice detection and bait consumption after an initial knockdown of the rat population. The level of interspecific impact and response (if any) to the initial baiting application were unknown, but data gathered during this trial will inform strategic decisions for the eradication.

The trial on Floreana Island was designed to occur concurrently with the Pinzon operation to allow for the sharing of resources. The Floreana trial relied on the use of a helicopter to aerially broadcast toxic bait over a large enough area to account for immigration into the baited area. Two alternative strategies for the second application were designed; one using the helicopter and one using hand broadcasting. The helicopter was ultimately used for the second application which reduced complexity for the Floreana field crew and helped keep consistency for data collection across the two applications.

That the goal of this document is to provide an overview record of what was done and what occurred. Data sets and other relevant records will be stored on the IC server and available for further analysis or to aid in future projects.

Island Description

Floreana Island is a 17,200 hectare volcanic island located in the Galapagos Islands. The island has two distinct zones, the dry lowlands and the wet highlands. The lowlands are largely covered with thick brush broken up in places by open lava fields. The highlands are highly vegetated and green all year, receiving moisture on an almost daily basis. A large portion of the highland areas is used for agriculture, both as farmland and pasture for cows and pigs.

A single road runs from the town on the western edge of the island up to the highlands. One "official" groomed trail runs from the highlands north toward Post Office bay. A water line runs from near the tortoise cages past the water tanks and back towards town, the area along the pipe is cleared and easily walked but not sufficient for bikes or vehicles. A series of cattle trails allows access to some additional parts of the highlands. Overall, the vast majority of the island is not easily accessible.

Methods

Bait Availability

We selected the locations of our 100 ha baiting areas prior to arriving to Floreana Island. Four possible work areas were designated, and our first objective was to select the best location in the lowlands and the best location in the highlands. The preferred lowland location proved to be satisfactory for our work, but we quickly found that owned and "feral" cattle were utilizing both possible highland plots and the majority of the highland areas designated as national park. We investigated building a fence around our preferred plot and removing the cattle, but that proved logistically impossible. We ultimately moved our highland plot to a roughly 50 ha pasture/farmland that had an existing fence.

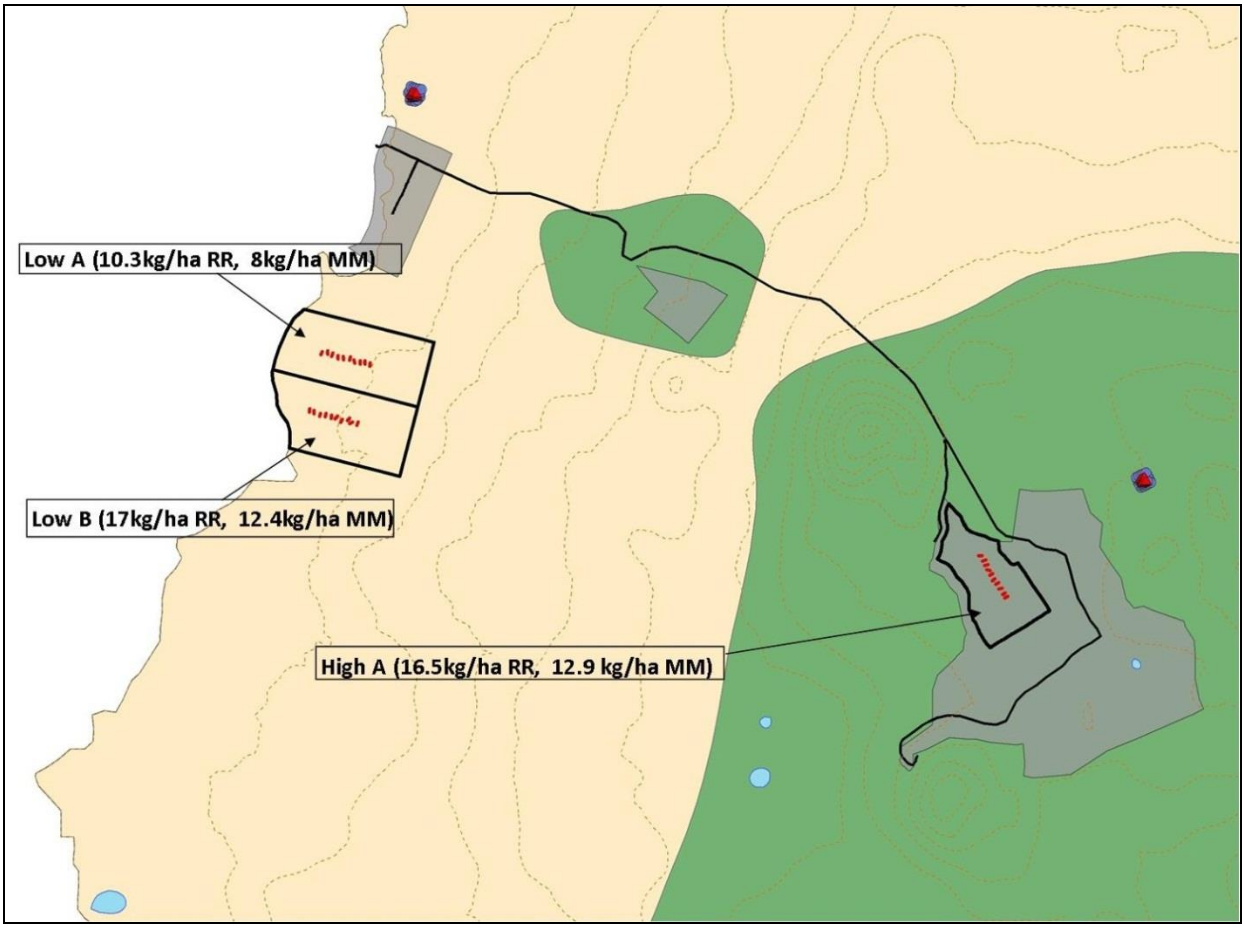


Figure 1. Areas where bait was applied

Each of the original 100 ha a plot was going to be divided in half to allow us to test two rates in each plot. We decided to move forward with testing two rates in the lowlands, but only test one rate in the highlands. We installed a total of 30 bait availability monitoring transects, 10 in each half of the lower plot and 10 in the highland plot. The 25mx1m transects ran roughly parallel to each other and were spaced 40 meters apart. The line of transects ran up the middle of each plot, providing a buffer of roughly 200 meters or more between each transect and the edge of the baiting area.

Transects were measured and marked with flagging tape. Pin flags to mark the bait, one mouse trap, and one rat trap were staged at each transect.

First Application

The first application occurred on November 18. All areas were baited with 2.3 gram pellets of Conservation 25 D, dyed blue. One half of the lowland plot (Low A) was baited at 10.3kg/ha and the other half (Low B) at 17 kg/ha; the highland plot (High A) was baited at 16.5 kg/ha. After receiving an exact baiting rate from the baiting crew, we calculated the number of pellets that needed to be marked and monitored in each transect. We marked and monitored 11 pellets in Low A and 18 pellets in Low B and High A. Field staff made sure the appropriate number of pellets were marked in each transect and pellets were moved into or out of transects to ensure the exact amount were marked.

Second Application

The second application occurred on December 3 and all areas were baited 1.1 gram pellets of inert bait, dyed blue. Low A was baited at 8kg/ha and Low B at 12.4 kg/ha; High A was baited at 12.9 kg/ha. We marked and monitored 18 pellets in Low A, 28 in Low B and 29 in High A

Bait was checked and the pellets were counted daily for ten days after the first application. Bait was then checked every other day until the second application (on day 15). All flags marking 2.3g pellets were marked with an “X” prior to the second application, to allow us to continue to monitor both types of pellets simultaneously. All bait was checked daily for another ten days after the second application, and was checked ever other day until Island Conservation staff left the island on December 19.

Rodent Trapping

Trapping for rats and mice occurred in three scenarios: trapping in the baited areas, trapping grids in unbaited areas, and miscellaneous trapping around the farms and the town to gather DNA samples. Island Conservation’s Tomahawk and Sherman traps got stuck in customs so we were forced to use traps the park had on hand. We were sent four types of rodent trap: tomahawk traps and three sizes of small folding traps similar to the Sherman style, but manufacturer was unknown. Trap types were counted but traps were not measured, table 1 shows the quantity and best estimate of sizes of the traps used, for this document the Sherman-style collapsible traps will be referred to as small, medium, and large. The tomahawk traps could only catch rats (mice could escape) ,the small collapsible traps could only catch mice (or in theory, immature rats), the medium and large collapsible traps could capture both rats and mice, but were not ideal for catching either. All traps were baited with peanut butter purchased in Ecuador that came in bag and was a consistency that allowed it to easily be rolled into balls and placed in traps. (La Cena brand Mani, small plastic pouch with a green and yellow label and a chef on it, recommended on future trips).

Trap type	Collapsible rodent trap (small)	Collapsible rodent trap (medium)	Collapsible rodent trap (large)	Tomohawk 201
Dimensions (WxHxL) in inches	2" x 2.5" x 6.5"	3" x 3.5" x 9"	3" x 3.5" x 12"	5.5" x 5" x 16"
# in Highland baited area	10	0	5	5
# in Lowland baited area, north	9	1	5	5
# in Lowland baited area, south	10	0	5	5
# in Highland trapping grid	14	30	4	1
# in Lowland trapping grid	25	12	1	12
Total	**68**	**43**	**20**	**28**

Table 1. Quantity of each trap size and type used in each area.

We recorded basic morphometric data (species, sex, reproductive status, and weight) as well as some standard museum measurements (total length, tail length, hind-foot length, and ear size) for each captured rodent.

Two tail clippings were taken from each euthanized rodent, one sample was given to the Galapagos National park and one was for Island Conservation. We sent our rat samples to Ecogene in New Zealand and our mouse samples to the genetics lab at the University of North Carolina. The samples were sent to two different locations because we have a partnership with the UNC lab working on future innovations regarding mouse eradication, but the lab wasn't interested in storing or processing our rat samples. We collected DNA from 48 rats and 49 mice.

Trapping on transects

A small collapsible trap and one of the other traps was placed at each availability transect. Traps were opened for two nights prior to bait being applied. Trapping stopped after observing a high rate of death in trapped animals due to heat and ant attacks. Trapping began again three nights after the first application and continued for seven nights, a second week of trapping began three nights after the second application.

All animals captured in the baited areas prior to the second application were marked and released, so as to not reduce the number of consumers in the plots. Animals trapped after bait was applied were checked for evidence of bait consumption, such as blue around the mouth or anus, blue scat in the trap, or behaving poisoned. After the second application, animals showing signs of bait consumption were euthanized to simulate them dying after consuming toxic bait.

Trapping grids outside of baited areas

Rats and mice were trapped in two grids outside the baiting area. Each grid consisted of a 5x5 grid of rat traps at a 20 meters spacing and a smaller 5x5 grid of mouse traps at a 10 meters spacing with the two grids sharing a center point. The highland grid was a grassy area with apple guava trees (*Psidium guajava*) just inside the park border that was similar to the pasture area that was baited. The lowland grid was just north of the town and approximated the lowland baiting areas. All animals trapped in the baiting grids were euthanized.

The traps in the highland grid were opened on November 14 and the lowland grid was opened on November 19. Trapping in the grids stopped on November 26 because we felt we'd learned what we'd hoped from the trial and there was a need for the small Sherman-style traps on confirmation trips to other islands.

Other trapping

After the baiting grids were stopped we used the extra tomahawk traps to target rats in the agricultural areas and in the town. The extra trapping was not documented in full detail, and traps were placed sporadically or moved when not capturing rats. The sole purpose of this trapping was to gather additional DNA samples.

Cameras

Time-lapse

We used camera traps to detect rodents and to identify consumers of bait and carcasses. Four cameras were set on time lapse and took a photo every minute from 6pm to 6am each night. The motion triggers were active 24 hours a day and took the standard 3 picture set after being triggered. Three time-lapse cameras were placed on availability transects and were used to get an index of rodent detection before and after bait was applied. One camera was placed on a bait degradation cage to observe potential consumers and how much effort animals put into trying to access the bait in the cage.

Cameras not performing or gathering relevant information were moved or used for another purpose. For example, the time-lapse camera on the bait degradation cage was moved to the lowlands and placed on a bait pile outside the baited area to identify what invertebrates were consuming bait.

Carcasses and bait piles

One camera was placed on a chicken carcass in the highlands and another was placed on rat carcasses in the lowlands. The purpose of this was to monitor what larger vertebrates, such as cats or owls, consumed the carcasses. Two more cameras, one in the highlands and one in the lowlands, were placed on small bait piles within the baited area but away from availability transects to monitor consumers.

Degradation

Bait degradation

Bait degradation was examined by placing ten 2.3 gram pellets in cages made from 5mm wire mesh. One bait degradation cage was placed in the lowlands and two were placed in the highlands. One cage in the highlands was specifically placed next to two ant hills in order to monitor the effect ants have on bait. The two other cages were placed in locations ants did not appear to be using regularly.

Bait was checked regularly, usually every-other day. Field staff noted the number of pellets remaining, the Craddock degradation score (see appendix 2), and a general description of the pellets focusing on what (if anything) was consuming bait and how the bait had changed since the previous check.

Carcass degradation

Chicken and rat carcasses were placed in the open and in degradation cages in the lowlands and the highlands. A chicken carcass was not placed in the open in the lowlands because we were unable to source four animals. Checks occurred regularly, usually every other day. The observer noted if the animal would potentially be a food source to larger island animals (cats, dogs, owls), the overall condition of the carcass, and what had happened since the previous check.

All degradation cages were secured firmly to the ground with rebar or nails driven into the rock. Lids were secured with re-usable zip ties to allow the lid to be removed for photographs or to get a better look at what was occurring. Carcasses placed in the open were secured to a nearby plant, rock, or stake with wire.

Non-target and other observations

Observations of things such as evidence of bait consumption by targets and non-targets, and possible target and non-target mortalities were recorded opportunistically throughout the study.

Snails

We assisted Christine Parent and Penny Fisher in testing the survival rates of endemic snails exposed to various bait formulations. One hundred individuals of *Naesiotus unifasciatus* were collected at Cerro Pajas and divided into four groups. Each group was divided into five Tupperware containers with five snails in each container. All containers had a kimwipe, sticks and leaf litter from the collection area, and were covered with plastic fly screen secured with a rubber band. One group of 25 snails acted as the control, and a bait pellet was placed into each container for the other three groups. Three formulations were tested: pellets containing brodifacoum and blue dye, inert pellets with blue dye, and inert pellets with a pyranine biomarker.

The snails were kept in an abandoned office building near the park office. All containers were kept on top of a large desk which prevented rodents from interfering. Snails were misted with water and counted twice daily. The number of active, estivating and dead snails was recorded. Dead snails were put into a vial and frozen for later testing. The snails exposed to inert baits were monitored for ten days and then returned to Cerro Pajas. Snails in the control group snails exposed to toxic bait were monitored for 21 days before being frozen and stored for testing for brodifacoum residues.

A detailed report or publication on the snail work will be written separately.

Rail surveys

The Galapagos rail (*Laterallus spilonotus*) occurs in wet highland areas throughout the Galapagos. Surveys by Rosenberg (1990) in 1986-87 failed to detect the rail on Floreana, but the rail has been subsequently detected on the island. We attempted to establish a general distribution of the rail by talking with locals about sightings, recording incidental detections and conducting survey points similar to Rosenberg 1990. Our methods weren't highly rigorous and do not provide a census or estimate of population size.

Field staff sat quietly at each survey point for five minutes before beginning the survey point. Percentage of tall and short vegetation cover in a 25 meter radius, and general habitat type were recorded. A Galapagos rail call was loaded onto cell phones and field staff played the call for fifteen seconds in each direction (forward, backward, left and right). The cell phone was held approximately three feet off the ground to extend the range at which the call could be heard. After the call was played the observers listened for two minutes for any rail calls. Any rail calls heard during the playback or two minute listening period were recorded.

Survey points occurred at three different spacings, which allowed us to strike a balance between covering a lot of area and surveying likely habitat more intensely. The entire perimeter of the highlands agricultural area was surveyed at a spacing of one point every 300 meters. Each of the perimeter plots including roughly 50% agriculture land and 50% park land. A few trails in the GNP were surveyed at a spacing of one point every 100 meters. Agricultural land, specifically Claudio Cruz's farmland was surveyed using a 40-50 meter spacing.

Ten survey points were taken in highland pasture where bait was applied approximately 20 days after toxic bait was applied and five days after non-toxic bait was applied. An additional five of the perimeter plots were located on the border of the baited area.

Rail locations based on conversations with locals, as well as incidental observations were recorded. No incidental observations were recorded prior to the beginning of our efforts to detect the Galapagos rail.

Cat trapping

Rory Stansbury visited Floreana Island for three between applications on Pinzon days to trap cats. He focused on the coastal area north of the town, around the recycling center, along the road leading to the highlands, and near a property known as Las Palmas which is roughly half way between the town and the highlands. Stansbury focused primarily on using leg-hold traps and snares. Scent or bait was not used.

Wes Jolley and the three local hires continued trapping beginning on December 9. The primary goal was for Jolley to refresh his trapping skills and to train the local hires how to use leg-hold traps. Four leg-hold traps were placed in the highlands along the pipeline that carries water from the spring to the town. Four more traps were placed around the dump and recycling center. All locations were chosen because they were easy to access, likely had cats, and were not frequently visited by people who may have dogs with them. One conibear trap was placed along the pipeline in order to start getting some practice using kill traps. Kill traps were not heavily used due to the risk of injuring or killing pet dogs or livestock near inhabited areas. Local hires were given some additional training on using conibear traps and snares, but the focus was primarily on the fundamentals of leg-held trapping.

We primarily used a "standard" leg-hold trap set that incorporated natural or created pinch points, guide rocks, and stepping sticks. Traps were initially scented with a bit of the oil from canned sardines. Later, a mixture of sardines, oil, scat and urine was used. All captured cats were euthanized, and ear clippings were taken to begin establishing a baseline DNA inventory of the island population.

Results and Discussion

Bait Availability

Baiting Block	Pellet size (g)	Initial Application Rate	Days until first plot zeroed out	Days until all plots zeroed out
Low A Application 1 (RR)	2.3	10.3	27	> 63
Low A Application 2 (MM)	1.1	8	21-28	>49
Low B Application 1 (RR)	2.3	17	14	> 63
Low B Application 2 (MM)	1.1	12.4	21-28	>49
High A Application 1 (RR)	2.3	16.5	8	15
High A Application 2 (MM)	1.1	12.9	9	14-21

Table 2. Summary of application rate and time until first and all plots zeroed out. Note that application 2 occurred 15 days after application 1.

The bait availability curves for the six combinations of rate, location, and pellet size are included in appendix 1. The highland plot was the only area to reach zero availability before the second application, although one transect in the southern half of the lowland plot had zero bait before the second application (table 2). The time reach zero availability, either in a single plot or overall, for the lowland plots is effected by the second application which occurred 15 days after the first application. Likewise, availability after the second application in the lowlands is impacted by presence of bait remaining after the first application. The availability data will help inform decisions on application rates and timing in the eradiation campaign.

Bait availability in the highlands was likely affected directly and indirectly by the high levels of moisture in the area. The thick grass held moisture and prevented pellets from drying out. Over time we observed that pellets in the tall grass were turning to mush and dissolving into loose piles of bait. These piles of bait may have contained sufficient bait to kill a rat, but the animals would have been willing to consume the in place because it could not be carried off. Wet and broken down bait was, at least observationally, much more easily consumed by finches and invertebrates which reduced the amount of time bait was available.

We did not do a direct comparison, but a wet formulation bait may be a better option in the highlands. The wet formulation would break down slower in the moist grass and may not be so readily eaten by finches, factors which may lead to needing to sow bait at a lower rate overall. It's important to note that finches can still readily eat dry bait pellets, but the handling time appears to be higher reducing the overall rate of consumption.

Rodent Trapping

The use of four different trap types complicates analysis of trapping rates. The problem is that the medium and large Sherman-style traps were able to catch both rats and mice, but were not ideal for catching either.

As an example of the capture bias, the trapping grid in the highlands had 25 traps capable of capturing rats, twelve of which were tomahawk traps. Sixteen rats were captured in this trapping area, 15 of which were in tomahawk traps. Observational analysis strongly suggests that the trap types were not equally effective at capturing rats. Statistical comparisons of expected versus actual capture rates for each trap type are possible if necessary in the future but likely not needed to inform operational strategy for the eradication campaign.

Trapping Location	Captures first night of trapping		Captures second night of trapping		Total first two nights of trapping	
	Rats	Mice	Rats	Mice	Rats	Mice
Low A baited area	3	2	2	2	5	4
Low B baited area	4	3	2	2	6	5
High A baited area	3	0	1	2	4	2
Highland trapping grid	5	1	2	2	7	3
Lowland trapping grid	0	5	0	11	0	16

Table 3. Rat and mouse captures for the first two nights of trapping in each area.

The important discovery from trapping rodents on Floreana Island is that we were able to detect mice in the presence of rats (table 3), which is not what we expected and contradicts the results of a study on Santa Cruz Island (Harper and Cabrera 2009). The data does not allow us to quantify what, if any, impact interspecific competition between rats and mice has on each species access to bait. However, the ability to detect mice in the presence of rats does allow us to assume that at least some portion of the mouse population will have access to the bait right away.

Only three animals were trapped in the baited areas after the application of bait. Two rats were trapped in the highlands area three days after the first application and both showed signs of poisoning and/or having consumed bait. One more rat was captured ten days after the second application (25 days after the first application), and showed no signs of poisoning or having consumed bait. It is possible that a rat originally living in the baited area did not have access to bait, but the relatively small size of the baited area along with a sudden and concurrent reappearance of rodents on camera traps in the baited area provide confidence that immigration had occurred.

Rats and mice in the highlands appeared to be in better condition than the individuals in the lowlands. Three pregnant mice were captured in the highlands, otherwise we detected no evidence of reproduction occurring but the possibility cannot be ruled out.

Cameras

Time-lapse

Cameras set on time-lapse did not prove to be an effective way of indexing animals before and after the bait applications because detection rates were too low even before bait was dropped. However, the time-lapse setting allowed us to detect cold blooded animals such as reptiles and invertebrates and provided insight into possible consumers.

Carcasses

A cat was photographed near the chicken carcass in the highlands, but it did not specifically investigate or consume the carcass. Two cats were photographed approaching the rat carcasses in the lowlands on two separate occasions, but neither consumed the carcasses. It appeared that the cats may have heard or seen the camera in the lowlands because they looked directly into the camera and moved off on both locations. The camera was repositioned farther away and two fresh rat carcasses were hung from a bush to prevent ants from covering them, but no further detections were made.

Bait piles

Cameras placed on bait piles in the highlands and lowlands both captured evidence that finches will readily consume the bait. When time-lapse was turned on, cameras in the highlands and lowlands both showed invertebrates eating the bait. In the lowlands large cockroaches vigorously consumed the bait pile, swarming the pile and dragging away many pieces on the first night.

Degradation

Bait degradation

Table 4 highlights time to key events in the bait degradation studies. Bait degraded/disappeared slower in the cages than in the surrounding areas, so we can be confident that we captured a worst-case scenario for how long bait is likely to be available in the environment after an application.

		Highlands	Highlands near ant hill	Lowlands
Key Events	**Consumed by ants**	Day 15: one pellet partially consumed by ants	Consumed sporadically from Day 3 when 2.5 pellets were consumed and ending on Day 39 when no pellets remained	N/A but on Day 32 one pellet fell to edge of cage and was consumed by ants or other invertebrates
	Molding	Day 21: all pellets covered in mold	N/A	N/A but on Day 32 one pellet fell to edge of cage and was consumed by ants or other invertebrates
	Completely degraded	N/A As of Day 70. 8 pellets left, all black and dry since day 49	Day 49	N/A as of Day 70. 8 pellets remain, all white dry and breaking apart

Table 4. Time to key events in bait degradation studies

Bait in the degradation cages in the highlands persisted much longer than in the surrounding areas. This was likely due to the exclusion of consumers, but may also be in part because the degredation cage reduced the amount of moisture reaching the bait.

Mold is likely to speed up the break-down of bait in the highlands that is not consumed by rodents, birds or invertebrates; unconsumed bait in the lowlands will likely persist until there is sufficient rainfall to break down the bait.

Ants consumed the bait in the degradation cage placed near two ant hills, but not as fast as expected. There seemed to be an initial consumption of bait followed by slow and inconsistent consumption. There were a few instances where the consumption rate seemed to increase for a day or two. Overall it appears that the ants in the highlands were willing to consume bait but preferred carrion.

Carcass degradation

Tables 5 and 6 highlight key events in the chicken and rat carcass degradation studies, respectively. Carcasses did not appear to be viable food sources for larger consumers (owls, cats, rodents etc.) for more than a few days. Most carcasses were immediately covered by ants, which likely reduced palatability for vertebrate consumers. The ant species on the carcasses in the lowlands and highlands were different, but both reacted aggressively when the carcass was disturbed.

		Chicken degradation cage, Highlands	**Chicken degradation cage, Lowlands**	**Chicken degradation no cage, Highlands**
Key Events	**Covered with soil by ants**	Ants began covering with soil on Day 1, was 3/4 covered on Day 5 and totally covered by Day 8	Never covered with soil, but ants present beginning Day 1	Ants began covering with soil on Day 1, was 3/4 covered on Day 5 and totally covered by Day 8
	Maggots present	Unknown. On Day 5 flies were first noted on carcass. Carcass was not opened during degradation trial, but likely had maggots inside	Day 3	Day 5
	nearly completely consumed/ no longer any visible meat	Day 25	Day 18	Day 18
	ants/maggots gone or greatly reduced	Day 25	Day 25	Day 25
	Only bones and hair/feathers remaining	Day 32	Day 25	Day 32

Table 5. Time to key events in chicken carcass degradation studies

		Rat degradation cage, Highlands	Rat degradation cage, Lowlands	Rat degradation no cage, Lowlands	Rat degradation hanging carcasses, Lowlands	Rat degradation no cage, Highlands
Key Events	**Covered with soil by ants**	1/2 covered on Day 2	Partially covered on Day 4, completely covered by Day 9	Day 3	N/A, but ants reached carcass on Day 26	Day 2
	Maggots present	Day 4	N/A	N/A	Maggots never noted, but covered in flies Day 1-7	N/A
	nearly completely consumed/ no longer any visible meat	Day 6	Day 6	Day 5-7	Day 19	Day 6
	ants/maggots gone or greatly reduced	Day 9	Day 19	Day 9-11	Day 26	Day 6
	Only bones and hair/feathers remaining	Day 9	Day 21	Day 9-11	Day 40	Day 9

Table 6. Time to key events in rat carcass degradation studies

Carcass degradation data was qualitative and had small sample sizes, but informative observations were made. Degradation "looked" different in the highlands and the lowlands, but overall occurred at approximately the same rate. There was no noticeable difference in the degradation rates of carcasses in the open and in cages because the primary consumers could fit through the wire mesh used to construct the cages.

The rat carcasses hung from a tree in the highlands was an effort to keep ants off the carcass in hopes that it would remain palatable to cats and we could capture a cat consuming rodent carcasses on camera. The hanging rat carcasses degraded much slower, but do not represent a natural scenario.

A cat carcass left in some rocks in the highlands gave us an idea of the fastest rates of carcass degredation. The carcass was not formally monitored, but after six days we noticed that it had been almost completely consumed by maggots. No ants were visible so one possible scenario is that maggots consume carcasses extremely fast, but the process is slowed down when ants are present and competing for the resource.

Non-target and other observations

Finches were seen consuming the bait. The finches did not appear to carry off whole pellets, instead they focused on consuming the small pieces of bait. Finches did not break apart dry pellets but could easily turn a wet pellet into a small pile of crumbs which they could consume rapidly. Bird scat containing blue dye was found in the highlands and the lowlands, which further confirms that finches were consuming the bait.

Four ground finches were found dead in the highland baited area and one was found dead in the lowland baited area. One carcass was fresh enough to necropsy which revealed a small amount of hemorrhaging. The bird likely died of poisoning but lacked strong evidence such as massive hemorrhaging or bait in the digestive tract. A few other piles of feathers were found that appeared to be where a cat had captured a finch, but it's unknown if the finches had consumed bait and may have been an easier target due to the effects of poisoning.

Snails

Most snails survived the duration of the trial. Table 7 shows the number of snails in each treatment that died.

Treatment (bait type)	Number of snail mortalities
Control (no bait)	1
non-toxic and pyranine	0
non-toxic and dye	2
toxic and dye	4

Table 7. Snail mortalities observed in each treatment

The snail data was sent to Christine Parent for analysis and no significant difference was found in the mortality rates.

Rail surveys

The cell phone speakers were probably not loud enough for effective call-back surveys. We were unable to definitively detect any rails purely using call-back methods, but we were able to confirm rails are present in multiple parts of the highlands. Survey points and observation locations are shown in figure 2.

Discussions with our local hires, park employees and other island residence revealed that rails are difficult to spot but likely not uncommon in the highland areas. Multiple people mentioned seeing rails near water and in more natural areas with light understory, especially on wet days. Locals occasionally encountered rail nests when walking through natural areas, though none were found during our time on island.

Figure 2. Rail survey points (yellow circles), sightings (red ovals), and possible call backs (blue ovals)

Cat trapping

Leg-hold trapping success exceeded expectations, with a total of 11 animals being captured in less than 100 trap nights. Rory Stansbury removed two cats in his three days of trapping, one from the coastal area north of town and one from near the Cruz family's property (Las Palmas). Five cats were removed from near the dump and recycling center and four were removed from along the pipeline running from near the tortoise pens towards town.

The locals had had some previous exposure to cat trapping, and improved their technique rapidly. Fortunately we were able to catch a lot of cats, which provides opportunities to see what works as well as more chances and motivation to reset a trap and make the set good quality. A couple weeks of trapping is not enough to make them ready to hit the ground running on an eradication campaign, but they have a good foundation that we can build on. The success also served to get them excited and helped provide a motivating factor to each day.

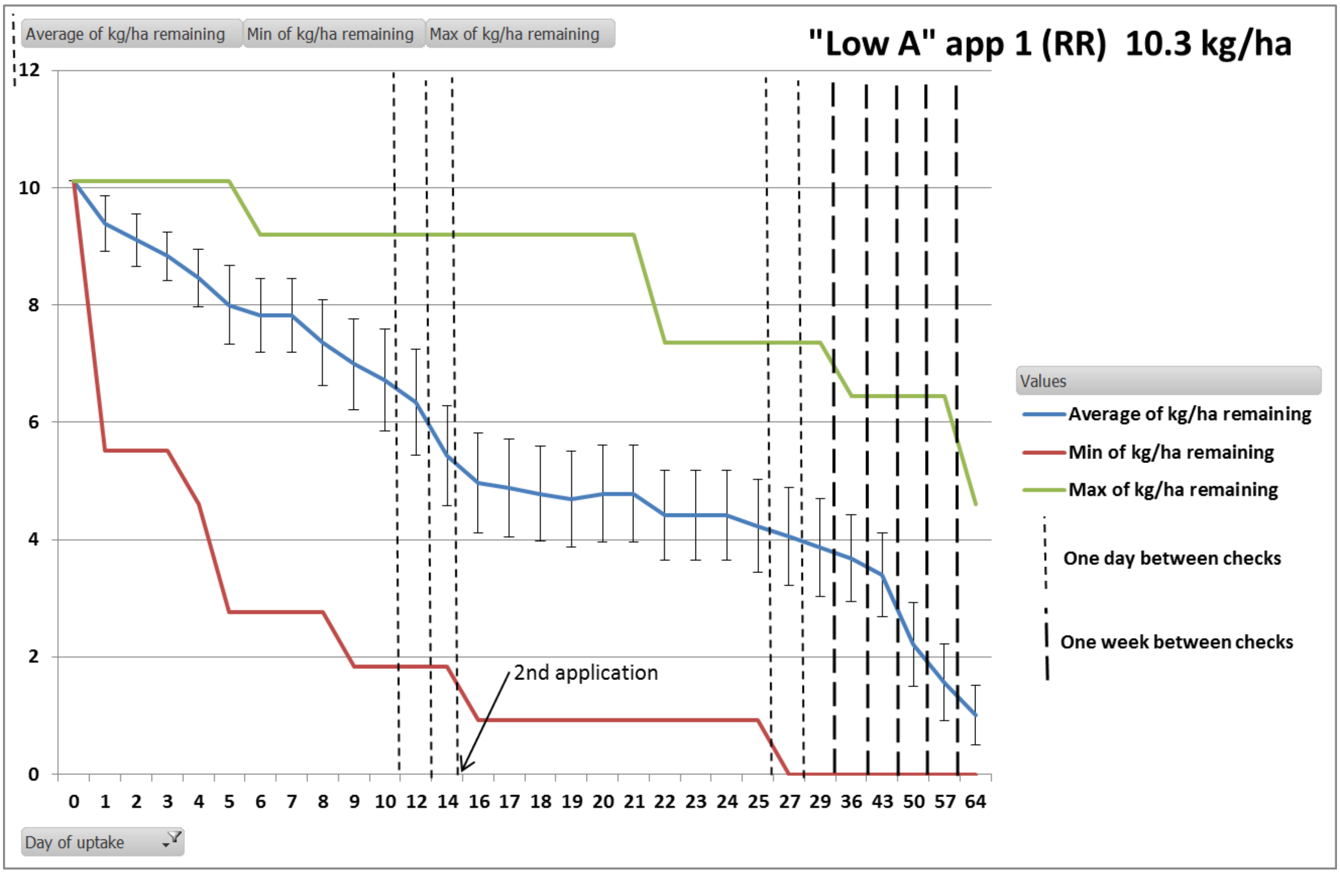
More time needs to be invested into trialing trapping methods for Floreana, specifically for kill traps. Island Conservation staff are generally inexperienced at using snares and conibears so there will be a learning curve during the project if staff don't gain experience prior. Snares will be much easier to deploy in large numbers over the island because conibears are heavy and need stakes, a box, or some other system for holding them in position.

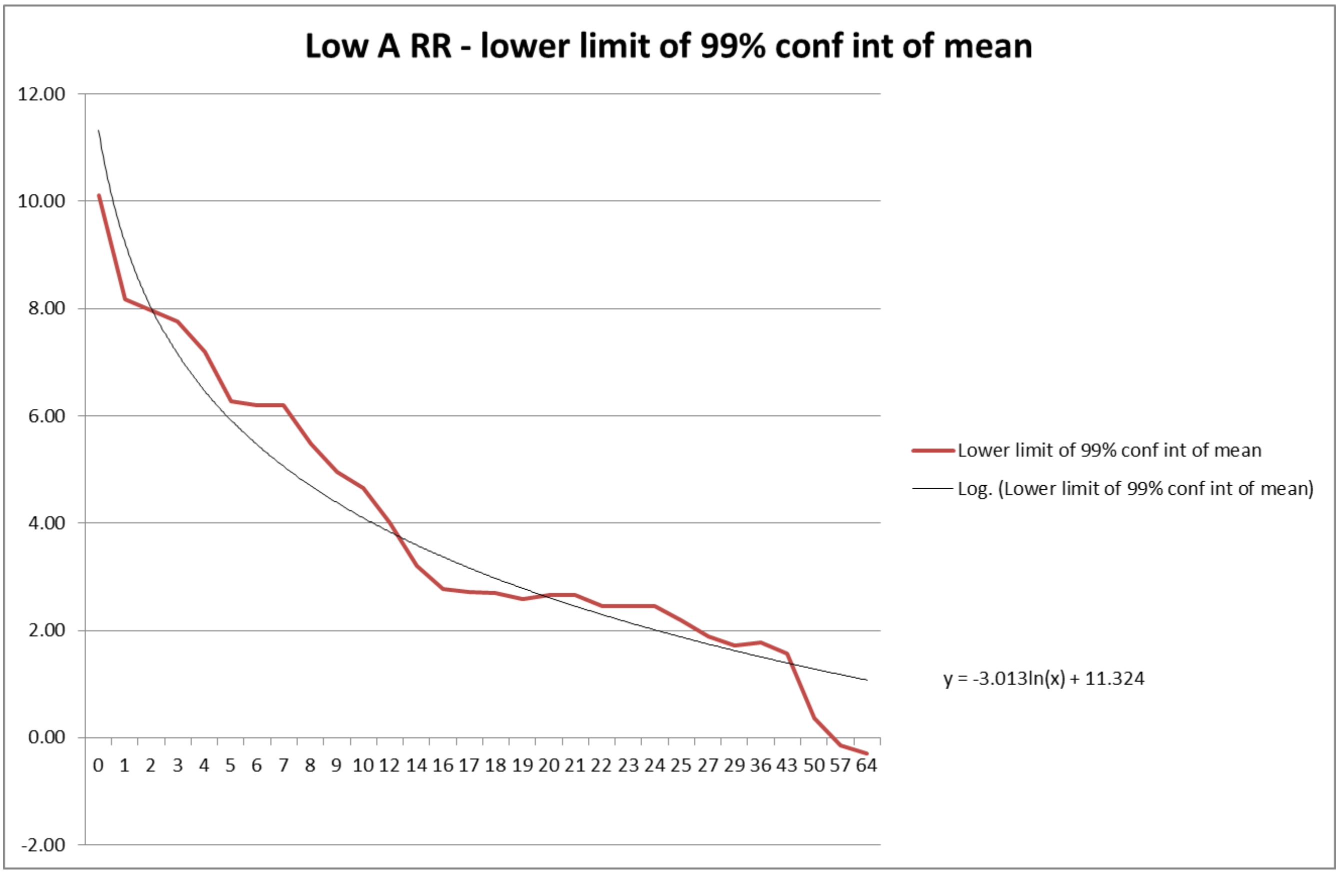
Literature Cited

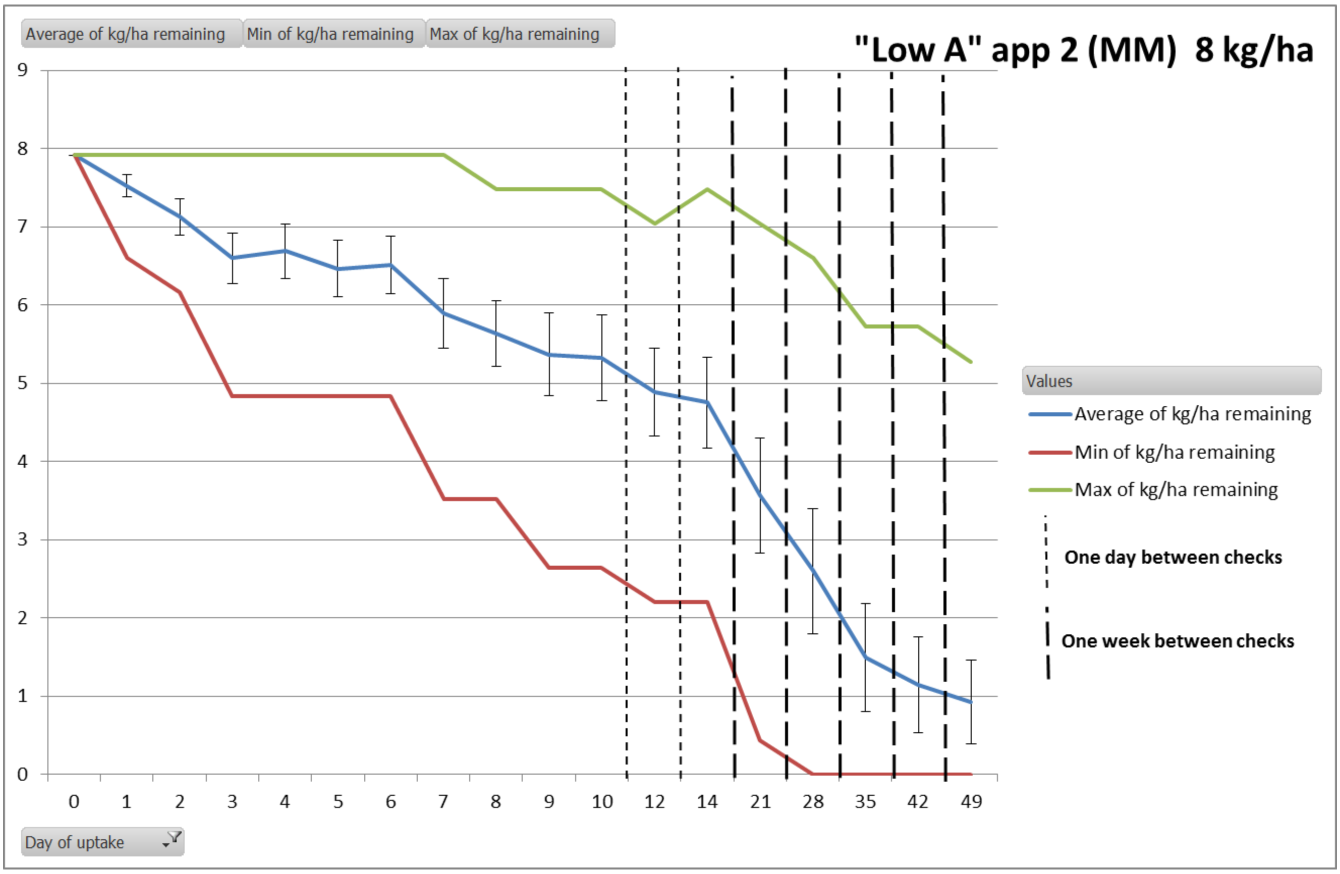
Harper, G. A., and L. F. Cabrera. 2009. Response of mice (Mus musculus) to the removal of black rats (Rattus rattus) in arid forest on Santa Cruz Island, Galápagos. Biological Invasions **12**:1449-1452.

Rosenburg, D. K. 1990. The impact of introduced herbivores on the galapagos rail (Laterallus spilonotus). Monogram, Systemic Botony, Missouri Botanical Gardens:169-178.

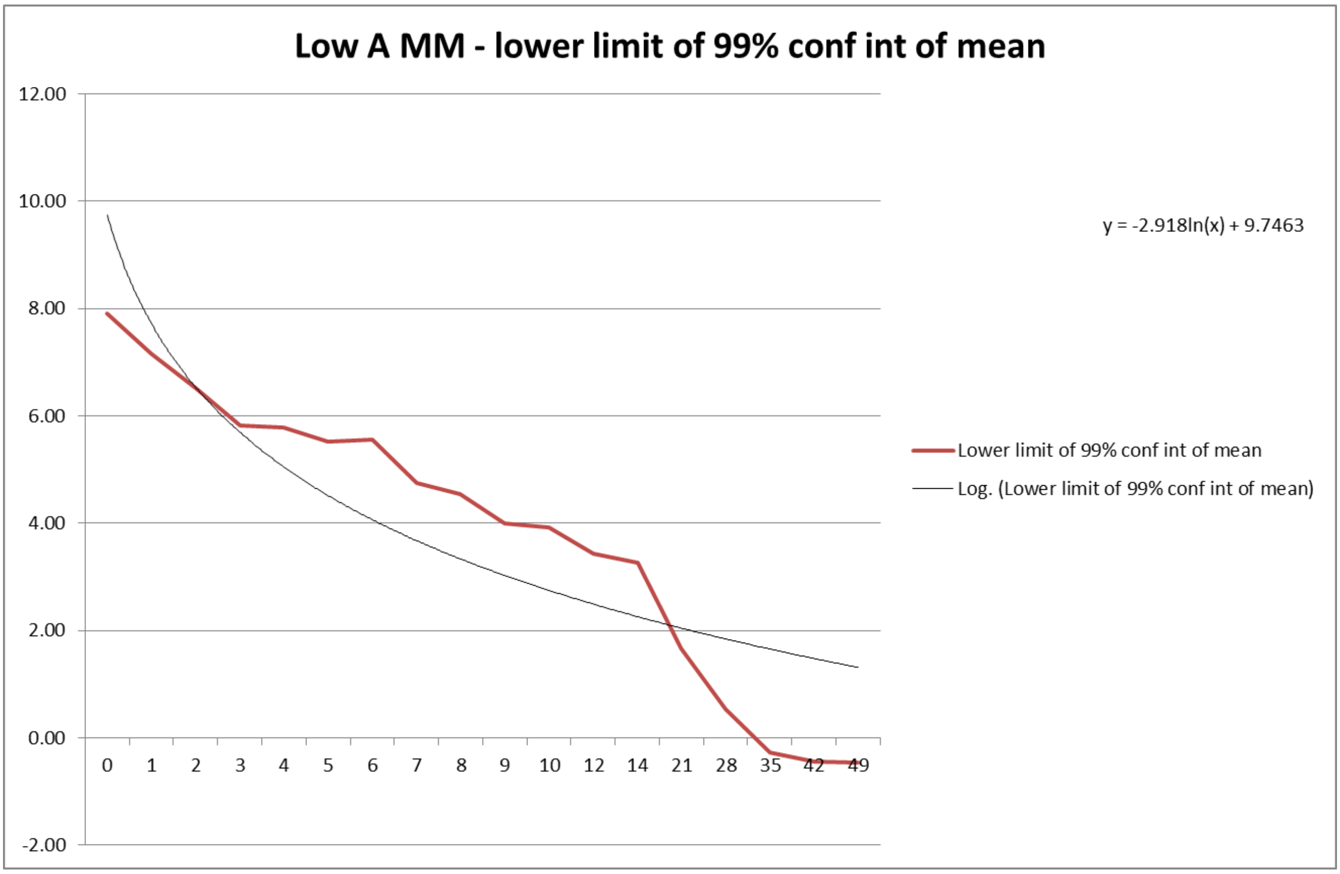
Appendix 1: Bait availability Charts


"Low A" app 1 (RR) 10.3 kg/ha
Average of kg/ha remaining
Min of kg/ha remaining
Max of kg/ha remaining
Values
One day between checks
One week between checks
2nd application
Day of uptake
0 1 2 3 4 5 6 7 8 9 10 12 14 16 17 18 19 20 21 22 23 24 25 27 29 36 43 50 57 64
0 2 4 6 8 10 12

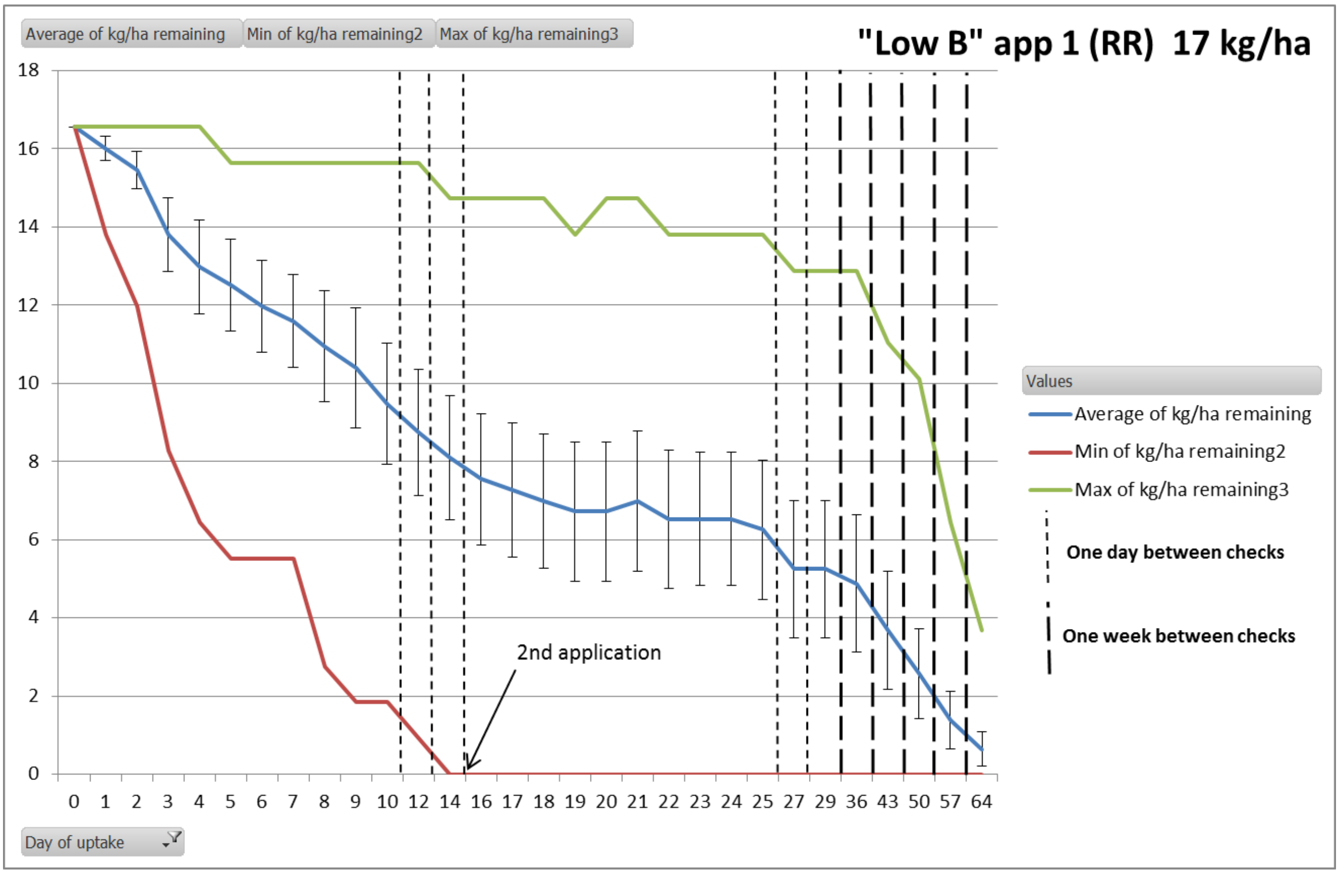

Low A RR - lower limit of 99% conf int of mean
Lower limit of 99% conf int of mean
Log. (Lower limit of 99% conf int of mean)
y = -3.013ln(x) + 11.324
0 1 2 3 4 5 6 7 8 9 10 12 14 16 17 18 19 20 21 22 23 24 25 27 29 36 43 50 57 64
-2.00 0.00 2.00 4.00 6.00 8.00 10.00 12.00



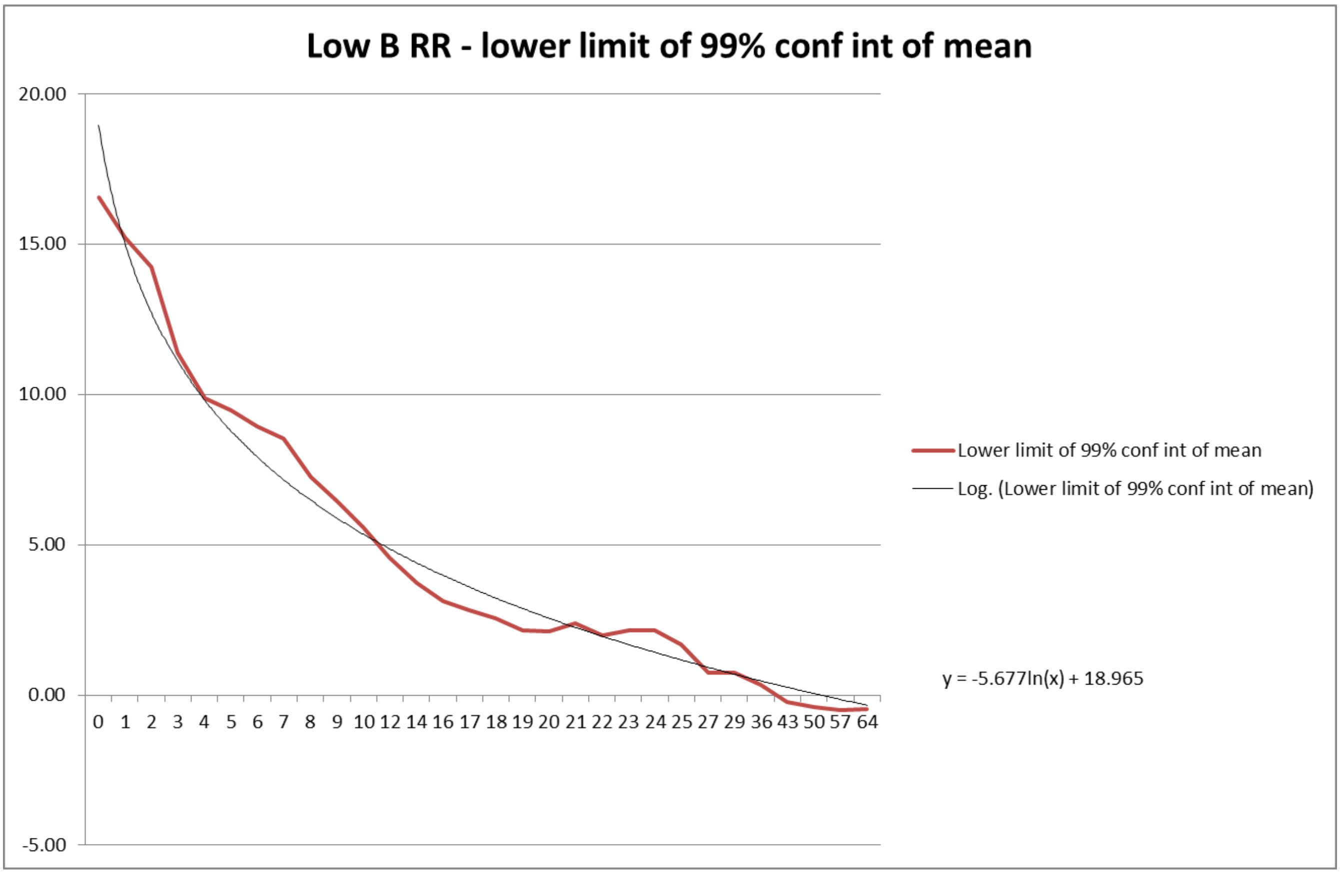
Average of kg/ha remaining
Min of kg/ha remaining
Max of kg/ha remaining
"Low A" app 2 (MM) 8 kg/ha
9
8
7
6
5
4
3
2
1
0
0 1 2 3 4 5 6 7 8 9 10 12 14 21 28 35 42 49
Day of uptake
Values
Average of kg/ha remaining
Min of kg/ha remaining
Max of kg/ha remaining
One day between checks
One week between checks



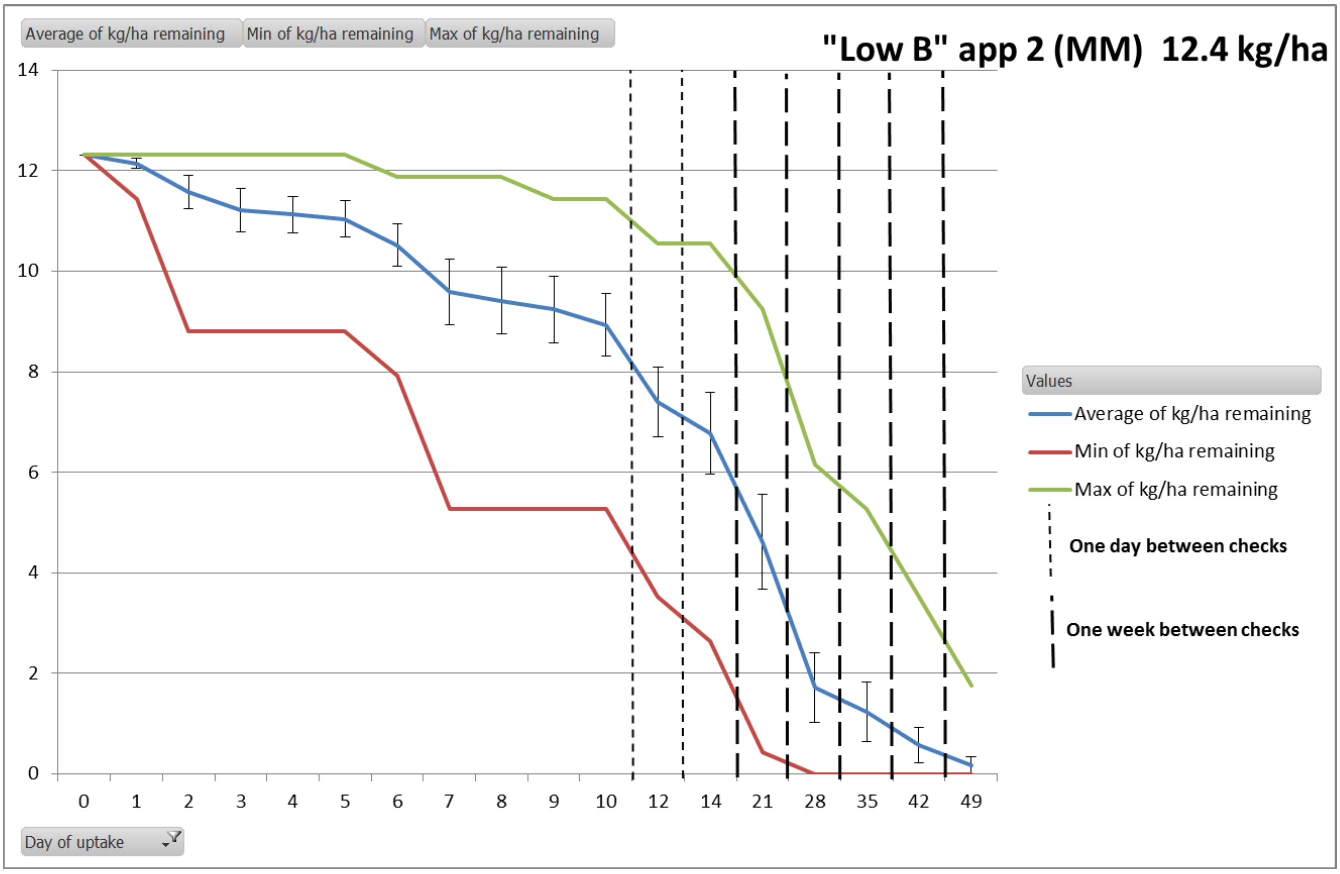
Low A MM - lower limit of 99% conf int of mean
12.00
10.00
8.00
6.00
4.00
2.00
0.00
-2.00
0 1 2 3 4 5 6 7 8 9 10 12 14 21 28 35 42 49
y = -2.918ln(x) + 9.7463
Lower limit of 99% conf int of mean
Log. (Lower limit of 99% conf int of mean)



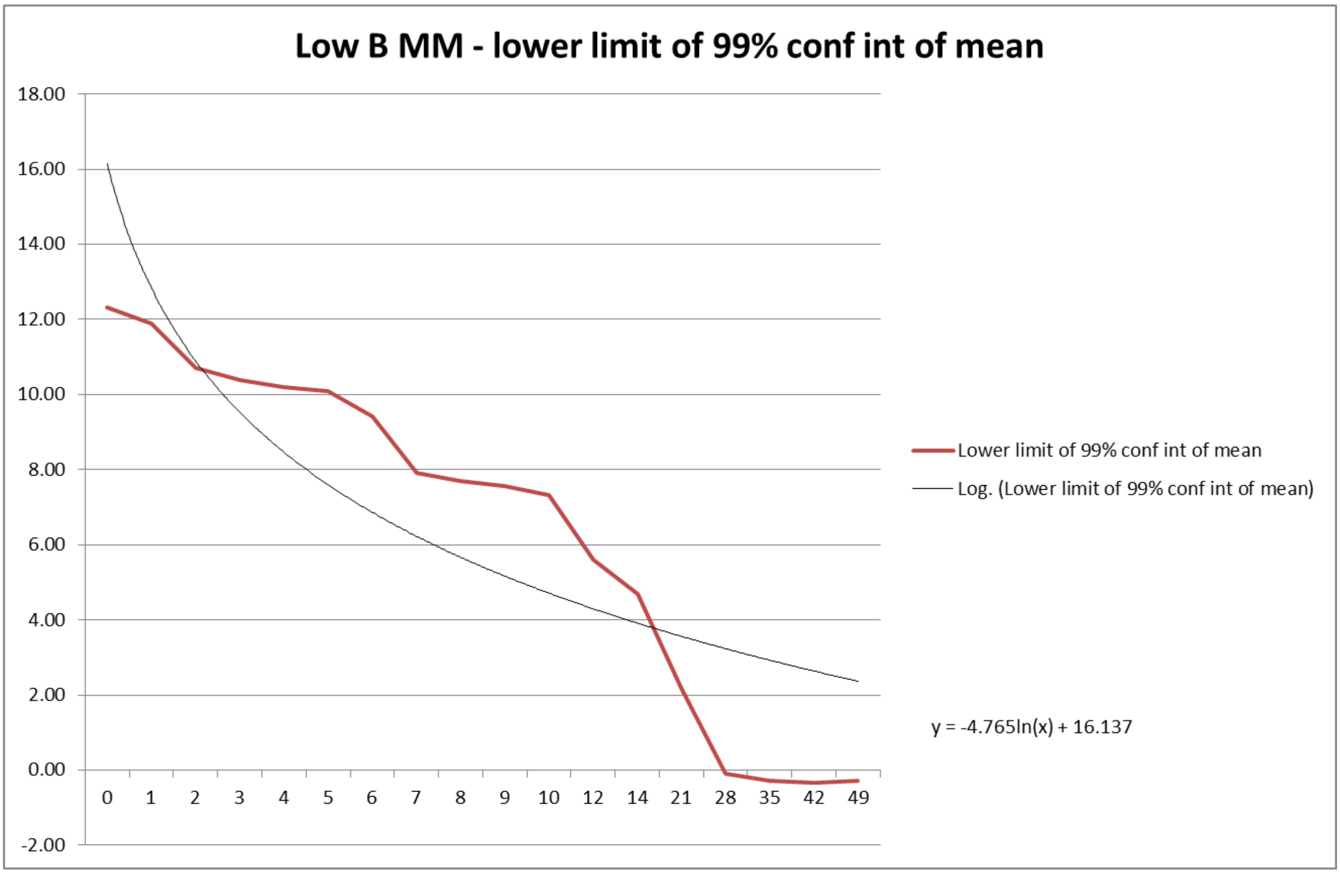
"Low B" app 1 (RR) 17 kg/ha
Average of kg/ha remaining
Min of kg/ha remaining2
Max of kg/ha remaining3
18
16
14
12
10
8
6
4
2
0
0 1 2 3 4 5 6 7 8 9 10 12 14 16 17 18 19 20 21 22 23 24 25 27 29 36 43 50 57 64
Day of uptake
2nd application
Values
Average of kg/ha remaining
Min of kg/ha remaining2
Max of kg/ha remaining3
One day between checks
One week between checks



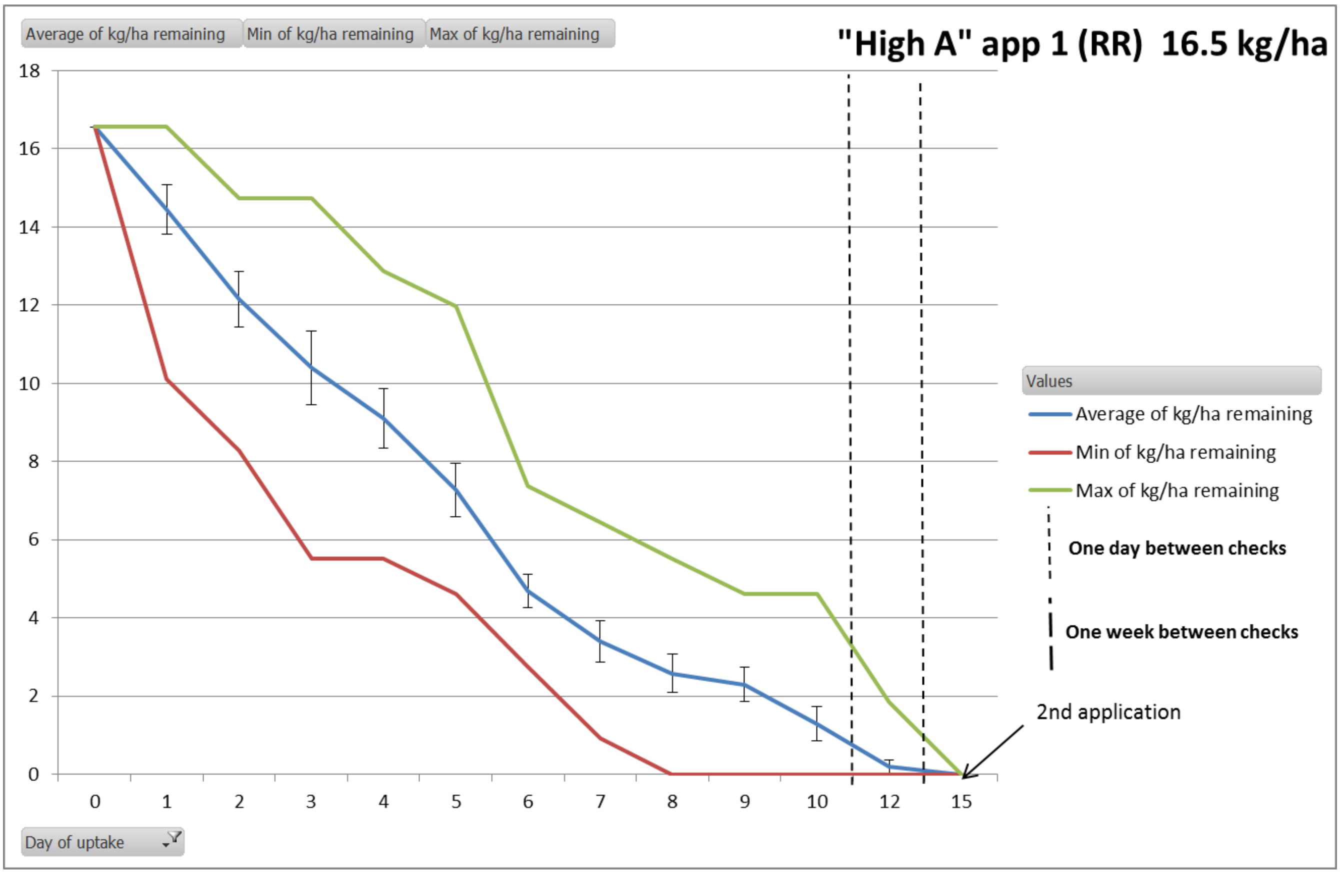
Low B RR - lower limit of 99% conf int of mean
20.00
15.00
10.00
5.00
0.00
-5.00
0 1 2 3 4 5 6 7 8 9 10 12 14 16 17 18 19 20 21 22 23 24 25 27 29 36 43 50 57 64
Lower limit of 99% conf int of mean
Log. (Lower limit of 99% conf int of mean)
y = -5.677ln(x) + 18.965

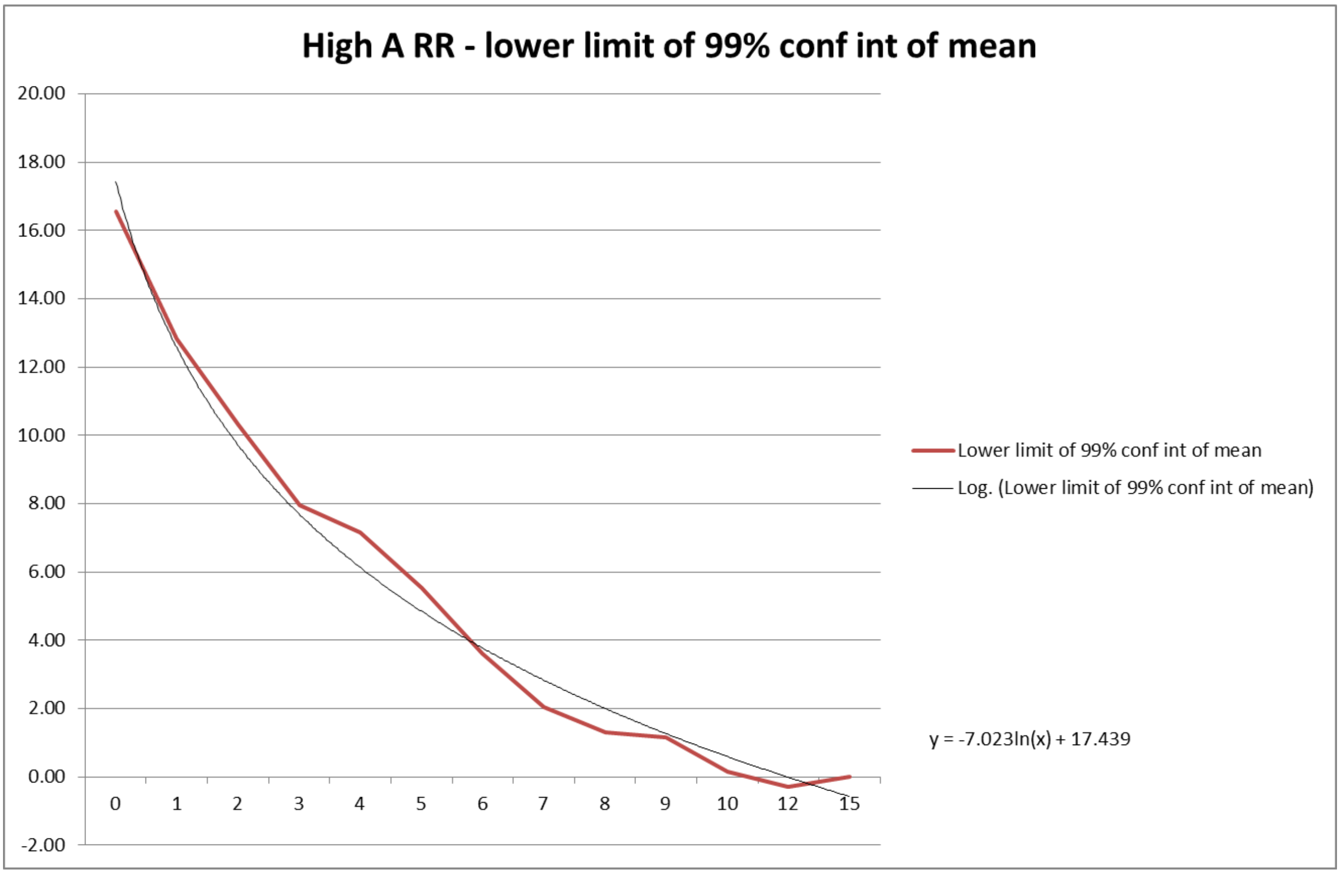


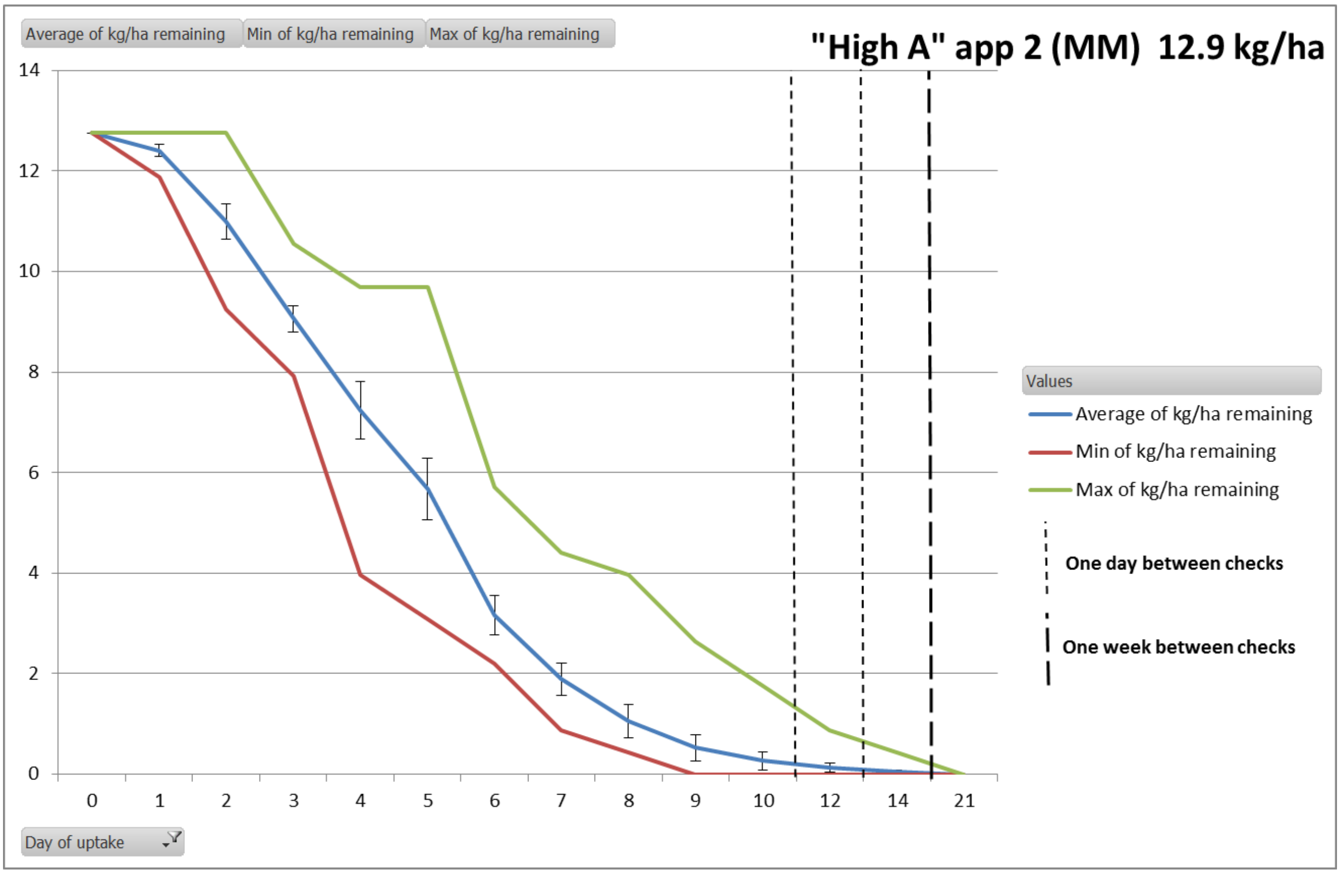
"Low B" app 2 (MM) 12.4 kg/ha
Average of kg/ha remaining
Min of kg/ha remaining
Max of kg/ha remaining
14
12
10
8
6
4
2
0
0 1 2 3 4 5 6 7 8 9 10 12 14 21 28 35 42 49
Day of uptake
Values
Average of kg/ha remaining
Min of kg/ha remaining
Max of kg/ha remaining
One day between checks
One week between checks



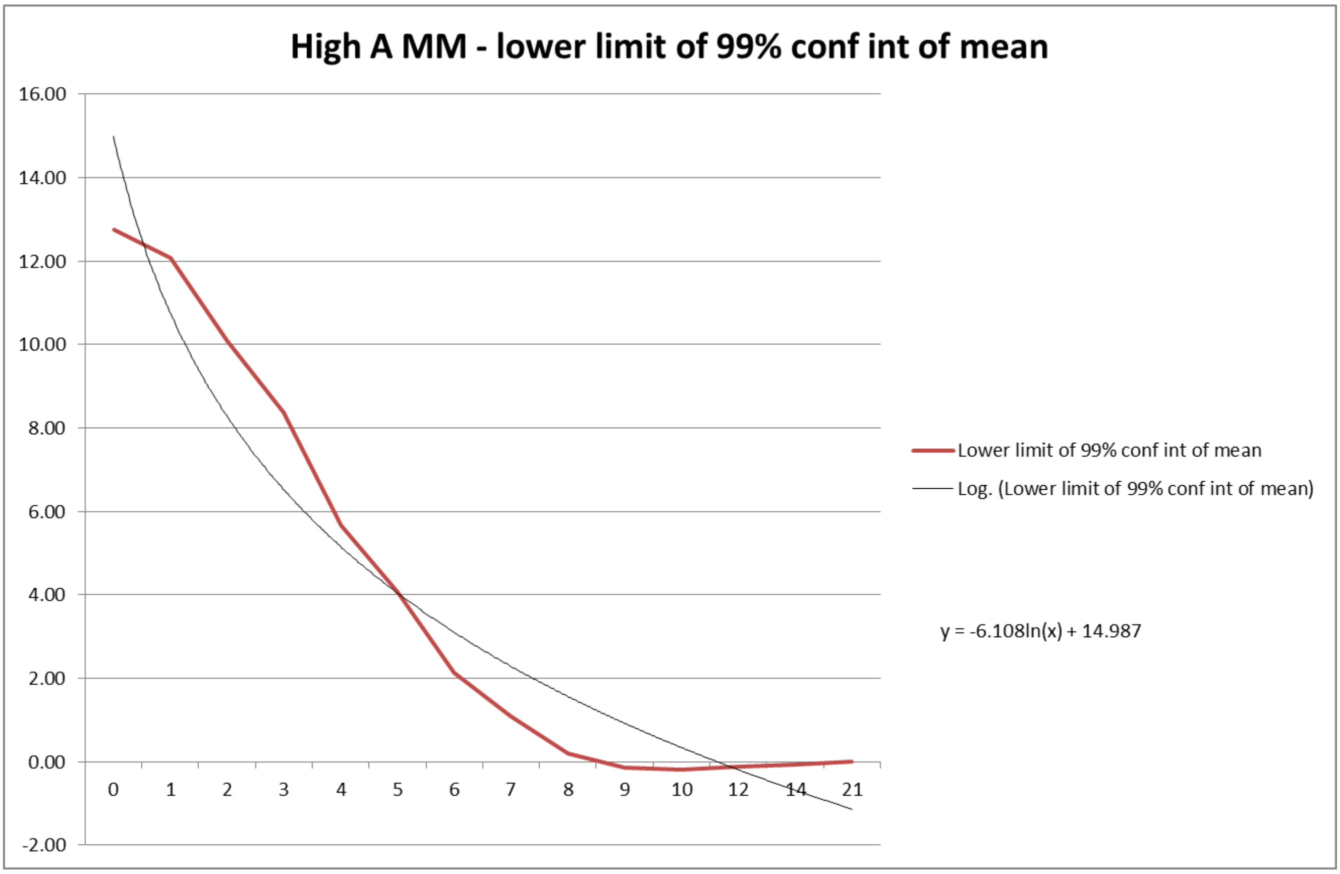
Low B MM - lower limit of 99% conf int of mean
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
-2.00
0 1 2 3 4 5 6 7 8 9 10 12 14 21 28 35 42 49
Lower limit of 99% conf int of mean
Log. (Lower limit of 99% conf int of mean)
y = -4.765ln(x) + 16.137


Average of kg/ha remaining
Min of kg/ha remaining
Max of kg/ha remaining
"High A" app 1 (RR) 16.5 kg/ha
18
16
14
12
10
8
6
4
2
0
0
1
2
3
4
5
6
7
8
9
10
12
15
Values
Average of kg/ha remaining
Min of kg/ha remaining
Max of kg/ha remaining
One day between checks
One week between checks
2nd application
Day of uptake


High A RR - lower limit of 99% conf int of mean
20.00
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
-2.00
0
1
2
3
4
5
6
7
8
9
10
12
15
Lower limit of 99% conf int of mean
Log. (Lower limit of 99% conf int of mean)
y = -7.023ln(x) + 17.439



Average of kg/ha remaining
Min of kg/ha remaining
Max of kg/ha remaining
"High A" app 2 (MM) 12.9 kg/ha
14
12
10
8
6
4
2
0
0 1 2 3 4 5 6 7 8 9 10 12 14 21
Day of uptake
Values
Average of kg/ha remaining
Min of kg/ha remaining
Max of kg/ha remaining
One day between checks
One week between checks



High A MM - lower limit of 99% conf int of mean
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
-2.00
0 1 2 3 4 5 6 7 8 9 10 12 14 21
Lower limit of 99% conf int of mean
Log. (Lower limit of 99% conf int of mean)
y = -6.108ln(x) + 14.987

Appendix 2: Craddock Bait Condition Scoring Scale

- **Condition 1:** Fresh Pellets/Pellets not discernible from fresh bait.

- **Condition 2:** Soft pellets. <50% of pellet matrix is or has been soft or moist. Bait is still recognisable as a distinct cylindrical pellet, however cylinder may have lost its smooth sides. <50% of bait may have mould. Bait has lost little or no volume.

- **Condition 3:** Mushy Pellet. >50% of bait matrix is or has been soft or moist. <50% of pellet has lost its distinct cylindrical shape. >50% of bait may have mould. Bait may have lost some volume.

- **Condition 4:** Pile of Mush. 100% of bait matrix is or has been soft or moist. Pellet has lost distinct cylindrical shape and resembles a pile of mush with some of the grain particles in the bait matrix showing distinct separation from the main pile. >50% of bait may have mould.
  Bait has lost some volume.

- **Condition 5:** Disintegrating Pile of Mush: 100% of bait matrix is or has been soft or moist. Pellet has completely lost distinct cylindrical shape and resembles a pile of mush with >50% of the grain particles in the bait matrix showing distinct separation from each other and the main pile. >50% of bait may have mould. Bait has definitely lost a significant amount of volume.

- **Condition 6:** Bait Gone: Bait is gone or is recognizable as only a few separated particles of grain or wax flakes.

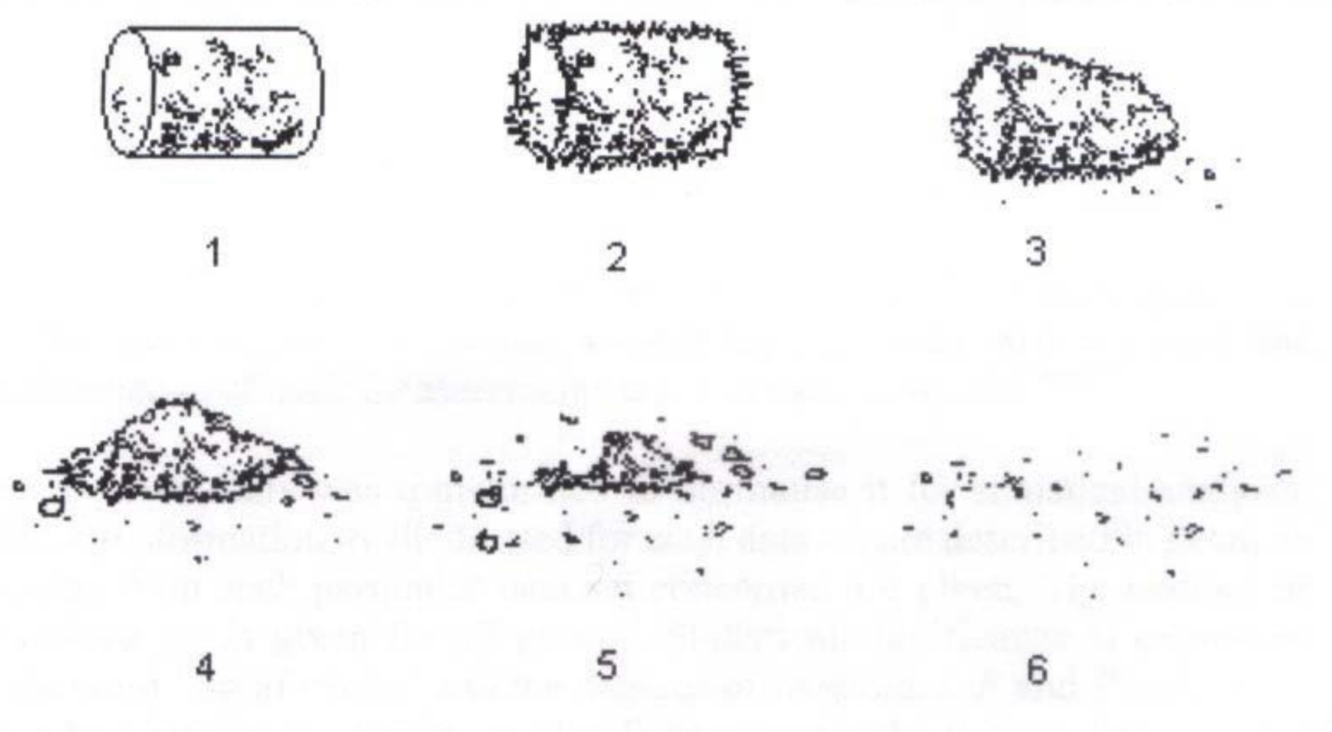


Illustration of typical bait condition at each ordinal score used in the trial (figure reproduced from Craddock, 2004)