FINAL ENVIRONMENTAL IMPACT STATEMENT
Palmyra Atoll National Wildlife Refuge Rat Eradication Project

U.S. Department of the Interior
Fish and Wildlife Service

Prepared by:

Pacific Region
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Executive Summary

The U.S. Fish and Wildlife Service (Service) is proposing to restore and protect the native species and habitats of Palmyra Atoll National Wildlife Refuge by eradicating all nonnative rats (*Rattus rattus)* from the atoll through the successful delivery of a lethal dose of toxicant to every rodent on the island in a manner that minimizes harm to the ecosystem while still maintaining a high probability of success. *This Final Environmental Impact Statement (FEIS or Final EIS) is the final analysis for this action and identifies the preferred alternative (Alternative C) as the option that would achieve the desired outcomes with the least harm to the environment. Modifications (greater than a few words) to the DEIS are italicized in the Final EIS.*

Eradicating rats from Palmyra is expected to result in obvious, empirically tested biodiversity benefits for seabirds, plants, terrestrial invertebrates, and other components of the atoll's terrestrial ecosystem. Eradicating rats will eliminate mammalian predation on existing seabird species breeding at the atoll and allow the recolonization of indigenous seabirds *such as Audubon's shearwater, Christmas Island shearwater, wedge-tailed shearwater, Phoenix petrel, white-throated storm-petrel, Bulwer's petrel, blue noddy, and gray-backed tern that cannot reproduce on islands invaded by rats. The benefits of rat eradication will be greatest for nesting species. However, migratory shorebirds will also benefit, especially the bristle-thighed curlew. Predation around the world by introduced predators, such as dogs, cats, pigs and rats, is an important source of mortality for wintering curlews during the molt-induced flightless period.* By removing the threat of rats, Palmyra's remnant native forest will be given the opportunity to recover to its natural species composition, structure, and function. Rats would be eliminated as an agent that prevents native tree recruitment by herbivory of seeds and seedlings. Ecological disruption by nonnative rats affects ecological function of the entire ecosystem, disrupting community relationships and biogeochemical cycles. The benefit of this conservation action is significant from a regional perspective because Palmyra is the only moist tropical atoll ecosystem in the Central Pacific with strong protections, as well as the only moist tropical atoll ecosystem in this region that is not experiencing exploitation of both marine and terrestrial natural resources by burgeoning human populations. From the regional perspective, removing rats from Palmyra will help prevent the loss of the Central Pacific moist tropical island ecotype. Nationally, the eradication of black rats at Palmyra Atoll supports the Service's priority to facilitate ecological adaptation in the face of accelerating global climate change removing a non-climate change ecosystem stressor in the relatively pristine Palmyra ecosystem.

Palmyra Atoll National Wildlife Refuge is located in the Northern Line Islands, approximately 1,000 miles south of Honolulu, Hawai`i, in the Central Pacific Ocean. The Refuge was established in 2001 to protect, restore, and enhance migratory birds, coral reefs, and threatened and endangered species in their natural setting and is managed in coordination with The Nature Conservancy who owns the largest island in the atoll and manages a preserve and research station there. Palmyra Atoll consists of approximately 25 small, heavily vegetated islets surrounding 3 central lagoons. Habitats consist of 618 acres of land and 15,512 acres of lagoons and shallow reefs. The Refuge's boundary extends seaward 12 nautical miles, encompassing 515,232 acres. Palmyra's terrestrial habitats support one of the largest remaining tropical coastal strand forests in the U.S. Pacific Islands. A diverse land crab fauna including the coconut crab, ecologically intact predator-dominated fish assemblages, and large seabird populations are important resources of this Refuge.

The original configuration of the atoll was significantly modified by the U.S. Navy during World War II. A network of roadways connecting the major islets and the construction of a north-south causeway altered natural water circulation. Invasive species are having negative impacts on Palmyra Atoll's native forests, fauna, and habitats. The major impacts on Palmyra are associated with World War II-era atoll restructuring and invasive species introductions that include plants (coconut palm, *Cocos nucifera*), insects (several ant species, mosquitoes, scale insects), and mammals (black rats, *Rattus rattus*). The black rat causes degradation of nearly all aspects of the atoll's terrestrial ecosystem from breeding seabird populations to the native *Pisonia* forest ecotype. Rats prey directly upon native seabirds and their eggs at Palmyra and are likely preventing the recolonization of eight additional seabird species indigenous to the area. Rats also prey on native land crabs and directly compete with them for food resources. Rats foraging on coconuts create habitat for invasive mosquitoes and disperse the seeds of invasive plants. These introduced rats are modifying the terrestrial ecosystem of this important atoll by limiting the reproduction, recruitment, and establishment of several native tree species through seed and seedling predation that is significantly more intense than seed and seedling predation by native land crabs. Furthermore, the coconut palm, an invasive tree, already dominates 45 percent of Palmyra's forests. The dominance of the coconut palm is likely aided by rat-related recruitment and limitation of native tree species, and the palm's ability to resist rat-related limitations to recruitment relative to that of native tree species. Left unchecked, the combined effects of rats and coconut palms could continue to alter forest structure and prevent the recovery of Palmyra's native forest. All of these impacts in turn affect the relationship between land and marine resources, and compromise the Service's ability to achieve Refuge purposes.

The National Wildlife Refuge System Administration Act of 1966 (Refuge Administration Act), as amended, requires all lands within the National Wildlife Refuge System to be managed in accordance with achieving the purposes for which a refuge was established. For Palmyra, the eradication of introduced rats would aid in achieving the following Refuge purposes.

- Perpetuate a functioning atoll ecosystem with natural diversity and abundance of fauna and flora.
- Preserve, restore, and enhance all terrestrial species of animals and plants that are endangered or threatened with becoming endangered.
- Provide for conservation of migratory bird resources at the Refuge.

Removing rats from Palmyra is the first step in a series of restoration efforts designed to restore the atoll to its pre-World War II status. Rat eradication is the first step in the process because the eradication of rodents is feasible and relatively quickly accomplished; and their removal would provide the framework to initiate the palm removal and native forest propagation stage of the restoration process, and allow extirpated breeding seabirds to recolonize the atoll.

We announced a Notice of Intent to prepare an Environmental Impact Statement on January 14, 2010. The action alternatives were developed to focus on the primary issues identified by resource specialists within the Service, national and international experts in island rodent eradication, public comments received after the Notice of Intent to prepare an EIS was released, and government regulatory agencies that have a stake in the decision-making process. In order to be retained for consideration, an alternative had to: 1) have a high likelihood of success, 2) have an acceptably low probability for adverse effects on the populations of non-target species and the environment, and 3) be permitted under regulations governing the Refuge. The potential impacts of a No Action Alternative and the three "action" alternatives were assessed *in the Draft Environmental Impact Statement (DEIS) and where appropriate, mitigation measures were identified to avoid the potential effect or reduce its intensity on non-target organisms. The DEIS was released for a 45-day public comment period from February 25, 2011 to April 11, 2011. Comments were received from 21 individuals, agencies, or organizations. The Service reviewed and considered all comments and determined whether or not they were substantive and warranted further analysis and documentation. Modifications (greater than a few words) to the DEIS are italicized in the Final EIS. Responses to those comments are included in Appendix M and helped inform the final analysis in this FEIS. The Service has identified Alternative C as the Preferred Alternative.*

The 4 alternatives are:

- Alternative A: No Action
- Alternative B: Aerial broadcast of brodifacoum
- Alternative C: Aerial broadcast of brodifacoum, with proactive mitigation of risk for vulnerable shorebird taxa – *Preferred Alternative*
- Alternative D: Bait stations with brodifacoum, with canopy baiting

Alternatives C, the *Preferred Alternative* entails aerial bait broadcast that would be accomplished by applying bait pellets containing the anticoagulant rodenticide brodifacoum (0.0025% active ingredient) from a helicopter using a specialized bait bucket. The bucket would broadcast bait in at the appropriate rate in a directional manner to deliver the material to all potential rat territories within a short operational period. Special measures to prevent the bait from entering the water include hand broadcast of narrow strands and tiny islands and baiting the canopy trees that overhang the water using bait packets installed by hand. Alternative C – *our Preferred Alternative* – proposes additional management of migratory birds in an effort to minimize the risk of exposure to the toxicant.

There would be some negative effects to migratory birds associated with the eradication program. However, the Preferred Alternative includes several measures to minimize these effects. Shorebirds would be the most vulnerable to direct and secondary poisoning during the eradication, so the eradication is scheduled to occur during the summer nesting season, when the number of migratory shorebirds is at its lowest (June-July). Not all shorebirds migrate to the nesting grounds in the Arctic and we plan to capture as many of the remaining shorebirds as possible and hold them under direct, constant veterinary care during the period when they would *be vulnerable to primary or secondary poisoning. Regular surveys of the island would be conducted and all carcasses that could potentially be a source of secondary poisoning would be removed. Color and size were considered when selecting the bait formulation to minimize the attractiveness of the bait to birds and minimize the time toxicant is available to birds. To minimize exposure potential to seabirds bait would be hand broadcast along the narrow causeways where the majority of the boobies nest, and this bait would not be distributed within reach of birds sitting in the nest. Areas known to host concentrations of shorebirds roosting would be baited using bait stations to further restrict bait availability.*

The action alternative that involves bait stations as the primary bait delivery method (Alternative D) would require that bait stations containing bait pellets containing the anticoagulant rodenticide brodifacoum (0.0025% active ingredient) be placed throughout the entire atoll and maintained until all rats were removed (or two years). Bait stations are box-like enclosures with small entryways designed to be attractive to rodents, but difficult to navigate for other species such as birds and land crabs. Bait stations reduce the risk of rodenticide exposure in non-target species by making bait more difficult to access and reducing the total amount of bait introduced into the ecosystem. The bait station design for Palmyra would need to effectively exclude land crabs, including the large coconut crab, and shorebirds while allowing easy access for rats.

Within this document, we provide a quantitative and qualitative assessment of the environmental consequences of all the alternatives. The potential significance of the environmental consequences (or "impacts") of each action alternative and the no action alternative are discussed on a case-by-case basis for each environmental issue considered. The issues analyzed in this document include:

- Impacts to physical resources
  - Water resources
  - Geology and soil

- Impacts to biological resources
  - Impacts to species vulnerable to toxicant use
  - Impacts to species vulnerable to disturbance
  - Indirect effects to biological resources

- Impacts to the social and economic environment
  - Impacts to refuge visitors and recreation
  - Impacts to historical and cultural resources

- Cumulative impacts

- Irreversible or irretrievable commitment of resources

- Relationship of short-term uses to long-term productivity

Within the section on impacts to biological resources, we provide a quantitative assessment of the risk to the shorebird species found at Palmyra that would be incurred from the three action alternatives. Four species of shorebirds are expected to be common at Palmyra during the operational window (June through July): bristle-thighed curlew, Pacific golden-plover, wandering tattler, and ruddy turnstone. None of these species nest at Palmyra. The population densities of shorebirds at Palmyra (and on other tropical Pacific islands) are significantly lower during the summer breeding season (June through August) when breeding individuals are at their northern breeding grounds. Some individuals of all four of the shorebirds mentioned above would likely be present during the eradication, and could potentially be exposed to rodenticide through several pathways including:

- Feeding directly on bait pellet

- Feeding on prey items that have consumed the bait or contaminated prey (e.g., land crabs, hermit crabs, rat carcasses)

Alternative C – *Preferred Alternative* includes measures to reduce risk to shorebirds that may be present during the operational period including the capture and captive holding of birds for a month until the availability of the toxicant in the environment was substantially diminished.

We also assess the risk to, or the impact on Palmyra's native biota that would be incurred from the no action alternative. The no action alternative would allow rat-related disturbance of Palmyra's migratory bird populations, land crab populations, and native forest system would continue. Furthermore, other efforts to restore Palmyra's terrestrial ecosystem would be hindered by such impacts.

The FEIS includes a working-draft biosecurity plan to prevent re-infestation of nonnative rats and a draft monitoring plan to assess efficacy of the operation and the ecological effects, both beneficial and deleterious of an eradication operation at Palmyra. These appendices continue to evolve and are considered "working" documents. The FEIS also includes the results of numerous scientific investigations conducted at Palmyra to develop appropriate eradication methods and quantify ecological risk, the supplemental registered label for brodifacoum 25W, and the comments received during review period and the Service's response to those comments. A Record of Decision on this project shall be signed no sooner than 30 days after this document is noticed in the Federal Register.

Table of Contents

Appendices

List of Tables

List of Figures

List of Acronyms

AM	Adaptive Management
APHIS	Animal and Plant Health Inspection Service
BTCU	Bristle-thighed curlews
CEQ	Council on Environmental Quality
CITES	Convention on International Trade of Endangered Species
CSIRO	Commonwealth Scientific and Industrial Research Organization
CWA	Clean Water Act
DEIS	Draft Environmental Impact Statement
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act
FEIS	Final Environmental Impact Statement
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
FWS	U.S. Fish and Wildlife Service
GECI	Island Conservation and Ecology Group, C.A. (Grupo de Ecología y Conservación de islas, A.C.)
GIS	Geographic Information System
GPS	Global Positioning System
IC	Island Conservation
IPM	Integrated Pest Management
ITCZ	Inter-tropical Convergence Zone
IUCN	International Union for Conservation of Nature
MBTA	Migratory Bird Treaty Act
MMPA	Marine Mammal Protection Act
NEPA	National Environmental Policy Act
NHPA	National Historic Preservation Act
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NOEL	No Observed Effect Level
NPDES	National Pollutant Discharge Elimination System
NWR	National Wildlife Refuge
NWRSAA	National Wildlife Refuge System Administration Act
OHA	Office of Hawaiian Affairs
PARC	Palmyra Atoll Research Consortium
PGPL	Pacific golden-plovers
PIFSC	Pacific Islands Fisheries Science Center
POBSP	Pacific Ocean Biological Science Project
PPE	Personal Protective Equipment
TNC	The Nature Conservancy

USCG	U.S. Coast Guard
USDA	U.S. Department of Agriculture
USFWS	U.S. Fish and Wildlife Service
EPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
UXO	Unexploded Ordnances
WS	USDA Wildlife Services
WWII	World War II

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1 Purpose and Need

1.1 Introduction

The United States Fish and Wildlife Service ("FWS" or "the Service") proposes to undertake the following actions on Palmyra Atoll, managed as a nature preserve and as the Palmyra Atoll National Wildlife Refuge ("Refuge" or "Palmyra") within the Pacific Remote Islands Marine National Monument:

- Eradication of the nonnative black rat (*Rattus rattus*); and

- Development of a prevention and emergency response plan for responding to reintroduction of rats, other nonnative rodents, and other nonnative animals to the atoll.

In accordance with the National Environmental Policy Act of 1969 as amended (NEPA) (42 U.S.C. 4321 *et seq.*,), and the Council on Environmental Quality (CEQ) regulations for implementing NEPA (40 CFR 1500 *et seq.*), Federal agencies must consider the environmental impacts of actions – projects, programs, policies, or plans that are implemented, funded, permitted, or controlled by a Federal agency or agencies – they propose to undertake. Specifically, Federal agencies must consider the environmental impacts of a reasonable range of alternatives for implementing an action and make the public aware of the environmental impacts of each of the alternatives presented. If adverse environmental impacts are identified, NEPA requires an agency to show evidence of its efforts to reduce these adverse impacts through mitigation. An environmental analysis, such as this Final Environmental Impact Statement (FEIS), documents that an agency has considered and addressed these impacts.

In the Draft Environmental Impact Statement (DEIS or Draft EIS), the Service solicited public involvement and assessed whether implementation of any of the alternatives would have a significant effect on the quality of the human environment. This Final (FEIS or Final EIS)) identifies the Preferred Alternative (Alternative C) and will be used by the Service to inform the public and constitutes our final assessment of effects on the quality of the human environment. *Modifications (greater than a few words) to the Draft EIS are italicized in the Final EIS.*

1.2 Purpose of This Document

This Final EIS evaluates the environmental effects of proposed black rat eradication on the natural and cultural resources of Palmyra. It is part of the Service's decision making process in accordance with NEPA, as amended, and implementing regulations.

1.2.1 Description of Palmyra Atoll

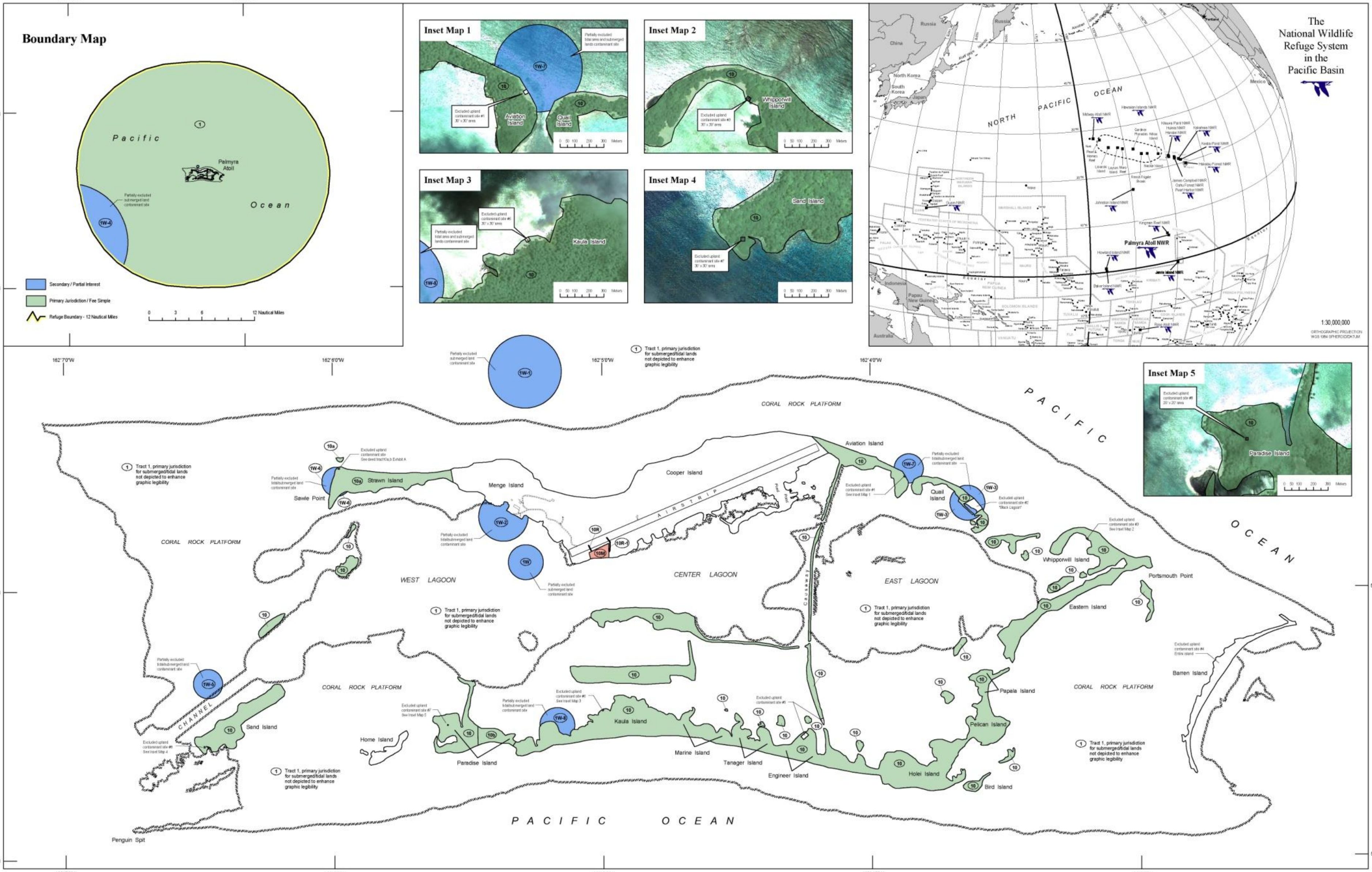
Located in the Northern Line Islands, approximately 1,000 miles south of Honolulu, Hawai`i, Palmyra Atoll is an incorporated territory of the United States in the Central Pacific Ocean. The atoll originally consisted of approximately 54 small, heavily vegetated islets surrounding 3 central lagoons. Many of these islets were modified or joined during U.S. Navy occupation in World War II. On January 18, 2001, Secretary's Order 3224 established the area as the Palmyra Atoll National Wildlife Refuge to protect, restore, and enhance migratory birds, coral reefs, and threatened and endangered species in their natural setting. The Refuge now includes approximately 446.25 acres (180.57 ha) of emergent land, approximately 503,963 acres (203,946 ha) of submerged lands and associated waters, including roughly 16,094 acres (6,515 ha) of coral reef habitat (Federal Register 2001).

U.S. Fish & Wildlife Service

Palmyra Atoll National Wildlife Refuge

Pacific Islands

Land Status



Produced in the Division of Realty & Refuge Information
Portland, Oregon
Land Status Current To: 11-13-2006
Map Date:
Basemap (Date): 2002
Meridian:
File: 05-219-6.mxd

SCALE: 1:9,000

LEGEND:

Acquired Interest: Fee Title; Easement/Lease; Secondary; Agreement

Boundaries: Approved Refuge Boundary; Outgrants/FWS Issued Permits; Tract Boundary

Other FWS Facilities: Fee Title; Less than Fee

Other: Coral Reef

UTM ZONE 3N
WGS 84

Palmyra Atoll is currently owned and managed by the Service, The Nature Conservancy (TNC), and the Cooper family. The majority of the islands, waters, and the coral reef surrounding Palmyra up to 12 nautical miles to sea are owned and managed by the FWS as the Refuge for the "conservation and management of native species of wildlife and fish and their habitats" (Federal Register 2001). In 2000, TNC purchased Palmyra from the Fullard-Leo family to protect its waters and lands. Now TNC owns Cooper and Menge islands (TNC 2005) and cooperatively manages the atoll with FWS. The Cooper family has retained ownership of Home Island.

Prior to 2001, Palmyra was a privately owned atoll with a history of military and other government use. In 2009, Presidential Proclamation 8336 included Palmyra Atoll NWR and its surrounding waters out to 50 nautical miles in the Pacific Remote Islands Marine National Monument.

Palmyra Atoll represents a globally important biodiversity center and conservation opportunity. It is the only fully protected moist tropical forest ecosystem in the Central Pacific. The atoll is replete with dense seabird colonies, a globally imperiled forest ecotype, native terrestrial flora and fauna, and relatively pristine predator-dominated coral reef communities. Palmyra's six species of land crabs make up one of the largest, richest, and most robust populations in the Central Pacific region. Notwithstanding the protective status, multiple pressures continue to threaten the native biota. Chief among these threats are an introduced, invasive rodent species – the black rat (*Rattus rattus*).

1.3 Purpose of the Proposed Action

The purpose of the proposed action is to aid the protection and restoration of the native species and habitats of Palmyra Atoll by eradicating all nonnative rats from the atoll by ensuring the successful delivery of a lethal dose of toxicant to every rodent on the island in a manner that minimizes harm to the ecosystem while still maintaining a high probability of success.

1.4 Need for Action

Palmyra is an important center of biodiversity and species abundance in the Central Pacific region. The atoll is the only seabird nesting habitat within 450,000 square miles of ocean and is an important marine feeding ground for seabirds. It is home to one of the largest red-footed booby populations in the world, ranking in global importance behind the Galapagos Islands (Flint 1992). Numerous shorebirds and other migrants forage and rest at Palmyra. The atoll supports one of the last remaining stands of *Pisonia* forest communities in the world and is home for a vibrant and diverse land crab assemblage, including the world's largest land invertebrate: the coconut crab. In the surrounding waters, the Refuge coral reefs are home to five times as many coral species as the Florida Keys and three times as any as Hawai`i and the Caribbean, ranking it as one of the most diverse and spectacular coral reef systems in the world.

No baseline record of Palmyra's terrestrial ecosystem prior to the 19th century exists. It is possible, however, that Polynesian voyagers altered Palmyra's environment prior to European exploration of the Pacific by introducing coconuts (*Cocos nucifera*). During World War II the original configuration of the atoll was significantly modified by the U.S. Navy when a network of roadways connecting the major islets and the construction of a north-south causeway altered natural water circulation. The pace of anthropogenic impacts accelerated during and after World War II with introductions of additional plants, terrestrial arthropods, and mammals. Rats were likely introduced to the atoll during this period. The introduced rats are now severely degrading the terrestrial ecosystem of this important atoll by limiting the reproduction, recruitment, and establishment of several native tree species. Furthermore, the coconut palm, an invasive tree, already dominates 45 percent of Palmyra's forests. The spread of coconut palm is believed to be aided by rat-related recruitment and limitation of other tree species. Left unchecked, the combined effects of rats and coconut palms drastically alter forest structure. Introduced rats on islands are also known to prey heavily on seabirds, which is likely preventing eight seabird species from successfully nesting on the atoll. The rats also prey on native land crabs and directly compete with them for limited food resources. All of these impacts in turn affect the relationship between land and marine resources, and compromise the Service's ability to achieve Refuge purposes.

Rats have likely contributed to the extirpation of as many as eight seabird species from Palmyra: Audubon’s shearwater (*Puffinus lherminieri*), Christmas Island shearwater (*Puffinus nativitatis*) wedge-tailed shearwater (*Puffinus pacificus*), Phoenix petrel (*Pterodroma alba*), white-throated storm-petrel (*Nesofregetta fuliginosa*), Bulwer’s petrel (*Bulweria bulwerii*), blue noddy (*Procelsterna cerulea*), and gray-backed tern (*Onychoprion lunatus*). These are species that are known to not coexist with introduced predators of the size of rats or larger (Flint 1999). While no historical or paleontological records are found for Palmyra, there is evidence of the Pacific faunal assemblages prior to the introduction mammalian predators such as rats in Hawai`i, the Cook Islands, Easter Island, the Marquesas, Tonga, the Pitcairn Group, and the Northern Marianas. These studies document that islands with introduced mammals including rats have lost large components of their original seabird fauna. The global patterns of seabird distributions we observe today are not natural (Steadman 1995). (Jones et al. 2008) found that rats depress many similar bird taxa and that rats are likely preventing them from nesting at Palmyra. Many seabird species are found regionally, but are not breeding at Palmyra. Species known to nest at adjacent rat-free islands or islands in the Line archipelago (Kiritimati Island, Republic of Kiribati) typically nest on the ground, and some (the shearwaters and petrels) characteristically leave eggs and chicks unattended in nesting burrows. Black rats would effectively prevent the establishment, or reestablishment of breeding populations of any of these species (Norman 1975).

Small, oceanic islands have simplified seed dispersal systems that generally lack mammalian vectors and are vulnerable to disruption by invasive species (Drake et al. 2002). Rats can disrupt seed dispersal mutualisms by depositing seeds in microhabitats that are ill-suited for germination or subsequent growth. Native crab species prey on seeds as well, although they only eat the fleshy pulp, leaving the seed coat intact, allowing the seed to germinate. Rats are able to consume the fleshy pulp and chew through the seed coat killing the existing seed and preventing germination and recruitment of native plants. It is possible that rats can also indirectly reduce plant fitness by reducing the effectiveness or numbers of native dispersers through competition and predation (Wegmann 2009). As there is no mention of rodents in accounts of Palmyra’s biota prior to World War II (Rock 1916, Christophersen 1927, Rock 1929), it is theorized black rats (*Rattus rattus*) were introduced to Palmyra during U.S. military operations in the 1940s.

There is good evidence that the introduction of black rats and possible introduction and recorded cultivation of coconuts limits the reproduction, recruitment, and establishment of several native tree species at Palmyra. The introduction of both coconuts and rats led to a change in plant-animal interactions and canopy dynamics that favor coconut establishment over that of native tree species. The coconut palm, an invasive tree dominating 45 percent of Palmyra's forests (Wegmann 2005) is possibly aided by rat-related recruitment limitation of other tree species. Furthermore, tree-nesting seabirds exhibit a strong preference for native tree canopy over coconut canopy as nesting habitat (Young et al. 2010).

Most of Palmyra's ten native tree species are locally rare and show limited or no recruitment (Wegmann 2009). In order to initiate the restoration of Palmyra's rainforest and protect the species found there in, it is desirable to eradicate rats. Left unchecked, the combined effects of rats and coconuts could lead to an invasion-caused meltdown (Simberloff and B. Von Holle 1999) of native forest structure and a transition to a coconut monoculture. The seabird communities at Palmyra show preference to nesting in native forests as opposed to stands of coconuts. Sea birds are a critical link between the marine and terrestrial environments, a relationship clearly seen at Palmyra. These bird species are known to feed over thousands of square kilometers of ocean but are dependent on small isolated islands for safe breeding. Foraging in the pelagic environment, sea birds transport critical marine nutrients back to the atoll, depositing nutrients in the form of guano as they roost and breed in native forests. This influx of nutrients fuels the growth of native forests. Introduced rats have been shown to have detrimental impacts on ground nesting sea birds, preying on eggs and chicks. The detrimental impacts of rat on native forest recruitment and breeding sea birds, negatively affects the crucial link and nutrient cycling between marine and terrestrial environments, resulting in a break down in community and ecosystem functioning. To restore Palmyra's forest to a natural state where crabs encourage native tree recruitment through dispersal without recruitment-limiting seed predation, rats must be completely removed from the atoll.

This project to implement eradication of black rats at Palmyra Atoll is consistent with the Service's 2010 <u>Rising to the Urgent Challenge: Strategic Plan for Responding to Accelerating Climate Change</u> (FWS 2010c). This project identifies a number of objectives that will move us toward the priority of Adaptation – to plan and deliver management actions to help reduce the impacts of climate change on fish, wildlife, and their habitats. Rat eradication will facilitate system resilience by reducing a non-climate-change ecosystem stressor. It will promote habitat connectivity and improve genetic resources by adding to the total area of safe habitats for vulnerable species. It will restore key ecological processes such as seed dispersal and nutrient cycling, and reduce nonnative pests and pathogens.

1.4.1 Background: The Problem of Introduced Rats on Islands

The Importance of Island Ecosystems

It is widely accepted that the natural world is currently facing a particularly high rate of species extinction (Raup 1988); most recent extinctions can be directly attributed to human activity (Diamond 1989); and that for ethical, cultural, aesthetic, and economic reasons, this current rate of extinction is cause for considerable concern (Ehrlich 1988, Ledec and Goodland 1988). One of the major worldwide causes of anthropogenic extinctions is the introduction of nonnative species. Introduced species are responsible for 39 percent of all recorded animal extinctions since 1600 for which a cause could be attributed (World Conservation Monitoring Center 1992).

Island ecosystems are key areas for conservation of global biological diversity. While islands make up only about 3 percent of the earth's surface, they are home to 15 – 20 percent of all plant, reptile, and bird species (Whittaker 1998). Small population sizes and limited habitat availability make species endemic to islands especially vulnerable to extinction and their adaptation to isolated environments makes them especially vulnerable to aggressive introduced species (Diamond 1985, Diamond 1989, Olson 1989). Of the 484 recorded animal species extinctions since 1600, 75 percent were species endemic to islands (World Conservation Monitoring Center 1992).

Islands are high-value targets for conserving biodiversity because a large percentage of their biota consists of endemic species and subspecies with small populations, which makes them particularly extinction-prone. In addition, islands are crucial habitat for animals such as seabirds and turtles, which feed over thousands of square kilometers of ocean but are dependent on small isolated islands for safe breeding. Protection of these animals at their island breeding sites may be easier and more cost-effective than protecting them from threats at sea (such as plastics pollution and accidental or deliberate entanglement in fishing tackle), which could affect them anywhere along their travels (Wilcox and Donlan 2007). Finally, many smaller islands are sparsely inhabited or uninhabited by humans, keeping the socioeconomic costs of protection relatively low.

Impacts of Rats on Island Ecosystems

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). Rats 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 about 90 percent 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, Daniel and Williams 1984, Meads et al. 1984, Atkinson 1985, Tomich 1986, Hutton et al. 2007), and estimates of 40 – 60 percent of all recorded bird and reptile extinctions globally were directly attributable to invasive rats (Atkinson 1985) (Island Conservation analysis of World Conservation Monitoring Centre data).

Even if species are not extirpated, rats can have negative direct and indirect effects on native species and ecosystem functions. For example, a comparisons 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, Thibault 1995, Jouventin et al. 2003), reptiles (Whitaker 1973, Bullock 1986, Towns 1991, Cree et al. 1995), plants (Pye et al. 1999), and terrestrial invertebrates (Bremner et al. 1984, Campbell et al. 1984). In particular, rats 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, Towns et al. 2006, Jones et al. 2008). *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 rats feed opportunistically on plants, and alter the flora communities of island ecosystems (Campbell and Atkinson 2002); in some cases degrading the quality of nesting habitat for birds that depend on the vegetation. On Tiritiri Matangi Island, New Zealand, ripe fruits, seeds, and understory vegetation underwent significant increases after rats were eradicated from the island, indicating the rats' previous impacts on the vegetation (Graham and Veitch 2002).

Rats 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 alter key ecosystem properties. For example, total soil carbon, nitrogen, phosphorous, mineral nitrogen, marine-derived nitrogen, and pH are lower on rat-invaded islands relative to rat-free islands (Fukami et al. 2006). In rocky intertidal habitats, invasive rats affected invertebrate and marine algal abundance, changing intertidal community structure from an algae-dominated system to an invertebrate dominated system (Kurle et al. 2008). Such changes led to indirect negative effects of rats causing a reduction in seabird populations and predation by rats often drives seabird colonies to near-extirpation (Moller 1983, Atkinson 1985, McChesney and Tershy 1998). This predation further leads to the loss of seabird-derived nutrients on islands (Fukami et al. 2006). Where rats 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 (Moors and Atkinson 1984, Atkinson 1985).

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

Eradication of Rodents from Islands

The first successful rodent eradication was in 1951 on Rouzic Island in France (Lorvelec and Pascal 2005). Through the 1970s and 1980s, New Zealand biologists developed the methodology for systematic rodent eradication techniques and successfully eradicated rats from several small islands (Moors 1985, Thomas and Taylor 2002). Building on these successes, and with the application of new strategies and research to monitor the campaigns, rats were eradicated from increasingly larger islands culminating in Campbell Island in 2002 (11,300 ha), the largest island to date from which rats have been completed eradicated (Taylor and Thomas 1989, Taylor and Thomas 1993, Cromarty et al. 2002, Morris 2002, Clout and Russell 2006). *The successful eradication of rats on Midway Atoll in the 1990s has had significant positive impacts on small nesting seabirds such as Bonin petrels and storm-petrels (Rauzon 2007).*

As of this writing, more than 332 successful rodent eradications have been completed on 284 islands in 18 countries, totaling over 47,628 ha (Howald et al. 2007). The fundamental methodology that all but one of these eradications used was the delivery of bait containing a rodenticide into every potential rodent territory on the island. Bait was typically delivered during a time of year when rats were relatively food deprived, as indicated by annual resource-dependent population declines. Depending on island topography and size, climate, native species assemblages, operational logistics and other factors, these eradication projects applied bait using either bait stations, broadcast, or both. Bait stations were typically laid out on a grid pattern. Bait broadcast could be delivered by hand or by using spreaders suspended under a helicopter (Howald et al. 2007).

Benefits of Rat Eradication Worldwide

The global conservation benefits of these rat eradications include increases in abundance and population parameters of a variety of taxa including seabirds, landbirds, reptiles, mammals, and plants, as well as overall ecosystem recovery. Owing to the well-documented effect of rats on seabirds (Jones et al. 2008), removal of rats almost automatically provides protection for existing seabird colonies. 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 (Jouventin et al. 2003, Whitworth et al. 2005, Smith et al. 2006, Amaral et al. 2010). At Midway Atoll National Wildlife Refuge, Bonin petrel populations increased from fewer than 5,000 nesting pairs in the 1980s to over 135,000 pairs in 2008 subsequent to eradication of rats in 1997 (Pyle and Pyle 2009, FWS 2010a) Change in productivity was the most commonly reported demographic response in bird populations after rat 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 native land birds after rat eradication have also been reported. In New Zealand, the abundance of 4 species of native landbirds increased between 10 and 178 percent during the 3 years after rat eradication (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). Also in New Zealand, rodent eradication has been used to restore endemic and native reptile populations. By 1998, rodents had been removed from 25 islands providing measurable or potential benefits for Tuatara (*Sphenodon* sp.), 2 species of *Naultinus* geckos, 6 species of *Hoplodactylus* geckos, 5 species of *Cyclodina* skinks, and 7 species of *Oligosoma* skinks (Towns 1994, Cree et al. 1995, Towns et al. 2007). Island-dwelling mammals have also benefited from rodent eradication, including an endemic deer mouse in California (Howald et al. 2010) and 2 species of shrew in France (Pascal et al. 2005). 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).

In addition to direct biological diversity benefits, rat eradications have been carried out to create rat-free refuges for native and endemic fauna and flora that are at risk from rat 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).

1.4.2 Summary of Rat Impacts on the Palmyra Ecosystem

Invasive species are having negative impacts on Palmyra Atoll's native forests, fauna, and habitats. The major impacts on Palmyra are associated with World War II-era atoll restructuring and invasive species introductions that included plants (coconut palm, *Cocos nucifera*), insects (several ant species, mosquitoes, scale insects), and mammals (black rats). The black rat causes degradation of nearly all aspects of the atoll's ecosystems, from breeding seabirds to the native *Pisonia* ecosystem. Rats compete for food with land crabs, prevent nesting of at least eight seabird species, provide habitat for invasive mosquitoes, and spread the seeds of invasive flora throughout the atoll.

Throughout the last 200 years, since Polynesian and Western discovery, Palmyra has experienced major habitat manipulation and numerous plant and animal invasions, including the introduction of black rats. The black rat is a common invader of island ecosystems throughout the world (Campbell and Atkinson 2002, Towns et al. 2006). This species is known to prey on seabird eggs and chicks, diminishing reproduction and changing population dynamics (Jones et al. 2008). Comparisons to similar islands nearby (Flint et al. 1996, Spennemann 1998, Rauzon and Wegmann 2004), and the composition of the seabird community observed in the immediate region, indicate that rats are likely the primary limiting factor preventing at minimum eight seabird species from successfully nesting on the atoll: Audubon's shearwater (*Puffinus lherminieri*), Christmas Island shearwater (*Puffinus nativitatis*) wedge-tailed shearwater (*Puffinus pacificus*), Phoenix petrel (*Pterodroma alba*), white-throated storm-petrel (*Nesofregetta fuliginosa*), Bulwer's petrel (*Bulweria bulwerii*), blue noddy (*Procelsterna cerulea*), and gray-backed tern (*Onychoprion lunatus*).

Rats prey on native land crabs and directly compete with them for food resources (Wegmann 2009). Rats also limit the reproduction, recruitment, and establishment of several native tree species. Small, oceanic islands have simplified seed dispersal systems that generally lack mammalian vectors (Carlquist 1967), and thus are vulnerable to disruption by invasive species (Drake et al. 2002). Invasive animal species can disrupt seed dispersal mutualisms (Bond 1994, Compton and McCormack 1999) by depositing seeds in microhabitats that are ill-suited for germination or subsequent growth (Zettler et al. 2001, Traveset and Richardson 2006), and by destroying the seed coat of native seeds, preventing germination and propagation. In many island systems, both land crabs and introduced rats are known seed dispersers (Fall et al. 1971, Lee 1985, O'Dowd and Lake 1991, Sherman 2002, Lindquist and Carroll 2004, Fall et al. 2007). Where land crabs aid in dispersal of native seeds, subsequently increasing recruitment of native tree species, rats have a detrimental effect, killing seeds before they germinates. Furthermore, the coconut palm, an invasive tree dominating 45 percent of Palmyra's forested area, is aided by rat-related recruitment limitation of other tree species. In Palmyra rats have been shown to preferentially prey on native seeds and seedlings, allowing for the spread of coconut palms throughout the atoll. If left unchecked, the combined effects of rats and coconut palms could lead to an invasive meltdown of native forest structures forcing the transition to a forest community dominated by a single invasive tree – namely, the coconut palm (Wegmann 2009, Young et al. 2010).

Benefits of Rat Eradication to the Palmyra Ecosystem

Removing rats from Palmyra is the first step in a series of restoration efforts designed to restore the atoll to its pre-World War II status. Rat eradication is the first step in the process because the eradication of rodents is relatively simple and fast; their removal will slow the spread of invasive coconut palms, allow extirpated breeding seabirds to recolonize the atoll, and provide the framework to initiate the palm removal stage of the restoration process. Additionally, rats out-compete native fauna for resources and provide habitat for other invasive species to invade Palmyra. By removing rats, we are removing non-climate-related impacts to the species and habitats and enhancing the resistance of the ecosystem to global perturbations from accelerating climate change.

Eradicating rats from Palmyra is expected to result in obvious, empirically tested biodiversity benefits for seabirds, plants, terrestrial invertebrates, and other components of the atoll's terrestrial ecosystem. By removing the threat of rats, Palmyra's remnant native forest and the extant and likely extirpated seabird species will be given the opportunity to recover. The benefit of this conservation action is significant from a regional perspective because Palmyra is the only moist tropical atoll ecosystem in the Central Pacific that is entirely protected, as well as the only atoll ecosystem in this region that is not experiencing exploitation of both marine and terrestrial natural resources by burgeoning human populations. From the regional perspective, removing rats from Palmyra will help prevent the loss of the Central Pacific moist tropical island ecotype and improve the adaptability of the system to global climate threats.

1.5 Authority and Responsibility to Act

The eradication of nonnative rats from Palmyra Atoll is authorized and in many cases mandated by several Federal laws requiring FWS resource managers to conserve and restore wildlife and habitats under their jurisdiction.

The U.S. Fish and Wildlife Service's mission is to work with others to "conserve, protect and enhance fish, wildlife, and plants and their habitats for the continuing benefit of the American people." The threat that introduced species pose to habitat and native wildlife makes addressing their impacts one of the Service's top management priorities. Lessening or eliminating the impacts of introduced species on Palmyra is essential to the Service's management strategy for the island.

The Fish and Wildlife Act of 1956 (16 U.S.C. 742a-742j, not including 742 d-l, 70 Stat. 1119), as amended, gives general guidance requiring the Secretary of the Interior to take steps "required for the development, management, advancement, conservation, and protection of fish and wildlife resources."

***The National Wildlife Refuge System Administration Act of 1966 (Refuge Administration Act),* as amended** (16 U.S.C. 668dd-ee), established the unifying mission of the National Wildlife Refuge System "to administer a national network of lands and waters for the conservation, management, and where appropriate, restoration of the fish, wildlife, and plant resources and their habitats within the United States for the benefit of present and future generations of Americans." Among other mandates, the Refuge Administration Act requires the

Service to provide for the conservation of fish, wildlife, and plants, and their habitats within the System; and to ensure that the biological integrity, diversity, and environmental health of the System are maintained. The National Wildlife Refuge System Improvement Act of 1997, which amended the Refuge Administration Act, serves as an "Organic Act" for the Refuge System and provides comprehensive legislation on how the Refuge System should be managed and used by the public. The act clearly establishes that wildlife conservation is the singular Refuge System mission, provides guidance to the Secretary of the Interior for management of the System, provides a mechanism for refuge planning, and gives refuge managers uniform direction and procedures for making decisions regarding wildlife conservation and uses of the System.

The Endangered Species Act of 1973 (ESA) (16 U.S.C. 1531-1544, 87 Stat. 884), as amended, directs the Service to conserve ecosystems upon which threatened and endangered species depend.

The FWS policy for maintaining biological integrity and diversity and environmental health (601 Fish and Wildlife Manual 3, 2001), directs Refuges to "prevent the introduction of invasive species, detect and control populations of invasive species, and provide for restoration of native species and habitat conditions in invaded ecosystems." Furthermore, 601 FW 3 further directs refuge managers to "develop integrated pest management strategies that incorporate the most effective combination of mechanical, chemical, biological, and cultural controls while considering the effects on environmental health."

Presidential Executive Order 13112 on Invasive Species (February 3, 1999): Section 2(a)(2), on Federal agency duties, states: "Each Federal agency whose actions may affect the status of invasive species shall, to the extent practicable and permitted by law, subject to the availability of appropriations, and within Administration budgetary limits, use relevant programs and authorities to: (i) prevent the introduction of invasive species; (ii) detect and respond rapidly to and control populations of such species in a cost-effective and environmentally sound manner; (iii) monitor invasive species populations accurately and reliably; (iv) provide for restoration of native species and habitat conditions in ecosystems that have been invaded; (v) conduct research on invasive species and develop technologies to prevent introduction and provide for environmentally sound control of invasive species; and (vi) promote public education on invasive species and the means to address them."

Executive Order 13112 defines "invasive species" as "an alien species [a species that is not native with respect to a particular ecosystem] whose introduction does or is likely to cause economic or environmental harm or harm to human health."

1.6 Scope of the Proposed Action

This Final EIS has been developed in accordance with the National Environmental Policy Act. Its purpose is to inform decision makers and the public of the likely environmental consequences of the action alternatives. This FEIS identifies, documents, and evaluates the effects of the proposed action: to aid the protection and restoration of the native species and habitats of Palmyra Atoll, U.S.A. by removing nonnative rats from the atoll that harm populations of native trees, nesting seabirds, and land crabs.

The FEIS is composed of four alternatives. The alternatives are described in Chapter 2. Other actions that may occur in the future as a result of any of the various actions being implemented will not be analyzed in detail in this document. The potential implications of the various alternatives in relation to future actions will be discussed in the Cumulative Impacts sections of the Environmental Consequences section (Chapter 4). *Comments received during a 45-day public comment period are in Appendix M, along with Service responses to the substantive comments.*

An interdisciplinary team of environmental scientists and other specialists has analyzed the proposed action in light of existing conditions and has identified relevant effects associated with implementing the Proposed Action compared to the No Action alternative.

1.7 Environmental Issues Identified

Section 1501.7 of the CEQ guidelines for NEPA requires that agencies implement a scoping process to determine the range of issues to be addressed in an environmental impacts analysis, as well as identify the major environmental issues related to the proposed action that need to be analyzed in the environmental consequences section. The scoping process included research in published and unpublished literature, consultations with experts on the ecology of Palmyra, in nonnative species eradication, with relevant government agencies, and with the public through an open comment period. More details on the Service's scoping process conducted for this Final EIS is described in Chapter 5. During the scoping process, the Service identified the major environmental issues, or "impact topics," that are described below. These issues guided the development of the alternatives, and the scope and content of the environmental impacts analysis found in Chapter 4.

Physical Resources

Subtopic: Impacts to water resources

Because the proposed action includes the delivery of a toxicant into the Palmyra environment, the potential impacts of the toxicant to local water quality was identified as an important environmental issue.

Subtopic: Impacts to geology and soils

Because the proposed action includes delivery of a toxicant into the Palmyra environment, the potential for transfer and persistence of the toxicant in soils was identified as an important environmental issue.

Biological Resources

Subtopic: Nontarget impacts from toxicant use

Rat eradication would include the use of a toxicant that is lethal to rats and other nontarget species. Toxicants should only be used in the environment if the behavior of that toxicant can be predicted with some accuracy. The effect of the toxicant to species other than rats and the persistence of the toxicant in the environment are important environmental issues that must be analyzed further because animals other than rats, including birds, could ingest the toxicant through primary or secondary pathways.

Subtopic: Disturbance to sensitive species

Similar to most other oceanic islands, Palmyra provides crucial habitat for species such as seabirds and marine turtles that are especially sensitive to disturbance. The risk of disturbance to sensitive species from the proposed action is an important environmental issue particularly because of Palmyra's importance as a breeding and overwintering environment for seabirds and shorebirds.

Social and Economic Environment

Sub-topic: Impacts to Refuge visitors and recreation

Due to its remote location and difficulty to access, there are very few visitors to Palmyra. FWS manages the limited visitation to protect the Refuge's sensitive biological resources and to enhance species' survival throughout their entire range. However, the biological resources found on or near Palmyra are important for wildlife enthusiasts who do visit the nearshore waters around Palmyra. Recreational boaters use the marine region surrounding the atoll for wildlife-dependent recreational wildlife observation through snorkeling and scuba diving, as well as recreational fishing. Finally, a small number of FWS and TNC personnel, contractors, and visiting researchers reside at the atoll throughout the year.

Subtopic: Impacts to historical and cultural resources

The effect of the action on historical structures and artifacts at Palmyra is an important environmental issue.

2 Alternatives

2.1 Introduction

As part of the analytical process mandated by NEPA, section 102(2)(E) requires all Federal agencies to "study, develop, and describe appropriate alternatives to recommended courses of action in any proposal which involves unresolved conflicts concerning alternative uses of available resources." Based upon the existing site conditions, need for action and constraints and concerns identified during the initial scoping process, four alternatives were identified: three action alternatives (Alternatives B-D), and the No Action Alternative (Alternative A). The No Action Alternative is included in NEPA analysis to provide a benchmark with which to compare the magnitude of environmental effects of the action alternatives. The No Action Alternative describes the Service's current management regime on Palmyra Atoll with regard to the rat population and its impacts to the island ecosystem. *The Service has identified Alternative C as the Preferred Alternative for the Final EIS.*

The action alternatives were developed to focus on the primary issues identified by resource specialists within the Service, experts in island rodent eradication, and government regulatory agencies that have a stake in the decision making process. All individuals, agencies, and organizations that provided substantive input regarding the proposed action are listed in Chapter 5. In order to be retained for consideration, an alternative had to: 1) have a high likelihood of success, 2) have an acceptably low probability for adverse effects on the populations of nontarget species and the environment, and 3) be permitted under regulations governing the Refuge. The alternatives are:

- Alternative A: No Action

- Alternative B: Aerial broadcast of brodifacoum

- Alternative C: Aerial broadcast of brodifacoum, with proactive mitigation of risk for vulnerable shorebird taxa

- Alternative D: Bait stations with brodifacoum, with canopy baiting

2.1.1 Integrated Pest Management (IPM)

In accordance with the Interior Departmental Manual policy, 517 DM 1 and FWS Manual policy, 569 FW 1, an integrated pest management (IPM) approach would be used, where practicable, to eradicate, control, or contain pest and invasive species (herein collectively referred to as pests) on refuge lands. Integrated Pest Management would involve using methods based upon effectiveness, cost, and minimal ecological disruption, which considers minimum potential effects to nontarget species and the refuge environment. Pesticides may be used where physical, cultural, and biological methods or combinations thereof, are impractical or incapable of providing adequate control, eradication, or containment. If a pesticide would be needed on refuge lands, the most specific (selective) chemical available for the target species would be used unless considerations of persistence or other environmental and/or biotic hazards would preclude it. In accordance with 517 DM 1, pesticide usage would be further restricted because only pesticides registered with the U.S. Environmental Protection Agency (USEPA or EPA) in full compliance with the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) and as provided in regulations, orders, or permits issued by EPA may be applied on lands and waters under refuge jurisdiction.

Environmental harm by pest species would refer to a biologically substantial decrease in environmental quality as indicated by a variety of potential factors including declines in native species populations or communities, degraded habitat quality or long-term habitat loss, and/or altered ecological processes. Environmental harm may be a result of direct effects of pests on native species including preying and feeding on them; causing or vectoring diseases; preventing them from reproducing or killing their young; outcompeting them for food, nutrients, light, nest sites or other vital resources; or hybridizing with them so frequently that within a few generations, few if any truly native individuals remain. Environmental harm can also be the result of an indirect effect of pest species. For example, decreased waterfowl use may result from invasive plant infestations reducing the availability and/or abundance of native wetland plants that provide forage during the winter.

Environmental harm may involve detrimental changes in ecological processes. For example, extirpation of seabird populations on islands by introduced rodents reduces the rate of nutrient flow in the form of guano from the pelagic zone to the island and surrounding reefs. This change in nutrient regime in turn, favors different coral reef species and modifies communities. Environmental harm may also cause or be associated with economic losses and damage to human, plant, and animal health. For example, invasions by fire-promoting grasses that alter entire plant and animal communities, eliminating or sharply reducing populations of many native plant and animal species can also greatly increase fire-fighting costs.

A number of action alternatives that were evaluated as part of using the IPM approach and subsequently dismissed from detailed consideration are also described, and a rationale for their dismissal is given (Section 2.3).

2.2 Alternative A: No Action

Analysis of the no action alternative is required under NEPA. Under the no action alternative, the island's rat population would not be subject to any targeted management actions. Rat management currently consists of trapping rats for human health and safety around human use areas on Cooper Island, including the TNC galley and camp area, workshop, and laboratory. There are currently no other activities taking place at Palmyra with respect to rat control. Other ongoing invasive species management programs at Palmyra would continue based on previous agency decisions. Furthermore, any other related programs or projects decided and implemented under different authority, now or in the future, would also continue.

Taking no action to address the effects of rats would be contrary to the purposes of the Refuge. It would also be contrary to the mission of the National Wildlife Refuge System, which is to administer a national network of lands and waters for the conservation, management, and where appropriate, restoration of the fish, wildlife, and plant resources and their habitats within the United States for the benefit of present and future generations of Americans. Furthermore, taking no action would be contrary to the FWS policy on maintaining the biological integrity, diversity, and environmental health of the National Wildlife Refuge System.

2.3 Alternatives Considered and Dismissed from Detailed Analysis

2.3.1 Rat Removal with the Goal of "Control"

The net conservation gain achieved by successful rat control (i.e., reducing and maintaining rat populations at extremely low levels) compared to complete eradication could be similar. However, the risks to nontarget wildlife from control operations are greater than the risks from an eradication operation due to the indefinite timeline for which a control operation must be continued. Long-term bait presence and repeated disturbances from control operations puts nontarget wildlife at constant risk. In addition, should scheduled control operations be interrupted, rats could quickly reproduce and rapidly repopulate the island, thereby achieving former population sizes and requiring an intensification of control operations once more. The constant maintenance of an ecologically beneficial rat control program (i.e. control of island-wide rat populations to levels low enough to eliminate them as an ecosystem threat) would be far less cost-effective, increase personnel safety risks, and would not result in the permanent conservation benefits of entire-island eradication. It is thus disqualified from detailed consideration.

2.3.2 Use of Disease

While there is ongoing research focused on the development of taxon-specific diseases that can control populations of nonnative species (such as by the Australian agency Commonwealth Scientific and Industrial Research Organization (CSIRO), www.cse.csiro.au/research/rodents/publications.htm), there are no pathogens with proven efficacy at eradicating rodents (Howald et al. 2007). Even a highly lethal rat-specific pathogen would be ineffective at eradicating rats from Palmyra because if the rat population rapidly declined, transmission rates of the introduced pathogen would also decline so as to be ineffective in eradicating the few remaining individuals. Furthermore, the introduction of novel pathogens into the environment carries tremendous potential risks to nontarget species. Therefore, the use of pathogens is disqualified from detailed consideration.

2.3.3 Trapping

This alternative would call for the use of live traps and/or lethal ("snap") traps to eradicate rats. This action would be highly unlikely to succeed at Palmyra. The use of live traps and/or lethal traps to remove rats from an area is a strong selection agent in favor of rats that are "trap-shy". Thus, after extensive trapping the only rats that would remain would be those that are behaviorally less likely to enter a trap, and these rats would be very difficult to remove without the introduction of alternate methods such as toxicants. The high densities of land crabs found at Palmyra also make effective trapping almost impossible due to interference from crabs being captured as soon as the traps are set. The use of snap traps at Palmyra would result in high mortality of land crabs. Furthermore, the widespread use of traps is not feasible because of the extensive effort and considerable personnel risk required to set and monitor traps. Therefore, this alternative is disqualified from detailed consideration.

2.3.4 Biological Control

The introduction of predators on rats, such as snakes and cats, was dismissed because biological control most often only reduces, rather than fully eliminates the target species and thus fails to achieve the desired ecological benefit gained through complete rat removal. There is no known effective biological control agent for rats on islands, and some forms of biological control would result in unreasonable damage to the environment. The introduction of cats to islands in order to control introduced rodents has been attempted numerous times since European explorers began crossing the Atlantic and Pacific Oceans. The introduction of a rodent predator, such as cats, generally results in a greater combined effect on birds than if one or the other were present alone. When seabirds are present, cats have been shown to prey heavily on seabirds (Atkinson 1985), consuming fewer rodents during these times. When seabirds leave the islands following the end of the breeding season, cats switch prey to rodents, which allow the islands cat population to remain stable at a higher level than if no rodents were present on the island (Atkinson 1985, Courchamp et al. 1999, 2000).Thus, birds are affected not only by rodents but also the larger number of cats that are sustained by rodent presence on the island. Introduction of another species onto an island can have severe and permanent consequences to the ecosystem (Quammen 1996). Therefore, this alternative is disqualified from detailed consideration.

2.3.5 Fertility Control

Fertility control has been used with limited success as a method of pest management in a few species. Experimental sterilization methods have included chemicals and proteins delivered by vaccine, and genetically-modified viral pathogens. However, the effectiveness of these experimental techniques in the wild, and their impacts to nontarget animals are unknown. Aerial application of rodenticide is a more practical, effective, and a safer method to eradicate rats than repeated baiting of uncertain oral contraceptives on a remote island across seasons or capturing, vaccinating, and releasing every member of a single gender of the Palmyra rat population. This lack of data and tools disqualifies the use of fertility control from detailed consideration (Tobin and Fall 2005).

2.3.6 Aerial Broadcast or Bait Stations with Diphacinone and Diphacinone-50 Bait Products

Aerial broadcast and bait station alternatives employing the Diphacinone-50 bait product (the only other bait product besides Brodifacoum-25W Conservation and Brodifacoum-25D Conservation registered with the USEPA for conservation-based rodent eradications on islands) were considered in the development of this Final EIS, but not put forward as Action Alternatives. Factors considered in this decision include:

1) the multi-agency/organization collaborative report (the Feasibility Study, Appendix C), which evaluated causes of an initial failed eradication attempt at Palmyra in 2002-2004;

2) field and laboratory trials conducted in 2004-2010 (Appendices C through G);

3) reported results of Diphacinone-50 laboratory and field studies, such as relative toxicity and efficacy of the product (including palatability);

4) exceptional biological conditions of Palmyra Atoll, including the inordinately dense population of land crabs, their extreme ability to penetrate enclosures, and their voracious consumption (which influences application rates needed); and

5) relative financial costs.

The collaborative report from 2004 which followed the failed Palmyra rat eradication effort (the Feasibility Study, Appendix C) examined the feasibility of broadcast treatment with a product equivalent to Diphacinone-50 but, at that time, diphacinone – although effective at rat <u>control</u> under different conditions – had not been proven to be an effective tool for rat <u>eradication</u> from tropical islands, or for broadcast-based eradications in general. The 2005 field trial at Palmyra followed the recommendations of the 2004 Feasibility Study (Appendix D and C, respectively). In 2005, the investigators elected not to trial a diphacinone broadcast product because of a) the significantly greater application rates, relative to brodifacoum, necessary for testing to ensure availability of bait, for a long enough period, to all rats; b) a limited number of discrete islets at Palmyra for adequate sample sites; and c) limits on funding available to conduct tests in the unconventional Palmyra ecosystem.

Ultimately, while Diphacinone-50 was included in the palatability and environmental fate studies conducted at Palmyra in 2010 (Appendix F) (Alifano and Wegmann 2010), the service does not have enough information on the efficacy of Diphacinone-50 within Palmyra's rat eradication environment to proceed with this bait product employed in a broadcast or bait station-based Action Alternative. Additional and expensive field trials would be required to evaluate the viability of this product for meeting a high probability of eradicating rats from the

extreme conditions at Palmyra Atoll; however, they may not remove uncertainties. Furthermore, incurring the added expense, with continued uncertainty, is not practical for the Palmyra eradication because there is sufficient documentation on the success of brodifacoum.
A total of 12 successful island rodent eradications have been reported using diphacinone as the primary toxicant (Table 2.1) (Howald et al. 2007, Island Conservation unpubl. data). One additional successful eradication, on Nonsuch Island in Bermuda, also used diphacinone but as a supplement to warfarin which was the primary toxicant used. Of the 12 successful eradications using diphacinone as the primary toxicant, 3 used hand broadcast as the primary delivery technique, 8 used bait stations as the primary delivery technique, and 1 used aerial broadcast. Fifteen eradications using diphacinone are reported to have been unsuccessful: Lehua Island in Hawaii (Dunlevy and Swift 2011) ; Mukojima, Torishima, and Higashijima Islands in Japan (Hashimoto 2010) using aerial methods; and 9 Islands in Alaska, Congo Cay in U.S. Virgin Islands, and Nishijima in Japan (Pierce 2003, Hall et al. 2006). Although diphacinone has less of a record of success for island rodent eradication in comparison to brodifacoum, some success has been achieved. And, it is often a preferred rodenticide because of the reduced environmental risk to nontarget species in comparison to brodifacoum (Fisher et al. 2003, Eason and Ogilvie 2009). Additional successful island rodent eradications would be needed to adequately demonstrate that diphacinone could be a substitute for other proven anticoagulants in efficacy and cost-efficiency, particularly for large scale and complex eradication projects, such as at Palmyra. Based on available data and historical failure to remove rats from Palmyra, no conclusions of Diphacinone-50's reasonable likelihood of success could be made to meet the purpose and need of this project.

Toxicological Properties of the Rodenticides (relative toxicity and efficacy)

The physiological action of diphacinone on target organisms is the same as for brodifacoum: diphacinone interferes with the blood's clotting ability and causes profuse bleeding. However, diphacinone and other first-generation anticoagulants have a reduced affinity for the enzyme that produces vitamin K-dependent clotting agents (in comparison to brodifacoum and other second-generation anticoagulants,) resulting in a slower depletion time of these clotting agents in the bloodstream (Eason and Ogilvie 2009). Also, diphacinone is more actively metabolized and excreted by rats than brodifacoum. In one trial, after a single dose of diphacinone, 80 percent of the toxicant was eliminated in feces and urine within 8 days (Yu et al. 1982).

As a result of these properties, diphacinone requires multiple exposures to ensure a lethal dose is obtained. Although diphacinone can be lethally toxic to some rats when administered in a single, large dose, it is relatively more potent in small doses administered over several days (Buckle and Smith 1994, Timm 1994). Single lethal doses of 1.93 - 43.3 mg/kg have been reported for laboratory rats, but doses of less than 1 mg/kg over 5 successive days are more effective (Hone and Mulligan 1982, Jackson and Ashton 1992). Laboratory studies demonstrate that both single-dose and multiple-dose LD_{50} values for rats exposed to diphacinone are higher than for brodifacoum (Table 2.6) and, that for mortality to occur, diphacinone generally must be ingested regularly over a period of days (Buckle and Smith 1994, Erickson and Urban 2004). Jackson and Ashton (1992) reported LD_{50} values over a 5-day period of 0.21 and 0.35 mg/kg/day in domestic and wild Norway rats respectively. Tobin (1992) demonstrated that for mortality to occur, black (R. rattus) and Polynesian rats (R. exulans) required a mean of 8.6 mg/kg (11.8 -

28.4 g of pellet), and Norway rats required a mean of 10 mg/kg (34.6 g pellet) ingested over an average of 6 to 7 days, with a range of between 4 and 12 days. From laboratory bioassays against wild-caught black and Polynesian rats in Hawai`i, Swift (1998) found Ramik® Green [Diphacinone-50] was effective at very low amounts and for half the exposure time generally recommended for diphacinone. She concluded minimum exposure times and bait amounts of 7 days and 37.5 grams (15 commercial-sized pellets) for R. rattus and 6 days and 30.0 g (12 commercial-sized pellets) for R. exulans (90% mortality) should be sufficient to effectively control wild rats in Hawaiian ecosystems with Ramik® Green [Diphacinone-50]. After considering these studies, we concluded that, to ensure 100 percent mortality to the rat population at Palmyra Atoll (eradication rather than control), if Diphacinone-50 bait was used, it would need to be consistently available and consumed by some rats for up to 12 days.

The primary advantage of diphacinone as a rodenticide for conservation purposes is the low risk it poses to nontarget organisms in comparison to second generation anticoagulants. Diphacinone has comparatively low persistence in animal tissues, which makes toxicity to nontarget birds through primary and secondary exposure less likely than for brodifacoum (but does not eliminate the risk) (Fisher 2009). Furthermore, laboratory trials have indicated that diphacinone has low toxicity to birds when compared with brodifacoum (Erickson and Urban 2004, Eisemann and Swift 2006). However, recent research suggests that the toxicity of diphacinone to some birds may be considerably higher than previously thought (Rattner et al. 2010 (submitted)), although the overall toxicity of diphacinone still remains low compared with brodifacoum. From the perspective of nontarget risk, particularly for birds, diphacinone is the optimum choice. However, the choice would be risky when gauged with overall baiting efficacy on Palmyra. The long exposure to diphacinone necessary to achieve rat mortality ultimately decreases the probability that all rats would consume enough bait, given the conditions at the atoll. For example, the availability of other, natural food items and competition with other consumers (e.g., land crabs) both could decrease the probability of all rats consuming enough bait. Competition with other consumers also would potentially leave some rat territories with inadequate access to bait. All of these factors increase the risk of eradication failure.

Diphacinone-50 is a cereal bait product, available in 1-2 g pellets, with an added fish flavor. The bait contains 50 ppm diphacinone. Pellets are dyed dark green, which has been shown to make them less attractive to some birds and reptiles (Pank 1976, Tershy et al. 1992, Tershy and Breese 1994). The Diphacinone-50 bait product is identical to commercially available Ramik® Green bait products. Diphacinone-50 has been tested for rodent eradication with equivocal results in the Aleutian Islands of Alaska (Table 2.1). Rats were reportedly eradicated from some but not all trial islets (mostly < 0.5 ha in size) during a bait station trial eradication near Adak Island (Dunlevy and Spitler 2008). However, successful eradication has been achieved with bait station application of Diphacinone-50 elsewhere.

While diphacinone has been tested or used with favorable results in a number of landscape-scale rodent <u>control</u> efforts (Dunlevy et al. 2000, Spurr et al. 2003a, Spurr et al. 2003b), the success of these control efforts does not provide assurance that Diphacinone-50 would be successful as a tool for rodent <u>eradication</u> when competition for bait between the target species and nontarget consumers is high (such as at Palmyra).The goal of a rodent control operation is to reduce a *rodent population to an acceptably small size and maintain low density populations, whereas the goal of an eradication operation is to permanently remove every rodent. This is a critical fundamental difference when assessing the relative merits of different bait products; a bait product that is available for use, attractive to rodents, but has an uncertain efficacy may be an excellent tool for a control operation but not for a broadcast eradication operation at this time.*

Table 2.1. Known rat eradication attempts worldwide using diphacinone bait products.

Island Name	Country	Species	Area (ha)	Year	Primary Delivery	Rodenticide	Outcome	Reference
Kalkun Cay, USVI	USA	*R. rattus*	1.4	1982	hand broadcast	diphacinone	successful	Parkes and Fisher 2011
Dog Cay, USVI	USA	*R. rattus*	4.8	1983	hand broadcast	diphacinone	successful	Parkes and Fisher 2011
Steven Cay, USVI	USA	*R. rattus*	0.8	1983	hand broadcast	diphacinone	successful	Parkes and Fisher 2011
Nonsuch, Bermuda	UK	*R. norvegicus R. rattus*	5.8	<1985	bait stations	warfarin, diphacinone	successful	Wingate 1985
Buck Island Reef National Monument, USVI	USA	*R. rattus*	80	2000	bait stations	diphacinone	successful	Witmer et al. 2007
San Jorge East, Gulf of Mexico	MEX	*R. rattus*	5	2000	bait stations	diphacinone	successful	Donlan et al. 2003
Mokoli`i, Hawaii	USA	*R.rattus*	1.5	2002	bait stations, traps	diphacinone	successful	Smith et al. 2006a
Congo Cay, USVI	USA	*R. rattus*	10.6	2003	bait stations	diphacinone	failed	Pierce 2003
Cormorant (Bay of Islands, Alaska)	USA	*R. norvegicus*	2.1	2003	bait stations, spot baiting	diphacinone	failed	Dunlevy & Scharf 2007
Dutchcap Cay, USVI	USA	*R. norvegicus R. rattus*	12.9	2003	bait stations	diphacinone	successful	Pierce 2003
Green (Bay of Islands, Alaska)	USA	*R. norvegicus*	22.4	2003	bait stations, spot baiting	diphacinone	failed	Dunlevy & Scharf 2007
Saba Cay, USVI	USA	*R. norvegicus R. rattus*	12.3	2003	bait stations	diphacinone	successful	Pierce 2003
South (Bay of Islands, Alaska)	USA	*R. norvegicus*	11.4	2003	bait stations, spot baiting	diphacinone	failed	Dunlevy & Scharf 2007
Aureola (Bay of Islands, Alaska)	USA	*R. norvegicus*	0.3	2004	bait stations	diphacinone	failed	Dunlevy & Scharf 2007
Black (Bay of Islands, Alaska)	USA	*R. norvegicus*	1	2004	bait staitions	diphacinone	failed	Dunlevy & Scharf 2007
Bubba (Bay of Islands, Alaska)	USA	*R. norvegicus*	0.5	2004	bait stations	diphacinone	successful?	Dunlevy & Scharf 2007
Camoflage (Bay of Islands, Alaska)	USA	*R. norvegicus*	4.3	2004	bait stations	diphacinone	failed	Dunlevy & Scharf 2007
Channel (Bay of Islands, Alaska)	USA	*R. norvegicus*	2.9	2004	bait stations	diphacinone	successful?	Dunlevy & Scharf 2007
Duh (Bay of Islands, Alaska)	USA	*R. norvegicus*	0.1	2004	bait stations	diphacinone	failed	Dunlevy & Scharf 2007
Earl (Bay of Islands, Alaska)	USA	*R. norvegicus*	6.4	2004	bait stations	diphacinone	failed	Dunlevy & Scharf 2007
Ina (Bay of Islands, Alaska)	USA	*R. norvegicus*	4.5	2004	bait stations	diphacinone	failed	Dunlevy & Scharf 2007
North Rocks (Bay of Islands, Alaska)	USA	*R. norvegicus*	0.7	2004	bait stations	diphacinone	successful?	Dunlevy & Scharf 2007
Sweet (Bay of Islands, Alaska)	USA	*R. norvegicus*	0.5	2004	bait stations	diphacinone	successful?	Dunlevy & Scharf 2007

Buck Island NWR, USVI	USA	*R. norvegicus R. rattus*	16.8	2005	bait stations	diphacinone	successful	Pierce 2007
Capella Island, USVI	USA	*R. norvegicus R. rattus*	8.8	2005	bait stations	diphacinone	successful	Pierce 2005
Canna Island	UK	*R. norvegicus*	1130	2006	bait stations	diphacinone	successful	Bell et al. in press
Nishijima, Ogasawara	JPN	*R. rattus*	49	2007	bait stations	diphacinone	failed	Hashimoto 2010
Higashijima, Ogasawara	JPN	*R. rattus*	28	2008	aerial	diphacinone	failed	Hashimoto 2010
Lehua, Hawaii	USA	*R.rattus*	117	2008	aerial	diphacinone	failed	Dunlevy & Swift 2011
Mokapu, Hawaii	USA	*R. rattus*	4	2008	aerial	diphacinone	successful	FWS 2008b
Mukojima, Ogasawara	JPN	*R. rattus*	268	2008	aerial	diphacinone	failed	Hashimoto 2010
Torishima	JPN	*R. rattus*	11	2008	aerial	diphacinone	failed	Hashimoto 2010
Cocos (Guam)	USA	*R. exulans*	33.6	2009	hand broadcast, some bait stations with brodifacoum trapping	diphacinone	pending	Parkes and Fisher 2011
Egmont Cay	JPN	*R. rattus*	112	2009	bait stations, hand broadcast	diphacinone	pending	Parkes and Fisher 2011
Tea Island, Falkland Islands	UK	*R. norvegicus*	320	2009	hand broadcast	diphacinone	pending	Poncet 2009
Anijima	JAP	*R. rattus*	785	2010	aerial	diphacinone	pending	Harrison 2010
Higashijima, Ogasawara	JPN	*R. rattus*	28	2010	aerial	diphacinone	pending	Harrison 2010
Mukojima, Ogasawara	JPN	*R. rattus*	268	2010	aerial	diphacinone	pending	Harrison 2010
Nishijima, Ogasawara	JPN	*R. rattus*	49	2010	aerial	diphacinone	pending	Harrison 2010
Otoutojima	JPN	*R. rattus*	530	2010	aerial	diphacinone	pending	Harrison 2010
Torishima	JPN	*R. rattus*	11	2010	aerial	diphacinone	pending	Harrison 2010

Country codes: UK = United Kingdom, MEX = Mexico, USA = United States of America, JPN = Japan.

Table 2.2. LD_{50} values for *Rattus* sp. exposed to brodifacoum and diphacinone.

Species	**LD_{50}** mg/kg **brodifacoum**	**LD_{50}** mg/kg **diphacinone**
Laboratory rat	0.41 (0.35 – 0.50)	2.5 (1.3 - 3.4)
	0.56 (0.47 – 0.66)	2.1 (1.5 – 2.9)
		7.0 (5.2 – 9.5)
		5-day dose @ 0.21/day=1.05
		1.9
Norway rat (wild)		5-day dose @ 0.35/day=1.75
Rat (unspecified)		3.0 (< 1 over 5 days)
Norway rat		10 (40% mortality)
Black rat		8.6 (90% mortality)
Polynesian rat		8.6 (90% mortality)
Rat (unspecified)	0.39	
Norway rat	0.3	3
Norway rat-male	0.4 (0.35-0.46)	
Norway rat-female	0.49 (0.43-0.56)	
Norway rat-male	0.42 (0.37-0.48)	
Norway rat-female	0.56 (0.46 – 0.73)	
Norway rat-male	0.98 (0.78 – 1.2)	
Norway rat-female	1.3 (1.0 – 1.6)	
Norway rat-male	0.81 (0.7 – 0.95)	
Norway rat-female	1.0 (0.4 – 2.1)	
Norway rat	0.22-0.27	
Black rat	0.65-0.73	

Data from Hone and Mulligan (1982); Buckle (1994); Erickson and Urban (2004)

Brodifacoum has a higher success rate for rat eradication than diphacinone likely, in part, because brodifacoum has a higher toxicity (less bait would need to be consumed to achieve mortality; in some cases, one feeding of brodifacoum bait would be lethal) (see Section 2.5.1 of this document). It is expected that some rats on the island would consume only a little bait due to the natural variation in the population with some rats preferring natural foods vs. the presented bait. Thus, there would be a greater probability of eradication success using brodifacoum. In addition, higher toxicity may be more important for aerial broadcast because of the relatively short duration of bait availability, compared to a bait station approach where bait can be made available for long periods of time. Rodent eradications using brodifacoum have been successful using either 1 or 2 broadcast applications. For diphacinone, the few successful eradications using broadcast application indicates that a strategy for aerial application has not been extensively tested and proven. Given that diphacinone is physiologically more effective with repeated doses and that diphacinone bait was consistently available for long time periods in successful eradications using bait stations, broadcast application of Diphacinone-50 would require either multiple applications (>2) or significantly higher application rates (if only 1-2 applications) to ensure availability for a longer period of time. For this reason, an eradication effort on Palmyra using brodifacoum and broadcast techniques would be more cost-effective and more effort-efficient (Table 2.8), with a higher probability of success than a diphacinone broadcast. Diphacinone broadcast would require a higher application rate and more frequent *applications to make bait consistently available for long time period, resulting in an overall higher volume of pesticide introduced into the environment. Diphacinone, delivered by aerial broadcast, has been reported to be successful in removing rats from only a single island and has failed on 4 islands (Table 2.1).The multiple-feed requirement of diphacinone and its measured acceptance rates (palatability) (Pitt et al. 2010) cannot be ruled out as possible contributors to operational failure for aerial applications. With respect to Lehua Island, Hawai`i, where aerial broadcast of diphacinone in 2009 was unsuccessful in eradicating rats, Parkes and Fisher (2011) conclude that diagnosis of the cause of failure at Lehua is difficult while recognizing there is some cause for caution on the use of diphacinone as an eradication tool. In comparison, brodifacoum, delivered by aerial-broadcast, hand-broadcast, or a combination of both, has been used successfully for rodent eradication on at least 75 occasions (Howald et al. 2007) with one or two bait applications. It is acknowledged that there have been failures with the use of brodifacoum, some causes of which are unknown, others due to operational deficiencies, or reintroductions.*

Bait palatability is another important factor affecting the likelihood of successful rat eradication. In a laboratory setting, Pitt et al. (2010) found that the Ramik® Green (Diphacinone-50) product they tested had lower average consumption and lower percent acceptance rate than the second generation anticoagulant products tested, including brodifacoum. The diphacinone product did not meet a minimum threshold of at least 80% mortality in two-choice tests after 7 days of exposure. The result was attributed to low product toxicity, limited exposure times, and low palatability compared to the other products tested (Pitt et al. 2010).The lower acceptance rate directly affected efficacy and fewer animals succumbed to the diphacinone product under test conditions as compared to other products. If the animals do not eat the bait product, efficacy will be compromised. For field uses, such as what is proposed on Palmyra, if a bait product fails basic laboratory acceptance and efficacy trials (regardless of toxicant), the acceptance of the product under field conditions is questionable, and potentially risks the success of the eradication effort.

At Palmyra, however, the products Brodifacoum-25W and Diphacinone-50 have both been shown to be preferred when presented to rats along with naturally available food items (Appendix F). Brodifacoum-25 bait products have been used to successfully eradicate rats on at least 5 islands and have shown favorable results in at least 3 other eradication trials. The bait product Diphacinone-50 was reported to be successfully used on Mokapu Island, Hawai`i by aerial broadcast. Diphacinone-50 has shown equivocal results in bait station eradication trials in the Aleutian Islands, Alaska, but was successfully used to remove rats from Buck Island, USVI (Witmer et al. 2007).

From an operational perspective, the essential difference between Diphacinone-50 and Brodifacoum-25W for eradicating rats from Palmyra is that the quantity of Diphacinone-50 would need to remain relatively high across a period of up to 12 days (potentially per application), while a brodifacoum operation would require only that bait be available long enough for each rat to receive a single-dose, about 4 days per application. With a brodifacoum operation, because of brodifacoum's toxicity, a rat that ingests bait on day one will likely not need to ingest bait again (brodifacoum has a high binding affinity in the liver and is metabolized *slowly). However, with a diphacinone operation, bait needs to be available to all rats and consumed almost exclusively for up to12 days; this requires that 1) the bait is highly attractive to rats to ensure that they consistently prefer bait above natural food items, 2) that sufficient bait is available daily to ensure rats frequently encounter bait within their environment, and 3) that the consistent bait loss in the environment to other rats, crabs, and other animals, and degradation by invertebrate, microbial, and other environmental action, does not diminish the amount of bait available to a level at which sufficient bait is no longer available to rats. For these reasons, it was determined that aerial use of Diphacinone-50 would require three times the bait for Palmyra, at more cost, than aerial use of Brodifacoum-25W. Relative costs of treatment options are outlined in Table 2.8.*

As outlined in this section and discussed in detail in the Environmental Consequences section (Chapter 4), the use of diphacinone is acknowledged here to impart a considerably lower risk to nontarget species than does brodifacoum. However, the product's variable results in laboratory and field acceptance studies and efficacy trials, combined with varying degrees of success in island eradication efforts, questions a successful use of Diphacinone-50 on Palmyra at this time. Additional and expensive trials may increase the understanding of the product in Palmyra's extreme conditions; however, they may not remove uncertainties. A failed eradication attempt with lower nontarget risk would provide no conservation returns at great expense since rats would quickly re-establish throughout the atoll (Appendix D).When considering other important factors, such as the demonstrated eradication success of Brodifacoum-25W in comparison to Diphacinone-50, the technology for distributing the toxicant effectively when feasibility was considered in 2004 and trialed in 2005, and the probability of administering toxic levels to all rats, Brodifacoum-25W was concluded to be more desirable at this time when coupled with mitigation strategies to minimize the risks to nontarget species at the atoll. Subsequently, the use of Diphacinone-50 for Palmyra at this time was considered and dismissed.

2.3.7 Bait Broadcast Using Brodifacoum-25W at the Maximum Application Rate Allowed by the 2010 Product Use Label

The 2008 Bait Broadcast Application Rate Assessment (Appendix E) conducted at Palmyra (Wegmann 2008) showed that the current bait sowage rate maximum for Brodifacoum-25W is not sufficient to expose all rats to bait, and thus would not achieve eradication success. *A supplemental label for this product for use on Palmyra was approved April 15, 2011.*

2.3.8 Hand Broadcast of Brodifacoum-25W

Applying Brodifacoum-25W by hand rather than via aerial application was considered but rejected as a viable action alternative because of the following factors:

- There are several islands at Palmyra where unexploded ordinance from WWII U.S. military activities still persist. Such areas would have to be surveyed by qualified technicians and found ordinance would have to be removed.

- Palmyra's dense vegetation would limit the distance between hand baiting transects to 15 feet. Based on the effort required to broadcast bait by hand to the ground and coconut palm canopy during the 2005 trial eradication (19.5 person-hours/ha) (Buckelew et al. 2005), it would take a 20-person team 243 days to complete each of the two bait applications. While some efficiencies could be expected with a larger operation (the 2005 trial islands were baited by teams of 4-5 people), the effort required for a hand broadcast eradication at Palmyra would be monumental.

- The risk to nontarget species during a hand broadcast operation would not be decreased from that incurred during an aerial broadcast operation.

2.3.9 Use of Other Toxicants

The use of other rodenticides registered with the EPA was dismissed from further consideration for one or more of the following reasons: 1) greater toxicity to other refuge wildlife such as terrestrial arthropods; 2) lack of proven effectiveness in island rat eradications; 3) potential for development of bait shyness in the rat population; and 4) the lack of an effective antidote in case of human exposure. Each of these issues and the associated rodenticides are discussed below.

Most documented island-wide rodent eradication programs (226, 68 percent) have used second-generation anticoagulants, including brodifacoum (Howald et al. 2007). Twenty-nine have used first-generation anticoagulants such as diphacinone. Nine additional eradications have used non-anticoagulant toxicants including zinc phosphide, strychnine, and cholecalciferol. Acute rodenticides, such as zinc phosphide and strychnine, have the ability to kill rats quickly after a single feeding. However, because poisoning symptoms appear rapidly, the acute rodenticides can induce learned bait avoidance if animals consume a sub-lethal dose. Studies with zinc phosphide have demonstrated that rodents associate toxicity symptoms with bait they had consumed earlier if the onset of symptoms occurs as long as 6 to 7 hours after consumption (Lund 1988). Thus, any individual that consumes a sub-lethal dose is likely to avoid the bait in the future (Record and Marsh 1988). Also, acute rodenticides are often extremely toxic to humans and effective antidotes are not always available. The combination of these factors disqualifies the acute rodenticides from detailed consideration.

Cholecalciferol, which is classified as a “subacute” rodenticide, has the ability to kill rats more quickly than the anticoagulant rodenticides, but most often more slowly than the acute rodenticides. Cholecalciferol has a lower level of toxicity to birds. It has been used successfully to eradicate rats from very small islands (Donlan et al. 2003). These characteristics give cholecalciferol potential as a candidate toxicant for eradications, but it has not been extensively tested for eradication efficacy (Howald et al. 2007) or impacts to nontarget species. Thus, its use at Palmyra would be largely experimental in nature. The presence of unique taxa at Palmyra, and the need for a high probability of conducting a successful eradication on the first attempt, disqualifies cholecalciferol from detailed consideration. Additionally, no EPA labeled cholecalciferol bait product is currently available for rodent eradication or control activities.

2.4 Features Common to All Action Alternatives

2.4.1 Introduction

The purpose of eradicating rats from Palmyra Atoll is to restore and protect historic seabird colonies, to conserve, protect and enhance habitat for all native wildlife species, and to restore the biotic integrity of the island. The overarching goal of successfully eradicating rodents is dependent upon ensuring the delivery of a lethal dose of toxicant to every rodent on the island in a manner that minimizes harm to the ecosystem while still maintaining a high probability of success.

2.4.2 Adaptive Management

Based upon 522 DM 1 (Adaptive Management Implementation policy), refuge staff shall use adaptive management (AM) for conserving, protecting, and, where appropriate, restoring lands and resources. Within 43 CFR 46.30, AM is defined as a system of management practices based upon clearly identified outcomes, where monitoring evaluates whether management actions are achieving desired results (objectives). The recently published DOI Adaptive Management Technical Guide also defines AM as a decision process that "promotes flexible decision making that can be adjusted in the face of uncertainties as outcomes from management actions and other events become better understood." Adaptive Management accounts for the fact that complete knowledge about fish, wildlife, plants, habitats, and the ecological processes supporting them may be lacking. The role of natural variability contributing to ecological resilience also is recognized as an important principle for AM. It is not a "trial and error" process, but rather AM emphasizes learning while doing based upon available scientific information and best professional judgment considering site-specific biotic and abiotic factors on refuge lands.

2.4.3 Project Support Operations

Equipment and supplies for all action alternatives would be transported to Palmyra via a chartered ocean-going vessel. The vessel tender would require that the vessel be inspected for rodents and declared free of rodents no more than 2 days prior to departure from the port of call to Palmyra Atoll. All equipment and supplies loaded onto the vessel would be inspected for stowaway rodents and other biosecurity hazards, such as propagules from invasive plants and invasive insects. Project personnel would either fly to Palmyra on a chartered airplane departing from Honolulu, HI, or ride with the equipment and supplies aboard the chartered vessel. Small quantities of equipment and supplies would be transported via airplane; all such equipment and supplies would be inspected for rodents and other pest species prior to departure from Honolulu.

2.4.4 Rodenticide

Pressed-grain bait pellets that are between 0.04 – 0.1 oz (1 – 5 g) containing a rodenticide will be applied at a rate that is expected to successfully eradicate rats from the treatment area according to EPA -approved pesticide label instructions, which define the legally allowable uses and restrictions of the specific pesticide under the FIFRA. All bait application activities will be conducted under the supervision of a Pesticide Applicator *holding a* commercial pesticide applicator *(State of Hawai`i Category 2 (Forest Pest Control))* certification.

2.4.5 Protecting Cultural Resources

Project personnel would exercise caution in general in order to avoid disturbing cultural or historical resources at Palmyra. Personnel would be briefed on the identification of archaeological and historical resources that may be present on the island. Personnel would not dig into the ground or alter the physical environment except at discrete locations for the installation of bait stations.

2.4.6 Monitoring Eradication Efficacy and Ecosystem Response

Rats at Palmyra would be monitored to determine the effectiveness of the eradication action. Rat presence/absence at Palmyra would be monitored for 2 years from the onset of the eradication operation to confirm eradication success.

Resistance to rodenticide exposure is a potential concern; however, it has been 7 years since rodenticide was made available to rats at Palmyra, and because of this, if there were rats in the population that were resistant, it is likely that this trait would not have been selected for and is no longer present in the population (Bailey and Eason 2000, Pitt 2010). *The survival of one ship rat (from a sample of 48) for 21 days during a study evaluating the 'resistance' of rats at Palmyra to brodifacoum (Appendix C) generated concern that that there may be other rats on Palmyra that have similar or greater level of 'resistance'. In evaluating the risks of resistance posed as a result of 2 years of intensive use and then 3 years of localized use of brodifacoum at Palmyra, it is instructive to review literature from studies completed elsewhere. Literature reveals that resistance in three commensal rodents (*R. norvegicus, R. rattus and Mus musculus*) is widely documented for first-generation anticoagulants such as warfarin, and cases of resistance have been observed for two of the three commonly used second-generation anticoagulants (diphenacoum and bromadiolone). While some instance of increased tolerance to brodifacoum have been noted, resistance has never been encountered in black rats or in any of the world's most important pest species (Lund 1984). A study completed in New Zealand also found no evidence of anticoagulant resistance in rats living in areas with a history of 2-5 years of use of brodifacoum (Bailey et al. 2005). Confidence can also be taken from the number of successful rodent eradications completed on islands or in areas with an extensive history of brodifacoum use (e.g. Tawharanui Regional Park; and Motuhora, Rangitoto, and Motutapu islands (all in NZ)).*

Resistance to rodenticide exposure is always a concern. However, the lack of evidence for resistance to brodifacoum in other eradication scenarios, even in situations where brodifacoum had been used for sustained periods of longer than the 6 years, suggest that the risk to the proposed rat eradication on Palmyra is negligible.

For Alternatives B and C that employ aerial bait-broadcast as the primary rodenticide delivery method, rodent detection devices such as traps, flavored chew blocks, tracking tunnels, and motion-sensing cameras would be deployed in a post bait application efficacy monitoring program that would attempt to detect remnant rodents on islands where "mop up" response baiting is feasible. Also, radio collars would be deployed on rats captured on Cooper Island prior to the bait application. The collared rats would be monitored prior to the bait application to confirm vitality and then after bait application to confirm mortality.

For Action Alternative D that employs bait-stations as the primary rodenticide delivery method, eradication efficacy would be measured by the record of station activity and by rat chew blocks and tracking tunnels associated with the stations.

Passive observation by field station staff, visiting scientists, and Service personnel would be a very effective post-eradication efficacy monitoring measure. Due to the aseasonal abundance of natural food resources at Palmyra, a remnant rat population should become readily detectible within 1 year of the eradication effort.

For aerial broadcast alternatives, 4-6 weeks after the second bait application, a small team would return to Palmyra to establish rat detection stations throughout the atoll. Every station would have a corrugated plastic indicator block, and tracking tunnels and motion-sensing camera traps will be spaced intermittently throughout the detection station network. The stations would be checked and serviced every 3 days over a 15-day period. If rat signs are encountered on an isolated land mass that is small enough to effectively retreat by hand, the monitoring team would consult with the project management team about conducting a follow-up bait application on this land mass. Detection stations that are placed in the camp area would be monitored and serviced by trained TNC station staff according to this schedule: once per week for 6 months following the eradication, once per month after 6 months. At 1 year and 2 years after the eradication, a monitoring team would return to Palmyra and re-establish the rat detection stations. During these monitoring efforts, live traps would be added to the detection station network, and stations would be monitored and serviced every 3 days for 15 days.

As part of the atoll's biosecurity program, all station staff would be trained in the detection of rat sign. If signs are observed, indicator blocks would be placed in the surrounding area and any blocks with potential rat chew marks would be sent to rodent identification experts for verification.

Please refer to the eradication monitoring plan presented in Appendix A for a more detailed description of the monitoring activities that would surround the rat eradication.

In addition to the above biosecurity plan, the Service would work with others to conduct biological monitoring both before and after rat eradication in order to detect any positive or negative changes to native biodiversity and ecosystem functioning. Monitoring activities would largely consist of repeated measures on native taxa including birds, reptiles, invertebrates, and plants, and would continue for 5 years post-eradication. Supplemental monitoring activities that require animal handling or alteration of the physical environment may be conducted as well. If required, these supplemental activities may be subject to additional Refuge Special Use permitting.

The timing of the eradication prior to the arrival or after the departure of migratory shorebirds would be the most effective strategy to minimize the risk of short-term rodenticide exposure in a bait broadcast scenario. The Service and its partners would actively monitor the resident shorebird populations by searching known roosting sites for dead or moribund individuals during and directly after the bait application for a period of 2 months. The long-term risk of rodenticide exposure to nontarget shorebirds is low given the low rates of toxicant migration into the soil and the quick decline in toxicant residues in crab tissues post bait application (USDA 2006, Alifano and Wegmann 2010); however, regular and opportunistic monitoring of the shorebird populations would continue throughout the year as part of the Service's resource management for the Refuge. All sick or moribund shorebirds found during and directly after the eradication may be captured and treated with vitamin K, an antidote to anticoagulant rodenticides, as directed by a veterinarian.

2.4.7 Reducing Wildlife Disturbance

Before eradication operations begin, personnel would be briefed on strategies and techniques for minimizing wildlife disturbance. These techniques would be implemented during actual eradication operations. Requirements would include:

- Moving slowly and deliberately to avoid frightening birds.

- Traveling carefully by foot and avoiding sensitive areas when possible to reduce unnecessary impacts.

- All staff would be shown a map detailing areas with sensitive wildlife.

2.4.8 Public Information

Access by the general public onto Palmyra is restricted but the waters surrounding the islands provide diving and snorkeling opportunities. In addition, TNC also conducts occasional visits to the atoll with philanthropic donors and administers an innovative research consortium. Visitors or scientists with an interest in Palmyra would be directly informed about eradication activities and timing and all research activities would be adjusted to accommodate the eradication project. Palmyra Atoll would be closed to all non-essential access during eradication efforts.

With a bait-broadcast approach, public access to the Refuge would be suspended during the operational period of the eradication action. With a bait-station approach, public access to the refuge would be suspended for the first 2 months of the eradication period. Permitted researchers and noncritical FWS and TNC staff would not be present at Palmyra during the eradication implementation period.

All Service-approved island users, including Service personnel, researchers and technicians, contractors, and volunteers would be given written materials stating that rodent bait containing a rodenticide is currently in use, or was recently used, for a rodent eradication. The material would describe its appearance and provide guidelines to avoid unintended human interaction or interference with rodenticide.

Approved pesticide warning signs would be placed along the coastline at typical island access points and would remain in place until bait pellets are no longer found on the atoll after the bait application has been completed. Signs would be posted in English informing any individuals about the presence of and risks associated with rodenticide. Adequate signage would be installed to ensure that even unauthorized visitors to the island are aware of the temporary presence of a toxicant.

2.4.9 Timing Considerations

The seasonal timing for the action alternatives would be an important factor for both the likelihood of conducting a successful eradication and the risk of negative impacts to the biological resources of Palmyra. For most rodent eradications on temperate or subarctic and subantarctic islands, the likelihood of success is influenced by three seasonally dependent factors: 1) the demographic patterns of the local rat population; 2) the availability of alternative food sources for rats; and 3) local weather conditions and seasonal patterns that would affect the feasibility of conducting operations. Furthermore, the risk of negative impacts to biological resources depends on the seasonal breeding and migratory patterns of animals other than rats that may be vulnerable to rodenticide exposure, and to disturbance caused by the bait application process.

Wet, tropical islands and atolls like Palmyra are characterized by aseasonal, productive environments that provide rats with year-round access to food resources. Because of this, rat reproduction on wet tropical islands does not adhere to the seasonal patterns observed in temperate regions (Storer 1962). For the Palmyra rat eradication, the time period for bait application under the preferred alternative would be determined by the seasonality in the local abundance of migratory shorebirds that are at risk of exposure to the applied rodenticide.

Seasonal Patterns of Native Wildlife

Effects of the operational activities associated with rat eradication (e.g., exposure to toxicants, helicopter operations) on the native wildlife could be reduced by avoiding seasons in which large numbers of animals, such as migratory shorebirds, are present. Palmyra's shorebird populations reach an annual low during the months of June and July, while the birds are at breeding grounds in North America. A more detailed description of shorebird residency patterns at Palmyra is given in Chapter 3.

Weather Consideration

Palmyra is within the Intertropical Convergence Zone (ITCZ), a wet, warm climatic region that encircles the Earth near the equator. Palmyra's weather is aseasonal, with regular precipitation year-round and very little fluctuation in temperature and humidity. The aerial bait broadcast action alternatives (Alternatives B and C) are designed with the assumption that 1 week of contingency time may be required to wait out weather conditions such as heavy rainfall that preclude bait application.

2.4.10 Equipment and Materials

Bait Design Requirements

The grain-based matrix of the bait pellets would be attractive as a food item only to granivorous and opportunistic omnivorous animals. Insectivores such as some landbirds, most shorebirds, and some reptiles, would not intentionally consume pellets as food. There would likely be unintentional consumption. Seabird species that reside at or visit Palmyra would also not intentionally consume pellets as food. Additionally, pellets would be dyed blue, which has been shown to make them less attractive to birds (Pank 1976, Tershy et al. 1992, Tershy and Breese 1994) (H. Gellerman unpubl. data).

Aerial Broadcast Equipment

Aerial bait broadcast would be conducted using a single primary-rotor/single tail-rotor helicopter. Helicopter models considered for use in the operations would include the Bell 206B Jet Ranger, Bell 206L4 Long Ranger, MD500, or other small- to medium-sized aircraft.

Bait would be applied from a specialized bait bucket, known as a hopper, and slung beneath the helicopter. The hopper would be composed of a bait storage compartment, a remotely triggered adjustable gate to regulate bait flow out of the storage compartment, and a motor-driven, broadcast spinner that can be turned on (to broadcast bait over a wide swath) and off (to dribble bate in narrow swaths) remotely and independently of the outflow gate. The broadcast device would include a deflector that can be installed when directional (rather than 360°) broadcast is necessary, such as along the coastline.

Bait Stations

Bait stations are box-like enclosures with small entryways designed to be attractive to rodents, but difficult to navigate for other species such as birds and crabs. Bait stations reduce the risk of rodenticide exposure in nontarget species by making bait more difficult to access and reducing the total amount of bait introduced into the ecosystem. The bait station design for Palmyra would need to effectively exclude land crabs, including the large coconut crab, and shorebirds while allowing easy access for rats. U.S. Department of Agriculture-Animal and Plant Health Inspection Service-Wildlife Services (USDA-APHIS-WS) has developed a bait station that meets these criteria (Dunlevy personal comm.); this station design would be deployed at Palmyra during the rat eradication.

2.4.11 Post-Bait Application Rodent Detection and Rodent Reintroduction Prevention and Response

The conservation and socioeconomic benefits of eradicating rats from Palmyra would only be fully realized if *it is successful and any* rodent reinvasion is prevented. *Rat detection response and* pest reinvasion mitigation or biosecurity plans are critical components of successful eradication campaigns. *A quantity of bait (not to exceed 2000 lbs/ 907 kg) would be stored on-island. The Service would appropriately secure, label, and store all bait left at Palmyra in a dry location, ready for use should residual or incursion rats be detected.*

If rat sign were encountered or a rat sighting occurred, rat detection devices (e.g., indicator blocks, live traps, and tracking tunnels) would be established in the area surrounding the sign or sighting and on adjacent islands. Confirmed rat presence would initiate a rat removal response to eradicate a residual population or an incursion (See Appendix B), The area surrounding the confirmed rat detection would be treated with rodenticide applied by hand broadcast or bait station, or by live trapping, or by a combination of the three control methods. The area would be monitored.

The risk of rat reintroduction is high because Palmyra Atoll is a remote Refuge and scientific research station that is maintained through periodic shipments of supplies including consumable and bulk goods, as well as personnel via regular airplane and annual barge service from Honolulu. Occasional visiting research and recreational vessels from all areas of the Pacific also come to Palmyra.

To mitigate for post eradication rodent reinvasion risk, a biosecurity plan that was drafted by the U.S. Geological Survey (Hathaway and Robert 2010) and amended by the Service and TNC and is currently in effect (See Appendix B).

2.4.12 Aerial Broadcast Alternatives

For the aerial broadcast alternatives, helicopter operations would be staged on Cooper Island. Helicopters would fly to designated staging areas where personnel would refill the bait hopper, refuel the helicopter(s), and conduct other necessary maintenance. The staging area would be adequately stocked with bait, fuel, Personal Protective Equipment, and other supplies and equipment to support the helicopters and project personnel during the bait application process. The camp area would be excluded from the aerial broadcast and would be treated by hand-broadcast and placement of bait stations. All inland standing bodies of water and the runway will be excluded from the aerial bait application.

2.4.13 Applying Bait to the Forest Canopy

Previous studies have found that rats frequent the forest canopy at Palmyra (Appendix C) and spend more time in the crowns of coconut palm trees than in the crowns of other tree species comprising the forest's canopy *(Wegmann et al. 2007). Removal of the coconut palms was considered in early planning (2005-2008) as a way to reduce available rat habitat. However, while this action would reduce rat habitat, it would also greatly hinder personnel movement on the ground for rat eradication because of successional plant growing in the resulting light gaps (Wegmann 2009), and would remove a large component of the only crab-free habitat within Palmyra's terrestrial environment (the forest canopy). Bait applied to coconut crowns would not be available to land crabs that would compete with rats for bait, but would be available only to rats. Therefore, the application of bait to coconut palm crowns became a consideration in all of the action alternatives*.

2.5 Pre-Eradication Rodenticide Studies

2.5.1 An Analysis of the Eradication Success of Brodifacoum-25W (Alternatives B, C, and D): an Anticoagulant Rodenticide Registered Under FIFRA

Brodifacoum (3-[3-(4'–bromobiphenyl-4-yl)-1,2,3,4-tetrahydro-1-naphthyl]-4 hydroxycoumarin) is an anticoagulant rodenticide used for the eradication and control of rodents. Brodifacoum25W Conservation (*registrant: Animal and Plant Health Inspection Service (APHIS), USDA; registration number is 56228-36; manufactured Bell* Laboratories, Madison, WI)) is an anticoagulant rodenticide registered under FIFRA for use in the United States and its territories for conservation purposes eradicating rodents from islands. Anticoagulant rodenticides are the most widely used toxicant for control of small mammals worldwide (Eason et al. 2002, Hoare and Hare 2006a, Howald et al. 2007). They act by inhibiting the synthesis of vitamin K-dependent clotting agents in the liver, interfering with the blood's ability to form clots and causing sites of even minor tissue damage to bleed continuously (Hadler and Shadbolt 1975, Eason and Ogilvie 2009). Mortality from anticoagulant rodenticides is caused by internal hemorrhaging, typically within 3-10 days of initial consumption (Buckle and Smith 1994, Howald et al. 2007, Eason and Ogilvie 2009)

.Anticoagulants are classified as first or second-generation according to their toxicity (Eason et al. 2002). *The term "first generation anticoagulants" was introduced to contrast anticoagulants that were not effective against rodents with genetic resistance to them with anticoagulants that could kill resistant individuals (Dubock and Kaukeinen 1978). The chemistries that became known as "second-generation anticoagulants" – a term apparently first used in print by Marsh et al. (1980) – were developed through a search for rodenticides (Hadler and Shadbolt 1975) that would be effective against individual commensal rodents that are resistant to warfarin, pindone, diphacinone, chlorophacinone, and other first-generation anticoagulants. See also Jackson and Ashton (1992). Why the second generation anticoagulants can kill warfarin-resistant individuals (greater affinity for the "Vitamin-K receptor") was fully characterized after the compounds were put into use as rodenticides. The so-called "single-feeding" effect attributed to brodifacoum (Dubock and Kaukeinen 1978), and other second-generation anticoagulants results from this greater affinity, but is dependent upon the amount of the compound that is ingested on the first day of exposure to it. The amount of anticoagulant ingested on the first day of exposure is determined by the rodent's willingness to consider the bait as a food item; the concentration of the rodenticide in the bait; the palatability of the bait to the rodent; and, in a control situation, the amount of bait available to the rodent. The last of these is an issue on Palmyra due to documented competition for bait with other terrestrial animals, chiefly crabs.*

First-generation anticoagulants generally appear to be most effective at achieving mortality in rodents when consumed over several consecutive days, although a single high dose may be toxic to some animals (Eason and Ogilvie 2009). Second-generation anticoagulants are more toxic than first-generation, with lower LD_{50} values (median lethal dose, or the amount required to kill 50 percent of a test population), and are typically 'single feed' poisons in high enough concentrations (Hone and Mulligan 1982, Eason and Ogilvie 2009). The generally lower toxicity of first-generation anticoagulants compared to second-generation anticoagulants is attributed to a poorer ability to bind to sites in the liver. Second-generation anticoagulants have a greater binding affinity than first-generation anticoagulants, which increases the rate of metabolism by 10; therefore, requiring only one feeding to be effectively kill a rat (Parmar et al. 1987). In order for either toxicant to be lethal, levels in the liver must reach a toxic threshold and this level can vary widely between species and even between individuals within a species. However, any rodenticide can be effectively used to eradicate an entire rodent population *where there are no resistant individuals,* if all individuals within the population consume enough bait over an appropriate amount of time.

Table 2.3. The composition of Brodifacoum-25W

Bait product name	**Bait pellet size (g ± 1SD)**	**Active ingredient**		**Inert ingredients**		**Optimal environmental conditions**
		Rodenticide name	**Conc^n** (ppm)	**Description**	**Conc^n** (%)	
Brodifacoum-25W	1.55 – 2.3[1]	Brodifacoum	25	Sweet, cereal flavor	99.9975	Wet climates[1]

Note: [1](Wegmann 2008, Alifano and Wegmann 2010)

Brodifacoum-25W is designed to be highly attractive to rodents, such that island rodents are more likely to choose the bait over natural food sources. The predominant inactive ingredients in these bait products are non-germinating grains (either sterile or crushed) (Table 2.3).

Brodifacoum-25W is a "restricted use pesticide" according to the EPA-approved pesticide label developed for each product under FIFRA:

- The product may only be used on islands or vessels [marine is implied].

- The product may only be used for the control or eradication of invasive rodents.

- The product are only available for sale to 3 Federal government agencies: US Department of Agriculture (Animal and Plant Health Inspection Service and Wildlife Services), U.S. Fish and Wildlife Service, and U.S. National Park Service; although these agencies can make the bait available to other agencies or private parties under their oversight.

- The product may only be applied by Certified Pesticide Applicators (a certification generally provided by the State or Territory in which the bait is to be applied) or persons under their direct supervision.

Brodifacoum-25W Bait Product

Brodifacoum is the most frequently used rodenticide for rodent eradication from islands. Of the 278 successful island rodent eradication events worldwide (where the toxicant applied was known), 197 (71 percent) used brodifacoum as the primary rodenticide (Howald et al. 2007, Island Conservation unpubl. data). On 47 percent of successful eradications bait stations were the primary technique used to deliver brodifacoum; on 29 percent, aerial broadcast was the primary technique; on 21 percent, hand-broadcast was the primary technique; and on 17 percent, a combination of all three techniques and/or the use of traps were used. The most commonly used technique was aerial broadcast supplemented with hand-broadcast (14 or 7 percent) (Howald et al. 2007, Island Conservation unpubl. data).

Brodifacoum is highly toxic to rats and requires the consumption of no more than a few bait pellets (weighing 2g each) during a single feeding event, or during several feeding events, to result in mortality (Erickson and Urban 2004, Eason and Ogilvie 2009). The LD_{50} dose has been achieved in Norway rats (*Rattus norvegicus*) ingesting 1.5 g (0.052 oz) of brodifacoum bait in a single feeding (0.3 mg/kg at 50 ppm brodifacoum) (Buckle and Smith 1994), but within and between *Rattus* species variations do occur. The toxicity of brodifacoum to rats makes it desirable as a tool for rat eradication because it reduces the need to make bait consistently available to rats for an extended period of time.

Brodifacoum-25W is an unwaxed cereal bait product with 25 ppm brodifacoum, available in 0.05 – 0.1 oz (1.5-3 g) pellets with a sweet, grain flavor. The product is manufactured specifically for conservation purposes; Brodifacoum-25W is for use in wet climates and is designed to break down slowly (≤ 14 days) after exposure to moisture, including both dew and rainfall, making this bait product suitable for use in Palmyra's humid wet environment.

Compressed cereal bait products containing brodifacoum at a concentration of 25 ppm (Bell Laboratories, Madison, WI) have been used to successfully eradicate rats from at least 5 islands using aerial broadcast as the primary technique (Samaniego-Herrera et al. 2009, Buckelew et al. 2010, Howald et al. 2010), and from one island using hand-broadcast (Hall et al. 2006). In addition, the bait product has been tested for efficacy and palatability under laboratory conditions prior to their use in eradication operations.

To successfully eradicate rats from an island, every rodent must be exposed to a sufficient quantity of rodenticide, by either consuming bait or by eating other animals that have consumed bait, to acquire a lethal dose of brodifacoum. A bait trial must similarly demonstrate that 100 percent of the rodents in the trial area were lethally exposed to bait. Compressed cereal bait products containing brodifacoum at a concentration of 25 ppm (Bell Labs, Madison, WI) have also been tested with favorable results in at least 3 field sites: the Aleutian Islands in Alaska (Buckelew et al. 2008), Palmyra Atoll in the equatorial Pacific (Buckelew et al. 2005), and Pohnpei, Micronesia in the western Pacific (Wegmann et al. 2007).

During field trials, Brodifacoum-25W was shown to be palatable to rats in comparison to naturally-available food sources (Buckelew et al. 2005, Buckelew et al. 2008, Alifano and Wegmann 2010). The palatability of Brodifacoum-25W to rats makes it a desirable tool for rat eradication because it increases the probability that every rat on the island will consume the bait.

While high toxicity and high palatability are desirable bait characteristics from the perspective of successfully eradicating rats, these same characteristics can be undesirable from the perspective of minimizing nontarget impacts (Hoare and Hare 2006a). Brodifacoum is highly toxic to many bird species (Erickson and Urban 2004), and can be toxic to secondary consumers that prey on primary bait consumers (Rammell et al. 1984, Dowding et al. 1999, Stone et al. 1999). Furthermore, because brodifacoum can persist in the body tissues of vertebrate and invertebrate species, potential nontarget impacts from brodifacoum through secondary exposure of predators, has been shown to be extended beyond the period of time that bait pellets themselves are available in the environment (Eason et al. 2002, Fisher et al. 2004). The pellets are manufactured with a grain base to be attractive as a food item to rodents, but the pellets are also likely attractive to other granivorous, opportunistic, and omnivorous animals. Other species such as insectivores (some landbirds, shorebirds, reptiles), frugivores (e.g., fruit-eating pigeons), and piscivores (e.g., fish-eating seabirds) would be highly unlikely to identify the pellets as a food item, would not be as attracted to the pellets as food, and thus would be unlikely to intentionally consume them. Additionally, pellets would be dyed blue to act as a deterrent; this technique has been shown to make pellets less attractive to some birds and reptiles (Pank 1976, Tershy et al. 1992, Tershy and Breese 1994). Despite these efforts, mortality in individual nontarget birds during several rat eradication operations has been attributed to brodifacoum bait products that were used for the eradications (Eason and Spurr 1995, Eason et al. 2002, Buckelew et al. 2010).

In an effort to reduce risks to wildlife and people, but allow rodenticide products to remain available, the EPA recently limited the use of brodifacoum and nine other rodenticides. The EPA's *registration* of Brodifacoum-25W explicitly exempted its use for island rodent eradications (U.S. Environmental Protection Agency 2008). The New Zealand Department of

Conservation, the world's leader in island pest eradications, identifies brodifacoum as the preferred toxicant for island rodent eradication (Eason and Ogilvie 2009). These explicit exemptions are logical in light of the fact that island rodent eradication operations are fundamentally different from rodent control operations. Rodent eradications are primarily attempted on islands with minimal human use or isolated land masses that provide a finite area; the intent of an eradication is the complete removal of rodents, where experts can ensure that every rodent will receive a lethal dose of the toxicant. Control efforts on the other hand, are primarily used on the mainland, for agricultural purposes, or on large islands that are heavily used; the intent of a control effort is to keep the rodent population as small as possible in the treatment area because it is impossible to ensure that every rodent will receive a lethal dose of the toxicant. The potential risks of using brodifacoum for eradication can be avoided or reduced more effectively on an isolated island, with a finite time period of bait availability, than for rodent control operations on mainland or larger-island sites where rodenticide is chronically available in the environment. The generally high cost and logistical complexity of conducting a whole-island rodent eradication necessitate techniques and tools that maximize the probability of successful eradication on the first attempt.

2.5.2 Preliminary Eradication Trials Conducted at Palmyra Atoll

Prior to project implementation, the Service and partners from Island Conservation (IC) conducted trials at Palmyra as part of the detailed operational planning process, including a determination of a successful bait application rate for aerial broadcast, as well as the development and design of bait stations and canopy baiting techniques. All studies have focused on the need to maximize the probability of eradication success while minimizing the risk of harming nontarget individuals through exposure to rodenticide (as described above).

2004 Rat Eradication Feasibility Study (see Appendix C for the Full Report)

In August 2004, a team of nine people with representatives from Island Conservation (IC), USDA-National Wildlife Research Center, USDA-Wildlife Services, FWS-Ecological Services, FWS- Refuges, and the Department of Conservation New Zealand visited the atoll for 8 days to investigate the previous, failed eradication attempt in 2001-2002 and to develop strategies for a subsequent eradication program. Two IC staff and one FWS representative remained on the atoll for an additional month to complete the planned research. The main goals of this expedition were to:

- Assess the previous effort to eradicate rats from Palmyra Atoll, both to learn why it was not successful, and what experiences from that effort could be used to develop methods for a follow up rat eradication.

- Conduct site-specific research needed to develop a plan for successful rat eradication.

Palmyra's high rainfall and aseasonal environment were recognized as obstacles to successful rat eradication. They make it difficult for bait to maintain its palatability and attractiveness to all rats for longer than 1 - 2 weeks post-delivery. In addition, abundant land crabs compete with rats for bait and make it difficult to ensure that enough bait is available to all rats for an adequate time period of 4 days (Wegmann 2008).

Results from a study of rat home range size and habitat use, conducted during the 2004 site visit, indicated that the bait station spacing of 50 x 50 m used in the previous rat eradication attempt at Palmyra may have been insufficient to deliver bait into every rat's ranging territory. This is due to the fact that the rats at Palmyra live in a three-dimensional habitat, using resources and habitat that includes the coconut palm canopy. For future eradication projects, it was recommended that a 25 m grid for the placement of bait stations would be needed to increase the proportion of rats coming into contact with bait stations, but that alone might not be adequate to intercept all rats.

The site assessment indicated that a bait broadcast treatment would require an application rate of 60 - 80 kg/ha to ensure that enough bait was available on the ground for 4 days to overcome competition from land crabs that are attracted to and consume the bait. Land crabs are not negatively affected by the anticoagulant rodenticides. This study was unable to precisely determine an effective broadcast application rate because of the high density of crabs and a lack of enough placebo bait with which to complete the studies.

To test the efficacy of several bait station designs, the team ran 35 separate lab trials with a total crab exposure time of 41,175 hours. Three bait stations were evaluated: pipe stations, bucket stations, and box stations. Of the three, only the pipe station was accessed by crabs, and coconut crabs (*Birgus latro*) were the only species that entered the station and consumed bait. The bucket stations excluded all crab entries across each taxonomic group, although coconut crabs easily accessed the top of the bucket station. The box station also excluded all crab entries across each taxonomic group; coconut crabs were able to climb the PVC pipe that supported the box and reach the delivery device, but were unable to access the secured bait inside the box. Hermit crabs (*Coenobita* spp.) were able to climb the support pipe for both the pipe and box stations, but were unable to access bait as the platforms on both stations precluded entry. Only large adult hermit crabs were observed climbing the PVC pipe supporting the box station. Both adult and larger sub-adult hermit crabs were able to climb the half-inch diameter pipe supporting the bait station. In several instances, sub-adult hermit crabs were observed clinging to the shell of adult crabs as they climbed, and were therefore capable of reaching higher on the stations than if climbing unaided. Land crabs (*Cardisoma* spp.) were not observed making any entry attempts into any of the bait stations during the lab trials. It is possible that land crabs would have a greater effect to eradication efforts if broadcast methodologies were incorporated. However, given the small number of stations available for use in this study, and the short duration of testing, field evaluations provided limited information on crab exclusion and rat accessibility. In 3 nights of field use, only a single bucket station received a rat visit. All stations in the field trial were free of any indication of crab entries.

The group also conducted a study to determine if Palmyra's rat population includes individuals that were resistant to brodifacoum due to previous, chronic baiting efforts. Seven rats died with a single dose at the LD_{50} level for black rats. Furthermore, 28 of 29 rats died within 2 weeks of the initial dose. These results indicate that there may be a relatively small portion of the population that is resistant to the effects of brodifacoum. The length of time between the initial dose and death of at least one rat supports the notion that a small portion of the population may be resistant to effects of brodifacoum. This conclusion is further supported by the lack of hemorrhaging observed during the necropsy of the rat that persisted 21days after the initial dose;

this rat received 4 times the LD_{50} for its body weight and did not show obvious signs of hemorrhaging.

Finally, the 2004 feasibility study identified non-resident migratory shorebirds as being at risk of either primary or secondary exposure to the rodenticide. The species of concern include the bristle-thighed curlew (*Numenius tahitiensis*), and the Pacific golden-plover (*Pluvialis fulva*). Both species overwinter on the atoll, with some individual juvenile birds present throughout the year. The most effective mitigation strategy is to time the eradication when the minimum number of birds is present on the atoll.

2005 Trial Hand Broadcast Eradications (see Appendix D for the Full Report)

In July 2005, a team of six FWS, IC, and New Zealand Department of Conservation personnel returned to Palmyra to test trial rat eradication broadcast methodologies discussed in the 2004 feasibility assessment. The main goals of this expedition were to:

- Evaluate the palatability and efficacy of the newly formulated bait (Brodifacoum-25W bait, containing 25 ppm brodifacoum, Bell Laboratories, Inc.) on the local rat population under laboratory and field conditions.

- Conduct a broadcast trial rat eradication using Brodifacoum-25W bait.

- Evaluate rodenticide exposure risks to nontarget species.

The group conducted trial eradications on 5 small islets at Palmyra, totaling 4.08 ha. Each island was treated with a hand broadcast on the ground using PI-25 (the prototype of Brodifacoum-25W), and by slingshot, pole or hand broadcast into every coconut palm tree on each island. At the time of the study there were no examples of broadcast eradications using diphacinone so products using that toxicant were not included in the study design.

The team developed a bait application rate that ensured bait availability to all potential rat territories in the study area for a minimum period of 4 days. A calibration trial indicated that between 54–80.4 lb/acre (60 - 90 kg/ha) would be required to successfully treat all rats; however, due to uncertainty in the data the team initially applied bait at a high application rate on the first treated island, and reduced the application rate for subsequent islands based on bait uptake monitoring. The bait was broadcast at 84.8 lb/acre (95 kg/ha; Whippoorwill Island), 75.9 lb/acre (85 kg/ha; Home Island), 71.4 lb/acre (80 kg/ha; Fern Island), 62.5 lb/acre (70 kg/ha; Bunker Island), and 54lb/acre (60 kg/ha; Little East Island). The team then monitored bait uptake and the effect on the local rat population.

The team determined that bait applications of 80 kg/ha or less would be inadequate to ensure that bait would be available in every potential rat territory for at least 4 days on islands with a high abundance of land crabs and hermit crabs that consume the bait (but are not negatively affected by the rodenticide). The bait consumption study indicated that an application rate of 85 - 95 kg/ha would be adequate to overcome competition from land crabs, with 99.9 percent bait removed from the islands by 7 days post-broadcast. Direct (radio collared rats and live traps) and indirect (wax chew blocks) monitoring of efficacy indicated that these application rates were successful in eradicating rats from all the treated islets.

A small juvenile, weanling rat was detected live 8 days after the broadcast on the 95 kg/ha treated island but was found moribund on day 10. The discovery of a live weanling rat strongly suggests that a second bait application is necessary to ensure bait is available to all weanling rats that would not have left the nest while bait would be available from the first application. For the rat eradication to have a high probability of succeeding by broadcast with PI-25, it was recommended by the team that bait be applied twice at 90 kg/ha, 10 - 14 days apart, to overcome competition by the abundant land crabs and hermit crabs, and to ensure enough bait is available to the entire rat population for a minimum of 4 days.

To evaluate the risk of rodenticide exposure to nontarget species, the team monitored the local shorebird population before and after the bait applications, and sampled land crabs for brodifacoum residues on days 2, 6, 10, 21 and 56 post-broadcast. Of the 4 shorebird species that are common to Palmyra, bristle-thighed curlew, wandering tattler, Pacific golden-plover , and the ruddy turnstone, the curlew and plovers were believed to be at the greatest risk of primary and secondary exposure to the rodenticide due to foraging habits that could lead them to directly consume bait, or feed on hermit crabs that consumed bait. The frequency of detection of these shorebirds was consistently higher post broadcast and was likely due to migratory influx. No dead or moribund birds were detected in the treated areas.

2008 Bait Broadcast Application Rate Assessment (see Appendix E for the Full Report)

The main goals of this expedition were to:

- Test the maximum bait application rate stipulated by the bait product label against Palmyra's challenging eradication environment.

- Test an application rate that is greater than what is currently allowed by the bait product label yet lower than the rates tested during the 2005 trial eradications.

- Measure rat carcass longevity (assess risk of rodenticide exposure for nontarget species).

- Measure invertebrate and reptile (gecko) exposure to Brodifacoum-25W in a bait broadcast scenario.

From June 19 to July 5, 2008, non-toxic (placebo) Brodifacoum-25W Biomarker bait (produced by Bell Laboratories) was hand-broadcast to the ground and forest canopy on 3 islands at Palmyra Atoll: Home Island (1.7 ha), Whippoorwill Island (1.9 ha), and Portsmouth Island (0.8 ha). Rats were eradicated from Home and Whippoorwill Islands during trial broadcast-based eradications in 2005 (Buckelew et al. 2005), but have since re-established at densities that matched those found prior to the 2005 trial eradications (Wegmann and Middleton 2008).

The biomarker bait used in this study contained pyranine, a non-toxic hydrophilic, pH-sensitive fluorescent dye. Pyranine is non-toxic, odorless and tasteless, and is fluorescent green when exposed to UV light. While biomarkers are commonly used in wildlife management studies (Fry and Dunbar 2007), the use of pyranine as a biomarker agent within an eradication scenario is a relatively new convention (Towns and Broome 2003, Greene and Dilks 2004, Griffiths et al. 2008).

Bait was broadcast to the ground and forest canopy at the label-specified maximum application rate (18 kg/ha followed by 9 kg/ha 5 days later) on Whippoorwill and Portsmouth Islands, and at more than twice the maximum label application rate (36 kg/ha followed by 36 kg/ha 5 days later) on Home Island. Bait was hand-broadcast by a 6-person baiting line in which broadcasters were spaced 5 m apart. Bait consumption data were collected to describe the amount of bait consumed by both target and nontarget species: Whippoorwill (18 plots), Home (22 plots), and Portsmouth (7 plots). Bait consumption plots were 25 m long x 1 m wide.

Hagaruma live catch rat traps were placed 10 m from each other along transects traveling the length of each island. Captured rats were brought to a central processing location at each study site. Rats were first inspected for external signs of biomarker using handheld UV flashlights. If a rat showed external any signs of biomarker (paws, anus, tail, mouth), it was euthanized and inspected for internal signs. Rats without external signs were marked with a permanent marker on the proximal-dorsal section of their tails and released at their point of capture.

Both of the bait application rates tested in this study failed to expose 100 percent of rats from each sample population. On Whippoorwill and Portsmouth Islands (treated with 18 kg/ha + 9 kg/ha), 32 percent (29/91) and 3 percent (1/31), respectively, of the rats sampled showed no external or internal signs of biomarker. On Home Island (treated with 36 kg/ha + 36 kg/ha), 5 percent (1/21) of captured rats showed no signs of biomarker.

Lower application rates (9 kg/ha and 18 kg/ha) resulted in rapid bait consumption. Following the 9 kg/ha application on Whippoorwill, only 2 of 180 pellets (4.6 g of 414 g of bait) remained in 18 bait consumption plots 24 hours after the bait application; the 2 remaining pellets were consumed by day 2 (Figure 2.1), and bait was not observed elsewhere on the island. Bait consumption on Portsmouth showed a similar trend, as nearly all of the 9 kg/ha application was consumed within 24 hrs, and all pellets within bait consumption plots were consumed within 3 days. The 18 kg/ha baiting regimes on Portsmouth and Whippoorwill resulted in more bait remaining after the initial 24 hours; however 100 percent bait consumption occurred in all plots on both islands within 3 days of the bait application. The 36 kg/ha bait applications at the Home study site resulted in 60 percent bait consumption within 24 hours, and small amounts of bait persisting until day 4 after the first and second applications.

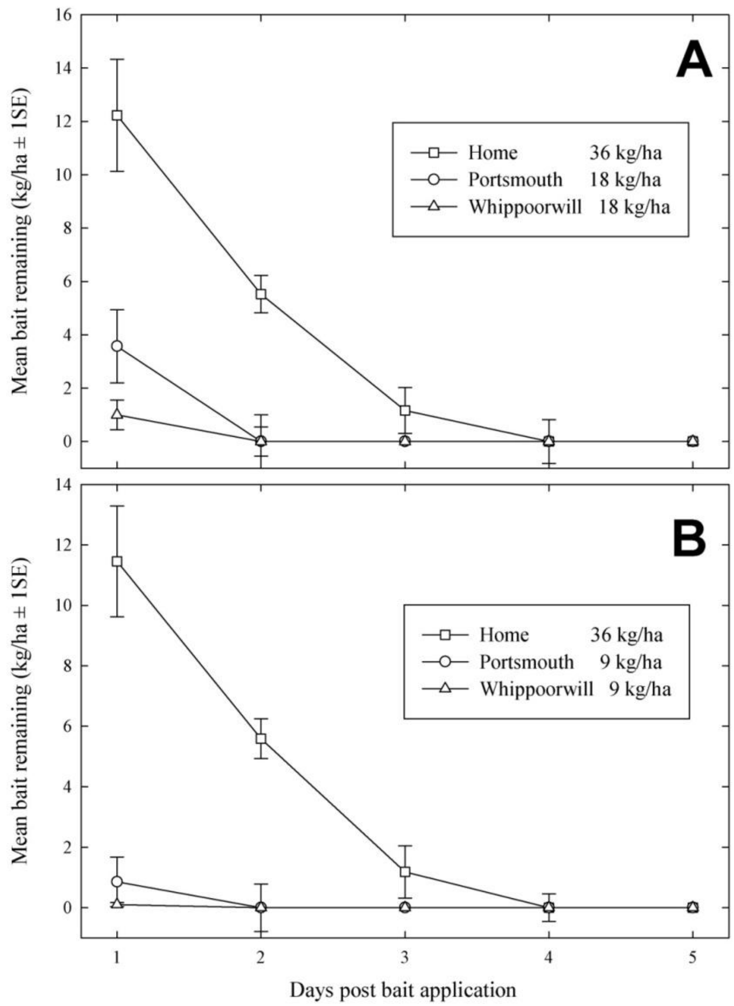


Figure 2.1. Daily bait consumption estimates for the first “A” and second “B” bait applications on Home, Portsmouth, and Whippoorwill Islands. Mean bait consumption was measured by observing bait pellet removal from fixed 25 x 1 m plots: Home = 22 plots, Portsmouth = 7 plots, Whippoorwill = 18 plots. Error bars represent ± 1 standard error of the sample mean.

At Palmyra, the bait consumption trends and rat bait-exposure ratios suggest that high bait application rates are needed for bait broadcast campaigns to succeed on crab rich islands. Even with 2 bait applications of 36 kg/ha – 3 times more bait than is typically applied to temperate islands (Veitch and Clout 2002, Towns and Broome 2003) – the operation failed to expose 100 percent of the rat population. Furthermore, an increase in bait consumption was observed during the second application at Home Island, and this happened in the absence of rats (n = 17) removed from the population during the sampling session that followed the first bait application. This suggests that at Palmyra, crab-related bait consumption prevents repeat bait applications more than 5 days apart from having a cumulative effect on the amount of bait made available to target rodents. To be effective, the bait application rate for the second broadcast should be *high enough to overcome competition for bait by land crabs.*

Also, for the 2 sites treated at 18 kg/ha + 9 kg/ha, bait consumption was greater at the study site with the highest crab index of abundance value – Whippoorwill Island. Across the 3 study sites, bait consumption was greatest at the site treated with the highest bait application rate – Home Island. These results suggest that crab abundance has a positive correlation with bait consumption, as does the bait application rate. Therefore, increased bait application rates are needed to overcome crab-related bait consumption; however, this is not a linear function because an increase in bait application rate leads to an increase in bait consumption – to an unspecified asymptote.

To successfully eradicate rats from Palmyra Atoll using a bait broadcast technique, an application rate greater than 36 kg/ha (shown to be unsuccessful in this study) is required. The 2005 trial eradications demonstrated that rats can be eradicated from islands with high land crab densities when bait is broadcast at rates from 85kg/ha to 95 kg/ha. The findings of the 2008 biomarker study, in concert with the results from the 2005 trial eradication, indicate that a Palmyra-specific amendment, under FIFRA, to the existing bait product label that permits bait application rates as high as 90 kg/ha (specific to Palmyra Atoll) will be needed to conduct a successful bait broadcast-based eradication at Palmyra Atoll.

2010 Bait Palatability and Ecotoxicology Studies (see Appendix F for the Full Report)

From April 29 to May 28, 2010, two IC personnel visited Palmyra Atoll to assess the fate, palatability, and environmental impacts associated with the broadcast application of two rodenticide products: Diphacinone-50 (50 ppm Diphacinone), and Brodifacoum-25W (25 ppm brodifacoum). The main components of this study were:

- Measure the concentration of toxicant found in the surface soil (≥ 2 cm) after exposure to bait pellets for time periods that would be expected during a real broadcast-based eradication.

- Assess the concentration of rodenticide residue in the tissue of hermit crabs *(Coenobita spp.*) and excrement from land crabs (*Cardisoma carnifex*) in a simulated bait broadcast setting.

- Assess the palatability, for rats and land crabs, of the two bait products currently approved for use to eradicate rats at Palmyra Atoll.

- Conduct site-specific research needed to inform the development of operational plans for a successful rat eradication.

Palmyra consists of 618 acres 250 of emergent land (fragmented into 25 islands), 16 of which were used during these studies. Rats were live-captured on the following islands: Strawn, Cooper, Aviation, Quail, Whippoorwill and Bunker, Eastern, Portsmouth, Barren, the South Island Complex, Paradise, Home, Sand, Fern, Lost, and the North-South Causeway (Figure 2.1). Soil samples were obtained from Lost Island and Cooper Island. All land crabs were collected haphazardly from Cooper Island and Strawn Island. Hermit crabs were collected from Whippoorwill Island.

Analysis of the soil samples, collected from the plots in the study that looked at rodenticide leaching from pellets placed on the ground into the surface soil, found low amounts of rodenticide in sandy and organic soil regardless of the exposure period (2, 7, 28, 36, and 50 days). The concentrations of brodifacoum found in sandy soil samples were similar across all sample periods (DF=3 F=1.59 P= 0.26), and diphacinone was not detected in sandy soil samples, regardless of the exposure period. In organic soil, we found no difference in the brodifacoum concentration (DF= 3 F= 0.33 P=0.80) or diphacinone concentration (DF= 3 F= 2.67 P= 0.11) between exposure periods.

Out of 48 samples (not including controls), only two contained a toxicant concentration that was high enough to quantify. The rest of the samples yielded a zero value (toxicant not detected) or a ‘trace’ value (toxicant detected but < method detection limit) (Figure 2.2). This study suggests that only minimal amounts of both rodenticides (from either Diphacinone-50 or Brodifacoum-25W bait) remain in the surface soil after the maximum period of exposure (the time a bait pellet would be expected to be in contact with the soil) that would be experienced during a broadcast bait application at Palmyra.

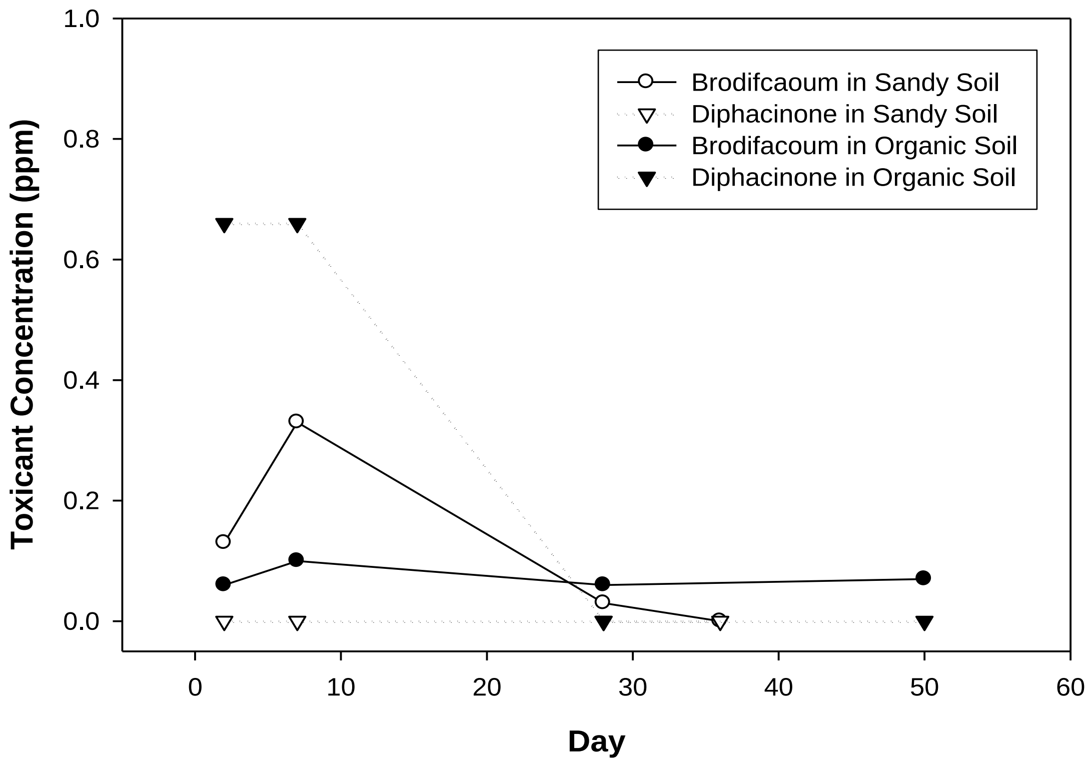


Figure 2.2. Mean concentration of brodifacoum (N=3 per day) and diphacinone (N=3 per day) found in surface samples of sandy soil and organic humus soil over four exposure periods. Samples were taken directly beneath bait pellets (or remains of pellets) on day 2 and day 7. Samples taken on days 28, 36, and 50 were taken directly beneath where a pellet had rested for 7 days.

The mean concentration of toxicant residue within crab excrement varied by exposure period for both rodenticides (Table 2.4). Toxicants were most concentrated within crab excrement during the first two sampling periods. Both brodifacoum and diphacinone were actively consumed during these periods, until the bait products were removed from crab diets on day 7. A reduction in the toxicant concentration in sampled excrement was observed between day 6 and day 10 (Figure 2.3).

Table 2.4. Mean concentration of toxicant (ppm) within excrement samples from crabs that consumed 25W or D-50 bait pellets ad lib for 7 days.

Analyte	Day 2 concentration ± (1SD)	Day 6	Day 10	Day 23
Brodifacoum (ppm)	2.8 (1.2)	2.6 (1.3)	1.0 (0.7)	0.25 (0.3)
Diphacinone (ppm)	8.4 (2.9)	8.9 (8.4)	2.5 (0)	2.5 (0)

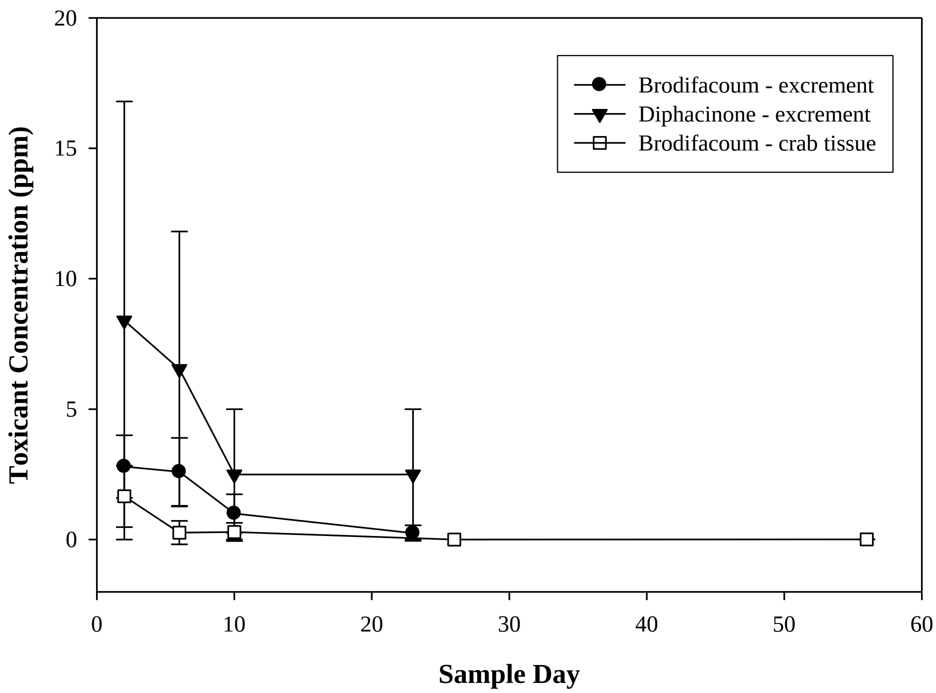


Figure 2.3. Comparison of the concentration (ppm) of brodifacoum in crab excrement and tissue over time to the concentration (ppm) of diphacinone in crab excrement. The concentration of brodifacoum in crab tissue was determined by the National Wildlife Research Center Analytical Lab (USDA 2006) after a trial broadcast eradication in 2005. Crabs consumed rodenticide until day 7, and subsequently fed on natural food items. Positive “trace” results were included as ½ the reporting limit (0.1 for brodifacoum and 2.5 for diphacinone).

Palatability trials were run using 68 rats. While both bait products were consumed when challenged against naturally available food items (solid coconut endosperm, coconut meristem, and *Pandanus* mesocarp), neither bait product was found to be significantly more palatable than the other.

2010 Genetic Sampling, Rat Detection, and Canopy Baiting Studies (see Appendix G for the Full Report)

Primary Objectives:

- Collect genetic samples from the *R. rattus* population at Palmyra Atoll.

- Measure the baseline detection success of three devices: chew blocks, tracking tunnels, and live traps.

- Construct and deploy bait stations in a variety of environments to measure variability in bait removal rates, crab interference, structural integrity of the stations, and overall attractiveness to rats.

- Determine the degradation rates and effects of weathering and decay for different types of canopy bait designs, and measure the persistence of canopy baits in the crowns of coconut palms.

- Document rats consuming pellets and canopy baits in the crowns of coconut palms; determine which type of bola material is preferred by rats.

- Field-test three canopy bait launching devices and establish the situations in which each performs best.

- Monitor placebo bait pellets in the marine environment to determine degradation rates of the matrix under varying conditions.

- Quantify the degradation rate of rat carcasses in areas with high shorebird densities, and photograph any avian species interested in consuming the carcasses.

A team of three people conducted several studies at Palmyra Atoll from September 22, 2010 until October 17, 2010. Rodent live-trapping confirmed that rats were present on all landmasses visited, with the exception of Dudley Island where no rats were detected. Captured rats (304 total) ranged from juvenile to adult (24 g to 227 g), indicating that breeding had recently taken place. Chew blocks were slightly more successful at detecting rats in comparison to live traps, but needed frequent replacement, as the hard candy interior lasted less than 24 hours due to rats, crabs, ants, rain, and humidity. Tracking tunnels were unsuccessful at detecting rat presence until coconut bait was placed inside as an added incentive. Bait station performance, pellet removal rate, and station resistance to crab-related interference varied widely depending on the location of the station.

Surgitube, a tubular gauze dressing, was the most effective material for canopy bait ("bola") construction. It was easy for rats to chew through, retained pellets during high-velocity launches, and prevented inside bait from molding. Three launching devices were tested, the HyperDog slingshot, the Big Shot pole-mounted sling shot, and the Squall 250 air cannon. Each device performed best within specific conditions, and it was evident that a combination of methods may be required for fast and accurate canopy baiting. Once in the palm canopy, bolas were typically consumed within 24 hours.

Placebo bait pellets placed in the marine environment degraded completely within 48 hours, disappearing faster on the intertidal ocean-facing side of the atoll (within 24 hours). Rat carcasses placed in locations frequented by shorebirds and typified by low crab densities (North Beach and along the runway), degraded due to consumption by invertebrates and environmental decay within 72 hours; carcass feeding by shorebirds was not observed in the images captured by motion sensing cameras that were monitoring the rat carcasses.

2.5.3 Actions Taken to Develop the Action Alternatives Presented in this Document

- **Alternative B: Aerial Broadcast of Brodifacoum**

  2004
    - Bait weathering study
    - Toxicant efficacy (field) study

  2005
    - Bait weathering study
    - Trial eradication
    - Bait palatability study
    - Measurement of toxicant residue in crab tissue

  2008
    - Bait application rate study
    - Nontarget species bait exposure pathways study

  2010
    - Toxicant bioavailability study
    - Measurement of toxicant integration into soil
    - Bait palatability study
    - Canopy bait design and testing
    - Bait station design and testing
    - Bait fate in the marine environment study
    - Rat detection device testing
    - Eradication monitoring plan

- **Alternative C: Aerial Broadcast of Brodifacoum, with Proactive Mitigation of Risk for Vulnerable Shorebird Taxa**

  2004
    - Bait weathering study
    - Toxicant efficacy (field) study

  2005
    - Bait weathering study

- Bait palatability study
- Toxicant residue in crab tissue

2008

- Bait application rate study
- Nontarget species bait exposure pathways study

2010

- Toxicant bioavailability study
- Measurement of toxicant integration into soil
- Bait palatability study
- Canopy bait design and testing
- Bait station design and testing
- Bait fate in the marine environment study
- Rat detection device testing
- Eradication monitoring plan
- Testing of shorebird capture methods

- **Alternative D: Bait Stations with Brodifacoum, with Canopy Baiting**

2004

- Bait weathering study
- Toxicant efficacy (field) study

2005

- Bait weathering study

2008

- Nontarget species bait exposure pathways study

2010

- Toxicant bioavailability study
- Measurement of toxicant integration into soil
- Bait palatability study
- Canopy bait design and testing
- Bait station design and testing
- Rat detection device testing

2.6 Alternative B: Aerial Broadcast of Brodifacoum-25W

2.6.1 Rationale

Brodifacoum is the most extensively used rodenticide for rodent eradication from islands. Of the 332 successfully reported island rodent eradication efforts worldwide as of 2007, 71 percent used brodifacoum as the primary rodenticide (Howald et al. 2007). The specific product Brodifacoum-25 has been used successfully on four islands, all using aerial broadcast as the primary technique. Three of these islands were treated with Brodifacoum-25D (especially formulated for dry environments), and one was treated with Brodifacoum-25W (especially formulated for wet environments). While every project is unique, and techniques have varied substantially between projects, many of the basic parameters for success using brodifacoum are now well-established within the conservation world. Brodifacoum is highly acutely toxic to rats; this classification describes a chemical that has a high level of acute toxicity and the ability to cause harmful local and systemic effects after a single exposure.

Brodifacoum-25W has also been tested with favorable results in 2 similar tropical study sites: Palmyra Atoll in the equatorial Pacific (Buckelew et al. 2005), and Pohnpei, Micronesia in the western Pacific (Wegmann et al. 2007).

2.6.2 Summary of Bait Delivery Methods

Brodifacoum-25W bait would be systematically applied to all land areas above the mean high tide mark. *Draft operational details for Alternative C (Preferred Alternative) are presented in Appendix K and include elements such as eradication techniques, team members and roles, communications, timing, health and safety, monitoring, bird mitigation, and logistics. Many lessons learned from the Rat Island, Alaska eradication project (Salmon and Paul 2010); such as minimizing risks to nontarget species while maintaining a high probability of eradication success, comprehensive logistical planning, structured communications, recording keeping, and documentation of impacts; have been taken into consideration and incorporated.*

For areas at Palmyra that cannot be baited by helicopter, such as sections of land that are too narrow to avoid bait spread into the marine environment, personnel would broadcast bait by hand, including placing bait in the coconut palm canopy by hand. Coconut palm crowns that overhang the mean high tide mark will be baited by hand. Personnel would also install bait stations in limited circumstances around the research station and wharf areas, on the support vessel, and at select shorebird roosting sites that are thought to be rat-free.

2.6.3 Timing and Weather

Aerial broadcast operations would be conducted in June and July, and would coincide with the seasonal low in populations of migratory shorebirds. Aerial broadcast operations would be conducted when weather conditions are favorable for flight operations.

2.6.4 Bait Application Plan

Bait broadcast by helicopter would consist of multiple low-altitude overflights of Palmyra. The baiting regime would follow methods based on successful island rodent eradications elsewhere in the U.S. and globally (Howald et al. 2007); in which overlapping flight swaths are flown across the interior island area, and overlapping swaths with a deflector attached to the hopper (to prevent bait spread into the marine environment) are flown around the coastal perimeter. The width of a flight swath would be determined beforehand in calibration trials, and would likely range between 33 – 131 feet (10 - 40 m).

Each flight swath would overlap the previous one by approximately 50 percent to ensure no gaps in bait coverage. The precision of bait application to the island would be guided by a TracMap® GPS guidance system that shows baiting coverage and cautions the pilot against baiting outside predetermined areas (Figure 2.4).

Figure 2.4. Onboard TracMap GPS used by a helicopter pilot to monitor and guide the aerial bait broadcast at Rat Island, 2008**.**

The bait would be applied according to a flight plan that would take into account:

1. The need to apply bait evenly, according to label rates, and without gaps in coverage or excessive overlap.
2. Current and forecasted weather conditions.
3. The need to avoid bait broadcast into the marine environment.
4. The need to minimize disturbance to native wildlife.
5. The need to minimize the substantial costs associated with helicopter flight time.

The helicopter would fly:

1. At a speed ranging from 25 - 50 knots (29 - 58 mph or 46 - 93 km/hr).
2. At an average altitude of approximately 164 ft (50 m) above the ground.
3. With the bait hopper on a long-line 49 - 66 ft (15-20 m) slung below the helicopter.

Concurrent to the aerial bait application, four or five personnel trained in GPS-guided hand-broadcast baiting (Wegmann et al. 2009) would treat land areas that are too narrow for aerial treatment. During each bait application, emergent land areas suitable for aerial broadcast would be subject to at least one pass with the bait hopper, and likely two.

In order to ensure eradication success, it would be necessary to conduct a second bait application, 7 - 14 days after the first, to minimize the likelihood of competitively inferior adult rats or juvenile rats surviving the initial broadcast because they were not given an opportunity to feed on bait. For each aerial bait application there would likely be no more than 3 consecutive days of aerial baiting followed by up to 7 days of placing bait in overhanging palms. Bait would be applied according to the limitations set by the EPA’s pesticide regulations under FIFRA.

Bait Sowage Rate

With Alternative B, Brodifacoum-25W bait would be applied to Palmyra's emergent land area. For each day of aerial broadcast baiting (2-3 days/application), baiting would follow a section-by-section plan so that an unexpected halt to baiting operations would result in a minimized unbaited edge for the previously baited sections. Two bait applications would be conducted; the second would follow the first by 7 to14 days, and would be at a lesser application rate to account for the reduction in bait consumers – rats that died from rodenticide exposure following the first bait application. The bait application will be as uniform as is possible given current bait application technology at a target rate not expected to exceed 80.4 lb/acre (90 kg/ha) or lower than 53.6 lb/acre (60 kg/ha).

Justification for the Bait Sowage Rates Proposed in Alternative B

Sowage rates for broadcast-based rodent eradications are driven by the need to have bait on the ground for multiple nights, and in adequate density and distribution to ensure that all rats have access to enough bait to ensure 100 percent removal of the target population. The factors and considerations leading to the determination of bait sowage rates for Alternative B are:

1. The registration of anticoagulant baits with the EPA were based, in part, on laboratory efficacy studies that are 3-day choice trials, with a minimum of 90 percent mortality as the target threshold for registration purposes (Schneider and Hitch 1982). In 1998, the EPA switched to 24-hour choice test trials for the registration of second generation anticoagulants; these trials do not result in 100 percent mortality of the test population (P. Martin, pers. comm.). Furthermore, recent laboratory studies where *R. rattus* were provided brodifacoum bait (in a no-choice scenario) for a 3-day exposure period did not result in 100 percent mortality of the sample rats (Pitt et al. 2010). This demonstrates that a 1 - 3 day exposure period is inadequate to ensure 100 percent mortality of rats when using brodifacoum. As such, 1- 3 days is an inappropriate benchmark for calibrating baiting rates for eradications on islands where 100 percent mortality of the target population is the defined goal. In Alternative B, the sowage rates selected will, according to the best available information, provide 4 days of bait availability for every rat.

2. Rats on islands compete with other species in their environment for access to food resources. Once bait is placed on the island, biotic (molds, microbes, and insects) and abiotic (moisture, temperature fluctuations) factors begin to degrade the bait. This competition for, and subsequent degradation of bait over time, could lead to low bait availability to rats, and ultimately to failure of the eradication. That bait rates are directly correlated with the density of rats is intuitively logical; however, it does not account for competition for the bait by other species that are attracted to the highly nutritious and energy-rich bait matrix. The broadcast bait sowage rates presented here are not directly correlated with rat densities at Palmyra, and will by necessity be more than is strictly needed to expose every rat to a lethal dose.

3. Rats are noted for their neophobic behavior toward new or novel food items, including bait products that contain rodenticide (Galef and Clark 1971).To counter this bait needs to be available to all rats in the target population for a long enough period so that all rats

will repeatedly encounter bait, identify it as a food resource, and choose to consume it over the available natural foods that they normally seek out. It takes time for rats to overcome their wariness over new food resources, such as bait pellets broadcast into their environment.

4. The bait application must account for the variation in individual vulnerability due to age, behavior, body size or mass, food supply, and range size (Cromarty et al. 2002). On any given night, any given rat may choose not to forage because of the availability of cached food, or behavior that may limit their time devoted to foraging such as (but not limited to) defending territories, constructing and maintaining nests, reproductive behavior, or caring for young. Thus, bait availability must be long enough to account for the real possibility that individual rats will not consume bait directly after the bait application.

The bait application rate for Alternative B is based on the results of several bait availability studies conducted at Palmyra (Section 2.4.4), and real and trial rat eradications conducted on island ecosystems that are similar to that at Palmyra (Table 2.3). “Bait availability” is defined as the time period in which rats would have direct access to bait pellets broadcast on the ground. The 2005 trial eradication conducted at Palmyra found that with bait sowage rates as high as 80.4 lb/acre (90 kg/ha), bait is available to rats for a maximum of 7 days and is only uniformly available for 4 days (Figure 2.5).

Bait consumption by land crabs (counted at 300 crabs/ha) is the primary factor determining bait availability. In order to ensure that rats have access to bait for 4 days, Alternative B would require bait application rates that exceed the maximum bait application rate specified by the bait product’s FIFRA registration. Alternative B is being considered concurrently with an effort to acquire a FIFRA registration specifically for Palmyra that would allow for bait application rates that carry a high probability of eradication success that can overcome the limitations at Palmyra. The proposed broadcast alternative will knowingly expose crabs, ants, cockroaches, etc. to bait; however, these organisms are not target species and are not expected to be harmed by the exposure. Additionally, FIFRA only limits pesticide applications where nontarget species are unreasonably adversely affected by the toxicant. That is not the case for invertebrates because brodifacoum is not known to cause adverse effects to invertebrates (see FIFRA Code Section 2).

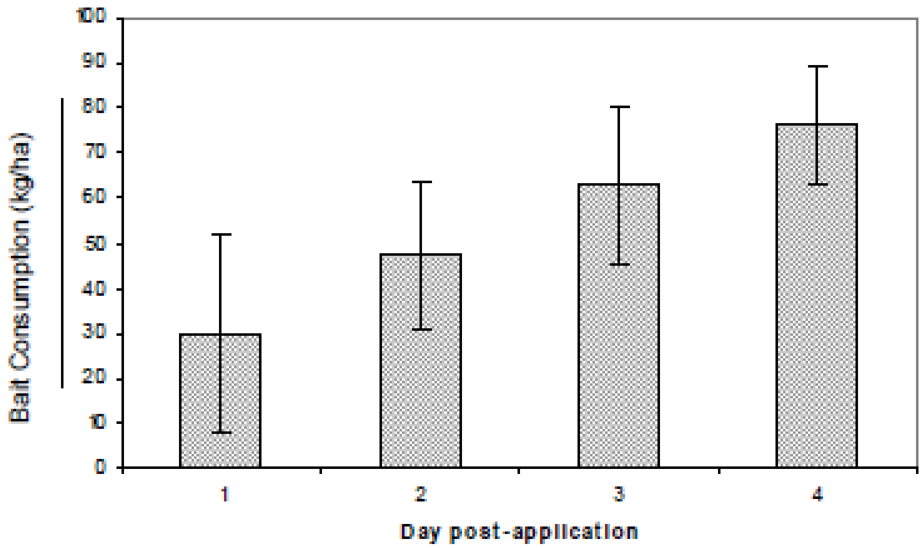


Figure 2.5. Results from the bait consumption study conducted on Whippoorwill Island during the 2005 trail rat eradication at Palmyra (Buckelew et al. 2005). The vertical bars represent 99% confidence intervals for the mean consumption estimates, and show that in order to maintain bait availability for 4days, the sowage rate should be between 60 and 90 kg/ha.

Table 2.5. A record of bait broadcast-studies at Palmyra and rat eradications in similar environments to those found in Palmyra's eradication environment: in terms of climate, plant community, and land crab densities to inform such rat eradications on tropical islands.

Island	Context	Method	Sowage rate (kg/ha)	Rodenticide	Target species	Project year	Eradication result	Source
Whippoorwill Island, Palmyra Atoll	Trial eradication	Hand broadcast w/canopy baiting	95	Brodifacoum	*R. rattus*	2005	Successful	Buckelew et al. 2005
Bunker Island, Palmyra Atoll	Trial eradication	Hand broadcast w/canopy baiting	70	Brodifacoum	*R. rattus*	2005	Successful	Buckelew et al. 2005
Little East Island, Palmyra Atoll	Trial eradication	Hand broadcast w/canopy baiting	60	Brodifacoum	*R. rattus*	2005	Successful	Buckelew et al. 2005
Fern Island, Palmyra Atoll	Trial eradication	Hand broadcast w/canopy baiting	80	Brodifacoum	*R. rattus*	2005	Successful	Buckelew et al. 2005
Home Island, Palmyra Atoll	Trial eradication	Hand broadcast w/canopy baiting	85	Brodifacoum	*R. rattus*	2005	Successful	Buckelew et al. 2005
Dekehtik Island, Pohnpei, FSM	Trial eradication	Hand broadcast w/canopy baiting	50	Brodifacoum	*R. exulans*	2007	Failed	Wegmann et al 2008
Pein Mal Island, Pohnpei, FSM	Trial eradication	Hand broadcast w/canopy baiting	50	Brodifacoum	*R. rattus*	2007	Successful	Wegmann et al 2008
Whippoorwill Island, Palmyra Atoll	Biomarker study	Hand broadcast w/canopy baiting	18 + 9	Brodifacoum	*R. rattus*	2008	Failed	Wegmann et al 2008
Portsmouth Island, Palmyra Atoll	Biomarker study	Hand broadcast w/canopy baiting	18 + 9	Brodifacoum	*R. rattus*	2008	Failed	Wegmann et al 2008
Home Island, Palmyra Atoll	Biomarker study	Hand broadcast w/canopy baiting	36 + 36	Brodifacoum	*R. rattus*	2008	Failed	Wegmann et al 2008
Fanna Island, Palau	Eradication	Hand broadcast	25 + 25	Brodifacoum	*R. exulans*	2009	Failed	Isechal 2009
Henderson Island, UK OST	Eradication	Aerial broadcast	60 + 60[1]	Brodifacoum	*R. exulans*	2011	Pending	(Brooke et al. 2010)

[1] Brooke et al. (2010) recommend two applications at 60 kg/ha for the areas of the island with the highest land crab density; the rest of the island, with markedly lower land crab density, will be treated with lower application rates.

A sowage rate range (53.6 lb/acre to 80.4 lb/acre) was selected for Alternative B because bait efficacy studies have shown that “standard” application rates would not expose all individual rats within the target population (Wegmann 2008), while “higher” bait application rates (53.6 lb/acre to 84.8 lb/acre) carry a high probability of eradication success (Buckelew et al. 2005). Admittedly, there is a substantial information gap between the boundaries of the tested bait sowage rates (32 lb/acre – 53.6 lb/acre); however, bait consumption studies conducted at Palmyra show that even at high bait sowage rates (84.8 lb/acre), bait is uniformly available to rats for only 4 days and essentially not available 7 days after application (Buckelew et al. 2005). Limitations to bait availability are due primarily to the abundance of land crabs that consume large quantities of bait at Palmyra. Because land crabs travel great distances in short periods of time (Wegmann 2009), it is not possible to predict areas of low crab density and treat such locations with “lower” bait application rates. During the 2005 trial eradication, rats were successfully removed from the study site with the highest crab density using 84.8 lb/ha; after subsequent analysis of the results from bait consumption studies and rat exposure studies (biomarker studies) conducted at Palmyra. The Service believes that an application rate between 53.6 lb/acre and 80.4 lb/acre will successfully remove rats from the atoll while creating a relatively short window of bait availability for nontarget species (Buckelew et al. 2005, USDA 2006, Alifano and Wegmann 2010).

Palmyra’s *tropical* rat eradication environment is vastly different from the environment(s) in which current bait product label specifications and general rat eradication models were developed (Wegmann 2008), *and it has been well documented that rodent eradications on tropical islands require special consideration (Varnham 2010)*. In considering what is appropriate for rat eradication at Palmyra, we must shift our baseline from the model based on rat eradications in temperate regions to that of one based on the nuances of moist tropical island ecosystems. Two applications at 25 kg/ha (brodifacoum) spaced ten days apart failed to eradicate *R. exulans* from Fanna Island in Palau (tropical, high density of land crabs) (Isechal 2009), and a single hand broadcast application of 50 kg/ha (brodifacoum) augmented by canopy baiting failed to eradicate *R. exulans* from Dekehtik Island in Pohnpei State, FSM (tropical, high density of land crabs) (Wegmann et al. 2007). The sowage rates employed in both cases would be considered “high” compared to sowage rates used for rat eradications in temperate climates, yet they failed to eradicate the targeted rat populations. Because of the risk of missing rats in areas of high crab density, the Royal Society for the Protection of Birds (RSPB) has selected 60 kg/ha (brodifacoum) as the sowage rate for specified areas in an upcoming eradication on Henderson Island.

The sowage rates proposed for Alternative B are “high” when compared to sowage rates typically used on temperate islands, or even tropical islands with low land crab density; however, when compared to sowage rates selected for eradication projects on islands that share Palmyra’s eradication environment (land crab rich, fast rate of bait degradation) (Table 2.5), the sowage rates proposed here are not extraordinary.

Avoiding Bait Drift into the Marine Environment

To avoid spreading bait into the marine environment, bait would be applied with application methods that are tailored to the width of the treated area; see Figure 2.6 for an example of how different bait application methods could be employed to minimize bait drift into the marine environment.

In between the first and second bait applications, the crowns of palms that overhang the lagoon and the ocean-facing shoreline would be baited by hand. As a precautionary measure, bait stations containing a second generation anticoagulant rodenticide product would be placed around the research station, the wharf, and at select shorebird roosting sites.

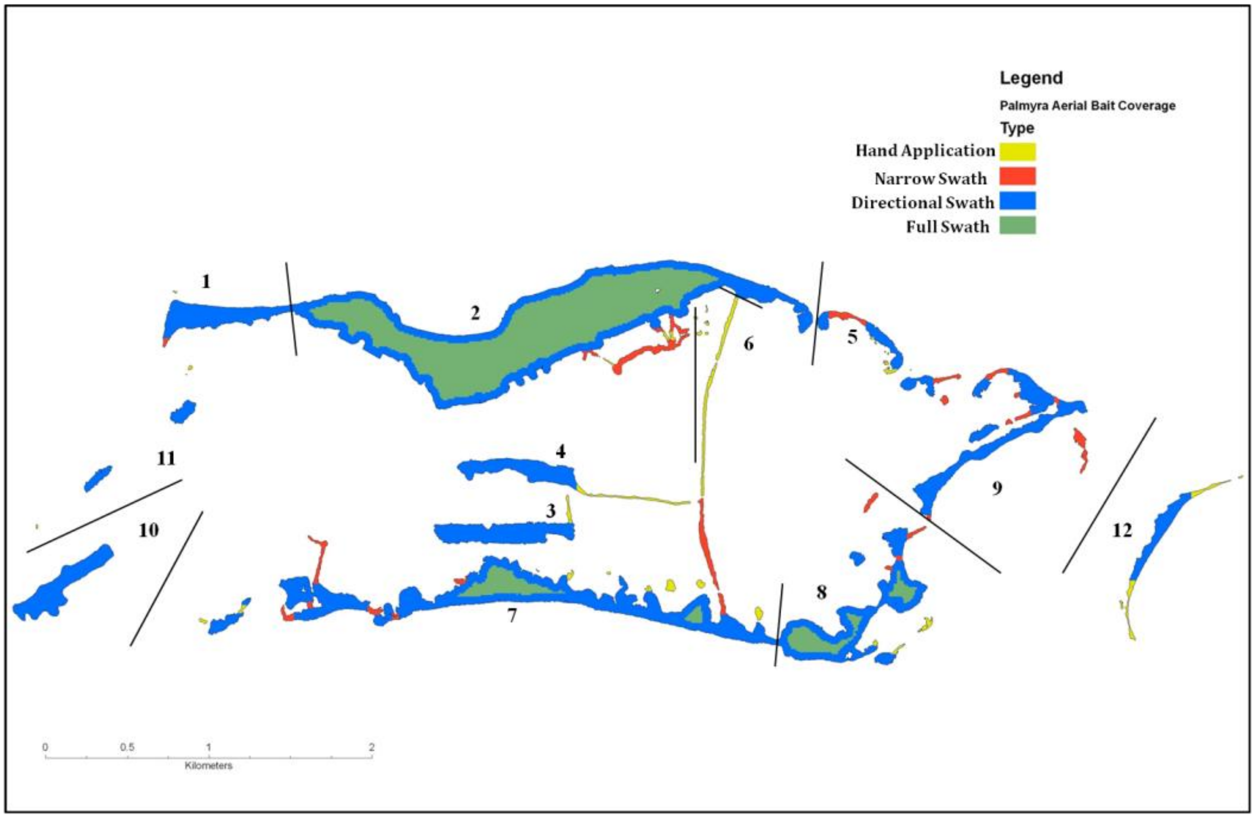


Figure 2.6. Bait broadcast application plan for eradicating rats from Palmyra Atoll. The treatment is scheduled for 2 days, and each day is divided into 6 sequential segments, with each segment representing a stand-alone area that would not need to be re-baited if the baiting operation is temporarily suspended (for up to 3 days). Different bait application methods (color coded in the figure) would be used to minimize bait spread into the marine environment.

Before the bait application process initiates calibration between the pilot, helicopter, and hopper would be conducted to ensure consistency and accuracy of the bait application using a placebo bait broadcast. The calibration would occur over a test site off-island in atmospheric conditions similar to those at Palmyra. A non-toxic version of Brodifacoum-25W bait would be used for the calibration.

To ensure complete and uniform application:

- The actual application path would be monitored onboard the helicopter using an onboard global positioning system (GPS), a navigation bar, and a computer to precisely guide, track, and document the application in order to avoid gaps and prevent unintended overlaps in application coverage.

- The application rate would be calculated using the known rate of bait flow from the hopper, the helicopter's reported velocity, and overlaps in the bait swath reported by the helicopter's onboard GPS tracking system.

- The application rate would also be monitored in plots established on Cooper Island.

- Adjustments in bait flow rates, helicopter speed, and flight lines would be made as necessary to meet the optimal application rate, while staying within the bait application limits legally required by the bait product's FIFRA registration.

Preventing Bait Drift into the Marine Environment

Every reasonable effort would be made to minimize the risk of bait drift into the marine ecosystem. A broadcast directional bucket would be attached to the hopper for treatment of shoreline areas (Figure 2.6). With this bucket configuration, there is a shunt inside the hopper that directs bait to just one side of the spinner, which results in bait being slung to one side of the bucket – the effective bait swath from the directional bucket is approximately ½ the width of the swath from the standard bucket. The directional bucket will be used to apply bait inland from the mean high tide line, broadcasting bait within approximately 120° of the onshore side of the helicopter, to minimize the risk of bait drift into the ocean in the opposite direction or seaward side. Observer teams would be on-the-ground to monitor proper operation of hopper and shunt and would move into treatment areas immediately after application to assess bait application rate and any accidental drift in the marine environment (Appendix A).

Coconut palms growing along the shoreline commonly hang over the high tide line. To prevent bait drift from vegetation, overhanging palms would be baited by hand rather than with the helicopter and bait hopper. Following each aerial bait application, the crowns of palms that overhang the lagoon-facing and ocean-facing shoreline would be baited at a rate not to exceed 3.5 oz of bait (100 g) for every stand-alone palm or every third interconnected palm; the number of overhanging palms was recently estimated to be 3,546 (Alifano and Wegmann 2010).

Coverage of Baiting Gaps

Unoccupied structures (from World War II-era operations on the atoll), which are potential rat habitat, may not receive the optimal bait coverage with helicopter broadcast alone. All identified structures would be hand-baited directly after or directly before the aerial broadcast over the adjacent land area.

In cases where it is evident or suspected that any land area did not receive full coverage, there would be supplemental systematic broadcast, either by foot, helicopter, or combination of the above. All personnel who would participate in hand broadcast baiting would be trained in systematic, Geographic Information System (GIS)-guided hand-broadcast bait application methods prior to the actual bait application (Wegmann 2009).

Bait stations would be placed around the research station and camp area, the wharf, and several shorebird roosting sites that are thought to be rat and crab-free (Figure 2.7). Bait stations would be loaded with a second generation anticoagulant bait product registered by the EPA and used in accordance with FIFRA. All stations would be checked regularly and bait would be replenished every 2 weeks for at least 45 days. *Tamper-resistant bait stations would be purchased for use in and around areas of human habitation. For uninhabited areas of the atoll, crab-resistant bait stations would be constructed with off-the-shelf materials (Appendix G.) and placed at shorebird roost sites.*

All personnel who handle bait would meet or exceed all requirements for personal protective equipment (PPE) required by the EPA. All bait application activities (aerial broadcast, hand broadcast, and bait station filling) would be conducted by or under the supervision of pesticide applicators licensed by EPA.

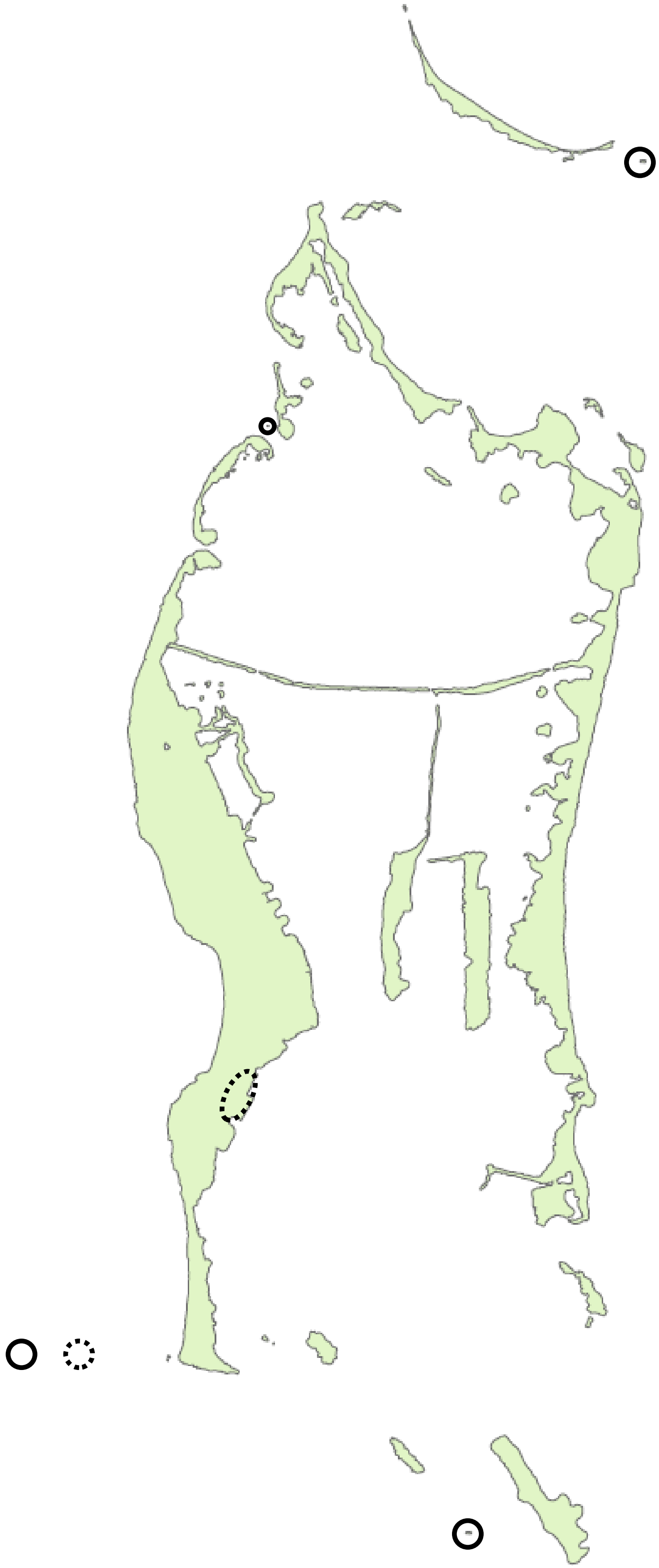


Figure 2.7. Alternative C – *Preferred Alternative* - Placement of bait stations during the rat eradication at Palmyra Atoll.

2.7 Alternative C: Aerial Broadcast of Brodifacoum, with Proactive Mitigation of Risk for Vulnerable Shorebird Taxa – *Preferred Alternative*

2.7.1 Rationale

The operational components of Alternative C would be identical to Alternative B, except that Alternative C, *as the Preferred Alternative,* includes the implementation of a shorebird risk abatement effort. Shorebird mitigation is a measure intended to reduce adverse impacts to vulnerable shorebird species. This effort is in addition to the timing of the bait broadcast and would occur during the period of year that has the lowest numbers of shorebirds present at Palmyra. We would capture and hold "at risk" birds prior to and during the period when they would be at risk of lethal exposure to rodenticide.

Regardless of the bait application method (broadcast or bait station) employed to eradicate rats from Palmyra, shorebirds, and in particular bristle-thighed curlews (BTCU) and Pacific golden-plovers (PGPL), are at risk of exposure to rodenticide. The first attempt to eradicate rats from Palmyra – a bait station operation that used both brodifacoum and bromethalin (Howald et al. 2004), resulted in the death of at least one BTCU. Some BTCU and PGPL mortality was recorded directly after a brodifacoum bait hand broadcast eradication effort in the Phoenix Islands (Pierce et al. 2008), and PGPL were observed consuming non-toxic "placebo" bait pellets at Wake Atoll (Wegmann et al. 2009).

Both BTCU and PGPL are seasonal migrants that overwinter on islands in the tropical Pacific Ocean and spend summers at breeding grounds in Alaska. The number of BTCU and PGPL present at Palmyra decreases significantly during the months of June and July; however, some juveniles or non-breeding adults (149 - 182 BTCU, 34-62 PGPL; FWS unpublished data) remain at Palmyra throughout the summer. An aerial broadcast of brodifacoum bait, as proposed in Alternatives B and C, would create a scenario of high exposure risk for individuals of both shorebird species for a short period of time – approximately 34 days (USDA 2006, Alifano and Wegmann 2010). Shorebird exposure risk from rodenticides is discussed in greater detail in Chapter 4.

The capture and captive holding of shorebirds would be a safeguard against negative impacts to individuals resulting from exposure to, and mortality from, brodifacoum bait during and directly after the eradication. However, bringing individuals into captivity, holding them for the required period, and re-releasing them onto the island, also presents risks of injury, deterioration in body condition, mortality of individuals, behavioral changes, and disease outbreak in the captive-holding facility.

2.7.2 Taxa

The bristle-thighed curlew (BTCU) and Pacific golden-plover (PGPL) are the most numerous shorebirds at Palmyra, and the species that are most likely to be put at risk by a rat eradication at Palmyra.

The BTCU is a medium-sized curlew with a wingspan of approximately 40-44 cm and blue-gray legs. During the breeding season, BTCUs are found in the remote mountainous regions of western Alaska in the Andreafsky Wilderness Area north of the Yukon River mouth and on the central Seward Peninsula (McCaffery and G. Pelota Jr. 1986, Kessel 1989, Gill et al. 1990, Marks et al. 2002). During the non-breeding season this species is found on remote Pacific Ocean islands and atolls (Marks et al. 1990) including the Hawaiian Islands (U.S.), U.S. Minor Outlying Islands, Northern Mariana Islands (to U.S.), Federated States of Micronesia, Marshall Islands, Nauru, Kiribati, Tuvalu, Tokelau (to New Zealand), Fiji, Tonga, Niue (to New Zealand), Samoa, American Samoa, Cook Islands, and French Polynesia, also reaching the Solomon Islands, Norfolk Island (to Australia), Kermadec Islands (New Zealand), Pitcairn Islands (to UK) (notably Oeno) and Easter Island (Vilina et al. 1992, Brooke 1995). Sub-adults may remain in the Pacific until they are nearly 3 years old (Collar et al. 1992). Site fidelity on both the breeding and wintering grounds is high with many birds returning to the same location on an island for multiple years (Marks and Redmond 1996).

Based on comprehensive surveys of the known breeding range on the Seward Peninsula, the global population size is estimated at approximately 3,200 breeding pairs (*6,400 breeding birds;* via a statistically valid sampling regime last assessed in 2000-2001, L. Tibbitts pers. comm.).*The total number of bristle-thighed curlews, including non-breeding adults and subadults is estimated at 10,000 (Morrison et al 2006). Population trends are unknown (Marks et al. 2002).*

The Pacific golden-plover is a medium-sized plover with gray-black legs (Johnson and Connors 1996). During the breeding season, this species frequents the arctic and subarctic tundra of *Russia and* western Alaska, nesting along the Chukchi and Bering Sea coasts, inland throughout the entire Seward Peninsula, and much of the Yukon-Kuskokwim region (Petersen et al. 1991, Connors et al. 1993, Johnson and Connors 1996). This species winters over a considerable portion of the Earth's surface. It is known to occupy upland and coastal habitats in the Hawaiian Islands, U.S. Minor Outlying Islands (including Johnston, Wake, and Palmyra Atolls) eastern central Japan, Polynesia, Micronesia, Melanesia, New Zealand, and Australia. Its wintering range further extends to Indonesia, Philippines, southern China, Southeast Asia, Bangladesh, Nepal, India, Sri Lanka, Pakistan, Iran, Bahrain, Ethiopia, and Somalia (Jones 1995, Johnson and Connors 1996, Johnson et al. 2004). Data are few about breeding site fidelity for this species in Alaska and Russia. Recent studies have shown individuals of this species will return year after year to the same breeding site (Johnson et al. 1993, Underhill et al. 1993). Studies on wintering populations in O`ahu, Hawai`i, show high rates of site fidelity at wintering grounds as well (Johnson et al. 1981, Johnson et al. 1989).

The global population estimate for PGPL is between 166,000 and 216,000 (Delany and Scott 2002). There is a consensus that the overall population trend is decreasing for the PGPL (Bamford et al. 2008, BirdLife International 2010). One study conducted between 1986 and 1995, showed a 72 percent decline in numbers at wintering sites in Australia. (Harris 1995).

2.7.3 Proportion of Population that Would be Captured

Personnel would attempt to capture 100 percent, or as many as is possible, of the BTCU and PGPL remaining at Palmyra after breeding birds had left the atoll for their summer breeding grounds in Alaska and just prior to the implementation of the eradication.

2.7.4 Capture Method(s)

Effective, safe capture methods for BTCU and PGPL at Palmyra Atoll are currently under development; however, shorebird experts maintain that it would be very difficult to capture BTCU (Gill 2010). When the lagoon flat habitat is flooded during high-tide cycles both species congregate on the runway, North Beach on Cooper Island, and Strawn Beach on Strawn Island (Figure 2.8). Single capture devices, such as pole-nets and soft-snares may be used, as well as multiple-capture devices, such as mist nets and net guns or walk-in traps. Because of anticipated shyness caused by trial capture events (successful or not), large-scale testing of capture methods would not be possible prior to the main capture event.

2.7.5 Retain Captured Birds in On-Island Captive-Holding Facility or Transfer to Off-Island Location

Captured BTCU and PGPL would be banded and immediately transferred to a captive-holding facility established in the camp and research station area of Cooper Island. A wildlife veterinarian would be present for the entirety of the capture and holding process and would supervise the design of the captive-holding facility and manage the care of captured birds. All personnel involved in the capture and care of BTCU and PGPL would have significant, prior experience with wild bird capture, bird banding, and wild bird care.

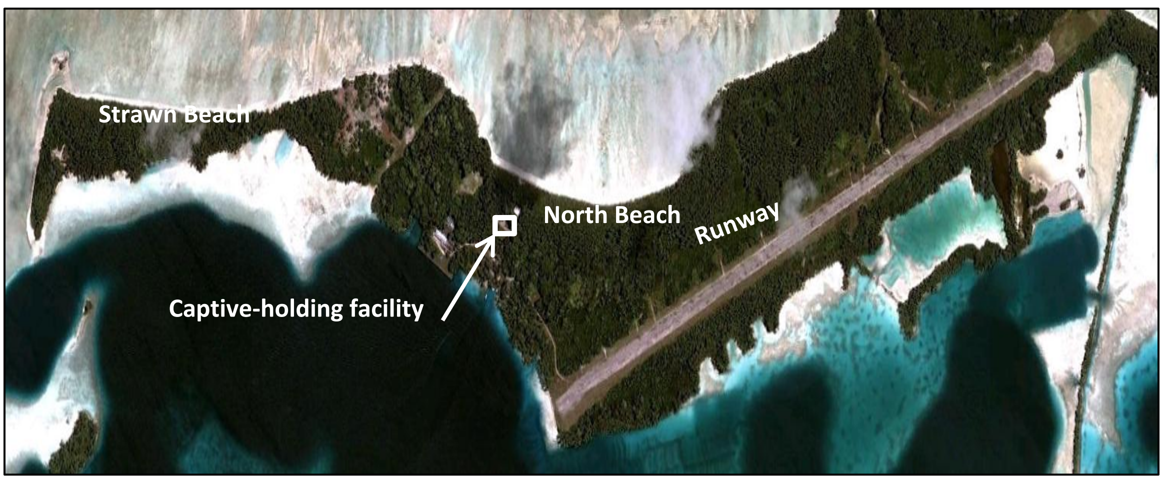


Figure 2.8. The location of bristle-thighed curlew and Pacific golden-plover roosting sites (capture sites) and a possible location for the captive-holding facility on Cooper Island, Palmyra Atoll. For scale, the runway is 1 mile long.

2.7.6 Captive Bird Care

A wildlife veterinarian and aviculturist familiar with captive care of shorebirds would be present for, and involved in, all bird capture and care scenarios. The veterinarian would regulate the diets of the captive birds, and, if necessary, modify their captive environment to reduce stress and the likelihood of stress-related illnesses.

2.7.7 Aspects of Captive-Holding Facility

The captive-holding facility would be located on a cement slab (approximately 50 m x 30m) on Cooper Island near the camp area. Shaded, rat- and crab-proof pens would be constructed at this location. Each pen would hold up to 20 birds, and birds would be segregated by species. Birds would be fed an appropriate diet, and fresh water would be provided ad-libitum during the captive period. The pens would be designed with flooring material appropriate to maintain foot health for the birds and cleaned daily. The condition of each bird would be monitored throughout the captive-holding period.

2.7.8 Length of Time Held

As previously stated, capturing and holding wild animals to avoid the risk of exposure to rodenticide carries inherent risk of injury, illness, or death for the captured birds. Efforts would be made to minimize the potential for harm caused by the holding process, but harm would still be expected. Minimizing efforts include that BTCU and PGPL would be kept in captivity only as long as is needed to avoid risk of mortality from exposure to rodenticide. The birds would be released after the risk of primary exposure to rodenticide through direct bait consumption has been eliminated – determined to be when bait pellets are no longer available to ground-based foragers, and after the risk of secondary exposure has decreased to a negligible level. This negligible level is determined as when rat carcasses have been consumed by invertebrates, and when invertebrates consumed by BTCU and PGPL have brodifacoum residue levels that have dropped below the risk-causing threshold. Bait pellets would not be available for primary consumption beyond 7 days post-bait application (Buckelew et al. 2005, Wegmann and Middleton 2008), and brodifacoum residue concentrations in hermit crabs (prey for BTCU) fall below 100 ppb 20 days after the second bait application. To minimize the exposure of BTCU and PGPL residing at Palmyra during the rat eradication, birds would be captured and held until a point at which their release would not incur a risk of harmful exposure to residual rodenticide.

2.8 Alternative D: Bait Stations with Canopy Baiting of Brodifacoum-25W

2.8.1 Rationale

Bait station operations, in contrast to aerial bait broadcast operations, mechanically limit the probability that nontarget species would come into direct contact with rodenticide, and thus reduce the risk of mortality for nontarget individuals.

2.8.2 Summary of Bait Delivery Methods

Bait stations armed with Brodifacoum-25W bait pellets would be placed on a 50 m x 25 m grid consisting of 7 - 8 stations per hectare (Figure 2.9). Palmyra has 250 hectares of emergent land, requiring 1,862 bait stations to completely cover the atoll. To account for bait station attrition during the operation, an additional 20 percent of the total number of bait stations would be purchased and brought to the atoll. *Tamper-resistant bait stations would be purchased for use in and around areas of human habitation. For uninhabited areas of the atoll, crab-resistant bait stations would be constructed with off-the-shelf materials (Appendix G.) and placed along the grid.*

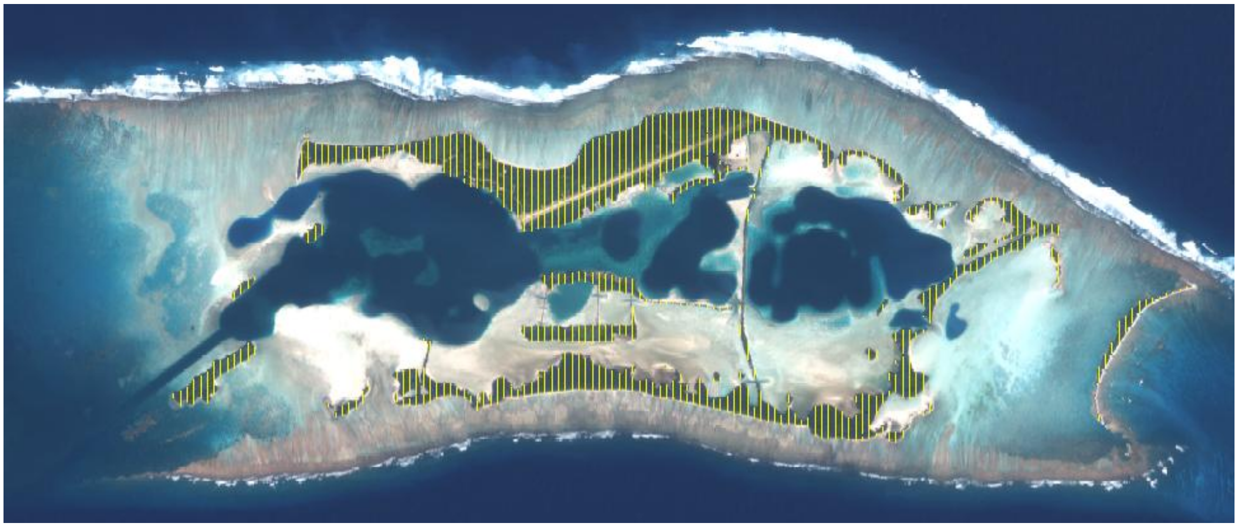


Figure 2.9. Bait station transects spaced 50 m apart to allow for a 50 m x 25 m bait station grid at Palmyra Atoll. The total length of all transects is 46,323 m.

For the first 6 weeks of the operation, each station would be checked every 2 days. During this time, bait would be continuously maintained in every station. Bait that has become moldy would be removed from the stations and replaced with fresh bait.

Rats at Palmyra have unusually small home ranges; female rat home range sizes have been measured at less than 400 m^2. To account for the small home range size, and to eliminate the possibility of "missing" rats that primarily forage in the forest canopy, bait would be applied to every third coconut palm crown (n = 26,666 palm trees) 4 times.

Management of the bait station operation detailed in Alternative D would be adaptive. If the bait station design selected for the operation proved ineffective in the long-term at excluding land crabs and/or shorebirds, or limited access to less than 100 percent of the rat population, modifications to station design would be made on-site. Additionally, there are two islands (Quail and Barren) that are known to have unsecured unexploded ordinance residual from WWII. A bait station operation would require that all transects and paths on these two islands be cleared by qualified personnel. Modification to the baiting plan would be made to address higher or lower than expected rates of bait removal from stations.

2.8.3 Monitoring for Eradication Success

For the duration of the bait station eradication described here, the bait stations would act as indicators of rat presence. To detect station-shy rats, chew-blocks would be associated with bait stations that showed little or no rat activity. Bait stations would be maintained until rat presence was not detected for 6 months, and then eradication success would be confirmed 2 years after the stations were deactivated.

2.8.4 Timing/timing Considerations

Similar to bait broadcast eradications, bait station operations entail significant rodenticide exposure risk for nontarget species, usually through secondary pathways or direct exposure due to bait station malfunction or human error. Because of this, the bait station operation would begin during the months of June and July when the carcasses of rats that succumb to brodifacoum toxicity are most prevalent, and “at risk” nontarget species bristle-thighed curlew and Pacific golden-plover) are least abundant at Palmyra. Some movement of brodifacoum from bait stations to the environment through the rats and insects that feed on the bait would continue for the full 2 year period of baiting, however.

2.9 Effort *and Estimated Costs*

2.9.1 Aerial Bait Broadcast – Helicopter Flight Time

Based on past aerial broadcast eradications (e.g., Rat Island, Alaska), it is estimated that bait can be applied by helicopter at a rate of 800 kg/hr. For an aerial broadcast of Brodifacoum-25W, 56 hours of flight time would be needed to complete both bait applications. The total personnel time for a Brodifacoum-25W broadcast application eradication (Alternative B) would be 616 person-days, or 684 person days if active shorebird mitigation occurred (Alternative C).

2.9.2 Bait Stations and Canopy Baiting

Palmyra’s emergent land area is covered with dense forest; transects would be cut and maintained to allow for easy access to the bait stations. The total length of transect required for a 50 m x 25 m grid is 50,659 yards (46.32 km). We estimate that transects can be cut at the rate of 546 yards/person-day (500m/person-day), and maintained at the rate of 5,468 yards/person-day (5,000 m/person-day). Vegetation grows quickly in Palmyra’s warm, moist climate; transects would need dedicated maintenance every 3 months. We estimate the total effort for cutting and maintaining (for the 2-year duration of the project) bait station transects at Palmyra to be 173 person-days (93 person-days for the initial cutting, 10 person-days for each of 8 transect maintenance sessions).

We estimate that one person can travel to, inspect, and resupply approximately 100 bait stations in a day. To restock 1,862 stations every other day for the first 6 weeks, a minimum of 20 people are required. After the first 6 weeks, a team of five would be able to cycle through all of the stations on a 2-week rotation.

We estimate that the rate at which palm crowns can be baited is 100 crowns/person-day. The total baiting effort is 267 person-days for each eradication action period, or 868 person-days.

The total effort for a bait station eradication with transect cutting and maintenance, and canopy baiting is estimated at 2,476 person-days. The effort (measured in person-days) that would be required to complete the major components of the action alternatives is presented in Table 2.4.

Cost estimates (Table 2.8) were calculated based upon 2008 market research and the effort estimates in Table 2.6. Because maintaining bait stations would not require highly skilled expertise, personnel costs are calculated at the technician level (based on the Federal General pay Schedule “GS” 7) for implementing bait stations. Aerial broadcast treatments would require more expertise and knowledge, and are calculated at the GS13 level.

1 **Table 2.6. The Minimum Effort Required to Achieve the Primary Operational Objective**
2 **for All Three Action Alternatives.**

Alternatives Included	Eradication Action Periodaction period	People Required	Number of Days	Effort (in Person-Days)
		(Prep for Aerial broadcast)		
B, C	0 – 2 months	4	7	**28**
		(Prep for shorebird capture)		
C	0 – 2 months	2	34	**68**
		(Post-bait application environmental and nontarget monitoring – 25W)		
B, C	0 – 2 months	4	32	**128**
		(Aerial broadcast – 25W)		
B, C	0 – 2 months	20	23	**460**
		(Transect cutting and maintenance)		
	4 – 0 months	10	9.3	93
	0 – 24 months	5	16	80
D	Total			**173**
		(Bait stations)		
	0 - 6 weeks	20	40	800
	6 weeks - 6 months	5	12	175
	6 - 12 months	5	46	230
	1 - 2 years	5	46	230
D	Total			**1,435**
		(Canopy baiting)		
	0 - 6 weeks	10	27	267
	6 weeks – 6 months	5	54	267
	6 - 12 months	5	54	267
D	1 - 2 years	5	54	267
	Total			**868**

	Action Alternative	Estimated Total Effort (Person-Daystotal effort (person-days)
	B - Aerial broadcast of brodifacoum	**616**
	C - Aerial broadcast of brodifacoum with proactive shorebird mitigation	**684**
	D - Bait stations with brodifacoum and canopy baiting	**2,476**

3
4

Table 2.7 Comparative Summary of Actions by Alternative

Action attribute	Alternative B: Aerial broadcast of brodifacoum	Alternative C: Aerial broadcast of brodifacoum with proactive bird mitigation	Alternative D: Bait station with hand broadcast of brodifacoum
Primary bait delivery method	Aerial broadcast	Aerial broadcast	Bait station
Secondary bait delivery methods	Hand broadcast; bait stations	Hand broadcast; bait stations	Canopy Baiting
Toxicant type	Brodifacoum	Brodifacoum	Brodifacoum
Actions to minimize risk to shorebirds	Seasonal timing	Seasonal timing Capture of "at risk" shorebirds	Seasonal timing Bait stations
Actions to minimize risk to reptiles	Minimizing bait drift into the marine environment	Minimizing bait drift into the marine environment	
Seasonal timing	June-July	June-July	June-July

Table 2.8 Budget Estimates for Treatment Options

	Bait Stations (diphacinone or brodifacoum)	Diphacinone (aerial, hand broadcast, and bait stations)	Brodifacoum (aerial, hand broadcast, and bait stations)
Bait	$ 118,000	$ 710,800	$ 240,300
Transporting bait to Palmyra and boat charter	$ 174,400	$ 366,300	$ 366,300
Equipment purchase and shipment	$ 5,800	$ 60,800	$ 60,800
Communications	$ 26,400	$ 19,000	$ 19,000
Environmental samples	$ 31,000	$ 31,000	$ 31,000
Helicopter calibration and operations	--	$ 412,000	$ 333,000
Travel and on-site logistics for implementation	$ 1,065,400	$ 70,400	$ 70,400
Demobilization	$ 30,500	$ 25,800	$ 25,800
Safety	$ 20,300	$ 6,800	$ 6,800
Supplies	$ 83,700	$ 27,000	$ 27,000
Salaries*	$ 396,000	$ 186,000	$ 186,000
Total	**$1,951,500**	**$1,915,900**	**$1,366,400**

* Salaries for bait station treatments calculated at GS7 level for 2,476 person-days. Salaries for aerial treatments calculated at GS 13 level for 684 person-days (which includes proactive shorebird mitigation).

3 Affected Environment

3.1 Introduction

Palmyra Atoll National Wildlife Refuge (Palmyra) located approximately at 6° N and 162° W in the Line Islands – Central Pacific, represents a globally important conservation stronghold. In 2001, after a history of military and private ownership, most of Palmyra Atoll and the surrounding coral reef were designated as a National Wildlife Refuge (NWR) by the Secretary of the Interior. In addition, The Nature Conservancy owns Cooper and Menge Islands, and the Cooper family owns 1.7 ha Home Island. The U.S. Fish and Wildlife Service (FWS or Service) and The Nature Conservancy (TNC) co-manage Palmyra's emergent land area, while the FWS retains sole management over marine resources extending 12 nautical miles out from the islands. In 2009, Palmyra Atoll National Wildlife Refuge and its surrounding waters out to 50 nautical miles from shore were included within the Pacific Remote Islands Marine National Monument (The White House 2009). The National Oceanic and Atmospheric Administration (NOAA) provides consultation to the FWS for management planning in the monument and the Service provides consultation to the NOAA, who retains primary responsibility for fisheries issues in monument areas from 12 to 50 nmi.

Palmyra is the only fully protected moist tropical forest ecosystem in the Central Pacific, yet native biota are currently threatened by an introduced, invasive rodent – the black rat. Palmyra is a breeding ground for 10 seabird species; however, predation by rats on eggs and chicks has likely led to the extirpation of 8 additional species. Palmyra's land crab community is one of the largest, if not the richest and most robust populations in the Central Pacific region. Palmyra is home to six land crab species (excluding the intertidal family *Ocypodidae* that includes fiddler and ghost crabs). Four of these land crab species occur in high densities at the atoll, with roughly 300 crabs per hectare.

Palmyra's high rainfall and complex vegetation structure make it very different from the other seabird colonies protected in the U.S. Pacific Islands. The wet *Pisonia* equatorial forest ecosystem found at Palmyra is a globally imperiled ecosystem, due to predation of seeds and seedling and by black rats and competition from introduced coconut palms. Since their introduction to Palmyra, black rats have affected migratory shorebird and seabird populations, as well as reptile, invertebrate, and plant communities.

3.2 General Description of Palmyra

3.2.1 Geographical Setting

Palmyra Atoll is one of the northernmost land masses in the Line Island chain, located approximately 1,000 mi (1,609 km) southwest of Hawai`i at 5° 53′ N latitude, 162° 05′ W longitude. Palmyra is in very close proximity to the Inter-Tropical Convergence Zone (ITCZ).

3.2.2 Size and Topography

Palmyra is a coral atoll with 618 acres (250 ha) of land area that is currently distributed between 25 islands(Collen et al. 2009). The atoll is approximately 7.5 mi (12 km) long (Collen et al. 2009). The atoll is shaped like a horseshoe and was originally composed of 54 small islands.

During the early 1940s the U.S. Navy increased the land area of the atoll by dredging, filling, and construction of islands runways, and causeways. The outer islands were connected, by roads and fill, into a ring and a channel was dredged. None of Palmyra's natural emergent land areas exceed 6.5 ft (2 m) above sea level, while dredge-fill islands reach 15 ft in elevation. The islands vary in size from approximately 0.24 to 242 acres (0.1 to 97.9 ha). The atoll has three lagoons, the eastern lagoon was separated from the central and western lagoons by the creation of a causeway. Palmyra is surrounded by an extensive reef flat on all sides with wide shallow reef flats and broad submerged reef terraces on the western and eastern ends (Collen et al. 2009).

3.2.3 Climate

Palmyra is considered to be a wet atoll with high humidity, typically greater than 90 percent, and warm temperatures, between 75-81°F (24-27 °C) (Hathaway et al. 2009). The climate at Palmyra is generally wet and humid, and predominantly governed by the proximity of the ITCZ (Anderson 2007). The ITCZ is characterized by moderate to strong convection currents that are interspersed with the doldrums, resulting in areas of flat calm winds and frequent torrential rains coupled with thunder and lightning (Anderson 2007). Doldrums are formed when trade winds from the northern and southern hemispheres meet, creating weather patterns with light winds and plentiful rains (Clark 2008). Precipitation patterns at Palmyra are largely governed by the strength and location of the doldrums (Barkley 1962).

Palmyra has a high annual precipitation rate averaging 175 inches (444.5 cm) per year (FWS 2001). The average annual wind speed is 8 knots (Sadler 1959). In an El Niňo year, Palmyra experiences periods of reduced rainfall, increased temperatures, and other climactic anomalies that are the direct result of the ITCZ shifting east, and creating warm ocean surface temperatures and weak trade winds (Burns 2002). Palmyra receives rainfall regularly throughout the year without a specific rainy season (see Table 3.1), creating a high resource environment. Due to an abundance of food available throughout the year rats are able to thrive and reproduce in all months of the year without a seasonal breeding period.

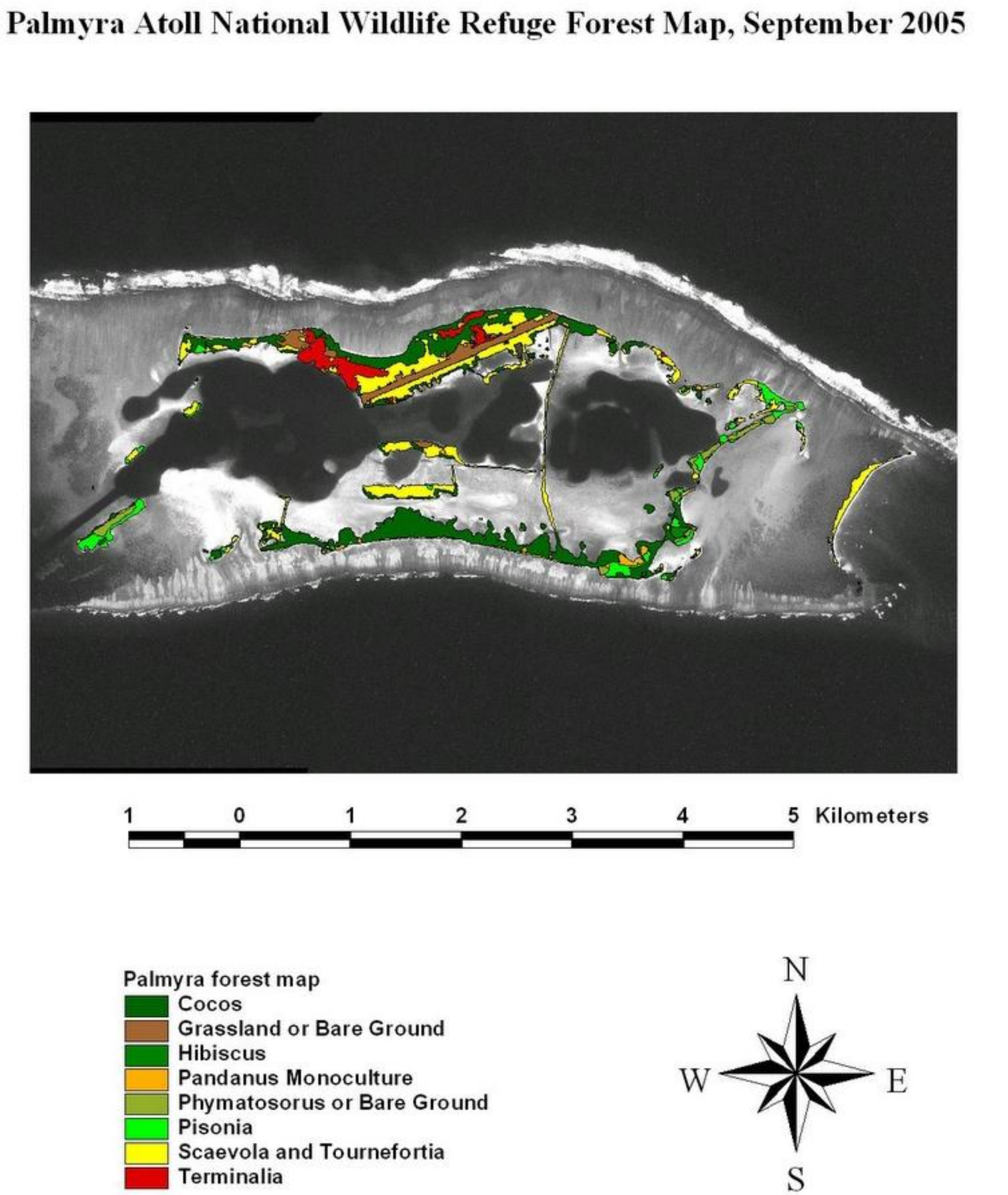


Figure 3.1. A map of the prominent forest types at Palmyra Atoll. The coconut palm canopy (dark green) is frequently used by rats and covers roughly 45 percent of Palmyra's land area.

Table 3.1. Palmyra Atoll Historical Rainfall Data in Inches (1977 – 2009)

	1977	1978	1979	1980	2001	2002	2003	2004	2005	2006	2007	2008	2009	AVG
Jan		28.5		18.9		17.3	15.9	8.83	14.0	17.8	19.0	11.7	16.9	15.3
Feb		9.05		9.8		11.6	17.6	21.43	25.6	9.9	12.3	7.4	23.7	13.5
Mar		12.8	6.3	15.7		13.0	11.6	19.6	24.7	8.9	11.5	15.4	5.2	12.0
Apr		12.8	6.9	14.8		17.4	9.2	7.5	19.9	12.8	6.3	8.3	6.2	10.2
May		8.5	3.5	11.8		11.3	15.1	13.0	25.2	17.1	19.4	11.4	16.4	12.7
Jun		9.8	9.8	26.6		12.7	20.8	15.3	22.5	7.2	15.0	9.6	9.8	13.3
Jul		8.26	14.76			17.0	16.1	9.6	23.3	20.1	19.4	16.1	18.5	14.8
Aug	14.8	4.3	12.8			19.0	22.3	20.5	27.0	16.9	9.8	12.7	9.1	14.1
Sept	3.9	7.9	12.2		9.1	10.8	7.4	8.4	7.1	13.2	3.0	8.7	7.5	7.6
Oct	9.8	6.3	16.1		12.1	14.1	16.4	18.5	15.6	17.3	9.4	22.0	17.5	13.5
Nov	14.7	11.2	17.7		11.2	19.9	17.2	16.6	10.8	18.3	5.7	17.5	20.0	13.9
Dec	23.6	11.8	19.3		17.1	35.2	34.4	21.0	19.4	25.6	17.6	9.3	22.7	19.8
Total		131.3	119.4			199.3	203.8	180.1	235.1	185.00	148.3	150.0	173.4	160.6

Source: Palmyra Atoll NWR Daily Weather Record

3.2.4 Physical Resources

Water Resources

Although Palmyra receives a high amount of rainfall, porous soil prevents the formation of freshwater wetlands (Scott 1993, FWS 2001). Due to the porous carbonate soils characteristic of the atoll, surface runoff is nearly nonexistent at Palmyra. Little to no information is available about groundwater at Palmyra because no significant groundwater sources are on any of the islands. Groundwater is most likely present as a saturated zone on the atoll. A 1998 report on the contaminants of Palmyra reported that the surface water table is typically found at depths of approximately 2-4 ft (0.6 – 1.2 m) below the ground surface and is greatly influenced by the tide (Environmental Chemical Corporation 1998).

Limited direct sources of water pollution at Palmyra are from small boats. Submerged waste and debris remains from World War II activities. It is unknown if these environmental contaminants had or continue to have an effect on water quality.

Military activities during World War II included construction of a north-south causeway between the East and Center Lagoons, construction of a smaller causeway and two islands in Center Lagoon, and dredging of a seaplane runway, and an entrance channel through the perimeter reef southwest of West Lagoon (Dawson 1959). Altered and reduced water circulation in West and Center Lagoons has been reported since the 1950s. Additionally, a decrease in water circulation in East Lagoon is reducing coral reef life and increasing temperature regimes in all 3 lagoons. Altered water circulation in the lagoons has caused an increase in coral bleaching, heightened predation by coral-eating sea stars, and increased lagoon shoreline erosion (Miller et al. 2008). Several breaks in the perimeter of the East Lagoon have allowed a minimal amount of mixing with the ocean at high tide. Continued high temperature and turbidity levels in all lagoons has dramatically slowed marine ecosystem recovery in the lagoons (Miller et al. 2008). Outside of the lagoon habitats, waters surrounding Palmyra Atoll are generally well mixed and clear with light transmission levels greater than 80 percent (Pacific Island Fisheries Science Center 2004).

There is significant evidence of weak but consistent upwelling along Palmyra Atoll's southern side and its connection to high biomass measured with bioacoustics. Poor water circulation within Palmyra's back reef areas causes variations in water temperature (Brainard et al. 2005).

Geology and Soils

Palmyra Atoll is one of only 12 seamounts or undersea mountains in the Central Pacific ocean that rise in excess of 16,405 ft (5,000 m) from the sea floor to form an atoll (Keating 1992). Palmyra was formed by a combination of carbonate coral reef growth along the side of an ancient volcano, coupled with erosion and subsidence of the basalt layer (Smith et al. 2006). Through a multibeam mapping process, Smith et al. (2006) identified a group of pinnacles on the south and west flanks and a flat-topped volcanic cone with a summit depth of 3,661 ft (1,160 m).

Almost all islands at Palmyra have a thin layer of soil and organic material over a limestone base. The soil found under the organic plant layer is brown, sandy soil that ranges in thickness from 4-12 in. The uppermost layer is approximately 4-in thick and is composed of dark gray and very dark gray brown, silty sand. The second layer is composed of pinkish white fine to very fine sand, intermixed with coralline gravel and cobbles (Aronson and Anderson 2000). Some of the soils at Palmyra are calcium phosphate with hard pans (Christophersen 1927). The organic matter and acidity of the soil varies throughout the atoll and few data are available for specific islands (FWS 2001). The two main types of soil found at Palmyra vary based on the type of vegetation found in that area. In the *Pisonia grandis* forests, the main soil type is highly phosphatic and composed almost entirely of organic matter (Christophersen 1927). In the coconut forests the soils are sandy and nonphosphatic with medium to low organic matter (Christophersen 1927).

Air Quality

Air quality at Palmyra is generally excellent. Sources of emissions on the atoll are minimal and include two diesel powered generators generating electrical power, a 25-ft diesel-powered boat for offshore activities, four smaller boats, two tractors, two pickup trucks, a front end loader, a compactor/roller, a waste incinerator, and several gasoline-operated garden tools. There is no record of natural- or human-initiated wildfires at Palmyra Atoll. Currently, airplane flights to Palmyra are determined on an as-needed basis for the purposes of transporting staff, scientists, visitors, and restocking perishable foods. Flights are typically more frequent during the summer than in winter months, with an average of two flights occurring per month in the summer and two flights total in the winter months between December and March.

3.2.5 Biological Resources

Introduction

No terrestrial mammals are native to Palmyra Atoll, but a variety of native birds, lizards, arthropods, and crabs, as well as several nonnative plants, vertebrate and invertebrate species have been inventoried to date. Palmyra Atoll's native flora and fauna have been altered due to World War II-era atoll restructuring and introductions of nonnative species, notably coconut palms, ants, scale insects, and black rats. Nevertheless, Palmyra is an important center of biological diversity and species abundance in the Central Pacific region. Now protected within the FWS's National Wildlife Refuge System, a national monument, and as a Nature Conservancy Preserve; Palmyra sharply contrasts with other moist Central Pacific island groups where the degradation of terrestrial and marine ecosystems keeps pace with increased human population and the resultant anthropogenic resource use. The continued presence of black rats at Palmyra Atoll hinders recruitment for extant indigenous species, may preclude the reestablishment of extirpated species of seabirds, and may thwart nesting attempts by endangered green turtles (*Chelonia mydas)* and hawksbill turtles (*Eretmochelys imbricata)*.

Palmyra is a breeding site for seabird species, but predation by rats on eggs and chicks has likely led to reduced breeding success of these species and the extirpation of 8 additional species (Table 3.2). Due to the absence of predation pressure by an established human population, Palmyra's land crab community is among the richest and most robust in the Central Pacific region. Palmyra is home to six species of terrestrial crabs (excluding the intertidal family *Ocypodidae*), four of which are super abundant (Table 3.3).

Birds at Palmyra

Systematic observations of all bird species found at Palmyra were first made during visits of scientists from the Pacific Ocean Biological Sciences Project between 1964 and 1965. On subsequent visits starting in 1987 Service staff or visiting scientists made additional estimates of population sizes for all birds seen. Ten species of seabirds breed at Palmyra, and it is home to one of the largest colonies of red-footed boobies in the world. Additional seabird species have been documented foraging in the waters surrounding the islands of Palmyra, several of which would likely breed there if no rats were present. These including the wedge-tailed shearwater, Christmas Island shearwater, Audubon's shearwater, Bulwer's petrel, and blue noddies have been documented visiting land at Palmyra Atoll.

Table 3.2. Breeding seabirds of Palmyra Atoll

Family	Common Name	Scientific Name	Status	IUCN-list
Procellariidae	Audubon's shearwater	*Puffinus lherminieri*	Believed extirpated	Least Concern
	wedge-tailed shearwater	*Puffinus pacificus*	Extirpated	Least Concern
	Phoenix petrel	*Pterodroma alba*	Believed extirpated	Endangered*
	Christmas Island shearwater	*Puffinus nativitatis*	Believed extirpated	Least Concern
	Bulwer's petrel	*Bulweria bulwerii*	Believed extirpated	Least Concern
Hydrobatidae	Polynesian storm-petrel	*Nesofregetta fuliginosa*	Believed extirpated	Endangered*
Laridae	black noddy	*Anous minutus*	Breeding	Least Concern
	blue noddy	*Procelsterna cerulea*	Believed extirpated	Least Concern
	brown noddy	*Anous stolidus*	Breeding	Least Concern
	sooty tern	*Onychoprion fuscatus*	Breeding	Least Concern
	gray-backed tern	*Onychoprion lunatus*	Believed extirpated	Least Concern
	white tern	*Gygis alba*	Breeding	Least Concern
Fregatidae	great frigatebird	*Fregata minor*	Breeding	Least Concern
	lesser frigatebird	*Fregata ariel*	Resident	Least Concern
Phaethontidae	white-tailed tropicbird	*Phaethon lepturus*	Breeding	Least Concern
	red-tailed tropicbird	*Phaethon rubricauda*	Breeding	Least Concern
Sulidae	red-footed booby	*Sula sula*	Breeding	Least Concern
	brown booby	*Sula leucogaster*	Breeding	Least Concern
	masked booby	*Sula dactylatra*	Breeding	Least Concern

* = Declining population trend

Palmyra is the only undisturbed site left for seabirds within the Northern Line Islands that prefer *P. grandis* trees as nesting habitat (Flint 1999). Seabirds are marine foragers and travel long distances to feed (e.g., red-footed boobies will travel over 200 km per day), returning to Palmyra to rest and breed (Young et al. 2010). In addition to their important role as seed dispersal agents for *P. grandis*, seabirds are important drivers in the ecosystem because they bring marine-derived nutrients (guano) to the islands. To a lesser extent, seabirds provide nutrients used throughout the food chain, in the form of feathers, regurgitated fish, addled eggs, and bird carcasses.

The distribution, population, status and trends, ecology, and conservation concerns for these seabird species can be found in the Regional Seabird Conservation Plan, Pacific Region (FWS 2005). The greatest local and global threats to the seabirds found at Palmyra include; introduced black rats and other invasive species, fishery interactions, contaminants, marine debris, and climate change.

Black rats may be responsible for the current absence of burrow-nesting seabird species at Palmyra. Species such as wedge-tailed shearwaters, Audubon's shearwaters, and Polynesian storm-petrels have been observed offshore (Depkin 2002) and (J. Smith; M. McKown; E. Flint, FWS; L. Ballance; and R. Pitman oral communication 2008) or collected on the atoll (i.e., Smithsonian Institute; USNM 496523; petrel specimen from 2008 - Matthew McKown) in the past. Pre-World War II accounts of Palmyra's terrestrial ecology focused on botanical aspects, supplying little information about the avian fauna, and no record of these species breeding at Palmyra (Rock 1916).

Palmyra also supports overwintering populations of shorebirds, including bristle-thighed curlews, Pacific golden-plovers, wandering tattlers, ruddy turnstones, and sanderlings. The bristle-thighed curlew and Pacific golden-plover are designated by the FWS Shorebird Conservation plans as species of high conservation concern in National and Regional Shorebird Plans, including the U.S. Pacific Islands Regional Shorebird Conservation Plan (Engilis Jr. and Naughton 2004). The bristle-thighed curlew has also been designated as a Bird of Conservation Concern by the FWS at the regional and national scale (FWS 2008a) due to limited breeding and non-breeding distributions, low relative abundance, and threats during the non-breeding season. Both of these species overwinter at Palmyra Atoll, with low numbers of juvenile or non-breeding birds also present through the summer months.

There are currently no records of breeding land birds at Palmyra Atoll. Two nonnative bird species are known to have been introduced to Palmyra Atoll. The myna (*Acridotheres tristis*) has been reported as introduced but has since been extirpated (Fefer 1987). Domestic chickens (*Gallus gallus*) were also reported (Flint 1992), but are no longer present.

<u>*Seabirds*</u>

Palmyra Atoll NWR is the only seabird nesting habitat within 450,000 square miles of ocean and is an important marine feeding ground for seabirds (Flint 1992). Located on the boundary between the North Equatorial Countercurrent and other ocean currents in the vicinity, several species of nesting seabirds regularly visit the atoll. No long-term monitoring time series for seabird populations exist due to the previous irregularity of visits, the aseasonality of seabird breeding at Palmyra, and the high inter-annual variability of seabird population size and breeding success in low latitude colonies.

Pacific Ocean Biological Science Project (POBSP) staff did not find any masked boobies breeding in 1964 or 1965, nor did Fefer in 1987, though both groups observed a few individuals at the site. The masked booby has more recently been reported on Whippoorwill, Portsmouth, Holei, Tanager, and the Fighter Causeway (Flint 1999, Depkin 2002). In 2010 Meyer reported nests from small islands in the Milky Way, North and South fighter strips, the East-West Causeway, Paradise Spit, and the North-South Causeway. The masked boobies found in this area are believed to be of the subspecies *S. dactylatra personata* because adults do not have black colored eyes (Depkin 2002). Two adult birds were observed roosting by Fefer (1987) and 13 masked boobies were seen by Flint in 1992. Nest inventories by Flint (1992) indicate that the nest sites of the species are usually solitary and clutch size is two eggs. Depkin (2002) estimated that approximately 35 pairs of masked boobies inhabit Palmyra. Nineteen active nests were found on the East-West Causeway during a count in April 2010.

The largest concentration of brown boobies has been observed on the East-West Causeway (Flint 1992, Depkin 2002). They are also found on Ainsley, Dudley, Leslie, North-South causeway, North and South fighter strips, Paradise Spit, Whippoorwill, and The Milky Way. These birds nest and roost on the ground and typically forage in pelagic waters off Palmyra Atoll. The global population of brown boobies is approximately 221,000 – 275,000 pairs (FWS 2005). The POBSP staff documented breeding and estimated 600 birds in the fall of 1964. Early counts by Fefer

(1987) documented 600 birds and 286 nests at Palmyra. Approximately 60 percent of the nests observed on this visit contained eggs and most were located underneath *Tournefortia* and *Scaevola* shrubs. A total of 253 brown boobies were seen by Flint (1992), including two identified as male *Sula leucogaster brewsteri*. This subspecies has a gray head as opposed to brown head and throat prominent in the remainder of the population (Flint 1992). This subspecies native to the Eastern Tropical Pacific is still seen in small numbers every year at Palmyra. The highest recent population estimate for brown boobies at Palmyra Atoll is 371 pairs (Depkin 2002). Depkin banded a total of 379 chicks between early September 2001 and late August 2002. In September 2009 there were 302 active nests counted on the East-West Causeway. During this sampling period, the hatch rate was 44 percent and a recruitment rate was 97 percent. Typically, pairs of brown boobies lay two eggs with only one surviving chick due to siblicide (FWS 2005).

Palmyra supports the second or third largest colony of nesting red-footed boobies (*Sula sula*) in the world with current total population estimates around 6,250 pairs (FWS 2005). During the POBSP, 25,000 red-footed boobies were reported from Palmyra Atoll in March 1965 (Clapp, unpublished). Sixty-five hundred birds and 2,100 nests were counted in 1987 (Fefer), and 8,880 birds were seen in the 1992 FWS survey (Flint). In 2002, Depkin documented 929 nests with eggs and 1,243 nests with chicks in three index plots. Their most common nesting and roosting sites is in tree heliotrope (*Tournefortia argentea)* along the water's edge and nests were most frequently lined with Primrose Willow (*Ludwigia octivalvis)*. Due to the high number of nests and varied stages of nesting activity, it has been suggested that nesting of the red-footed boobies occurs year round at Palmyra (Fefer 1987, Depkin 2002). Surveys conducted prior in 1992 showed important colonies of red-footed boobies in *Pisonia* forests on Eastern, Holei, Bird, and Papala Islands (Flint 1992).

Clapp (1966, unpublished) called the great frigatebird a fairly common resident and estimated 200 birds were present at Palmyra in April of 1964. The great frigatebird is widespread in the tropical Pacific, Indian, and Atlantic oceans. Their plumage is not waterproof and these birds are considered the most aerial of all seabirds (Berger 1981). This species is also notorious for being kleptoparasitic: they dive in pursuit of other seabirds to force them to forfeit their catch. In 1987, a total of 200 birds and 65 nest sites were recorded on Eastern Island, Lost Island, and Papala Island (Fefer 1987). During a survey in December of 2001, Depkin recorded 307 individuals, suggesting that the potential breeding population is probably over 200 pairs. Primary nesting habitat for the great frigatebird is within the *Pisonia* forest (Fefer 1987, Redmond 1990, Depkin 2002); however, 34 great frigatebird nests were recorded in *Tournefortia* on 3 islands near Whippoorwill Island (Flint 1992). An accurate measurement of the reproductive success for the great frigatebird population at Palmyra has been difficult to determine due to the great height of most of their nest sites in the *Pisonia* forest (Depkin 2002). In recent years this species has also used trees on the North-South Causeway and Bunker Island for nest sites.

On drier islands of the tropical Pacific, brown noddies nest primarily on open ground or under vegetation. At Palmyra, brown noddy nests are more common in the interior and were only found in *Pisonia*, *Tournefortia*, and *Cocos* canopies (Fefer 1987). Brown noddies and white-tailed tropicbirds are the only species at Palmyra known to use *Cocos* for nesting (Depkin 2002) and are most common on Eastern, Sand, Leslie, Dudley, and the South Fighter Strip. Females lay a single egg per clutch, and chicks vary in color from solid black to solid white (Berger 1981). Clapp (1966) estimated 2000 brown noddies inhabiting Palmyra in March of 1965. More recent estimates of the brown noddy population have ranged from 400 (Fefer 1987, Depkin 2002) to 564 birds (Flint 1992).

Palmyra shelters the largest nesting colony of black noddies in the central Pacific (FWS 2001). The black noddy can be differentiated from the brown noddy by their smaller size, darker color, and longer, thinner bill. This species also tends to be less pelagic, feeding in flocks over near-shore waters (Pratt et al. 1987). It is not uncommon for black noddy pairs to lay a second egg while still tending to the first chick (FWS 2005). Clapp (1966) provides an estimate of 8000 birds for November 1964. A crude estimate of 3,500 birds and 1,100 nests was made on Sand Island in a survey conducted by Fefer in 1987. During the 1992 FWS survey (Flint 1992), 6,498 black noddies were recorded, and the following year Marks (1993) estimated approximately 20,000 black noddies at Palmyra. A survey in December 2001 found approximately 1,350 black noddies concentrated in two colonies on Eastern Island (Depkin 2002).

White terns are most common in *Pisonia* and *Tournefortia* areas, but small numbers have been observed in other habitats throughout the atoll as well. POBSP scientists estimated as many as 200 birds. In 1987, approximately 500 birds were common residents of the atoll (Fefer 1987). Depkin (2002) suggested that the white tern breeding population at Palmyra was minimal. Researchers throughout the Pacific Islands have found that this species does not build nests, but lays elliptical eggs in any suitable depression (FWS 2005).

The sooty tern, commonly found throughout the tropical Pacific Ocean, is an abundant resident of Palmyra. This species spend most of its time at sea, only coming to land to breed. Clapp (1966) suggests there were as many as 750,000 birds. An estimated 260,000 birds and 126,000 nests were reported in 1987 (Fefer 1987). Flint (1992) estimated the number of eggs on the ground to be around 219,000. A survey the following year estimated that a total of 750,000 sooty tern nests occur at Palmyra (Marks 1993). The most recent seabird survey found 69,867 pairs or 139,734 birds (Depkin 2002). Evidence suggests that sooty terns may have two breeding seasons at Palmyra. This may be a result of nest site limitations or high nest failure rate due to anthropogenic activities (Depkin 2002). Irregular breeding seasonality and periodic large-scale failure may also be attributed to conditions at sea on the foraging grounds. All studies found that the highest population of the tern colonies was located on the runway on Cooper Island. Thus, airplane arrivals and departures have historically had a negative effect on sooty tern colonies at Palmyra (King 1973). In hopes of luring the terns away from the runway, areas on the range marker on Strawn Island were cleared as possible nesting sites. Depkin estimated there were 40,611 eggs on the North Fighter Strip during the 2001-2002 survey (Depkin 2002). Egg predation by rats has also been a significant threat to the population in the past (Fefer 1987) and is still regularly observed by island residents.

Scientists from POBSP observed as many as five White-tailed Tropicbirds during their visits but never found a nest. In 1992, two adult White-tailed Tropicbirds were seen together in a *Pisonia* grove on Holei Island. Redmond (1990) reported several White-tailed Tropicbirds flying above the canopy on Eastern Island and Fefer (1987) counted six throughout Palmyra. No nests were found on these visits. Adult White-tailed Tropicbirds were seen monthly from August 2001 through September 2002, with the highest numbers spotted above the *Pisonia* forests of Eastern and Holei Islands. Three nest sites were discovered on Eastern and another nest was found on Holei. All nests were in natural cavities in *Pisonia* trees, and nest height ranged from less than 15 to over 50 ft above ground (Depkin 2002). Nests have also been found on Lost and Paradise Islands and in coconut palm crowns and epiphytic bird's nest ferns in 2009 and 2010 (H. Young pers. comm.).

The red-tailed tropicbird tends to avoid land during nonbreeding periods (FWS 2005). Considered a rare resident by POBSP scientists, they found only one nest in April of 1964. Fefer (1987) reported a nest, which also contained a feathered chick, under heavy growth of *Tournefortia*. Fifteen red-tailed tropicbirds were observed by Flint at three islands in the atoll. Ten out of a total of 14 nests found were located on Ainsley Island, possibly due to lack of rats on this portion of the atoll. All nests contained eggs except for one, which sheltered a down-covered chick (Flint 1992). Between August 2001 and August 2002, Depkin banded a total of 261 red-tailed tropicbirds (128 chicks and 133 adults). The sites were located on causeways and could indicate a growing population, dominated by young individuals. It has also been suggested that because nest sites are typically under dense groundcover, earlier surveys underestimated the true population due to poor detection of nests (Depkin 2002). The increases also followed an attempted eradication of rats in 2001 that reduced the density of rats and most likely the incidence of egg predation. Nesting activity, although concentrated in the late winter and early spring, was reported year round. The reported hatch rate for red-tailed tropicbirds is approximately 57 percent, with a fledgling success for this period of approximately 45 percent (Depkin 2002). In May of 2010 Refuge manager Meyer banded 100 adult red-tailed tropicbirds and handled 131 birds, 28 of which had been previously banded. She also banded 23 red-tailed tropicbird chicks.

During the months of August 2001, September 2001, March 2002, and May 2002, May 2009, September 2009, June 2010, and November 2010. Wedge-tailed shearwaters were heard vocalizing over Cooper Island (Flint pers. comm.). In May 2002, 3 dark morph wedge-tailed shearwaters were found dead along the shoreline on North Beach and another dark morph was discovered in the West Lagoon (Depkin 2002). This dark color phase of the species is the most often observed type at sea in the waters around Palmyra Atoll. In 2005, a pair of wedge-tailed shearwaters attempted to nest on Cooper Island; the nest failed and the adults disappeared soon thereafter (Wegmann pers. comm. 2005). In 2009 and 2010 five wedge-tailed shearwaters were found on Cooper Island. These birds were attracted to the lights of the research station. The birds were captured, held overnight and released the following morning. These incidences are the only reported occurrences for this species at Palmyra Atoll. The Audubon's Shearwater, or tropical Shearwater as it has recently been renamed, has also been sighted at the atoll (Depkin 2002).

Other uncommon seabirds at Palmyra include the lesser frigatebird, red-billed tropicbird, Franklin's gull, laughing gull (Depkin 2002, Clapp 1966 unpubl. data), and the black tern (*Chlidonas niger*) (Wegmann pers. comm. 2008).

Shorebirds

The Pacific Islands function as an essential migratory habitat for maintaining global shorebird populations. The rocky shoreline and extensive sand flats that are exposed at Palmyra during low tide are important foraging areas for several wintering migratory shorebirds. Four shorebird species winter full-time at Palmyra; however, other species have been known to occur in small numbers. All of the shorebird species using Palmyra Atoll demonstrate a pattern of greater abundance during the winter months with very few or no individuals remaining throughout the summer when adult birds return to the breeding grounds in the Arctic.

Palmyra's tidal flats, beaches, and runway are important foraging and roosting habitat for bristle-thighed curlews that migrate between Alaska and the Central and South Pacific (Marks 1993). These are among the most numerous shorebirds at Palmyra. Between 1987 and 1992, shorebird surveys estimated more than 200 wintering curlews during each visit (Fefer 1987, Flint 1992). In the 1992 survey, four of the curlews observed at Palmyra had color bands from Alaskan breeding locations (Flint 1992). A December 2001 survey resulted in a total count of 84 wintering birds (Depkin 2002). An April 2010 all-atoll count yielded sightings of 266 bristle-thighed curlews at Palmyra Atoll. The highest weekly runway index counts occurred during the last week of May and from late August to early October, possibly because many birds were passing through Palmyra on their way further North or South during migration. During the 2000-2002 rat eradication attempts, several curlews were caught in traps while attempting to consume bait. In addition, there was one reported curlew death caused by internal bleeding from the ingestion of rodent bait containing the anticoagulant rodenticide brodifacoum. Because no rodenticide was found in the gizzard of the curlew, it has been suggested that the curlew died of secondary poisoning after preying on terrestrial invertebrates that had been exposed to brodifacoum (Depkin 2002).

Redmond (1990) suggested that curlew distribution within Palmyra varies regularly with the tide. At high tide most curlews are concentrated in open areas such as the airstrip and shoreline. At low tide, when the tidal sand flats are exposed, the curlews flocked to this habitat to forage on invertebrates (Redmond 1990). This species undergoes a molt-induced flightless period in autumn, and therefore, are more susceptible to predatory attacks in those months (Marks 1993). With a global population of approximately 10,000 individuals, the FWS has designated the bristle-thighed curlew as a Bird of Conservation Concern (FWS 2008), and it was also ranked as Vulnerable by the IUCN (Engilis Jr. and Naughton 2004).

Pacific golden-plovers prefer to forage in open spaces such as low vegetation fields, roadsides, sandy beaches, or mudflats. Although these plovers do not nest in the tropical Pacific, they may return to the same winter foraging island each year (Pratt et al. 1987). This species has been sighted regularly on the shoreline of Palmyra and in open, grassy areas near the camp. Direct counts in 1987 (Fefer) and 1992 (Flint) estimated a total wintering population at 75 and 144 plovers, respectively. Approximately 100 individuals were counted in December 2001 (Depkin 2002). Between September 2008 and July 2010 the highest index counts on the runway at high tide on May 21, 2010 (79 birds) and the lowest counts were on June 13, 21, and 27, 2009 (0 birds). This shows temporal patterns of Pacific golden-plover presence at Palmyra the U.S.

Pacific Islands Regional Shorebird Conservation Plan (2004) identified the plover as a species of high conservation concern.

Wandering tattlers have been seen in abundance along Palmyra's shoreline. The U.S. Pacific Islands Regional Shorebird Conservation Plan (2004) estimated that the total world population of wandering tattlers ranges from 10,000- 25,000 individuals. Fefer (1987) recorded 104 wintering wandering tattlers during a visit in 1987, and in 1992 Flint observed 126 wintering individuals. A survey in December 2001 reported 44 individuals at the atoll (Depkin 2002). Index counts on the runway ranged from nine birds in November 2009 and May 2010, and zero birds on 24 different counts over a 2-year period. The runway index count may not be as useful a tool for monitoring wandering tattler numbers as it is for other shorebird species, due to their more shoreline-oriented behavior.

The ruddy turnstone is common throughout the Pacific Islands; however, the wintering population in this region is small compared to the global total (Engilis Jr. and Naughton 2004). POBSP observers estimated 300 individuals in November 1964. Fefer (1987) reported 112 ruddy turnstones at Palmyra, mostly along the sand beaches and shoreline habitat of the atoll. Seventy-seven individuals were counted in the 1992 FWS visit (Flint 1992), and an August 2002 survey found 39 turnstones at Palmyra (Depkin 2002). These birds tend to flock in larger groups than the plovers or tattlers (Flint 1992).

The U.S. Pacific Islands Regional Shorebird Conservation Plan (2004) designated sanderlings as a species of "limited importance" in the Pacific Islands since the vast majority of these shorebirds winter in other parts of the globe. POBSP records indicate 5 birds were seen in November 1964. Sanderlings have been seen on the north beach of Cooper-Menge, Bird and Papala Island. Two sanderlings were observed in 1987 (Fefer), and 2 individuals were observed in November 2001(Depkin 2002). This species is an uncommon migrant to the atoll.

During the fall, infrequent sightings have been recorded for the following shorebirds: sharp-tailed sandpiper (*Calidris acuminata*), lesser yellowlegs (*Tringa flavipes*), semipalmated plover (*Charadrius semipalmatus*), buff-breasted sandpiper (*Tryngites subruficollis*), solitary sandpiper (*Tringa solitaria*), pectoral sandpiper (*Calidris melanotos*), and short-billed dowitcher (*Limnodromus griseus*).

<u>*Uncommon visitors recorded at Palmyra*</u>

Nonnative cattle egrets (*Bubulcus ibis*) were observed several times at Palmyra Atoll. Fefer (1987) saw one egret, and Flint (1992) reported five individuals roosting in a *Tournefortia* tree on the Cooper Island runway. Additionally, two sightings of individual egrets were documented in September 2002 (Depkin 2002). POBSP scientists sighted two American wigeons (*Anas americana*) and one Eurasian wigeon (*Anas penelope*) in November 1964. Two northern shovelers (*Anas clypeata*) were seen in a brackish pond on Holei Island and in the mudflats on Cooper Island during the 1992 FWS survey (Flint 1992). Depkin (2002) also reported a single shoveler in November 2001 at the east end of the runway. In 1987, a banded northern pintail (*Anas acuta*) that had been banded 82 days before in Utah was captured (Fefer 1987). Three Pintails were seen flying over Barren Island with a group of curlews in September 2002, and six individuals were observed on the runway in October 2002 (Depkin 2002). In addition to three green-winged teals (*Anas crecca*) sighted in April 1964, two individuals were seen at the east end and north side of the runway in November 2001 (Depkin 2002). A single lesser scaup (*Aythya affinis*) was reported on three separate occasions along the north side of the runway during November 2001 (Depkin 2002). A brief sighting of a bobolink (*Dolichonyx oryzivorus*) occurred in October 2001, the first recording of this species at Palmyra (Depkin 2002). An unidentified snipe was briefly observed in November 2010 (M. Naughton pers. comm.) A small population of crested mynas (*Acridotheres cristatellus*) was introduced to the atoll in 1950 but has subsequently been extirpated (Fefer 1987).

<u>*Special legal protection for birds at Palmyra*</u>

No bird species at Palmyra are listed under the Endangered Species Act (ESA) of 1973. All of the birds listed above are protected under the Migratory Bird Treaty Act (MBTA) of 1918, which prohibits the take of migratory birds without a permit. Additionally, the bristle-thighed curlew and Pacific golden-plover are designated as species of high conservation concern in National and Regional Shorebird Plans, as well as in the U.S. Pacific Islands Regional Shorebird Conservation Plan (Engilis Jr. and Naughton 2004). The bristle-thighed curlewhas also designated as a Bird of Conservation Concern by the FWS at the regional and national scale (FWS 2008a) due to limited breeding and nonbreeding distributions, low relative abundance, and threats during non-breeding season. Both of these species overwinter at Palmyra Atoll, with some juvenile and non-breeding birds remaining at Palmyra during the summer breeding season.

3.2.6 Terrestrial Wildlife of Palmyra

Invertebrates

Palmyra Atoll supports six species of native terrestrial crabs (Table 3.3), including the coconut crab (*Birgus latro*), two species of hermit crabs, two species of land crabs, and the brown tree climbing crab (*Geograpsis crinipes*). These crabs play an important role in breaking down organic matter and mixing soils, as well as dispersing seeds (Wiens 1962, Wegmann 2009). The existing literature for all terrestrial crab species found at Palmyra Atoll is limited, but there is slightly more information available for the coconut crab than the other crab species.

The coconut crab, the world's largest terrestrial arthropod, occurs on islands across the tropical Indo-Pacific region (Reyne 1939, Lavery et al. 1996). The coconut crab digs shallow burrows for mating and molting and frequently maintains several burrows within a territory. The species is omnivorous and will scavenge carcasses, climb trees to access food or escape, and can live up to 70 years. Because it is highly sought after for human consumption, it is rare on all inhabited islands and considered an imperiled species. Rock (1916) noted that the coconut crab "abounds in great numbers" and went on to note that the species eats their "brother crab".

Over the past several years, coconut crab populations throughout its range have declined due to overharvesting and habitat modification or destruction in many regions, and the species has become regionally extinct on Mauritius (Wells et al. 1983). Although progress toward sustainable use has been made in several countries, this species maintains an International Union for Conservation of Nature (IUCN) listing of 'Data Deficient', and information on natural populations remains sparse (Eldredge 1996).

At present, the coconut crab is the least abundant land crab at Palmyra Atoll, and coconut crab harvesting is prohibited (Howald et al. 2004). Limited quantitative data from four islands indicate variability in coconut crab densities at Palmyra Atoll (Buckelew et al. 2005). Qualitative accounts of differences in coconut crab densities around the atoll suggest that few islands currently support dense populations of this species. It is likely that black rats directly (through predation) and indirectly (through competition for food resources) adversely affect Palmyra's coconut crab population. Coconut crabs may also modify their activity patterns from nocturnal to diurnal in reaction to rat-related pressures. It is unknown to what extent coconut crabs are affected by rats at Palmyra, but evidence of predation (coconut crab carapace pieces in rat husking stations) has been observed (Wegmann and Fisher pers. comm. 2008), and there is considerable diet overlap between rats and land crabs (Wegmann 2009).

Palmyra hosts 2 species of hermit crabs at Palmyra. The most abundant crab species is the red hermit crab (*Coenobita perlatus)*, followed by the purple hermit crab (*C. brevimanus*) (Buckelew et al. 2005). These crabs use a gastropod shell (or other covering) to protect their unarmored abdomen and to prevent desiccation. Hermit crabs are omnivorous scavengers and are generally nocturnal; however, they are active diurnally in humid regions such as Palmyra Atoll. Rock (1916) reported sightings of "multitudes" of hermit crabs climbing the trees and eating *T. argentea* flowers, as well as its conspecifics.

Two species of land crab, the orange land crab (*Cardisoma carnifex*) and purple land crab (*Cardisoma rotundum*) are found at Palmyra. *Cardisomid* crabs construct well defined, deep burrows that go below the water table. They are primarily herbivorous, but will also scavenge dead animals. The brown tree climbing crab (*Geograpsis carinipes*) also has been recorded at Palmyra Atoll, though at much lower densities than the five crab species mentioned above.

Most terrestrial crabs are crepuscular or nocturnal to avoid desiccation, however, at Palmyra the aforementioned species are also active during the daytime (Wegmann pers. comm. 2008). Buckelew et al. (2005) found red hermit crabs to be the most abundant crab species at Palmyra Atoll (Table 3.3), no preference across vegetation types for any crab species, and that there was a general avoidance of open areas. Little is known about what might be affecting crab populations at Palmyra. Potential limiting factors include predation and competition for food resources by rats and limited access to suitable shells (for hermit crabs and juvenile coconut crabs).

Table 3.3. Crab abundance survey results, Palmyra Atoll (Howald et al. 2004). Units represent #/hectare estimates

Crab species	Mean # of crabs per hectare	Standard dev.	Mass (g)[2]
Birgus latro	7	38[1]	1000
Coenobita brevimanus	46	8	50
Coenobita perlatus	182	80	50
Cardisoma carnifex	33	8	300
Cardisoma rotundum	28	5	300

[1] Large variance probably due to low probability of encounter and patchy distribution.
[2] Approximate adult mass

Palmyra Atoll supports a few native and many accidentally introduced nonnative invertebrates (Handler et al. 2007). Little is known about the native invertebrates and their distributions and abundance across the atoll. In 2003, a terrestrial survey collected 115 arthropod taxa at Palmyra Atoll; most species were nonnative accidental introductions (Handler et al. 2007). The most detrimental nonnative insects include several ant species, a scale species, and mealy bugs. The most extensive invasive invertebrate distribution data available are included in *P. grandis* censuses (Nonner 2007) and an informal survey of the distribution of whiteflies (Aleyrodidea), scale (*Pulvinaria urbicola*), mealy bugs (Pseudococcidae), and aphids (Aphidoidea). In the latter survey, it was found that only 9 percent of plant species surveyed were not infested, and most observed plants harbored white flies (67 percent). In addition, 40 percent of plant species harbored mealy bugs while 28 percent harbored scale, and 18 percent harbored aphids (Freeman 2006). Additional studies have been undertaken to collect more data on the distribution and abundance of insects in general; however, these data have not yet been analyzed (Young et al. 2010).

Reptiles

Two species of marine turtles, the ESA-listed (Endangered) hawksbill turtle (*Eretmochelys imbricata*) and the ESA-listed (Threatened) green turtle (*Chelonia mydas*), are found at Palmyra Atoll with green turtles being the more common species (Fefer 1987) (Sterling pers. comm. 2008). Both species of turtles are known to forage in the nearshore waters and lagoons of Palmyra, and nesting has been documented at least twice for green turtles (Fefer 1987, Depkin 2002). Scientists from the FWS, American Museum of Natural History, and recently USGS have conducted surveys targeting both species abundance, and distribution in the eastern lagoons where turtles are most prevalent. Green turtles typically nest on sandy beach habitats, but may be prevented from nesting and laying eggs at Palmyra Atoll. One hypothesis for the lack of nesting may be the extreme abundance of coconut palms close to the beach where turtles might otherwise attempt to dig nesting pits (Suchanek et al. 2007). Additionally, turtle hatchlings are vulnerable to predation by rats as rats have been documented eating turtle eggs and hatchlings (Caut et al. 2008).

The ranges of at least 3 other species of marine turtles (all listed under the ESA) encompass the waters of Palmyra including the loggerhead turtle (*Caretta caretta*), the olive ridleyOlive Ridley (*Lepidochelys olivacea*), and the leatherback (*Dermochelys coriacea*) but have not been documented near shore.

Three terrestrial reptile species presently occur at Palmyra. These include an undescribed native gecko species (*Lepidodactylus n. sp.*), the potentially nonnative mourning gecko (*Lepidodactylus lugubris*) (a parthenogenic species represented on the atoll by many different clone types, of which there may be both native and nonnative clone types), and an introduced house gecko (*Hemidactylus frenatus*). The house gecko is suspected of transferring parasites to at least the mourning gecko (Fisher unpubl. data). Current studies are underway to investigate the distribution and habitat use of all three gecko species in order to gather baseline information and consider nonnative species eradication (Fisher and Hathaway 2007). One nonnative amphibian, the marine toad (*Bufo marinus*), was historically present at Palmyra Atoll but has not been observed since 2002 (Barclay pers. comm. 2008).

Nonnative Animals

Nonnative species have the potential to be invasive, which is defined by Executive Order 13112 as a species whose introduction has or may cause harm to environmental or human health (National Invasive Species Council 2008). Invasive species are known to be important factors in the decline of unique natural communities, threatened and endangered species, and ecological processes (Vitousek 1990, Veitch and Clout 2002, Engilis Jr. and Naughton 2004). Palmyra Atoll is home to a variety of nonnative invasive species, including plants, arthropods, and black rats.

The first invasive species to reach Palmyra Atoll are unknown, but likely arrived with early movement through the area by Polynesians over 1,500 years ago. It is widely held, though not proven, that the first introduction of coconut palms came to Palmyra from Polynesian movement, and it is clear that additional plantings have been made over the years. Coconut palms now dominate Palmyra's forest community, and often occur in monotypic stands that limit the recruitment potential for native tree species (Wegmann 2009). There are several other invasive plant species warranting investigation and prioritization for control and eradication, including Koa Haole (*Leucaena leucocephala)* and Pothos (*Epipremnum pinnatum)* (Hathaway et al. 2009).

Rats are well known to have severe effects on the ecosystems they invade, and there is extensive literature on the negative impacts of these mammals on Pacific Islands (Veitch and Clout 2002, Engilis Jr. and Naughton 2004, Howald et al. 2004, Buckelew et al. 2005, FWS 2005, Jones et al. 2008, Towns et al. 2009). They are thought to be responsible for the lack of burrow-nesting seabirds breeding at Palmyra Atoll, such as shearwater and petrel species that are often observed offshore (Depkin 2002) (J. Smith, M. McKown, E. Flint, L. Ballance, and R. Pitman pers. comm. 2008). Rats have been observed preying upon the ground nesting breeders at Palmyra, particularly sooty ternsTerns (Fefer 1987) (Wegmann pers. comm. 2008). While nesting events for green turtles have rarely been documented at Palmyra, it is worth mentioning that rats have been documented killing and consuming turtle hatchlings elsewhere (Caut et al. 2008). Furthermore, black rats at Palmyra have been observed attacking hermit crabs, and land crab carapace pieces are commonly found in rat husking stations (A. Wegmann and R. Fisher pers. comm. 2008). Aside from their impacts on the native fauna of Palmyra rats also affect the native flora by limiting native tree recruitment through seed and seedling predation (Wegmann 2009). Rats are also known to carry parasites, and recent studies have found that the parasites that accompanied rats to Palmyra use geckos as paratenic hosts (Lafferty et al. 2010)

Radio telemetry data comparing movements of rats that were live-trapped both in the crowns of coconut palms and on the ground, found that rats at Palmyra function in a 3 dimensional environment, and regularly move between the forest canopy and the ground. The planar home ranges of rats at Palmyra are small, between 475 ft^2 and 11,482 ft^2 (145m^2 and 3500m^2), n = 20) (Howald et al. 2004).

The Nature Conservancy, in conjunction with the U.S. Department of Agriculture's Wildlife Services, and the FWS initiated a rat eradication project at Palmyra Atoll in 2001. This eradication project was an attempt to restore Palmyra Atoll's terrestrial ecosystem. It was suspended in August 2003 after it became apparent that rats could not be eradicated at Palmyra Atoll through the methods in use at the time.

Various species of nonnative arthropods including scale insects, mealy bugs, ants, mud daubers, and mosquitoes are all present at Palmyra Atoll, and their effects are poorly understood. Ten species of nonnative ants have been recorded at Palmyra Atoll (Handler et al. 2007), 3 of which are considered highly invasive: the big-headed, crazy, and ghost ants (*Pheidole megacephala*, *Paratrechina longicornis*, and *Tapinoma melanocephalum*, respectively) (Pacific Invasive Ant Group 2004). It has been hypothesized that scale infestations were exacerbated by tending ant species, contributing to the recent decline of the *P. grandis* canopy area (Handler et al. 2007). The Big-headed ant is known to displace most native invertebrate fauna through aggressive behavior (Wetterer 2007). There have also been several noteworthy decreases in the abundance of vertebrates where the Big-headed ant is extremely abundant.

Wasps and mosquitoes are also prolific at Palmyra. Mosquitoes are of particular concern because they are potential vectors for a variety of human and wildlife diseases. Two of the mosquito species found at Palmyra, recently identified by Handler et al. (2007) are clearly threats. The Asian Tiger mosquito (*Aedes albopictus)* has a wide host range including humans and birds and is a known carrier of dengue, avian malaria, and West Nile Virus (Kyle and Harris 2008). The southern house mosquito (*Culex quinquefasciatus)* is a potential vector for avian diseases including avian malaria, avian pox, and West Nile Virus (C. van Riper III et al. 2002, LaDeau et al. 2008). Rats prey on coconuts, leaving behind the excavated shell to be filled by rain water, creating prime habitat for mosquitoes to lay their eggs.

Other nonnative animal species include house geckos, which also may be responsible for transmitting parasites and out-competing native geckos. House geckos are currently only found in association with buildings and other structures around the camp area.

3.2.7 Intertidal and Nearshore Ecosystems

Marine Wildlife

<u>Corals</u>

Extensive coral reef flats surround Palmyra, spanning 47 km^2 within the 10 fathom contour around the atoll (NMFS 2005). Palmyra Atoll supports three times as many coral species as found in Hawai`i, five times as the Florida Keys, and three times the species reported for the entire Caribbean (Maragos 2000). The coral fauna at Palmyra is even more diverse than other Line Islands, except for nearby Kingman Reef (Maragos 2006). Palmyra's specific location within the Equatorial Countercurrent may allow transportation of coral larvae from the highly diverse western Pacific region (Brainard et al. 2005). As a result, Palmyra likely functions as a coral larval source, dispersing species to atolls and reef islands in the central Pacific (Brainard et al. 2005).

The species composition and condition of coral reefs at Palmyra vary depending on the location within the atoll and have undergone drastic changes over time. The first significant survey of coral reefs at Palmyra was conducted by Maragos in 1987, when he noted evidence of reef damage from the negative impacts of previous military dredging and filling activities at Palmyra. Several important genera, especially *Acropora, Pavona,* and *Pocillopora* showed obvious signs of stress along the western reef (Maragos 1993).

Further impairment occurred in the mid-1990's, when the largest global coral bleaching and mortality event ever recorded damaged 16 percent of coral reefs around the world (Goldberg and Wilkinson 2004). Previously thriving *Acropora* staghorn coral thickets observed off Palmyra's broad western reef terraces in 1987 (Maragos 1988) degenerated into rubble deposits by 1998 (Brainard et al. 2005). The distribution of large *Porites* heads and numerous *Pocillopora* coral heads present on the terrace suggest that this collapse was due to mass coral bleaching rather than wave action. Bleaching was likely caused by warm ocean waters passing over the reef as a result of an El Niňo Southern Oscillation (ENSO) event. Degraded water circulation and increased temperature regimes due to earlier military activities were compounding factors contributing to the drastic collapse. Southern reefs down drift from the dredged channel also showed signs of sick or bleached corals, possibly due to turbid, warm water from the lagoons (Maragos et al. 2004). Corals along the north face of the terrace appeared unaffected by the event.

In 2002, rapid coral recolonization following the massive bleaching event of 1998 occurred on ocean facing reefs. Although not as abundant as 1987, corals off the broad western reef terrace appeared healthy and diverse (Maragos et al. 2004). Large colonies of *Porites* (6 – 12 ft or 2 – 4 m in diameter) were more dominant than *Pocillopora*, which was the most abundant coral at this location in 1998 and 2000. Coral abundance and diversity were dramatically higher off southeastern ocean facing reefs than earlier surveys, with coverage exceeding 50 percent at most sites (Maragos et al. 2004). All recent shifts indicate a slow ecosystem recovery process after the previous bleaching event (Maragos 2006).

In the southeastern reef pools, Coral Gardens has over 25 species of *Acropora* including rare species and species absent elsewhere at the atoll. No one genus accounted for more than 18 percent of the corals. Eighteen or more genera of coral faunal species were documented with the highest richness on the eastern and northern reef sites (Maragos 2006). While the most recent survey in March 2006 documented similar species richness as the 2004 survey, overall coral cover at this site has been declining over recent years. This may be due to lagoon water flowing out of a break in the islands surrounding the East Lagoon, bringing heated, sediment laden water into the Coral Gardens, thus stressing and killing corals there.

Despite the current health of Palmyra's coral reefs, one potential for devastation recently became apparent. In 1991, a long line fishing vessel wrecked on the western shelf of Palmyra, and was first examined by Maragos in 2004. Initial inspection of the wreck revealed low numbers of the corallimorph *Rhodactis howesii*, a cnidarian that can damage and overgrow benthic organisms, thus rendering it competitively superior to some coral species (den Hartog 1980). Corallimorpharians possess elongated marginal tentacles that allow them to kill scleractinian corals (Chadwick 1987, Williams 1991) and has several modes of clonal replication, allowing them to rapidly monopolize space on tropical coral reefs (den Hartog 1980, Langmead and Chadwick-Furman 1999). This corallimorph may be stimulated by substances dissolving from the wreckage such as iron, an essential trace element for primary producers on coral reefs (Entsch et al. 1983, Maragos 2004). In 2005 *R. howesii* cover expanded, and by 2006 the population increased dramatically. High densities were documented at the wreck site that decreased with distance from the shipwreck, while *R. howesii* was rare or absent in other parts of the atoll (Maragos 2004, Work et al. 2008). *R. howesii* still occupies over 2 km^2 of reef habitat, smothers thousands of corals, and is the largest corallimorph invasion of a reef known to date (Work et al. 2008). Given its ability to rapidly reproduce, *R. howesii* may continue to expand across Palmyra's western reef even if the shipwreck is removed. Management of the phenomenon may include manual removal or chemical sterilization of the benthos, however the efficacy of these methods is unknown (Work et al. 2008).

Fishes

Coral reefs like those at Palmyra Atoll can sustain inverted biomass pyramids, a phenomenon in which up to 85 percent of the fish biomass is composed of apex predators (Friedlander and DeMartini 2002, Sandin et al. 2008). Fish species diversity at Palmyra Atoll is higher than other remote Pacific refuges, consisting of 418 species (The White House 2009). Piscivore biomass is dominated by several species of sharks (gray reef shark (*Carcharhinus amblyrhynchos)*, black tip reef shark (*C. melanopterus)*, and white tip reef shark (*Triaenodon obesus*) (DeMartini et al. 2008). Shark abundance was fairly consistent between years, although a predominance of juvenile gray reef sharks (85 percent were less than 150 cm) may be indicative of fishing pressure (Brainard et al. 2005). Several giant hammerhead sharks (*Sphyrna mokarran*) have been observed at Palmyra (Pacific Island Fisheries Science Center 2004). Quite a few species of snappers are present, the most common are twinspot snapper (*Lutjanus bohar*), humpback snapper (*L. gibbus*), smalltooth jobfish (*Aphareus furca*), and onespot snapper (*L. monostigma*). giant trevally (*Caranx ignobilis*), bluefin trevally (*C. melampygus*), and black jacks (*C. lugubris*) were the most numerous of the jacks reported. Sixteen species of grouper were observed in 2004, with peacock grouper (*Cephalopholis argus*) the most abundant. Smaller numbers of the flagtail grouper (*C. urodeta*) and the camouflage grouper (*Epinephelus polyphekadion*) were also reported (Brainard et al. 2005). Combined, these large fishes account for 56 percent of the fish biomass at Palmyra (Stevenson et al. 2007).

Other marine fishes observed in the coral reef surrounding Palmyra include butterfly fish (Chaetodontidae), damselfish (Pomacentridae), parrotfish (Scaridae), wrasse (Labridae), and surgeonfish (Acanthuridae) or tangs (FWS 2001). Manta rays (*Manta birostris*), eagle rays (Myliobatidae), and bonefish (Albulidae) are frequently sighted in the lagoons. Palmyra also hosts one of the largest lightly fished (catch and release) round-jaw bonefish (*Albula glossodonta*) populations in the Pacific, being studied by participants of the Palmyra Bonefish Conservation Research Program (Ault 2008).

Turtles

2 species of turtles have been observed foraging at Palmyra Atoll: the hawksbill, and the more common green turtle (Fefer 1987). Large numbers of turtle sightings during survey periods indicates that Palmyra is a significant marine chelonian foraging area. Hawksbill turtles are typically found feeding in the vicinity of rock or reef habitats in shallow tropical waters with little turbidity (Witzell 1983). Hawksbill turtles are specialist sponge carnivores, selecting just a

few genera of sponges for their principal diet (Vicente 1994). This feeding strategy is unique, as few vertebrates are capable of digesting sponges without being injured by the sponges' silicate spicules (needles). Green turtles of nearshore habitats in the Hawaiian Islands feed on benthic algae of the following genera: *Codium*, *Amansia*, *Pterocladia*, *Ulva*, *Gelidium*, and *Caulerpa* (NMFS 1998). In 2009 the Eastern-Pacific green turtle, which is distinguished by its darker color, was found in the waters surrounding Palmyra (Meyer pers. Comm.)

Green turtles often nest on wide sandy beaches and nesting has been documented at least twice at Palmyra, primarily on the northwestern side of Cooper Island (Fefer 1987, Depkin 2002). However, the close proximity and great abundance of coconut palms on the beaches of Palmyra may deter green turtles from digging nesting pits. Predators of green turtles typically raid nests closest to the vegetation line, rarely destroying nests at low or mid-beach position (Fowler 1979). The outer islands of the refuge are less conducive to marine turtle nesting activity due to the narrow area, lack of sand during high tide, and continuous beach erosion exacerbated by World War II era alterations.

Marine mammals

Marine mammals of two orders, *Cetacea* and *Pinnipedia* have been observed in the pelagic waters surrounding Palmyra. The most commonly sighted cetaceans are bottlenose dolphins (*Tursiops truncatus*) (Fefer 1987, Yuen 1991), spinner dolphins (*Stenella longirostris*), and melon-headed whales (*Peponocephala electra*) (Brainard et al. 2005). Palmyra's surrounding waters also support populations of short-finned pilot whales (*Globicephala melas*) and false killer whales (*Pseudorca crassidens*) (Brainard et al. 2005). A possible recently re-discovered species of tropical beaked whale *Mesoplodon hotaula* was described from two specimens stranded at Palmyra and one at Christmas Island (Dalebout et al. 2007) and in 2010 killer whales (*Orcinus orca*), were also observed (A. Meyer, personal comm). Cetaceans have not been known to enter Palmyra's lagoons. Although protected under the Marine Mammal Protection Act, none of the cetaceans mentioned here are listed under the ESA or otherwise considered threatened.

Two sightings of Hawaiian monk seals (*Monachus schauinslandi*), ESA-listed as Endangered, have occurred at Palmyra decades ago (Redmond 1990, Westlake and Gilmartin 1990). These sightings are considered vagrant animals, as Palmyra is well outside of their known range (Gilmartin and Forcada 2002).

All marine mammals are federally protected under the Marine Mammal Protection Act (MMPA) of 1972.

Algae

Alga contribute to the health of coral reef ecosystems, providing trophic resources for grazers and herbivorous fish, and bioconstruction of calcified reef (Gattuso et al. 1998), as well as contributing to coral reef productivity (Rowan 1998). Transfer of nutrients from algae to coral occurs when fish or invertebrates forage on primary producers and excrete on the coral reef (Birkeland and Grosenbaugh 1985). *Lyngbya*, blue-green algae, was the most common algal species originally observed by Dawson (1959) on the broad reef-flats of the northern and southern portions of the atoll. *Lyngbya* tolerates high temperatures, turbidity, low salinity, and high organic content caused by restricted circulation, allowing its abundance on reef-flats (Dawson 1959). In 2006, 19 genera of algae were observed, compared to the 10 genera identified only 2 years prior (Pacific Island Fisheries Science Center 2006). *Caulerpa* and other Chlorophyta species are known to be an important food source for turtles (Bjorndal 1985). Macroalgal blooms usually associated with anthropogenic inputs of nutrients to coastal waters are absent at Kingman and Palmyra, which suggests that grazing activity, of an intact herbivore community, on unpopulated reefs may control macroalgal abundance even at high inorganic nutrient concentrations (Sandin et al. 2008).

<u>*Marine invertebrates*</u>

Noncoral marine invertebrates were rarely examined throughout the reef habitat at Palmyra Atoll. The first large-scale quantitative assessment of benthic fauna was conducted in 2008 by the Coral Reef Ecosystem Division of NOAA at the NOAA Pacific Islands Fisheries Science Center (PIFSC). Research divers conducted belt-transect surveys and counted common invertebrate components of the reef habitats within the phyla Cnidaria, Echinodermata, Mollusca, and Arthropoda. Marine invertebrate fauna included several species of anemones (*Heteractis, Stichodactyla, Phymanthus*), sea urchins, sea cucumbers, sea stars, *Spondylid* oysters, pearl oysters, *Tridacnid* clams (giant clams), *Charonia* (Triton's trumpet) and *Lambis* (spider conch), octopuses, hermit crabs, lobsters, and large crabs (Brainard et al. 2008). The most common macroinvertebrates observed during 2006 surveys were *Trapezid* crabs and hermit crabs, which were mostly associated with *Pocillopora* corals. Echinoderms were rare during surveys in 2006 (Pacific Island Fisheries Science Center 2006).

Fluted giant clams (*Tridacna squamosa)* and maxima clam (*T. maxima)* are the two giant clam species present at the atoll. Surveys in 2004 found that giant clams were not abundant at Palmyra, except on the shallow sheltered “coral gardens” reef (Pacific Island Fisheries Science Center 2004), and giant clams were recorded from only five sites in 2006 (Pacific Island Fisheries Science Center 2006). Throughout their adult lives, these species are firmly attached to coral reefs by byssal threads (Munro 1985), however, recruitment is poorly understood. Very little is known about source areas for larvae and whether some reefs act as stepping stones for species dispersal (Wells 1995). Like the coral reef, giant clams harbor enormous numbers of primary producing dinoflagellates, zooxanthellae (*Symbiodinium microadriaticum*). Giant clams benefit from a highly efficient internal food source, allowing them to grow faster and larger than other bivalves (Heslinga and Fitt 1987). Populations of these clams have been declining on other Pacific Islands over the years. Giant clams have been harvested in such numbers for their meat, that they have been listed in Appendix II of the Convention on International Trade of Endangered Species (CITES)(Wells 1985, FWS 2001) in an attempt to control their international movement.

Threatened and Endangered Marine Species

Many species that are threatened, endangered, and depleted at a global level thrive at Palmyra Atoll, including green and hawksbill turtles (ESA listed), black-lipped pearl oysters (*Pinctada margaritifera*) (CITES listed), maxima clams (CITES listed), reef sharks, groupers (CITES listed), humphead (ESA species of concern) or Napoleon wrasse (*Cheilinus undulates*) (CITES listed), green bumphead parrotfish (*Bolbometopon muricatum*) (ESA species of concern and candidate species), and various cetaceans. In addition, 21 of the 82 species of corals currently under petition for ESA listing by NOAA occur at Palmyra (Kenyon et al. 2011).

Worldwide populations of the green turtle have seriously declined as a direct result of overharvesting of turtles and eggs over the last centuries (Parsons 1962). In 1978, the green turtle was listed as threatened under the Endangered Species Act (ESA 1973). Additional protective regulations are enforced throughout all areas within U.S. jurisdiction in an effort to conserve and restore marine turtle populations to their former levels of abundance. Inclusion of green turtles into CITES made it illegal to trade any products made from this species in the U.S. and 130 other countries. Since 2001, the Hawai`i-based long-line fishing industry has undergone a series of regulatory changes to protect marine turtles and the short-tailed albatross (*Phoebastria albatrus*) (NMFS 2001).

Palmyra Atoll National Wildlife Refuge has been noted as a significant habitat for the threatened green turtle. Turtle hatchlings are also vulnerable to predation by rats (Caut et al. 2008), therefore successful rat eradication may expand the nesting habitat for threatened green turtles.

The hawksbill turtle is listed as an endangered species throughout its range by the International Union for the Conservation of Nature and Natural Resources and the Endangered Species Act of 1973. Despite protective legislation, international trade in hawksbill shells, meat, and eggs continues unabated in many countries and poses a significant threat to the survival of the species. More than one million hawksbill turtles have been killed for their shells since 1970 and illegal international trade continues to be the primary threat to the species.

3.2.8 Terrestrial Vegetation

Records of collections and descriptions of the vascular flora of Palmyra Atoll date as far back as 1873 (Streets 1877, Rock 1916, Dawson 1959, Herbst 1987, Depkin 2002, Freeman 2006). The most recent surveys, completed by Herbst in 1987 and 1992 (and subsequent identification of two additional species sent to him in 2002), provide a vascular plant species list and a brief description of the primary plant associations. These were later updated by Wegmann (2005) and Freeman (2006). According to Herbst (1987. 1992), three main vegetation associations, including *P. grandis* forest, *Scaevola-Tournefortia* (coastal strand forest), and coconut palm forest, were observed on the islands. Other minor vegetation types occurred, but were so small that they would not be plotted on a conventional vegetation map (Herbst 1992).

As early as 1862, coconut palms and food plants were being introduced to the atoll (report from Zenas Bent while he was under commission by King Kamehameha IV to take possession of Palmyra under the Hawaiian flag) (Rock 1916). Following Rock’s 1916 account describing 15 species of vascular plants, including coconut palms, many additional species were added to the list of both native and nonnative species. Some of the species added to the list were likely present when Rock visited in 1913, but were not encountered or not recognized at the time. The native Beach gardenia (*Guettarda speciosa)* was collected on the atoll in 1949, but several other species were not recorded until much later. These species include mareer (*Cordia subcordata),* mago *(Hernandia sonora),* and sea poison tree (*Barringtonia asiatica)* (Herbst 1987, 1992), and it has been assumed that they arrived at Palmyra relatively recently without human intervention. While unlikely to give a complete pre-historic snapshot of the flora of Palmyra, ongoing paleoecological collecting and analyzing fossil pollen may help resolve some of the uncertainties surrounding which species have been present over time. The practice of introducing and cultivating plants for food and as ornamentals continued until recently (Freeman 2006), however, the list of unintentional introductions is also large. Some introduced plant species were unable to persist, but many have naturalized. The total vascular flora identified in past and current records at Palmyra Atoll includes 129 species. Twenty-five are considered native and two of these may now be extirpated; 48 were cultivated ornamentals or food plants; and 56 were adventives or naturalized plants (Herbst 1992, Freeman 2006). Freeman (2006) suggests that in 2006, 78 vascular plant species were still present. Twenty-five of these were considered native species, while 53 species are considered nonnative. One subspecies of native grass, *Lepturus repens* var. *palmyrensis*, is considered endemic to Palmyra.

Dominant Vegetation Types

Palmyra's aseasonal climate, with high precipitation and warm temperatures, supports dense assemblages of native and nonnative trees, shrubs, and herbaceous understory plants. A forest map based on 2001 satellite imagery (Wegmann 2005) estimated that a large portion of the atoll (approximately 43 percent) is dominated by the potentially nonnative coconut palm (*C. nucifera*) followed by beach naupaka (*Scaevola sericea)* and *T. argentea* (~29.5 percent) and *P. grandis* (~12 percent). Other vegetation types include broadleaf forests dominated by potentially nonnative Bengal almond (*Terminalia catappa,* ~6.2 percent), native sea hibiscus (*Hibiscus tiliaceus,* ~0.5 percent), and monodominant stands of native *Pandanus fischerianus.* Understory plant assemblages include *L. repens* grassland, *P. scolopendria* stands, and bare ground (Wegmann 2005). Natural temporal succession within these communities has been shaped by biophysical interactions and natural disturbance regimes from strong winds and cyclones, precipitation, seabird derived nutrients, and land crab-driven herbivory, seed dispersal, and seed predation.

<u>*Pisonia grandis* forest</u>

Pisonia grandis (Nyctaginaceae) is a large fast growing tree with soft wood reaching heights up to 25 m at Palmyra (Herbst 1992). The distribution of *P. grandis* is limited to small remote islands in the Indian and Pacific Oceans (Airy-Shaw 1952), and was described in the 1890s as one of the most conspicuous forest types on coral atolls visited by the U.S. Fisheries Commission cruises (Fosberg 1994). It is now declining in much of its range due to human activities (Walker 1991), *Pisonia* trees primarily reproduce vegetatively, though the species does have sticky seeds that are dispersed long distances through adhesion to seabird feathers (Burger 2005).

There is little genetic differentiation between *P. grandis* individuals across the species' Pacific range. This suggests that bird dispersal was effective enough at mixing *P. grandis* genes between isolated islands throughout the Pacific (Walker 1991). The factors influencing the pattern of distribution and growth of *P. grandis* preclude a simple explanation. For instance, *P. grandis* is found on both very wet and very dry atolls, as well as with and without guano inputs. Walker (1991) suggests that multiple contributing factors include: low dispersal frequency, guano effects, precipitation patterns, competition, insect grazing, genetic variation, and mycorrhizal associations. He points out that *P. grandis* would likely be dispersed widely by seabirds through uncharacteristic dispersal events, such as cyclone scatter of seabirds. However, islands in relatively close proximity to each another, *P. grandis* may be present at some islands but not others. While it has been suggested that *P. grandis* requires guano for growth, its distribution shows that this is not necessarily the case provided the soil contains adequate nutrients (Wiens 1962, Spicer and Newberry 1979). *P. grandis* have very shallow root systems, adapted for using near surface water, as a results of these adaptations, *P. grandis* is found at both the wettest (e.g., approximately 4,500 mm/yr at Palmyra Atoll) and very driest islands (e.g., 70 mm/yr at Vago Island) (Walker 1991).

The *Pisonia* population at Palmyra Atoll suffered severe losses of most of the mature individuals between 2002 and 2005 possibly due to an unexplained population explosion of the nonnative scale insect *Pulvenaria urbicola* (Nonner and Woodward 2006). Several management options were evaluated including systemic application of the insecticide imidicloprid to specimen trees and control of ant species suspected of facilitating scale survival. Results were equivocal from all these experiments but there is currently good regeneration occurring in the *Pisonia* forest.

Coastal strand forest or Scaevola-Tournefortia

Native *S. sericea* and *T. argentea* are the dominant species of the coastal strand vegetation type. *S. sericea* is more dominant on lagoon borders, and *T. argentea* dominates on the ocean edges (Herbst 1992). Both are considered widespread, halophytic, pioneer species, and they can be found in monotypic stands, or co-dominant and mixed forest (Niering 1963, Kepler and Kepler 1994). These species are generally not dense enough to prohibit ground cover and appear to have no substrate preference (Fosberg 1957). This vegetation type, specifically *T. argentea,* is heavily used by red-footed boobies for roosting and nesting, and is comparable to *P. grandis* in native bird use overall (Young pers. comm. 2008). *T. argentea* is less abundant across the Pacific than it was formerly (Kepler and Kepler 1994). Kepler and Kepler (1994) report that most mature *T. argentea* trees occur at the *T. argentea - P. grandis* interface but die off as *P. grandis* expands. Geckos have been observed drinking the nectar from *T. argentea* flowers, and Rock (1916) reported that crabs feed on the flowers. Herbst (1992) noted that *S. sericea* is the dominant species on Barren Island with only a few *C. nucifera* and T. *argentea* present. Barren Island is the most recently formed island in the atoll and often disturbed by storms. The dominance of *S. sericea* on this island suggests that it represents a very early successional stage. Usinger and La Rivers (1953) reported that both *S. sericea* and *T. argentea* at Arno Atoll have their own distinct insect populations.

Pandanus fischerianus

Fosberg (1957) observed small groves of dense native *P. fischerianus* scattered throughout Palmyra Atoll. There were records or collections of *P. fischerianus* from 20 islands in 2006.

Lepturus repens var. palmyrensis

One of the other native but minor vegetation types occurring at Palmyra includes small patches of native grasslands. This grassland is composed of Palmyra's only endemic species *Lepturus repens* var. *Palmyrensis* (Herbst 1992). It is closely related to the taxa found on Malden and Christmas Islands as well as Pokak and Wake Atolls (Herbst 1992).

Cocos nucifera

The occurrence of the possibly nonnative coconut palm at Palmyra is likely the result of early introduction by Polynesian explorers. Subsequent expansions of this species through plantings occurred prior to and during military occupation and continued until at least 1957 (Dawson 1959). While this species could have arrived on its own via drift dispersal (Harries 1992), it is clear that its distribution is augmented by human movement. In addition, *C. nucifera* has displayed invasive behavior at Palmyra, increasing from approximately 9,600 coconut palms in 1886 to approximately 2 million currently (Rock 1916, Wegmann 2009). *C. nucifera* is now the dominant forest type at Palmyra. It rapidly colonizes canopy gaps opened in other forest types (Herbst 1992, Freeman 2006), and ongoing research by Hillary Young of Stanford University indicates that coconut palms outcompete native species for nutrients. In addition, Young found that the large nuts and fronds cause physical damage to native species when they fall, allowing for further expansion of already established coconut palm groves. Data collected recently regarding coconut palm grove habitat by native animal species is still being analyzed. However, it seems clear that few seabirds use coconut palms for roosting and even fewer for nesting (Young et al. 2010). The *C. nucifera* forest provides abundant food and habitat for nonnative black rats (Howald et al. 2004, Wegmann et al. 2007) and the fruits are used as a food source by the atoll's land crab community (Wegmann 2009). Abundant evidence demonstrating elevated native seed predation in *C. nucifera* dominated sites relative to other forest types further suggests significant cascading effects of *C. nucifera* forest dominance throughout the larger Palmyra Atoll system (Young et al. 2010).

Terminalia catappa

The history of *T. catappa* or Tropical Almond at Palmyra is unknown, but it is generally regarded as a nonnative invasive species. Dawson (1959) describes *T. catappa* and other species as being purposely introduced through original plantings on Menge Island. It is the dominant tree in several groves on Cooper Island, particularly near the TNC camp, but it apparently has not yet spread in large numbers to other islands. *T. catappa* should be considered for control plans similar to the plans suggested for coconut palms. At minimum it should be monitored to examine how quickly it is expanding in distribution.

Hibiscus tiliaceaus

The history of hibiscus (*H. tiliaceaus)* at Palmyra is also unknown, but it is also regarded by some as a nonnative invasive species. Dawson (1959) describes this and other species as being purposely introduced through original plantings on Menge Island. Small, very dense, monotypic hibiscus groves are scattered on several islands in the atoll. In addition, there is a nearly impenetrable hibiscus swamp in the central portion of Pelican Island and another smaller hibiscus swamp on Home Island. The rate of spread of hibiscus is unknown; expansion should be monitored and control plans considered.

Miscellaneous species

In addition to the aforementioned vascular plants, two species of terrestrial algae, three mosses, eight lichens, and four fungi species have been identified at Palmyra Atoll (Rock 1916, Dawson 1959, Herbst 1992).

3.2.9 Social and Economic Environment

Ownership, Management, Major Stakeholders

Ownership

Palmyra Atoll is currently owned and managed by the U.S. Fish and Wildlife Service, The Nature Conservancy, and the Cooper family. The majority of the islands, waters, and the coral reef surrounding Palmyra up to 12 nautical miles to sea is owned and managed by the FWS as a National Wildlife Refuge for the "conservation and management of native species of wildlife and fish and their habitats" (Federal Register 2001). Palmyra Atoll NWR was established on January 18, 2001, by Secretary's Order 3224; it includes approximately 446.25 acres (180.57 ha) of emergent land, approximately 503,963 acres (203,946 ha) of submerged lands and associated waters, including roughly 16,094 acres (6,515 ha) of coral reef habitat (Federal Register 2001). The Nature Conservancy purchased Palmyra from the Fullard-Leo family in 2000 to protect its waters and lands. TNC now owns Cooper and Menge Island (TNC 2005). The Cooper family has retained ownership of Home Island. The atoll is an incorporated territory of the United States. The Nature Conservancy operates a research station on Cooper Island that supports the Palmyra Atoll Research Consortium or "PARC" (http://www.palmyraresearch.org/). PARC is not a land owning entity.

The FWS manages the Refuge for the "conservation and management of native species of wildlife and fish and their habitats. Wildlife species identified as endangered or threatened will receive management priority, with a special emphasis on stewardship of endangered and threatened turtles, migratory seabirds that forage in the refuge waters, the coral reef, and pelagic wildlife. Management actions will include protection of the refuge waters and wildlife from commercial fishing activities" (Federal Register 2001).

Access

Public access to Palmyra Atoll is largely self-limiting due to the very high expense of flying to such a remote destination. TNC owns and operates the only airplane runway at Palmyra (Cooper Island) and travel to the atoll by boat is a 5-7 day voyage from Honolulu, Hawai`i. The public may gain access to the refuge in four ways: 1) working for, contracting with, or volunteering for TNC or FWS; 2) conducting scientific research via FWS Special Use Permits; 3) invitation through TNC, FWS, or PARC; or 4) by private recreational sailboat or motorboat. With prior approval by the FWS, privately owned vessels are permitted access to the Palmyra Atoll NWR for up to 7 days to observe and enjoy the natural resources of the Refuge. A maximum of two vessels are allowed at one time and up to six yachts may visit in a month. Private vessels must have U.S. Coast Guard (USCG) approved holding tanks for sewage and an appropriate and current USCG inspection certificate. Access to Cooper Island must be arranged and secured through TNC (FWS 2010e).

Historical and Cultural Resources and Values

Palmyra has undergone a series of private ownership turnovers and is one of the few wet atolls that was not permanently occupied or claimed by any Pacific Island culture (Maragos et al. 1999). Palmyra received its official name when Capt. Sawle landed his American vessel, *Palmyra,* on the atoll on November 7, 1802. In 1859, Dr. G.P. Judd of the American brig

Josephine, claimed possession of the atoll for the United States and the American Guano Company. In 1862, Kamehameha IV commissioned Hawaiian citizens, Captain Zenas Bent and Mr. Johnson Wilkinson to perform a formal ceremony taking possession of the atoll from the U.S. and the American Guano Company. Captain Bent sold his portion to Wilkinson in 1866 for $500, and his wife inherited the atoll following his death. The heirs of Mrs. Wilkinson sold Palmyra to the Pacific Navigation Company for a single dollar and "other valuable considerations" in 1885 (U.S. Supreme Court 1947). When the United States annexed the Hawaiian Islands in 1898, Palmyra Atoll was specifically included as part of the Hawaiian Territory. After a series of private ownerships, Hawai`i Circuit Court Judge Henry E. Cooper bought Palmyra in 1911 for $750, hoping to find an allegedly buried pirate treasure. The Fullard-Leo family of Honolulu purchased Palmyra (except Home Island) for $15,000 from Judge Cooper in 1922 (Aronson and Anderson 2000).

In 1939, the Fullard-Leo family received notice that the U.S. government was reclaiming Palmyra Atoll (U.S. Supreme Court 1947). Beginning in 1939, Palmyra was heavily used as a naval base until the end of World War II. Approximately 6,000 military personnel were stationed on the atoll for several years. Military activities included road construction along the perimeter, causeway construction between the lagoons, dredging a 200-foot wide channel through the western reef, enlarging Cooper Island to build an airstrip and port along the island's southern shore, dredging of a sea plane runway, and the creation of two fighter plane air strips. The U.S. Coast Guard also had operations at Palmyra during this time. After years of court battles with the Navy, the Fullard-Leo family was awarded valid title by the U.S. Supreme Court and the Navy abandoned the atoll in 1945. In 1947, the Federal Aviation Administration leased the atoll, stationing 970 personnel and their families on the atoll for 3 years (Aronson and Anderson 2000). In 1959 Hawai`i became the 50th State of the United States of America. Palmyra was specifically excluded from statehood and became the only completely privately owned U.S. insular area. Executive Order No. 10967 (dated October 10, 1961) stated that the Secretary of the Interior was responsible for the civil administration and executive and legislative authority of Palmyra.

In 2000, TNC purchased Palmyra from the Fullard-Leo family in an effort to help preserve its natural resources. Further protection was granted in January 2001 when the lagoons and surrounding waters within the 12 nm U.S. territorial seas were transferred via Secretarial Order from the Office of Insular Affairs to the FWS and designated as a National Wildlife Refuge. In March 2003, TNC sold a portion of the emergent lands to the FWS (Davis 2003). In 2007, TNC sold another 3 parcels to the FWS (Lyons pers. Comm.).

Several World War II military structures remain at Palmyra, including a basketball court, water cistern, bunkers, a collapsed building, a Quonset hut, a drainage ditch, a hospital, and several "pill-boxes" and supporting structures for gun batteries. Some of these structures are decaying due to vegetation growth, harsh climate conditions, and wave action (Aronson and Anderson 2000, FWS 2001).

The Office of Hawaiian Affairs (OHA) has indicated that the Hawaiian people are interested in cultural resources that may be found at Palmyra. Because Palmyra was once claimed by the

Hawaiian Kingdom, OHA believes the atoll has cultural importance to native Hawaiians. No sufficient documentation has shown that customary or traditional Hawaiian practices (such as fishing) occurred on the atoll (FWS 2001).

Human environment

Since purchasing the atoll in 2000, TNC has organized approximately four to six visitor trips to Palmyra each year (Lyons pers. comm.). Visitors participate in catch-and-release bonefishing, offshore blue-water recreational fishing, nature walks, kayaking, SCUBA diving, and other activities deemed compatible with the Refuge (Depkin 2002). TNC guests and staff are allowed three weekly catches of tuna, ono, or mahi for local consumption.

In 2004, TNC partnered with 10 academic institutions and government agencies in the establishment of the Palmyra Atoll Research Consortium. In 2005 a new research station facility was constructed on Cooper Island (TNC 2005). The station includes 16 small residential cottages, a galley, shower house, bathrooms, and a research laboratory. The station is capable of housing and supporting 25 staff and researchers at one time. Fresh water is supplied through a refurbished 100,000-gallon fresh water catchment tank. The station relies on an environmentally friendly septic system, which uses a multi-stage system to flush sewage through tanks before reaching a leach field. Nutrients are absorbed by native sedges and the remaining water irrigates a grassy area (Lyons pers. comm.). Electric power is generated and transmitted by 2,500 kv diesel generators on Cooper Island, but there are plans for the station to switch to solar power. A satellite dish was installed in 2006 to supply the station with internet connectivity and web-based telephones. Pre-existing infrastructure in use on Cooper Island includes a seaplane ramp, a crushed-coral runway, and concrete bunkers (Howald et al. 2004).

Currently, between five to six permanent and temporary TNC employees are stationed at Palmyra to manage conservation and research activities and support visitors and PARC researchers. Staff positions include a field station manager, a galley manager, one to two galley assistants, a maintenance manager, a boat captain and a chief of marine operations. These employees work in 3-month cycles. At least one FWS employee, a Refuge Manager or assistant, is stationed at Palmyra.

Recreational and aesthetic uses

The Conceptual Management Plan for Palmyra Atoll National Wildlife Refuge established five Interim Compatible Determinations for recreational uses at Palmyra Atoll NWR.

Environmental education

Members of the public are permitted to visit the Refuge to participate in environmental education, interpretive hikes, motorboat and kayak outings, and wildlife photography. Up to 30 participants at any one time are allowed to participate in Refuge environmental education and interpretive programs, including hikers and kayakers. A minimum of one approved guide for each group of hikers and kayakers is required. Groups of hikers or kayakers may not exceed 10 individuals.

Wildlife observation through diving and snorkeling

Up to 12 visitors at any one time are allowed to participate in recreational diving and snorkeling programs. Two groups of up to four divers or snorkelers are allowed per boat in the lagoon, channel, or ocean reef sites at any given time. An additional four snorkelers are permitted to use the third small skiff near the lagoon or channel area for diving and snorkeling.

Bonefishing

Recreational bonefishing is conducted at Palmyra on a catch-and-release basis with artificial flies and barbless hooks. A total of eight anglers are allowed in the lagoons at one time, with no more than two fishing outings permitted per day and must be accompanied by a FWS-approved guide. Catch rates are monitored through daily logs and tagging studies in order to assure sustainable fishery conditions.

Blue water (offshore) fishing

The offshore sport fishing program at Palmyra allows visitors access to pelagic game-fish, including tuna (ahi), wahoo (ono), and mahi-mahi. Fishing is limited to eight people per trip, one trip per day. Fishing logs are required for each trip. Only pelagic species are permitted for on-atoll consumption and only 150 lbs of pelagic fish maybe be taken each week from the waters surrounding the atoll. No bottom fish or reef fish are allowed to be targeted for consumption and any that are accidentally caught are to be immediately released. Jacks can be fished on a catch-and-release basis; none are permitted to be consumed or retained for any reason. An independent scientific research and monitoring program is required for jacks in order to form a basis for determining whether the jack catch-and-release program should be retained, scaled back, or cancelled. Boat captains and crews are required to be trained on the scope, restrictions, and associated rationale for the sportfishing program.

Sailing and motor boating

With prior approval by the FWS, privately owned vessels are permitted to access the atoll for up to 7 days to see and enjoy the natural resources of the refuge. A maximum of two vessels are allowed at one time and up to six yachts may visit monthly. Private vessels must have U.S. Coast Guard (USCG) approved holding tanks for sewage and an appropriate and current USCG inspection certificate.

Unexploded ordnance (UXO)

One safety issue at Palmyra is unexploded ordnance (UXO). UXO is explosive weaponry that did not explode when deployed, and subsequently poses a risk of detonation. During World War II, Palmyra was used by the U. S. Navy and Coast Guard as a Naval Air Station. Later in 1962, the U.S. Department of Defense used the atoll for an instrumentation site during high altitude atomic weapon tests over Johnston Island. In an effort to improve atoll safety, the Defense Environmental Restoration Program conducted a site survey of UXO at Palmyra in 1995. Survey results indicated that Whippoorwill Island, Barren Island, Quail Island, and Cooper Island (in total, 40 percent of the atoll’s emergent land area; 107 ha) contained UXO (Donaldson Enterprises 1995). In 2002, a cooperative team of the U.S. Army, Navy, and Coast Guard joined forces to dispose of UXOs at Palmyra. The team cleared out a storage magazine containing corroded and raw explosives, as well as other UXO that were exposed on the atoll. All of the removed UXO was taken to an environmentally safe location for proper disposal (Sekerak 2002). However, not all of Palmyra's land area has been surveyed for UXO, and it is likely that UXO is still present on the islands mentioned above, and on other islands as well.

4 Environmental Consequences

4.1 Purpose and Structure of Environmental Consequences

Chapter 4 analyzes the environmental consequences of the alternatives as presented in Chapter 2. For comparative purposes, Chapter 4 also includes a similar analysis of the consequences of taking no action to address the problems associated with the presence of nonnative black rats (*Rattus rattus*) at Palmyra Atoll. The purpose of the impact analyses in this chapter is to identify and compare the risks associated with the identified alternatives including the no action alternative. Additionally, this chapter will discuss the risks associated with the toxicity of, and exposure to brodifacoum and the potential disturbance to the ecosystem associated with the implementation of each alternative. The cumulative assessment of the environmental consequences of each alternative will inform the decision-making process and allow decision makers to identify the alternative that will accomplish our eradication goals, while decreasing the probability of causing harm to nontarget species and other environmental factors, and eradication personnel.

The concept of significance, according to the Council on Environmental Quality (CEQ) regulations (40 CFR 1508.27), is composed of both the *context* in which an action will occur and the *intensity* of that action on the aspect of the environment being analyzed. "Context" is the setting within which an effect is analyzed, such as a particular locality, the affected region, or society as a whole. "Intensity" is a measure of the severity of an effect. Determining the intensity of an effect requires consideration of the appropriate context of that effect, as well as a number of other considerations, including the following:

- Impacts may be both *beneficial* and *adverse*. A significant effect may exist even if on balance the overall effect of that action will be beneficial.
- The degree to which an action affects *public health or safety*.
- *Unique characteristics of the geographic area* (e.g., historical or cultural significance, specially protected lands, ecologically critical areas).
- The degree to which the impacts of an action are likely to be *highly controversial*. The courts have since elaborated on this consideration, stating that controversy would be in the form of "substantial dispute" as to "the size, nature or effect of the major Federal action rather than to the existence of opposition to a use [e.g., eradication of mice], the effect of which is relatively undisputed" (*Hanly v. Kleindienst*, 471 F.2d 823, 830 [2nd Cir. 1972]).
- The degree to which the possible impacts of an action are *highly uncertain, or involve unique or unknown risks*.
- The degree to which an action may 1) *establish a precedent* for future actions with significant effects; and/or 2) *represents a decision in principle* about a future consideration.

- Whether an action is related to other actions with individually insignificant but *cumulatively significant impacts*. Significance exists if it is reasonable to anticipate a cumulatively significant effect on the environment.
- The degree to which an action may adversely affect properties listed in or eligible for listing in the National Register of Historic Places, or may cause *loss or destruction of significant scientific, cultural, or historical resources*.
- The degree to which an action may *adversely affect an endangered or threatened species or critical habitat as listed under the ESA.*
- Whether the action *threatens a violation of Federal, State, or local law* or requirements imposed for the protection of the environment.

4.2 Environmental Issues Addressed

4.2.1 Scope for Environmental Issue

The FWS compiled a list of major environmental issues, or impact topics that warranted specific consideration in this analysis. The compilation of this list of issues was informed by a scoping process that included informal discussions with representatives from numerous government agencies, private groups and individuals with relevant expertise or a stake in Palmyra Atoll, and solicitation of public comments.

In the analysis below, the potential significance of the environmental consequences (or "impacts") of each action alternative and the no action alternative will be discussed on a case-by-case basis for each environmental issue considered.

4.2.2 Issues

The issues analyzed in this document include:

- Impacts to physical resources
  - Water resources
  - Geology and soil
- Impacts to biological resources
  - Impacts to species vulnerable to toxicant use
  - Impacts to species vulnerable to disturbance
  - Indirect effects to biological resources
- Impacts to the social and economic environment
  - Impacts to refuge visitors and recreation
  - Impacts to historical and cultural resources
- Cumulative impacts
- Irreversible or irretrievable commitment of resources
- Relationship of short-term uses to long-term productivity

Brief descriptions of many of these topics can be found in Section 1.7.

4.2.3 Aspects of Environment Excluded from Detailed Analysis (with Rationale)

4.2.3.1 Air quality

Impacts of the action alternatives on air quality at Palmyra Atoll will not be analyzed in detail because no activities are proposed that would represent a measurable change from the background levels of air pollution caused by use of machinery. The brief, localized helicopter operations that would occur as part of Alternatives B and C would have no more than a negligible contribution to local or regional changes in air quality. Additionally, the transportation of personnel to and from Palmyra during the eradication window will be coordinated with TNC and FWS to minimize the number of flights. The power generators that supply the research station with electricity would not experience increased use due to any of the action alternatives.

4.2.3.2 Marine mammals

Potential impacts of rat eradication activities to cetaceans (whales, dolphins, and their close relatives) in the waters surrounding Palmyra will not be analyzed in this Environmental Impact Statement (EIS) other than to establish a significance threshold under the Marine Mammal Protection Act (MMPA). The likelihood of cetacean exposure to brodifacoum would be negligible, and cetaceans would have to consume extremely large quantities of this toxicant to experience lethal or even sub-lethal effects because of their extremely large size. The only point of concern to cetaceans would be from small boat traffic around the atoll. With all action alternatives, such traffic would be limited to the lagoons inside of the barrier reef; cetaceans are not known to enter Palmyra's lagoons. The majority of the activities described in the action alternatives would be aerial or terrestrial, and the likelihood of these activities having measurable impacts on cetaceans would be negligible as well.

4.2.3.3 Environmental justice

The impacts of the action alternatives on environmental justice, mandated by Executive Order 12898 of 1994 identifies and addresses the potential for disproportionate placement of adverse environmental, economic, social, or health impacts on minority and low-income populations, will not be analyzed in detail because no minority or low-income populations would be affected by any of the action alternatives.

4.3 Consequences: Physical Resources

4.3.1 Water Resources

Significant impacts to water quality are analyzed for the identified action alternatives with respect to potentially adverse physical and biological impacts from the use of rodenticide with each of the alternatives. Water quality at Palmyra is regulated by the U.S. Environmental Protection Agency (EPA), which requires that Federal waters meet minimal criteria for a number of designated uses.

While the Federal Clean Water Act (CWA) prohibits the discharge of "pollutants" into waters of the United States, in 2007, the EPA clarified its interpretation of the term "pollutant" to exclude pesticides that may unavoidably enter the water through bait drift while being applied to control pests that occur "over, including near" water bodies (71 CFR 227 pp. 68483-68492). This ruling was vacated by the 6th Circuit Court of Appeals in 2009. Subsequently, the EPA was granted a stay until April 9, 2011 to allow time for the EPA to develop guidelines for permits and the permitting process. We will fully comply with all CWA National Pollutant Discharge Elimination System (NPDES) permitting required by the EPA pending the 2011 announcement. *On March 3, 2011, the EPA requested an extension on CWA permit requirement for pesticide discharges, and on March 28, 2011, the U.S. Court of Appeals for the Sixth Circuit granted EPA's request for an extension of the deadline for when permits will be required for pesticide discharges into U.S. waters from April 9, 2011 to October 31, 2011.*

Rats at Palmyra are frequently found on and near the shoreline. For this reason, it is essential that rodenticide is made accessible to rats all the way down to the high tide mark to ensure the exposure of all rats throughout entire atoll. Even though maximum effort will be taken to prevent bait drift into the marine environment, permitting for aerial pesticide use around the littoral zone will be sought to comply with EPA's new CWA guidelines for aerial pesticide applications over waters of the United States.

4.3.1.1 Analysis framework for water resources

Alternative A: No Action

Rats at Palmyra Atoll do not currently affect the quality or quantity of potable water or marine water resources; however, rats are a vector for Leptospirosis potable water stores could become contaminated with Leptospirosis, a bacterial zoonotic disease caused by spirochaetes of the genus *Leptospira* that affects humans and a wide range of animals, including mammals, birds, amphibians, and reptiles. Rats pass the disease to humans by urinating directly into potable water supplies. Even though rats at Palmyra are not known to carry the bacterium that causes Leptospirosis, their very presence incurs a significant risk by ensuring the presence of a vector for infecting humans and wildlife.

Alternative B: Aerial Broadcast with Brodifacoum

There could be accidental bait drift or into the nearshore marine waters surrounding Palmyra during aerial bait application operations. However, the bait application techniques described would include mitigation measures that minimize unintentional bait drift into water bodies .To minimize unintentional bait drift into the water, we would use an internal deflector fit to the bait hopper to direct the bait flow away from the water body. Furthermore, a tarp would be secured over roof of the potable water catchment to prevent bait from entering the drinking water supply. *After each bait application, all pellets will be cleared from the tarp.*

If bait were to unintentionally drift into a body of water at the full application rate, it would be very unlikely to contribute to detectable levels of brodifacoum in the water column. The low water solubility (U.S. Environmental Protection Agency 1998) and strong chemical affinity of brodifacoum to the grain matrix of the bait pellets prohibits the rodenticide from entering aquatic environments via runoff. Hypothetically, even if brodifacoum had greater water solubility, and bait was broadcast at the rate of 16 lb/ac (18 kg/ha) into water only 3.3 ft (1 m) deep, the resultant brodifacoum concentration in the water – about 0.04 parts per billion – would still be nearly 1000 times less than the measured LC_{50} value for trout (0.04 parts per million) (Syngenta Crop Protection Inc. 2003). *Empson and Miskelly (1999) investigated the impacts on reef fish* *during a rat eradication on Kapiti Island, NZ. They found no evidence that reef fish were negatively affected.*

Environmental testing during rodent eradications and eradication trials in the California Current marine system and elsewhere have failed to detect brodifacoum in any water samples taken after bait application (Buckelew et al. 2008, Island Conservation unpubl. data). *These studies, however, involve bait application rates that were several times lower than what is proposed for a Palmyra application, and results may also differ.*

Water supplies for personnel at Palmyra will be protected during bait application activities to prevent the entry of pellets into the water catchment. In summary, it is estimated that aerial application of brodifacoum bait pellets will result in a negligible risk to the marine water column or the drinking water supply.

Alternative C: Aerial Broadcast with Brodifacoum and Protective Bird Mitigation

It is likely that there will be accidental drift of some bait pellets into the nearshore marine waters surrounding Palmyra during aerial bait application operations. However, the bait application techniques described would include mitigation measures that minimize unintentional bait drift into water bodies. To minimize unintentional bait drift into the water, we would use an internal deflector fit to the bait hopper to direct the bait flow away from the water body. Furthermore, a tarp would be secured over roof of the potable water catchment to prevent bait from entering the drinking water supply. *After each bait application, all pellets will be cleared from the tarp.*

If bait were to unintentionally drift into a body of water at the full application rate, it would be very unlikely to contribute to detectable levels of brodifacoum in the water column. The low water solubility (U.S. Environmental Protection Agency 1998) and strong chemical affinity of brodifacoum to the grain matrix of the bait pellets prohibits the rodenticide from entering aquatic environments via run-off. Hypothetically, even if brodifacoum had greater water solubility, and bait was broadcast at the rate of 16 lb/ac (18 kg/ha) into water only 3.3 ft (1 m) deep, the resultant brodifacoum concentration in the water – about 0.04 parts per billion – would still be nearly 1000 times less than the measured LC_{50} value for trout (0.04 parts per million) (Syngenta Crop Protection Inc. 2003). *Empson and Miskelly (1999) investigated the impacts on reef fish during a rat eradication on Kapiti Island, NZ. They found no evidence that reef fish were negatively affected.* Environmental testing during rodent eradications and eradication trials in the California Current marine system and elsewhere have failed to detect brodifacoum in any water samples taken after bait application (Buckelew et al. 2008, Island Conservation unpubl. data). *These studies, however, involve bait application rates that were several times lower than what is proposed for a Palmyra application, and results may also differ.*

Water supplies for personnel at Palmyra will be protected during bait application activities to prevent the entry of pellets into the water catchment. In summary, it is estimated that aerial application of brodifacoum bait pellets will result in a negligible risk to the marine water column or the drinking water supply.

Alternative D: Bait Station Delivery of Brodifacoum

The use of bait stations will eliminate any threats to water quality by eliminating the potential for accidental delivery of bait into bodies of water. However, the use of bait stations would not preclude the risk of contaminating potable water stores with brodifacoum. Rats and terrestrial invertebrates would have ready access to bait via the bait stations for the entire duration of the operation. A rat or terrestrial invertebrate that recently fed on bait from a bait station could fall into and thus contaminate a potable water store. To prevent such contamination from happening, all potable water stores would be maintained as rodent and invertebrate free structures for the duration of the eradication operation.

4.3.2 Geology and Soils

4.3.2.1 Analysis framework for geology and soils

The major issues of concern for the geology and soil resources of Palmyra are: 1) permanent damage to carbonate rock formations, 2) increases in soil erosion, and 3) contamination of soils.

Alternative A: No Action

Under the Alternative A, the no action alternative, rats would remain on the atoll and would continue to disturb the soil layer by burrowing and scavenging for food resources. However, there are three land crab species that burrow in the soil, and it is assumed that rat burrowing activity would not cause more disturbances to the soil layer than does crab burrowing. Rats would not have a measurable effect on rock formations or contribute additional contamination to soils.

Alternative B: Aerial Broadcast with Brodifacoum

The activities in Alternative B would not have a noticeable effect on soil erosion, rock formations, or soil contamination. The installation and maintenance of bait stations in limited circumstances may cause highly localized, minor disturbance to soil and rock. If bait pellets were to remain in contact with soil for the maximum expected period of 7 days, the extremely low concentration of brodifacoum in the bait pellets (25 ppm) would not lead to major or lasting soil integration of brodifacoum into the soil (Alifano and Wegmann 2010) (Appendix F). In environmental monitoring after the brodifacoum-based rat eradication on Anacapa Island, all soil samples collected except one tested negative for brodifacoum residue (Howald et al. 2010).

Alternative C: Aerial Broadcast with Brodifacoum and Protective Bird Mitigation

The activities in Alternative C would not have a noticeable effect on soil erosion, rock formations, or soil contamination. The installation and maintenance of bait stations in limited circumstances may cause highly localized, minor disturbance to soil and rock. If bait pellets were to remain in contact with soil for the maximum expected period of 7 days, the extremely low concentration of brodifacoum in the bait pellets (25 ppm) would not lead to major or lasting integration of brodifacoum into the soil (Alifano and Wegmann 2010) (Appendix F). In environmental monitoring after the brodifacoum-based rat eradication on Anacapa Island, all soil samples collected except one tested negative for brodifacoum residue (Howald et al. 2010).

Alternative D: Bait Station Delivery of Brodifacoum

Each bait station would be secured to the ground with the use of metal or plastic anchors placed into the soil or bedrock; stakes will have negligible long-term impacts to the soil and will be removed once the bait station operation is completed. The bait stations would be durable enough to stay in place for 2 years and prevent crabs from entering or destroying them, but they would be removed at the end of the treatment period and not a permanent fixture on the atoll. Because bait would be retained in bait stations, there would be little risk of brodifacoum integration into soil through direct contact between soil and bait pellets.

4.4 Consequences: Biological Resources

4.4.1 Introduction

In order for this project to be considered a restoration success, the long-term benefits of rat eradication must outweigh any potential ecosystem costs associated with the implementation of the project. The eradication of rats is expected to have benefits for a number of animals and plants that are presently negatively affected by rats. However, it is also critical to identify the potential biological impacts of the actual eradication operation, including mortality and injury to nontarget species as a result of ingestion of rodenticide or disturbance from project operations. Furthermore, it is important to identify any biological resources that are currently dependent on nonnative rats in some way and may be negatively affected once rats are removed. This document's analysis of impacts to biological resources will identify both the benefits (positive effects) and the costs (negative effects) of rat eradication.

While the impacts of each alternative can be analyzed with relative confidence over the short term, it is more difficult to accurately predict specific long-term responses to rat eradication. The overall determination of the ecosystem response to rat eradication at Palmyra includes too many variables to analyze within the scope of this document; however, data from other island rat eradications can be used to predict long-term ecosystem responses. Whenever possible, these data will be used in the analysis sections below to help determine long-term effects.

The No Action Alternative will be analyzed for the impacts to biological resources from the continued presence of rats at Palmyra. Additionally, analysis of the three action alternatives will include toxicant exposure pathways, toxicant risk, exposure risk, disturbance risk, and the extent of risk from either the toxicant or disturbance to biological resources. Finally, cumulative impacts will be analyzed by identifying all of the past, present, and future projects that will likely contribute to the overall effect of the action alternatives, and determine the extent of the impact to the biota at Palmyra from the combined effects of every identified project.

4.4.2 Assessing Significance of Impacts to Biological Resources

As described in Section 4.1, the concept of significance is shaped by both the context of an action and the intensity of the action's effects. Although we are assuming that this project will put individuals of a few nontarget species at risk, we will still use the significance value to determine which species are most at risk from the action alternatives. In the case of the action alternatives analyzed here, the actions have a very limited, site-specific context. However, many of the species that use Palmyra have large ranges or interact, at a population level, with other individuals that may be spread out over an area much larger than Palmyra. Therefore, the most appropriate context within which to consider impacts to biological resources is at the population level rather than the individual level. The intensity of effects is dependent on a multitude of variables that are different for each taxon. This analysis will focus on additional legal protection (ESA listing and MMPA listing) as the primary defining criterion for determining the intensity of an effect to a species. In other words, impacts to species that have been assigned specific legal protection under the ESA or MMPA will be considered on an individual level and as "more intense" than similar impacts to unlisted species.

For all biological resources analyzed, except those identified in the "special considerations" sections below, the potential for significance will be determined using the following guidelines:

- Is there a high likelihood that the population of a species will experience noticeable changes that will be measurable throughout its range?

- Is there a high likelihood that impacts to species at Palmyra will be measurable elsewhere in the region?

4.4.2.1 Special significance considerations for Endangered Species Act (ESA)-listed species

There are five species that are likely to occur at or near Palmyra that are on the Federal Endangered Species list as a threatened, endangered, or a candidate species. Listed species include the threatened green turtle *(Chelonia mydas)*, the endangered hawksbill turtle *(Eretmochelys imbricata)*, the endangered Hawaiian monk seal *(Monachus schauinslandi)*, and two species of concern: the bumphead parrotfish (*Bolbometopon muricatum*), and the humphead wrasse *(Cheilinus undulates)*. The bumphead parrotfish has been designated a candidate species. Listing under ESA provides a context for impacts analysis which lowers the threshold of significance. This analysis will identify any ESA-listed species and any ESA-designated critical habitat that may be affected by the preferred alternative. The significance of these impacts will be determined separately, but the ESA-listed status of the species affected will be given special weight.

- For green turtle, the significance threshold for effects will be set at an action that causes the significant potential for mortality of one or more individuals.

- For hawksbill turtle, the significance threshold for effects will be set at an action that is likely to cause the mortality of one or more individuals.

- For Hawaiian monk seal, significance threshold for effects will be set at an action that is likely to cause the mortality of one or more individuals.

- For bumphead parrotfish, the significance threshold for effects will be set at an action that is likely to cause the mortality of one or more individuals.

- For humphead wrasse, the significance threshold for effects will be set at an action that is likely to cause the mortality of one or more individuals.

The ESA regulations also oblige Federal agencies to ensure that the actions they take are not likely to "jeopardize the continued existence of a listed species or result in the destruction or adverse modification of designated critical habitat" (ESA Section 7(a) 2 1973). If a Federal action is likely to adversely affect an ESA-listed species or its designated critical habitat, the action agency must initiate a formal process of consultation with either the FWS or National Marine Fisheries Service (NMFS) (depending on the species) to estimate the likely type and amount of take of the listed species and determine whether or not the action will put the affected species in jeopardy of extinction. If a non-jeopardy determination is made the action must include reasonable measures to avoid and minimize this take, which may then be authorized under section 7(a) (2) of the ESA. The Service will comply with all ESA requirements and conduct an informal Section 7 Consultation for any case deemed necessary by the FWS.

4.4.2.2 Special significance considerations for listed marine mammals under the Marine Mammal Protection Act (MMPA)

Listing under MMPA provides a context for impacts analysis that lowers the threshold of significance. The MMPA regulations generally prohibit the killing, injury, or disturbance of marine mammals, but permits can be granted allowing exceptions to this prohibition for actions that may affect a marine mammal if the affect is incidental rather than the intention of the action. This analysis will identify the potential for impacts to marine mammals that may require additional permits under MMPA.

The Marine Mammal Protection Act (MMPA) listed species that are found near or around Palmyra will be given special significance thresholds to minimize negative impacts to listed marine mammals. Therefore, the significance threshold for impacts to marine mammals will be set at an action that causes the mortality of an individual animal. *The MMPA prohibits "take" of marine mammals, which is defined as "to harass, hunt, capture, or kill, or attempt to harass, hunt, capture, or kill any marine mammal" (16 U.S.C. 1362 Sec. 3(13)). Further, the term "harassment" is defined as "any act of pursuit, torment, or annoyance which – (i) has the potential to injure a marine mammal or marine mammal stock in the wild; or (ii) has the potential to disturb a marine mammal or marine mammal stock in the wild by causing disruption of behavioral patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering" (16 U.S.C. 1362 Sec. 3(18)(A)). The acts described in the subparagraphs (A)(i) and (A)(ii) are also referred to as Level A and Level B harassment, respectively (16 U.S.C. 1362 Sec. 3(18)(C) and Sec. 3(18)(D).* Disturbance will not alone constitute a significant affect in this analysis, but other potential circumstances (including the analysis of cumulative impacts) may nevertheless contribute to an overall determination of significant impacts.

- For the Hawaiian monk seal, the significance threshold will be set according to the MMPA's definition of Level A Harassment: "any act which injures or has the significant potential to injure a marine mammal or marine mammal stock in the wild" (MMPA 515.18(A)).

- For the false killer whale *(Pseudorca crassidens)*, the significance threshold will be set according to the MMPA's definition of Level A Harassment: "any act which injures or has the significant potential to injure a marine mammal or marine mammal stock in the wild" (MMPA 515.18(A)).

- For the short-finned pilot whale *(Globicephala macrorhynchus)*, the significance threshold will be set according to the MMPA's definition of Level A Harassment: "any act which injures or has the significant potential to injure a marine mammal or marine mammal stock in the wild" (MMPA 515.18(A)).

- *For the spinner dolphin (Stenella longirostris), the significance threshold will be set according to the MMPA's definition of Level A Harassment: "any act which injures or has the significant potential to injure a marine mammal or marine mammal stock in the wild" (MMPA 515.18(A)).*

- *For the bottlenose dolphin (Tursiops truncatus), the significance threshold will be set according to the MMPA's definition of Level A Harassment: "any act which injures or has the significant potential to injure a marine mammal or marine mammal stock in the wild" (MMPA 515.18(A)).*

- For the melon-headed whale *(Peponocephala electra)*, the significance threshold will be set according to the MMPA's definition of Level A Harassment: "any act which injures or has the significant potential to injure a marine mammal or marine mammal stock in the wild" (MMPA 515.18(A)).

- *For the killer whale (Orcinus orca), the significance threshold will be set according to the MMPA's definition of Level A Harassment: "any act which injures or has the significant potential to injure a marine mammal or marine mammal stock in the wild" (MMPA 515.18(A)).*

- *For the tropical beaked whale (Mesoplodon hotaula), the significance threshold will be set according to the MMPA's definition of Level A Harassment: "any act which injures or has the significant potential to injure a marine mammal or marine mammal stock in the wild" (MMPA 515.18(A)).*

4.4.2.3 Special significance considerations for birds listed under the Migratory Bird Treaty Act (MBTA)

Listing under the Migratory Bird Treaty Act (MBTA) provides a context for impacts analysis which lowers the threshold of significance for this analysis. Take under the MBTA includes the unlawful pursuit, hunt, take, capture, or kill, of any migratory bird, nest, or egg of any such bird. MBTA listed species that are found near or around Palmyra will be given special significance thresholds. All of the birds found at Palmyra Atoll are protected under the MBTA. Therefore, the significance threshold for impacts to birds will be set at an action that causes the mortality of an individual animal.

Under certain circumstances where the goal is eradicating or controlling invasive species, the FWS will provide practitioners with a Special Purpose Permit under the MBTA that allows for the take of listed individuals for "projects where the applicant demonstrates expected benefits to migratory birds. These projects support the Service's bird conservation mandate and mission and are consistent with the Administration's emphasis on control of invasive species" (FWS 2010b).

The Service will comply fully with all MBTA requirements *including obtaining a special purpose permit*, prior to the implementation of any of the three action alternatives.

4.4.3 Impacts of Alternative A (No Action) on Biological Resources

4.4.3.1 Introduction

If no action is taken towards the removal of nonnative black rats from Palmyra, the impacts that rats have on the atoll's biological resources would continue. This section summarizes the known and suspected impacts from black rats on Palmyra's biological resources.

The most pronounced effect of introduced rodents on atoll ecosystems is the extirpation and extinction of endemic species. Introduced rats (*Rattus* sp.) are responsible for an estimated 40-60 percent of all bird and reptile extinctions (Atkinson 1985), Island Conservation analysis of World Conservation Monitoring Centre data), and have caused the extinction of endemic mammals, birds, and invertebrates on islands throughout the world's oceans (Andrews 1909, Daniel and Williams 1984, Meads et al. 1984, Atkinson 1985, Tomich 1986, Hutton et al. 2007).

Rat Impacts to Biological Resources

<u>Impacts on terrestrial reptiles</u>

Rats alter the floral component of the landscape, which directly affects the suitable habitat for reptiles. Additionally, rats are known to consume reptile eggs, insects, and other invertebrates that many reptiles rely on as a primary food source. Rats at Palmyra are thought to prey on native geckos, and overlap of rat and native gecko diets could limit food resources for native geckos. Additionally, rats are the obligate host of a parasitic nematode that is often found in geckos at Palmyra (Lafferty et al. 2010). The persistence of rats on the atoll will likely continue to have a negative effect on terrestrial reptile species.

<u>Impacts on green turtles</u>

While successful nesting attempts by green turtles have not been recorded at Palmyra, rats could have a negative impact on green turtle reproductive success if nesting attempts were successful (Caut et al. 2008).

<u>Impacts on hawksbill turtles</u>

While successful nesting attempts by hawksbill turtles have not been recorded at Palmyra, rats could have a negative impact on hawksbill turtle reproductive success if nesting attempts were successful (Caut et al. 2008).

<u>Impacts on shorebirds</u>

Rats often compete with shorebirds for food resources and may prey upon small-bodied species (Dowding and Murphy 2001). The following is a discussion of the impacts that rats likely have on the six most common shorebird species found at Palmyra.

<u>bristle-thighed curlew</u>

The bristle-thighed curlew's diet likely overlaps with the rat's diet in both the intertidal zone and forested habitat, which may result in resource competition. Curlews and rats both forage for invertebrates; however, we are uncertain if these resources are limited and if there is true competition between curlews and rats. Additionally, predation by rats on curlews is possible (Marks et al. 2002) as curlews experience a period of flightlessness while molting, but there is no direct evidence of this occurring at Palmyra.

Pacific golden-plover

The Pacific golden-plover's diet probably overlaps with that of rats; however, plovers are known to thrive in other locations where multiple mammalian predators are present. For example, plovers overwinter on the island of O`ahu, Hawai`i, where feral cats, rats, and mongooses are abundant.

ruddy turnstone and wandering tattler

Ruddy turnstones and wandering tattlers may have dietary overlap with rats at Palmyra; however, the rat-related impacts to these species are thought to be minimal.

pectoral sandpiper

Pectoral sandpipers are rare at Palmyra, however, there is thought to be a slight dietary overlap with rats.

sanderling

Sanderlings are rare at Palmyra, however, there is thought to be a slight dietary overlap with rats. Additionally, sanderlings are small enough to be vulnerable to predation by rats, but there is no direct evidence of this occurring at Palmyra.

Impacts on breeding seabirds

Rats are known to prey on or cause disturbance to breeding seabirds, resulting in failed breeding attempts and higher susceptibility to predation by other species (Tomkins 1985, Jouventin et al. 2003). Smaller seabird species and species that nest on the ground and in burrows are also likely to suffer from predation by rats of eggs, chicks, and adults (Atkinson 1985, Towns et al. 2006). Predation by rats often drives seabird colonies to near-extirpation (Moller 1983, Atkinson 1985, McChesney and Tershy 1998), resulting in the loss of seabird-derived nutrients on islands (Fukami et al. 2006). By reducing seabird populations, rats alter key ecosystem properties; for example, total soil carbon, nitrogen, phosphorous, mineral nitrogen, marine-derived nitrogen and pH are lower on rat-invaded islands relative to rat-free islands (Fukami et al. 2006). The following is a breakdown of the impacts that rats have on the 15 seabird species found at Palmyra.

masked booby, brown booby, and red-footed booby

Rats are thought to have little impact on the three tropical booby species: masked, brown, and red-footed (Hilton and Cuthbert 2010).

lesser frigatebird and great frigatebird

There are no known impacts from rats to lesser or great frigatebirds.

red-tailed tropicbird

Prior to the first rat eradication attempt in 2000, three thorough seabird surveys indicated that red-tailed tropicbird nesting was rare at Palmyra and primarily restricted to a single islet in the atoll that was likely too small to sustain a regular presence of rats (Fefer 1987, Clapp unpubl. data, Flint 1992). Nest numbers and distribution of red-tailed tropicbirds increased dramatically (from 14 nests in 1992 to 128 in 2002) immediately following the reduction in rat numbers in 2001. Predation by rats of red-tailed tropicbird eggs could negatively affect the productivity of this species at Palmyra.

white-tailed tropicbird

At Palmyra, white-tailed tropicbird nests are most often located in tree cavities and are difficult to observe, so little is known about the vulnerability of this species to predation by rats. However, it is likely that rat impacts on white-tailed tropicbirds are similar to rat impacts on red-tailed tropicbirds.

sooty tern

Rats prey on sooty Tern eggs and chicks (Feare 1979), and sooty tern egg fragments are regularly observed in rat husking stations at Palmyra (Fefer 1987, FWS unpubl. data). Rats are regularly observed by FWS staff taking and eating sooty Tern eggs at Palmyra.

black noddy and brown noddy

Rats likely prey on black and brown noddy eggs and chicks at Palmyra (Kepler 1967, Norman 1975); however there is no documentation of egg or chick predation at Palmyra.

white tern

Rats likely prey on white tern eggs and chicks (Kepler 1967, Norman 1975); however, there is no documentation of egg or chick predation at Palmyra.

Regionally present seabirds that are absent or uncommon at Palmyra

Rats have likely contributed to the extirpation of the following seabird species from Palmyra. These species fall into a category of seabirds that cannot coexist with introduced predators of the size of rats or larger (Flint 1999). While no historical or paleontological records exist for Palmyra itself there is evidence from studies of the faunal assemblages prior to the introduction of mammalian predators such as rats in Hawai`i, the Cook Islands, Easter Island, the Marquesas, Tonga, the Pitcairn Group, and the Northern Marianas that islands with introduced mammals, including rats, have lost large components of their original seabird fauna. The global patterns of seabird distributions we observe today are not natural (Steadman 1995). Jones et al. (2008) found that rats depress many similar bird taxa and that rats are likely preventing them from nesting at Palmyra. The following is a list of seabird species that are found regionally, but are not breeding at Palmyra. All of the below listed species nest at adjacent islands in the Line archipelago that do not have rats or have rat-free refugia on islets in the lagoon (Kiritimati Island). These species typically nest on the ground, and some (the shearwaters and petrels) characteristically leave eggs and chicks unattended in nesting burrows; black rats would effectively prevent the establishment, or reestablishment of breeding populations of any of these species (Norman 1975).

- wedge-tailed shearwater (– unsuccessfully attempted to breed at Palmyra in 2005 (Wegmann pers. comm.)
- Bulwer's petrel (*Bulweria bulwerii*) – sighted offshore
- Christmas Island shearwater *(Puffinus nativitatis)* – sighted offshore
- Audubon's shearwater *(Puffinus lherminieri)* – sighted offshore
- Polynesian storm-petrel *(Nesofregetta fuliginosa)* – regional breeding species
- Phoenix petrel *(Pterodroma alba)* – regional breeding species
- gray-backed tern *(Onychoprion lunatus)* – sighted flying over Cooper Island in 2005 (Wegmann pers. comm.)
- blue noddy *(Procelsterna cerulea)* – a pair was sighted at Palmyra (on Barren Island) in 2010

Impacts on Uncommon Visitors

laughing Gull *(Leucophaeus atricilla)* and Franklin's gull *(Leucophaeus pipixcan)*

These gulls are rare visitors to Palmyra and do not breed there. There is no expected effect to these species of continued presence of rats at Palmyra.

Northern shoveler *(Anas clypeata)* and Northern pintail *(Anas acuta)*

Ducks are very rare visitors that do not breed at Palmyra and there are no known impacts from rats to adult ducks.

Impacts on fish

Rats are not known to affect fish species at Palmyra.

Impacts on invertebrates

Rats negatively affect the abundance and age structure of intertidal invertebrates through predation (Navarrete and Castilla 1993). Terrestrial crabs have been known to shift from nocturnal behavior to diurnal behavior in the presence of introduced rats, and with the removal of rats, crabs have been known to return to their nocturnal nature (Burggren and McMahon 1988). This shift in behavior is likely the result of competition for food and other resources between crabs and rats. Furthermore, rats have been documented preying on crabs at Palmyra, (Wegmann 2009). Rats are not known to negatively affect coral species or other aquatic invertebrates. However, rats may be responsible for an increase in the mosquito population at Palmyra by creating an abundance of mosquito breeding habitat in water-filled coconut husks. Mosquitoes carry avian malaria, dengue, and other wildlife and human diseases.

Rat impacts to vegetation

Introduced rats feed opportunistically on plants, and alter the floral communities of ecosystems in which they are introduced (Campbell and Atkinson 2002, Wegmann 2009). At Palmyra, rats alter patterns of tree seedling recruitment by increasing the frequency of predation on tree seeds and seedlings, and by shifting tree seed dispersal from an interaction driven by land crabs to a directed dispersal model driven by rats; rats deposit seeds in microhabitats (husking stations) that are ill-suited for germination or subsequent growth. Furthermore, rats surpass crabs in the frequency of herbivore-seedling interactions, and rat impacts on seedling survival may be responsible for the structure of the atoll's current, alien species-dominated forest community (Wegmann 2009).

4.4.4 Impacts of Action Alternatives (B, C, and D) on Biological Resources

4.4.4.1 Impacts to Biological Resources vulnerable to toxicant use

Analysis Framework for Impacts from Toxicant Use

The risk of impacts from brodifacoum or any other rodenticide to individual animals is determined by two factors (Erickson and Urban 2004):

- The toxicity of the compound to that individual; and

- The likelihood that exposure to the compound will result in harm to that individual.

The three action alternatives differ in both factors in terms of the individual animals' likelihood of exposure to the toxicant.

Toxicity

Toxicity to birds and mammals – The toxicity of a particular compound to an individual animal is often expressed in a value known as the "LD_{50}" – the dosage (D) of a toxicant that is lethal (L) to 50 percent of animals in a laboratory test. The EPA has compiled laboratory data for brodifacoum LD_{50} values for a number of species. However, due to the difficulty and expense of obtaining extensive laboratory data, the LD_{50} values for many species, including most species at Palmyra, remain unknown for brodifacoum. Besides lethal toxicity, there are other physiological effects from ingestion of anticoagulants. Erickson and Urban (2004) report that individual birds and mammals that are exposed to anticoagulants and survive may nevertheless experience internal hemorrhaging, external bleeding, and other physical symptoms of anticoagulant toxicity.

The EPA has determined that the toxicity of brodifacoum to all birds, and mammals in general is high and only requires one dose to be lethal (Erickson and Urban 2004). Furthermore, animals that have a large body mass, such as pinnipeds or cetaceans, would generally need to ingest more of the compound in order to reach an LD_{50} threshold.

While the concentration of brodifacoum in bait pellets would be consistent, the number of bait pellets that individual animals would consume would vary considerably and unpredictably. Furthermore, predators and scavengers can also be exposed to a toxicant through secondary or tertiary pathways by consuming organisms that were previously exposed to the toxicant. It is difficult to predict the amount of toxicant that would be present in these prey animals, and difficult to predict how much a particular predator or scavenger would need to consume to reach a toxic threshold.

In addition to the following quantitative assessment of the acute toxicity of brodifacoum to shorebirds that overwinter at Palmyra, risk to nontarget species will be estimated using the organism's risk of exposure. However, the large body mass of animals, such as cetaceans, would likely reduce the risk of toxic effects and will also be taken into account.

<u>Potential impacts to migratory shorebirds present at Palmyra during the operational window</u>

Biology and Status

Four species of shorebirds are expected to be common at Palmyra during the operational window (June through July): bristle-thighed curlew, Pacific golden-plover, wandering tattler, and ruddy turnstone. None of these species nest at Palmyra. Populations at Palmyra *have an annual* range from 84 – 266 individuals for curlews, 75 – 144 for Pacific golden-plovers, 44 – 126 for wandering tattlers, and 39 – 112 for ruddy turnstones (Fefer 1987, Flint 1992, Depkin 2002, FWS 2010d). The population densities' of shorebirds at Palmyra (and on other tropical Pacific islands) are significantly lower during the summer breeding season - June through August (Engilis Jr. and Naughton 2004, FWS 2010d). *The Risk Analyses for each alternative consider the populations present during the corresponding period of risk (ie. June-July for Alternatives B and C and over two years for Alternative D.)*

Bristle-thighed curlews forage on intertidal and terrestrial invertebrates, Pacific golden-plovers feed on terrestrial insects and intertidal invertebrates, wandering tattlers feed on intertidal invertebrates and mollusks, and ruddy turnstones feed on marine invertebrates in the intertidal zone. Other shorebird species, all intertidal foragers, have been observed at Palmyra, but are not expected to be present in significant numbers during the operational window for Alternatives B and C, or during the highest activity period for Alternative D: sharp-tailed sandpiper, lesser yellowlegs, semipalmated plover, buff-breasted sandpiper, solitary sandpiper, pectoral sandpiper, and short-billed dowitcher.

Potential Brodifacoum Exposure Pathways for Palmyra Shorebirds

Bristle-thighed curlews, Pacific golden-plovers, wandering tattlers, and ruddy turnstones are likely to be present during the operational window at Palmyra and could potentially be exposed to the rodenticide through several pathways including:

1. Feeding directly on bait pellets (Pierce et al. 2008)

2. Feeding on prey items that have consumed the bait and/or contaminated prey (e.g., land crabs, hermit crabs, rat carcasses)

This quantitative risk assessment evaluates the degree of the toxicological risk to shorebirds via primary and secondary pathways. Tertiary and further pathways of exposure are possible, and multiple, repeated exposures via the exposure pathways are possible, but will not be evaluated in this analysis here as the likelihood of mortality from either single feeding exposure event(s) will lead to measurable impacts due to the high toxicity of brodifacoum to birds. The toxicological risk is impossible to precisely and accurately quantify because of the lack of species-specific toxicity data for the shorebirds found at Palmyra. However, using data from surrogate bird species (mallard duck, one of the most sensitive species measured), and statistical probability, we can predict the rough toxicological risk to these four shorebird species from exposure to rodenticide at Palmyra during and after the rat eradication. This analysis used data from the literature, and data collected during field trials at Palmyra in 2005 (Buckelew et al. 2005, USDA 2006). A conservative approach to the secondary exposure risk assessment was taken, by using the mean and maximum brodifacoum residue values found in tissues, i.e., a worst case toxicological assessment. The likely impact or measurable endpoint of exposure is mortality because of the very high toxicity of brodifacoum to birds.

This analysis quantifies the toxicological risk using the LD_{50} (Lethal Dose that will kill 50% of the sample population), LC_{50} (Lethal Concentration that will kill 50% of the sample population), and NOEL (No Observed Effects Level) data from other species which can be extrapolated to roughly predict the likely consequence of brodifacoum exposure to shorebirds at Palmyra. The NOEL is used here as a point of reference and demonstrates the level above which physiological effects of anticoagulant exposure has been measured in birds.

Toxicological Risk from Direct Consumption of Bait Pellets Containing Brodifacoum (Primary, Nontarget Exposure)

Table 4.1 indicates that all shorebirds are at a high risk of primary poisoning through consumption of relatively few bait pellets. There is a high likelihood that shorebirds that identify bait pellets as a potential food source will find more than enough to exceed the LD_{50} within 4- 7 days of each bait broadcast application, until land crabs, hermit crabs and rats remove bait pellets from the environment. It is expected that there will be some small areas of the island will have residual bait that may not be consumed by rats, land crabs, or other invertebrates within 7 days of the operation. In these areas, bait will likely degrade within 2 weeks due to molds, microbial action, and consumption by small invertebrates such as ants (Howald et al. 2004, Buckelew et al. 2005), reducing the primary exposure risk. Bait will mold exceedingly rapidly in Palmyra's warm, humid environment.

With the initial high availability of bait pellets after each broadcast event, mortality of individual birds will be the likely outcome of exposure. To minimize/reduce exposure potential to shorebirds, bait pellets will only be broadcast into Palmyra's vegetated environment, and directional baiting will be used to prevent bait drift into the intertidal and nearshore marine environment where many shorebirds show preferential, but not exclusive, foraging. Further, the color of the bait (blue), and timing of the operation (during the breeding season when the least number of shorebirds are present at Palmyra) would reduce (but not eliminate) the risk of primary exposure to the populations. For shorebirds present at Palmyra during the operational window, the risk of primary poisoning is very high.

The bumphead parrotfish, Bolbometopon muricatum*, has been designated as a candidate species under ESA. Bumphead parrotfish are the largest of the parrotfish attaining 120cm in length, are in decline throughout most of their geographic range, but are abundant at Palmyra. The fish are found on the terrace and fore reefs outside the atoll where coral is abundant, and they are not found on the lagoon flats. No bait is expected to reach terrace or forereef areas. If bait accidentally reached these areas, it is unlikely the fish would be exposed to it, as the bumphead parrotfish is a benthic corallivore, feeding solely on corals. The bumphead parrotfish should not be at risk of primary or secondary exposure to the toxicant.*

Potential Impacts from Indirect Ingestion of Brodifacoum through Prey Items (Secondary Nontarget Exposure)

Hermit and land crabs

Wegmann et al. (2008) confirmed that both land crabs and hermit crabs will be attracted to and consume bait that is broadcast into Palmyra's terrestrial environment. The crabs will compete directly with rats to gain access to bait pellets, thus to maximize the probability of eradication of rats, enough bait has to be broadcast to account for both rat and crab consumption. The consumption of bait pellets, and primarily poisoned rats and potentially birds, by hermit and land crabs will result in accumulation of brodifacoum residue in the tissues of crabs. For the purpose of this analysis, we used the residue levels from the hepatopancreas of land crabs of the genus *Cardisoma* (a worst case scenario) and brodifacoum body burden in hermit crabs of the genus *Coenobita* (Table 4.1). The data indicate that the residue levels in the crabs decline rapidly to near non-detectable levels within 2 months of the broadcast which suggests that the accumulation of residues is a function of contaminated prey items, and either retention time and/or metabolism of the rodenticide is quick. For the purpose of this analysis, the mean and maximum detected residues in hepatopancreas and hermit crab body burden were used to evaluate toxicological risk. We translated this risk into equivalent numbers of crabs needed to cause a high likelihood of poisoning.

The data (Table 4.1) indicates that crabs will accumulate enough brodifacoum residues to present a high secondary exposure risk within 10 days of the bait broadcast through single and repeated exposures. Relatively few crabs will need to be consumed to reach an LD_{50}, less than one crab hepatopancreas or hermit crab will exceed the NOEL, and a physiological response will be theoretically measurable. However, because of the high toxicity of brodifacoum to birds, and the possibility of repeated exposure via hermit crabs, and possibly land crabs, this analysis concludes that the shorebirds that are present at Palmyra within 10 days of the broadcast application, and are attracted to and consume either land crabs or hermit crabs, are at a very high risk of secondary poisoning, with a high likelihood of mortality. The risk of exposure and poisoning to shorebirds returning to Palmyra at, and after 2 months of the broadcast application are at risk of exposure to a low level of brodifacoum residue, and are at a relatively low risk of secondary poisoning via consumption of hermit and land crabs.

Filter feeders (mussels)

Shorebirds at Palmyra are not likely at risk of exposure to brodifacoum via mussels or other filter feeders because of the mitigation measures to prevent the broadcast of the bait into the marine environment (directional baiting), the insolubility of brodifacoum, and the low availability of mussels and filter feeders as prey items relative to the high abundance of fiddler crabs, land crabs and hermit crabs that may be preferred prey items for some shorebirds at Palmyra. However, as a conservative approach, this analysis evaluated the potential toxicological risk using data from the literature for mussel tissue (Table 4.1).

Table 4.1 indicates that there is a theoretical secondary poisoning risk if enough mussel tissue (or tissue from comparable filter feeders) is consumed by individual shorebirds. However, because of the reasons outlined above, the relatively low availability of mussel (or other filter feeders) at

Palmyra, and the high abundance of alternative prey (crabs), the consequence of this exposure pathway is believed to be relatively low for shorebirds.

Fish liver

The shorebirds at Palmyra are not known to prey on fish, but could be exposed to brodifacoum via fish if any fish were to consume a lethal dose from errant bait pellets, and subsequently wash up on shore for shorebirds to scavenge. While some fish in the nearshore environment at Palmyra are known to consume bait pellets (see Appendix F), the likelihood of this exposure pathway is very small as precautions are in place to minimize risk of bait drift into the marine environment, and minimizes this exposure pathway.

Should inadvertent bait pellets drift into the marine environment, and fish consume the bait pellets, and any dead or dying fish wash up on shore, shorebirds may be exposed to brodifacoum via a fish liver pathway. The data from the risk assessment (Table 4.1) suggest that a significant amount of fish liver tissue would need to be consumed to reach an LD_{50}/LC_{50}. However, while theoretically possible, the amount of liver to be consumed is greater than what could be realistically consumed during a single feeding). This analysis concludes that the risk to shorebirds via this pathway is very low.

Table 4.1 *Acute toxicity of brodifacoum to shorebirds and seabirds at Palmyra Atoll.*

Species	Estimated # of grams of pellets consumed					Estimated # of pellets consumed					Estimated grams of mussels consumed					Estimated grams of fish liver consumed				
	LD_{50}	LD_{50} probabilistic (0.11mg/kg)*	LD_{50} probabilistic (0.56mg/kg)*	LC_{50}	NOEL	LD_{50}	LD_{50} probabilistic (0.11mg/kg)*	LD_{50} probabilistic (0.56mg/kg)*	LC_{50}	NOEL	LD_{50}	LD_{50} probabilistic (0.11mg/kg)*	LD_{50} probabilistic (0.56mg/kg)*	LC_{50}	NOEL	LD_{50}	LD_{50} probabilistic (0.11mg/kg)*	LD_{50} probabilistic (0.56mg/kg)*	LC_{50}	NOEL
Bristle-thighed curlew	5.1	2.2	11.0	14.1	0.0	2.5	1.1	5.5	7.1	0.0	310.7	131.5	669.3	860.5	1.2	3185.0	1347.5	6860.0	8820.0	12.3
Pacific golden-plover	1.4	0.6	2.9	3.7	0.0	0.7	0.3	1.5	1.9	0.0	82.4	34.9	177.6	228.3	0.3	845.0	357.5	1820.0	2340.0	3.3
Wandering tattler & ruddy turnstone	1.1	0.5	2.5	3.2	0.0	0.6	0.2	1.2	1.6	0.0	69.8	29.5	150.2	193.2	0.3	715.0	302.5	1540.0	1980.0	2.8
Masked Booby	16.9	7.1	36.4	46.7	0.1	8.4	3.6	18.2	23.4	0.0										
Red-footed Booby	8.9	3.8	19.2	24.7	0.0	4.5	1.9	9.6	12.3	0.0										
Brown Booby	11.0	4.7	23.7	30.5	0.0	5.5	2.3	11.9	15.3	0.0										
Red-footed Booby	8.9	3.8	19.2	24.7	0.0	4.5	1.9	9.6	12.3	0.0										
Great Frigatebird	9.6	4.1	20.7	26.6	0.0	4.8	2.0	10.3	13.3	0.0										
Lesser Frigatebird	7.8	3.3	16.8	21.6	0.0	3.9	1.7	8.4	10.8	0.0										
Red-tailed Tropicbird	7.1	3.0	15.3	19.7	0.0	3.6	1.5	7.7	9.9	0.0										
White-tailed Tropicbird	3.0	1.3	6.5	8.3	0.0	1.5	0.6	3.2	4.1	0.0										
Brown Noddy	1.8	0.8	3.9	5.0	0.0	0.9	0.4	1.9	2.5	0.0										
Black Noddy	0.9	0.4	2.0	2.6	0.0	0.5	0.2	1.0	1.3	0.0										
Sooty Tern	2.2	0.9	4.7	6.0	0.0	1.1	0.5	2.3	3.0	0.0										
White Tern	1.1	0.4	2.3	2.9	0.0	0.5	0.2	1.1	1.5	0.0										

*Acute probabilistic LD50 for 95% of bird species with unknown sensitivity to brodifacoum: 0.11mg/kg (95% confidence) and 0.56mg/kg (50% confidence). From Howald et. al (1999).
**Crab hepatopancreas sampling on Day 10 included one outlying value of 1.19 mg/kg brodifacoum, which explains the lower LD50 for day 10 compared to Day 6.
***Based on average crab weight from 2005 Cardisoma tissue brodifacoum residue analyses data (USDA 2006).
****Average strawberry hermit crab weight was estimated at ~85 grams (range: 56-140g based on non-published 'internet' data)
†Day 56 for hermit crab tissue analyses only had one sample with Brodifacoum levels above MLOD

Table 4.1 (Continued: Acute toxicity of brodifacoum to shorebirds summering at Palmyra Atoll).

Species & Sampling Day	Using __MEAN__ brodifacoum ppm reported in tissue analysis																			
	Estimated grams of hepatopancreas consumed					**Estimated # of crabs consumed*** **					**Estimated grams of hermit crab consumed**					**Estimated # of hermit crabs consumed********				
	LD$_{50}$	**LD$_{50}$ probabilistic (0.11mg/kg)***	**LD$_{50}$ probabilistic (0.56mg/kg)***	**LC$_{50}$**	**NOEL**	**LD$_{50}$**	**LD$_{50}$ probabilistic (0.11mg/kg)***	**LD$_{50}$ probabilistic (0.56mg/kg)***	**LC$_{50}$**	**NOEL**	**LD$_{50}$**	**LD$_{50}$ probabilistic (0.11mg/kg)***	**LD$_{50}$ probabilistic (0.56mg/kg)***	**LC$_{50}$**	**NOEL**	**LD$_{50}$**	**LD$_{50}$ probabilistic (0.11mg/kg)***	**LD$_{50}$ probabilistic (0.56mg/kg)***	**LC$_{50}$**	**NOEL**
Curlew																				
Sampling day 2	76.7	32.4	165.1	212.3	0.3	3.7	1.6	8.0	10.3	0.0	245.8	104.0	529.3	680.6	0.9	2.9	1.2	6.2	33.0	0.0
Sampling day 6	475.6	201.2	1024.3	1317.0	1.8	23.0	9.7	49.6	63.8	0.9	390.7	165.3	841.4	1081.8	1.5	4.6	1.9	9.9	52.4	0.1
Sampling day 10**	432.7	183.1	931.9	1198.2	1.7	21.0	8.9	45.1	58.0	0.1	964.9	408.2	2078.2	2671.9	3.7	11.4	4.8	24.4	129.4	0.2
Sampling day 56	12536.3	5303.8	27001.2	34715.9	48.2	607.1	256.8	1307.6	1681.2	2.3	29627.9†	12534.9†	63814†	82046.5†	114.0	348.6†	147.5†	750.8†	3973.2†	5.5†
Pacific golden-plover																				
Sampling day 2	20.3	8.6	43.8	56.3	0.1	1.0	0.4	2.1	2.7	0.0	65.2	27.6	140.4	180.6	0.3	3.2	1.3	6.8	8.7	0.0
Sampling day 6	126.2	53.4	271.8	349.4	0.5	6.1	2.6	13.2	16.9	0.0	103.6	43.8	223.2	287.0	0.4	5.0	2.1	10.8	13.9	0.0
Sampling day 10**	114.8	48.6	247.2	319.9	0.4	5.6	2.4	12.0	15.4	0.0	256.0	108.3	551.3	708.9	1.0	12.4	5.2	26.7	34.3	0.0
Sampling day 56	3326.0	1407.1	7163.6	9210.3	12.8	161.0	68.1	346.9	446.0	0.6	7860.5†	3325.6†	16930.2†	21767.4†	30.2†	380.7†	161.1†	819.9†	1054.1†	1.5†
Wandering tattler & ruddy turnstone Tattler & Ruddy Turnstone																				
Sampling day 2	17.2	7.3	37.1	47.7	0.1	0.8	0.4	1.8	2.3	0.0	55.2	23.3	118.8	152.8	0.2	2.7	1.1	5.8	7.4	0.0
Sampling day 6	106.8	45.2	230.0	295.7	0.4	5.2	2.2	11.1	14.3	0.0	87.7	37.1	188.9	242.9	0.3	4.2	1.8	9.1	11.8	0.0
Sampling day 10**	97.1	41.1	209.2	269.0	0.4	4.7	2.0	10.1	13.0	0.0	216.6	91.6	466.5	599.8	0.8	10.5	4.4	22.6	29.0	0.0
Sampling day 56	2814.3	1190.7	6061.5	7793.4	10.8	136.3	57.7	293.5	377.4	0.5	6651.2†	2814†	14325.6†	18418.6†	25.6†	322.1†	136.3†	693.7†	891.9†	1.2†

*Acute probabilistic LD$_{50}$ for 95% of bird species with unknown sensitivity to brodifacoum: 0.11mg/kg (95% confidence) and 0.56mg/kg (50% confidence). From Howald et. al (1999).
**Crab hepatopancreas sampling on Day 10 included one outlying value of 1.19 mg/kg brodifacoum, which explains the lower LD$_{50}$ for day 10 compared to Day 6.
***Based on average crab weight from 2005 *Cardisoma* tissue brodifacoum residue analyses data (USDA 2006).
****Average strawberry hermit crab weight was estimated at ~85 grams (range: 56-140g based on non-published 'internet' data)
†Day 56 for hermit crab tissue analyses only had one sample with Brodifacoum levels above MLOD

Table 4.1 (Continued: Acute toxicity of brodifacoum to shorebirds summering at Palmyra Atoll).

Species & Sampling Day	**Using MAX brodifacoum ppm reported in tissue analyses**																			
	Estimated grams of crab hepatopancreas consumed					**Estimated # of crabs consumed*****					**Estimated grams of hermit crab consumed**					**Estimated# of hermit crabs consumed******				
	LD_{50}	**LD_{50} probabilistic (0.11mg/kg) ***	**LD_{50} probabilistic (0.56mg/kg) ***	**LC_{50}**	**NOEL**	**LD_{50}**	**LD_{50} probabilistic (0.11mg/kg) ***	**LD_{50} probabilistic (0.56mg/kg) ***	**LC_{50}**	**NOEL**	**LD_{50}**	**LD_{50} probabilistic (0.11mg/kg) ***	**LD_{50} probabilistic (0.56mg/kg) ***	**LC_{50}**	**NOEL**	**LD_{50}**	**LD_{50} probabilistic (0.11mg/kg) ***	**LD_{50} probabilistic (0.56mg/kg) ***	**LC_{50}**	**NOEL**
Curlew																				
Sampling day 2	33.4	14.1	71.8	92.4	0.1	1.6	0.7	3.5	4.5	0.0	158.9	67.2	342.1	439.9	0.6	1.9	0.8	4.0	21.3	0.0
Sampling day 6	75.8	32.1	163.3	210.0	0.3	3.7	1.6	7.9	10.2	0.0	229.1	96.9	493.5	634.5	0.9	2.7	1.1	5.8	30.7	0.0
Sampling day 10**	107.1	45.3	230.6	296.5	0.4	5.2	2.2	11.2	14.4	0.0	315.3	133.4	679.2	873.3	1.2	3.7	1.6	8.0	42.3	0.1
Sampling day 56	5137.1	2173.4	11064.5	14225.8	19.8	248.8	105.2	535.8	688.9	1.0	29627.9†	12534.9†	63814†	82046.5†	114.0	348.6†	147.5†	750.8†	3973.2†	5.5†
Pacific golden-plover																				
Sampling day 2	8.8	3.7	19.1	24.5	0.0	0.4	0.2	0.9	1.2	0.0	42.1	17.8	90.8	116.7	0.2	2.0	0.9	4.4	5.7	0.0
Sampling day 6	20.1	8.5	43.3	55.7	0.1	1.0	0.4	2.1	2.7	0.0	60.8	25.7	130.9	168.3	0.2	2.9	1.3	6.3	8.2	0.0
Sampling day 10**	28.4	12.0	61.2	78.7	0.1	1.4	0.6	3.0	3.8	0.0	83.7	35.4	180.2	231.7	0.3	4.1	1.7	8.7	11.2	0.0
Sampling day 56	1362.9	576.6	2935.5	3774.2	5.2	66.0	27.9	142.2	182.8	0.3	7860.5†	3325.6†	16930.2†	21767.4†	30.2†	380.7†	161.1†	819.9†	1054.1†	1.5†
Wandering tattler & ruddy Turnstone																				
Sampling day 2	7.5	3.2	16.1	20.7	0.0	0.4	0.2	0.8	1.0	0.0	35.7	15.1	76.8	98.8	0.1	1.7	0.7	3.7	4.8	0.0
Sampling day 6	17.0	7.2	36.7	47.1	0.1	0.8	0.3	1.8	2.3	0.0	51.4	21.8	110.8	142.4	0.2	2.5	1.1	5.4	6.9	0.0
Sampling day 10**	24.0	10.2	51.8	66.6	0.1	1.2	0.5	2.5	3.2	0.0	70.8	30.0	152.5	196.0	0.3	3.4	1.5	7.4	9.5	0.0
Sampling day 56	1153.2	487.9	2483.9	3193.5	4.4	55.8	23.6	120.3	154.7	0.2	6651.2†	2814†	14325.6†	18418.6†	25.6†	322.1†	136.3†	693.7†	891.9†	1.2†

*Acute probabilistic LD_{50} for 95% of bird species with unknown sensitivity to brodifacoum: 0.11mg/kg (95% confidence) and 0.56mg/kg (50% confidence). From Howald et. al (1999).
**Crab hepatopancreas sampling on Day 10 included one outlying value of 1.19 mg/kg brodifacoum, which explains the lower LD_{50} for day 10 compared to Day 6.
***Based on average crab weight from 2005 *Cardisoma* tissue brodifacoum residue analyses data (USDA 2006).
****Average strawberry hermit crab weight was estimated at ~85 grams (range: 56-140g based on non-published 'internet' data)
†Day 56 for hermit crab tissue analyses only had one sample with Brodifacoum levels above MLOD

Bristle-thighed curlew rodenticide risk: from Chris Gill's 2010 Summary of Risks and Potential Mitigation Options for Bristle-thighed curlews at Palmyra Atoll during a Rat Eradiation Campaign (See Appendix H for full report):

During the upcoming rat eradication, bristle-thighed curlews (BTCU) are expected to be at the greatest risk of mortality from rodenticide exposure at Palmyra Atoll. BTCUs are at risk of primary and secondary exposure to the rodenticide contained in the bait that will be deployed to eradicate rats from Palmyra. In May, breeding BTCUs depart their wintering grounds (such as Palmyra) for summer breeding grounds in Alaska. This migratory behavior creates a seasonal low in Palmyra's BTCU population. The proposed rat eradication action will take advantage of this seasonal low to minimize the risk of harming individual BTCUs.

BTCUs have a fairly small global population with approximately 3,200 breeding pairs and about 10,000 individuals (Marrison et al. 2006). Researchers also believe that BTCU numbers are slowly declining with an estimated population growth rate (λ) of 0.994 (appendix H). Furthermore, BTCUs winter on remote Pacific Islands, which are continually affected from anthropogenic activities and mammalian predators that disturb wintering grounds and consume ground-nesting seabird eggs that are a major source of nutrition for BTCUs in preparation for spring migration. Moreover, approximately 50 percent of the adult BTCU population becomes flightless for an estimated 92 days during a prebasic molt period that is typically between August and December. Researchers believe that "disturbance or mortalities on the wintering grounds could have a significant effect on the total (BTCU) population size" (Gill 2010). Fortunately, the maximum estimated number of individuals that would likely remain at Palmyra through the summer breeding season is 182 (based on 2010 all-atoll count data, USFWS unpublished data), which is less than two percent of the entire BTCU global population.

By using a population size of 10,000, modelers were able to calculate the deterministic population growth rate for the BTCU with a potential mortality rate of 80 percent for the Palmyra population during the time of the rat eradication. Model outputs indicated that impacts to the global BTCU population would only result in minor decreases in the population growth rate with diminishing impacts on the projected future population. Furthermore, with the current parameter estimates, "there is no risk of extinction over the next 50 years under any scenario" (Gill 2010).

Researchers believe that the benefits of rat eradication at Palmyra outweigh the potential, small affect to the global BTCU population. "Removal of rats from Palmyra would have a positive effect on the population" since it is believed that BTCUs are being negatively affected by introduced mammalian predators, including rats, on their wintering grounds (Marks et al. 2002, (Gill 2010). "Other researchers have suggested that the high density of introduced rats preying on eggs and nestlings greatly reduces nest success and fledging rates of sooty terns at Palmyra; therefore, removing rats from the Atoll may also indirectly benefit BTCUs by increasing the breeding population of sooty terns, and thus egg production at Palmyra" (Gill 2010).

Potential Impacts to Breeding Seabirds Present at Palmyra during the Operational Window

Biology and Status

Ten species of seabirds breed at Palmyra: black and brown noddies, sooty and white terns, great frigatebirds, white- and red-tailed tropicbirds, and red-footed, masked and brown boobies. One additional species (lesser frigatebird) is present, but does not breed. These equatorial nesting seabirds can nest during any season and there is high inter-annual variability in the number of birds present and nesting during any given month. Seabirds are abundant at Palmyra year-round. All 11 species, with the possible exception of sooty terns, are expected to be common at Palmyra during the operational window (June-July).

All of these seabirds forage in the marine environment and their diets are predominantly marine fish and invertebrates. A small number of birds forage within the lagoon at Palmyra but the overwhelming majority forage away from the atoll in the pelagic ocean environment.

Potential Brodifacoum Exposure Pathways for Palmyra Seabirds

Given their diet and foraging habits, it is extremely unlikely that any of the breeding seabirds will ingest contaminated prey or deliberately ingest bait pellets. However, it is possible that birds could accidentally ingest toxicant during nest maintenance or preening. Great and lesser frigatebirds are known to prey opportunistically upon small chicks of other seabird species at the colony. This is an insignificant component of their diet, and these two frigatebird species are the only breeding seabird on Palmyra known to derive any food items from the terrestrial environment. We do not anticipate that small seabird chicks will ingest any bait pellets, but the remote possibility exists that either of the frigatebird species would consume a small shorebird (e.g., a ruddy turnstone) that is contaminated (and therefore its ability to evade predators compromised).

Toxicological Risk from Direct Consumption of Bait Pellets Containing Brodifacoum (Primary, Nontarget Exposure)

Even though the risk of ingestion is extremely low, Table 4.1 indicates that, ingestion of relatively few bait pellets poses a high risk of primary poisoning for all but the largest seabirds. To minimize/reduce exposure potential to seabirds, bait pellets will be hand broadcast along the causeways where the majority of the boobies nest, and this bait will not be distributed within reach of birds sitting in the nest.

Potential Impacts from Indirect Ingestion of Brodifacoum through Prey Items (Secondary Nontarget Exposure)

Most seabirds will be foraging for fish and invertebrates at sea, away from the atoll. A few birds might forage within the lagoon. The potential for fish to be exposed will be minimized by hand baiting hear the shoreline and using an internal deflector system in the bait hopper to prevent bait from being broadcast in the water.; thus, it is unlikely that measurable amounts of brodifacoum will be incorporated into the lagoon food chain and then indirectly affect foraging seabirds.

Frigatebirds could possibly become secondarily poisoned by consuming a compromised and contaminated shorebird, but this is unlikely.

Toxicity to reptiles and amphibians

*Little is known about the effect that brodifacoum has on turtles. Rodenticide toxicity experiments have not been conducted in turtle species and therefore the LD_{50} values are unknown for both species of turtle present in the waters surrounding Palmyra. However, an initial assessment from preliminary findings of a USDA National Wildlife Research Center (NWRC) turtle-anticoagulant hazards study indicates ornate wood turtles (*Rhinoclemmys pulcherrima*) were not negatively affected by brodifacoum consumption. Turtles that were fed high brodifacoum doses received 1.6 mg/kg of brodifacoum, and none died or showed signs of ill health when euthanized one week later. The turtle with the highest liver residue level (2.02 ppm) weighed 319 g, which means that it received about 0.5 mg (500 ppm) of brodifacoum. Since a Brodifacoum-25W pellet contains 25 ppm, the turtle essentially received the equivalent of 20 pellets (G. Witmer APHIS USDA, pers. comm). Adult green turtles weigh on average 325 lbs. (147 kg) (NOAA Fisheries Service 2011a), thus, using similar metrics, one adult green turtle would have to consume approximately 9,200 pellets or 40.5 lbs. (18.4kg) of pellets to receive a comparable exposure to that the ornate wood turtle received (which did not cause death or signs of ill health). Adult hawksbill turtles weigh on average 125 lbs. (57kg) (NOAA Fisheries Service 2011b), thus one turtle would have to consume approximately 3,500 pellets or 15.4 lbs. (7.0kg) of pellets to receive a comparable exposure to that the ornate wood turtle received.*

No published studies have been identified on the laboratory testing of anticoagulants to reptiles. Major references listing the LD_{50} values for anticoagulants (Timm 1994, Tasheva 1995) do not list any values for reptiles. Brooks et al. (1998) found that warfarin (a first generation coagulant) was lethal to brown tree snakes (Boiga irregularis) when orally administered in ethanol (but not propylene glycol) at 40 mg/kg, but elicited no signs of discomfort or internal hemorrhaging upon necropsy. In the same study, diphacinone delivered orally to brown tree snakes was consistently lethal at dosages of 40 – 80 mg/kg, but snakes displayed no apparent clinical signs prior to death or evidence of internal hemorrhaging upon necropsy. Gopher snakes (Pituophis catenifer) fed with mice poisoned with lethal quantities of the anticoagulants Prolin® (0.05% warfarin, 0.05 % sulfaquinoxaline), Diphacin®, and warfarin showed no observable behavioral or physiological reaction (Brock 1965). Snakes fed brodifacoum-killed house mice (R. Marsh pers. comm.), and lizards (Uta sp.) force-fed 50 ppm brodifacoum (Tershy et al. 1992, Tershy unpubl. data) survived for at least several weeks.

Similarly, no published studies are found on the toxicity of brodifacoum to reptiles. Brodifacoum inhibits vitamin K dependent pathways in mammals and birds. Because reptiles are poikilothermic (cold-blooded), their blood chemistry and physiology is different from that of mammals and birds (homoeothermic or warm-blooded animals) (Merton 1987), and blood coagulation mechanisms in reptiles are slower than those of mammals (Frost et al. 1999, Kubalek et al. 2002). Reptiles have an active extrinsic clotting pathway (Spurling 1981) but, for example in spectacled caimans (Caiman crocodilus) several factors (Factors V, VIII, IX, and XI, and possibly XII) in the Vitamin K dependent (intrinsic) clotting pathway are missing in the blood (Arocha-Pinango et al. 1982). In the puff adder (Bitis arietans), other clotting activation factors, such as prothrombin, α2-antiplasmin (fibrinogen system) and kallikrein (kallikrein system) have significantly reduced activity when compared with humans (Frost et al. 1999). Bait consumption has been recorded in several reptile species in the wild where no evidence of *mortality was found. There are reports of larger skinks consuming baits containing brodifacoum during island rat and rabbit eradication efforts in the Seychelles, however, no observed mortality was detected (Wright's skinks Mabuya wrightii (Thorsen et al. 2000), Seychelles skinks Trachylepis seychellensis (Merton et al. 2002)). In brodifacoum baiting operations on two South Pacific islands two species, Duvaucel's gecko (Hoplodactylus duvaucelii) (Christmas 1995) and common gecko H. maculatus (Hoare and Hare 2006b), showed some evidence of having consumed brodifacoum baits in bait boxes. Wedding (2007) tracked visitation rates of shore skinks (Oligosoma smithi) to brodifacoum bait stations in Tawharanui, New Zealand and found rates reached 81 percent. One skink was observed consuming bait directly; of the 802 skinks captured in brodifacoum controlled areas, none showed clinical or behavioral signs of ill health (Wedding 2007).*

In a laboratory, McCann's skinks (Oligosoma maccanni) were offered two types of cereal-based bait with no alternative food. Skinks preferred dry pindone bait (a first-generation anticoagulant) to dry non-toxic RS5 bait (which is commonly infused with sodium monofluoroacetate (1080)). When bait was offered wet, both bait palatability increased and was similar. Both baits offered were infused with a green dye (Bayer V200) and the dye was detected in fecal pellets in 55 percent of skinks fed RS5 and in 97 percent of skinks fed pindone. However, relatively little bait was consumed over the 2-day trials (mean pindone = 0.020g; mean RS5 = 0.012g), and toxin ingestion levels were far below probable lethal doses for this species (Freeman et al. 1996). In another study, captive rainbow skinks (Lampropholis delicata) were fed brodifacoum loaded mealworms and none showed signs of ill health, although this may be attributed to low toxin concentrations (mean = 0.118 ug/g) (Wedding 2007). Marshall and Jewell (2007) tested free-ranging skinks palatability to three bait types that are commonly used in pest mammal control programs (RS5 cereal baits, carrot and FeraCol® paste). All bait types were presented in non-toxic form and were sampled by both species of skink (grand skink Oligosoma grande and Otago skink O. otagense) (Marshall and Jewell 2007). However, Booth et al. (2004) found that spotted skinks (Oligosoma lineoocellatum) did not consume any non-toxic paste or cereal blocks offered in trials to test for the palatability of FeraCol®.

Reports of reptile mortality associated with brodifacoum bait consumption are uncommon. In two separate observations, single dead moko skinks (Oligosoma moco) were found near baiting stations at two locations in New Zealand. On analysis, one skink had a brodifacoum residue (probably whole body) of 0.82 µg/g, while analysis of stomach contents in the second lizard showed consumption of 19 µg/g of pindone. Necropsy of the second skink found blood clots ventral and caudal to the heart (Tocher 2008) (though clotting signs are not normally associated with anticoagulant effects). A single Northland green gecko (Naultinus grayii) was found dead after pindone baiting operations near Boundary Stream, New Zealand, and contained 0.52 µg/g pindone residues. This level of pindone was similar to the concentration found in the baits (Tocher 2008). During a two month-long rabbit eradication program on Round Island, Mauritius, using Talon 20P® pelleted baits (20 ppm brodifacoum), Merton (1987) noted that out of several species of skinks and geckos, only Telfair's skinks (Leiolopisma telfairii) routinely consumed bait pellets. After three weeks of bait exposure, dead Telfairs's skinks began to be found, with increasing mortality for a further five weeks, when lizard mortality abruptly ceased. In all, over 100 dead Telfair's skinks (out of an estimated 5000 individuals) were found, *primarily during the hottest parts of the day and on the hottest days. However, because of the subsequent eradication of invasive rabbits, populations of Telfair's skink (and other endemic species) on Round Island expanded rapidly following anticoagulant baiting and skinks are now being translocated to other islands which were part of the species' historic range (ARKive.org 2011). Analysis of bulked livers (n = 10) from intoxicated Telfair's skinks yielded brodifacoum residues of 0.6 mg/kg, but only one lizard showed signs of internal hemorrhaging. Merton (1987) speculated that since dead lizards were only found during the hottest portion of the day, anticoagulant intoxication may have interfered with thermoregulatory mechanisms rather than inhibition of blood coagulation. The extent of the mortality may also have been due to the overly long exposure time.*

During a rat eradication campaign in the Montebello Islands Conservation Park, Australia, bungarras (Varanus gouldii) were observed scavenging dead or dying rats poisoned with Talon G® (50ppm brodifacoum) to the extent that some rat droppings contained the green dye from the bait, but no dead or moribund bungarras were found, and the following year, bungarra tracks were plentiful (Burbridge 2004). During a rat eradication campaign on Seymour Island in the Galapagos Islands, 6 of 134 Galapagos land iguanas (Conolophus subcristatus) were found dead 2-3 months after the bait application at least one of which was directly attributable to bait consumption (Harper pers. comm.). On Isabel Island, México, brown iguanas (Ctenosaura pectinata) were observed eating rodent bait pellets directly and 19 were found dead after an aerial bait application of brodifacoum bait in 2009 (M. Rodriguez Malagón pers. comm.).

In 1986, plans to eradicate rats from Monito Island, Puerto Rico, were stopped owing to concerns over the potential mortality of Sphaerodactylus macrolepsis from 0.005 percent brodifacoum (Talon-G®) deduced from a laboratory experiment (García 1994, Gaa 1986 in García et al. 2002). A rat eradication campaign was eventually implemented on Monito Island (García et al. 2002), but in order to address the earlier concern, a second captive experiment was conducted in 1994 to test the effect of the second-generation anticoagulant 0.005 percent bromadiolone (Maki® mini blocks) on a surrogate species, the Mona Island gecko Sphaerodactylus monensis (justification for using bromadiolone in the test and brodifacoum in the actual Monito island eradication is described in García et al. 2002). No mortality or change in behavior was observed. Prior to the Monito program, successful rat eradications had also been achieved on Cayo Ratones (Puerto Rico), and Steven Cay (U.S. Virgin Islands), with no apparent effect on nontarget reptiles including native Sphaerodactylus species.
Researchers have estimated the LD_{50} of brodifacoum for species with unknown LD_{50} values to be 0.56 mg/kg with a confidence level of 95 percent (Howald et al. 1999). For this reason, we assume the toxicity risk level for brodifacoum to be very high for terrestrial reptiles. However, there have been no indications of adverse population-level effects to reptiles or amphibians as a result of rodent eradications that used brodifacoum. On Anacapa Island, for example, monitoring of slender salamanders (Batrachoseps sp.) showed no changes in the population after rats were eradicated using brodifacoum (Island Conservation unpubl. data). In many cases, the removal of non-native rodents from the ecosystem has led to a large increase in native reptile and amphibian populations (Towns 1991, Newman 1994, North et al. 1994, Towns 1994, Eason and Spurr 1995, Towns et al. 2001, NMFS 2005, Parrish 2005, Daltry 2006). At Palmyra, the expected bait availability period is 4-7seven days (Buckelew et al. 2005). Therefore, the

probability of exposure will be high for 4-7days after the bait is applied, and the concentration of toxicant that reptiles could be exposed to via primary or secondary pathways will decrease quickly (USDA 2006, Alifano and Wegmann 2010). Although lethal toxicity in reptiles at Palmyra is possible, little impact to species at the population-level is expected and population increases are expected.

<u>Toxicity to invertebrates</u>
Arthropods are not thought to be susceptible to brodifacoum (Booth et al. 2001). Soft-bodied invertebrates such as mollusks may be affected, but the evidence for this is still inconclusive (Booth et al. 2001) and recent field studies suggest that at least some species of terrestrial mollusks are not affected by brodifacoum (Brooke et al. 2010). Furthermore, post-application sampling in the Anacapa Island rat eradication only detected minimal levels of brodifacoum residue in five out of ten of the intertidal invertebrates tested (Howald et al. 2010).

Invertebrates may also function as short-term intermediate carriers of brodifacoum that could be ingested by their predators. Land crabs have been documented to retain brodifacoum in their system for up to 56 days (USDA 2006).

<u>Toxicity to plants</u>
Plants are not known to be susceptible to toxic effects of brodifacoum.

Toxicant Exposure
Exposures to toxicants are primarily dependent on 2 factors:

- Food habits, behavior patterns, and other specific characteristics that increase or decrease an animal's exposure to the toxicant; and

- The availability of the toxicant in the local environment.

In the form used for rodent control, or eradication, brodifacoum can only effectively be delivered through oral ingestion; animals can either ingest the toxicant by consuming bait (known as "primary exposure"), by preying on or scavenging animals that previously consumed bait (known as "secondary exposure"), or by ingesting soil that contains bait fragments or other organic particles to which the toxicant has adhered. Brodifacoum molecules adhere strongly to the bait pellet grains, and are unlikely to be leached away by moisture. Once the pellets disintegrate into particles that are too small for most foraging animals to consume, the toxicant is essentially unavailable for direct consumption. Eventually, even the sub-measurable concentrations of toxicant remaining from a fully disintegrated pellet would break down into non-toxic compounds including carbon dioxide and water with no toxic intermediate compounds (U.S. National Park Service 2000).

<u>Primary exposure</u>
Herbivorous and omnivorous species are much more likely to consume bait (primary exposure) than carnivorous species (including insectivores and piscivores) because the bait is composed primarily of grain. It is unlikely that the carnivorous, piscivores, or insectivorous at Palmyra would intentionally consume bait pellets as food.

There is no direct information on shorebird soil consumption at Palmyra; however, we can assume that a small percentage (for example, less than 0.03% of the atoll's 618 acres of land would come into direct contact with a bait pellet if 0.4 inch x 1 inch bait pellets were applied at 80.4 lb/acre) of the topsoil at Palmyra will contain low concentrations (Alifano and Wegmann 2010)of brodifacoum for less than 1year beyond the eradication action; brodifacoum has a reported half-life of 157 days when in soil (World Health Organization 1995). Early studies of sediment consumption in shorebirds estimated between 10 – 60 percent of the contents in the digestive system were sand; no apparent correlation with feeding habits were found (Reeder 1951). More recently, Beyer et al. (1994) found that the diet of four species of sandpiper: stilt sandpiper (*Calidris himantopus*), semipalmated sandpiper (*Calidris pusilla*), least sandpiper (*Calidris minutilla*), and western sandpiper (*Calidris mauri*) contained on average 7 – 30 percent sediment in their digestive track. Black-bellied plovers (*Pluvialis squatarola*) and willets (*Tringa semipalmata*) consumed 29 percent and 3 percent sediment, respectively (Hui and Beyer 1998). Feeding habits of these species differ; black-bellied plovers have short bills and primarily peck at food, while willets have long bills and probe into the soil with their bills open. Mathot et al. (2010) found that the stomach contents of western sandpipers (*Calidris mauri*) contained more than 75 percent sediment, while the stomach contents of dunlins (*Calidris alpina*) contained more than 40 percent sediment. Dunlins probe with an open bill and western sandpipers forage by pecking or probing. Therefore, measureable amounts of sediment can be consumed by shorebirds while foraging for sediment-dwelling prey, and some correlation may be exist between feeding strategy and the amount of soil consumed while foraging. While it is possible that shorebirds at Palmyra will consume brodifacoum bound to organic particles within the soil that they are feeding, it is unlikely that this will be a high-risk pathway of exposure due to the following reasons: 1) Shorebirds primarily forage in the intertidal zone and on emergent lagoon flats; with the broadcast alternatives (Alternatives B and C) measures will be taken to minimize the amount of bait that will land in the intertidal and marine environments, and the bait station alternative (Alternative D) would all but eliminate bait from entering the intertidal and marine environments; 2) Brodifacoum concentrations in sandy and humus topsoil are low during and directly after a bait broadcast (Alternatives B and C), and quickly decline to trace or undetectable levels (Alifano and Wegmann 2010, Appendix F).

<u>Secondary exposure</u>

Rats and other animals that directly consume bait can also transfer some of the toxicant in their systems to predators or scavengers (secondary exposure). Different organisms show considerable variation in the amount of time that they retain toxicants in their bodies. For vertebrates that experience sub-lethal dosing, brodifacoum can be retained in the liver for many months. Specifically, brodifacoum concentrations in the livers of rats that experienced sub-lethal dosing took 350 days to reduced by 50 percent (Erickson and Urban 2004). Brodifacoum retention times for birds have not yet been determined. For invertebrates, the exact mechanisms of brodifacoum retention are unclear but the general understanding is that most invertebrates only retain brodifacoum briefly in their digestive system and body tissues (Booth et al. 2001). A recent study of brodifacoum in crab tissue at Palmyra indicated that crabs retain more of the toxicant in the hepatopancreas than in the claw meat, and all of the samples had negligible quantities of brodifacoum in their tissues by day 56 of the study (USDA 2006).

In a toxicant-based rat eradication scenario, rats that die from rodenticide exposure could become a secondary pathway of exposure for nontarget species (Salmon and Paul 2010). To determine the timeframe within which this exposure pathway presents a risk to nontarget species, 87 rats were captured and euthanized during the 2008 biomarker study and placed at their point of capture and monitored. Seventy-five percent of the sample rats were completely consumed within 24 hours, and the carcasses that were not completely consumed were mostly reduced to small pieces: teeth, tails, and skull fragments (Wegmann et al. 2008).

Land crabs are capable scavengers and will readily consume carrion and may consume rats that have been sub-lethally exposed to brodifacoum. Cox and Smith (1990) suggest that sub-lethal dosing in may alter thigmotactic behavior in rats, which in turn may alter exposure of secondary consumers to rodenticide residues in rat tissue. Aside from crabs, rats have no other terrestrial predators at Palmyra, and crabs are the primary scavengers of rat carcasses. Land crabs appear to have no ill effect from primary or secondary exposure to brodifacoum; therefore, it is unlikely that nontarget species will be harmed by direct consumption of sub-lethally exposed rats, or rat carcasses.

At Palmyra, only a few species are at risk of exposure to the applied rodenticide through a secondary pathway. Rats may be at risk of secondary exposure by consuming crabs and other invertebrates like cockroaches, dead shorebirds, and other rats that had all previously consumed bait. Crabs (hermit crabs, land crabs, and coconut crabs) may be at risk of secondary exposure to rodenticide through the consumption of crabs and other invertebrates, dead shorebirds, and dead or dying rats that had all previously consumed bait. Shorebirds, primarily the bristle-thighed curlew and Pacific golden-plover, may be at risk of secondary exposure to rodenticide through the consumption of invertebrates that had previously consumed bait; bristle-thighed curlews are the only shorebird species at Palmyra that are known to occasionally feed on terrestrial hermit crabs (see Appendix I Hermit Crab Predation by Bristle-thighed Curlews). Shorebirds showed no interest in rat carcasses during a rat carcass degradation study conducted at Palmyra in 2010 (Alifano and Wegmann 2010). The two gecko species at Palmyra may be at risk of secondary exposure to rodenticide through the consumption of invertebrates that had previously consumed bait; however, none of the 50 geckos sampled during the 2008 biomarker study showed any sign of primary or secondary exposure to bait (Wegmann et al. 2008).

4.4.4.2 Analysis framework for impacts from disturbance

Helicopter Operations

The operation of low-flying aircraft throughout Palmyra would likely result in disturbance to wildlife from sound, the sudden appearance of an aircraft, or a combination of both (Efroymson et al. 2001). Wildlife could be exposed to noise that exceed background levels. Due to the relatively low altitude at which helicopters would fly (50-100 feet above the canopy), the majority of the helicopter noise would be focused in a narrow cone directly underneath the aircraft, reducing the area of disturbance for each helicopter pass (Richardson et al. 1995). Animals on land would likely be exposed to higher-decibel noise than animals in the water;

however, researchers at Grupo de Ecología y Conservación de Islas, A.C (GECI) assessed the impact helicopter operations on breeding boobies on Isla Isabel (Mexico) and found no significant effect to the birds (GECI 2009). Also, rotor wash from helicopters landing or hovering near nesting white terns, black noddies, or brown noddies could cause disturbance to individual birds, eggs, or chicks; however, of these three species, only white terns, would be nesting near any of the designated helicopter landing zones. All helicopter landing zones would be surveyed for nesting seabird nesting activity prior to the commencement of helicopter operations. If nests were found close to pre-determined landing zones, alternate landing zones would be sought out. We do not anticipate that helicopter operations in association with the action Alternatives B and C would cause more than a nominal disturbance to wildlife at Palmyra.

Personnel Activities

Additional wildlife disturbance could result from personnel traveling by foot across the atoll (e.g., when hand-broadcasting bait, tending bait stations, and surveying for nontarget mortality), or traveling in small boats in the nearshore waters. Personnel associated with the rat eradication action would be based at Palmyra for approximately one month under Alternative B, two months under Alternative C, and for up to 2 years under Alternative D. Following eradication, there will be several monitoring visits to the atoll for at least 2 years post eradication. There are personnel at Palmyra conducting ongoing research, monitoring, and other management activities year-round, but rat eradication will increase the number of personnel on the atoll and the extent of affect. Most current monitoring activities take place in discrete and limited areas of the atoll, whereas rat eradication operations will require personnel to travel throughout the atoll. Personnel would be briefed on techniques to reduce wildlife disturbance, but minor disturbance events will likely still occur. Personnel will also be briefed on biosecurity practices and will adhere to biosecurity protocols to prevent the spread of invasive plants and animals (invertebrates) around the atoll.

4.4.4.3 Methods for impacts analysis to biological resources

Impact Indices

The following impacts analysis identifies the level of risk from the perspective of bait availability (the amount of time bait will be available through either primary or secondary exposure pathways), toxicant exposure (the number of exposure pathways available to individual species based on feeding ecology and toxicant fate), toxicant risk (the toxicity of the toxicant to different species based on toxicological properties), disturbance risk (the sensitivity to disturbance and the amount of disturbance risk that individuals may be exposed to during operations), extent of the risk (the number of individuals that may be affected by eradication operations and the influence that this could have global or regional breeding populations), and the duration of the risk (the period of time that individuals will be exposed to toxicant or disturbance risks). The following indices illustrate the methodology employed to analyze the impacts to each of the identified species for the three action alternatives:

- Bait availability
  - Short: Bait or rat carcasses with toxicant residue available for up to 36 days
  - Medium: Bait in crab excrement or animal tissue available for 37-90 days
  - Long: Toxicant persistent anywhere in the environment for more than 90 days

- Risk of mortality from toxicant use
    - None: No toxicological sensitivity
    - Low: Minor toxicological sensitivity
    - Medium: Moderate toxicological sensitivity
    - High: Severe toxicological sensitivity
- Toxicant exposure risk level
    - None: No exposure pathway
    - Low: Possible exposure pathway
    - Medium: One exposure pathway
    - High: Multiple exposure pathways
- Disturbance risk
    - None: No disturbance pathway
    - Low: Low sensitivity to disturbance
    - Medium: Moderate sensitivity to disturbance
    - High: Severe sensitivity to disturbance
- Extent of toxicant/disturbance risk within a population
    - Individuals: Few individuals affected
    - Island population: Many individuals affected with no affect to the global or regional breeding population
    - Global or regional population: Many individuals affected with impacts on the global or regional breeding population
- Duration of the Risk (Toxicant or Disturbance)
    - Short: Impacts for up to 2 months
    - Medium: Impacts for more than 2 months and up to 6 months
    - Long: Impacts for more than 6 months

4.4.4.4 Impacts of Alternative B on biological resources

Impacts on Birds

Generally, birds that primarily eat plant matter such as seeds and fruits would initially be at high risk for primary exposure to brodifacoum. Predators and scavengers would in some cases be at high risk of secondary exposure to brodifacoum. Animals that feed on rats, rat carcasses, or large ground-dwelling invertebrates such as land crabs would initially be at high risk of secondary exposure to brodifacoum. Birds that have a broad, omnivorous diet would initially be at high risk for both primary and secondary exposure.

The risk of exposure (either primary or secondary) in initially high-risk animals (terrestrial herbivores, many predators and scavengers, and omnivores) would begin to decline rapidly within 30 days of the final bait application session as the rat population declines, bait pellets are consumed or disintegrated, and bait becomes less available to invertebrate consumers. The risk of exposure in these initially high-risk animals would generally be low within 30 days of the final bait application and negligible within a few months thereafter.

On the other hand, birds foraging in the intertidal zone would be at lower risk for primary exposure because pellets that drift into the water would disintegrate and become unavailable within a few hours. Similarly, birds that forage primarily in the intertidal zone and specialize in intertidal invertebrates would initially be at a low risk of secondary exposure. Also, birds that feed primarily on flying insects and "micro-invertebrates" would be at an initial, lower risk of secondary exposure due to the low likelihood that these classes of invertebrates would be carrying brodifacoum in their systems; this risk would steadily decline to negligible within a few months. The likelihood of exposure in intertidal specialists would decline even more rapidly, becoming negligible within 30 days of the final bait application.

The following is a breakdown of the direct toxicant and disturbance impacts to each of the identified bird species that migrate to, breed at, and overwinter at Palmyra. Additionally, we have quantified the number of individuals per species that are likely to be adversely affected by Alternative B (we have assumed the worst case scenario and consider any individuals that may be present on the atoll during the eradication operations to be vulnerable to adverse impacts from the action alternative). The take numbers for action Alternative B are from runway and all-atoll shorebird counts conducted during the season (June-July) when breeding adults should be at their breeding grounds in Alaska, or from Depkin (2002).

<u>Bristle-thighed curlew</u>

Toxicant Risk

Bristle-thighed curlews could be exposed to brodifacoum through both primary and secondary exposure pathways. Generally, curlews forage in the intertidal zone for aquatic invertebrates and seabird eggs, and have been observed ignoring placebo (non-toxic) bait pellets when they are placed in the vicinity of more typical prey items – fiddler crabs (see Appendix F). Additionally, curlews are known to eat small fruit and insects in the forested areas of the atoll, and to a limited extent prey on terrestrial hermit crabs (see Appendix I). The primary exposure pathway is limited to curlews that forage in the forests and directly consume bait; whereas, the secondary exposure pathways include consumption of intertidal invertebrate species, hermit crabs, roaches, and other terrestrial invertebrates. The bait availability will be for the short-term, the mortality risk is high, and the exposure risk is high because of the range of toxicant exposure pathways. The duration of the risk will likely be for the medium-term due to the retention time of the toxicant in the tissue of species that provide a secondary exposure pathway to curlews. The extent of the affect will be to the entire atoll population.

Disturbance Risk

Bristle-thighed curlews could be exposed to disturbances from both ground and air operations, which will likely cause curlews to flush the area to an alternate site on the atoll. The impacts associated with disturbance risks for this alternative are low, the duration of the disturbance will be for the short-term, and the extent of the affect will be to the entire atoll population.

- *As many as* 182 individuals are likely to be exposed to impacts from Alternative B.

<u>Pacific golden-plover</u>

Toxicant Risk

Pacific golden-plovers could be exposed to brodifacoum through both primary and secondary exposure pathways. Generally, plovers forage in the intertidal zone for aquatic invertebrates and insects. Additionally, plovers are known to eat insects in the forested and grassland areas of the atoll. The primary exposure pathway is limited to plovers that forage in the forests and consume rodenticide; whereas, the secondary exposure pathways include consumption of hermit crabs, roaches, other terrestrial invertebrates, and possibly intertidal invertebrate species. The bait availability is for the short-term, the mortality risk is high, and the exposure risk is high because of the range of toxicant exposure pathways. The duration of the risk will likely be for the medium-term due to the retention time of the toxicant in the tissue of species that provide a secondary exposure pathway to plovers. The extent of the affect will be to the entire atoll population.

Disturbance Risk

Pacific golden-plovers could be exposed to disturbances from both ground and air operations, which will likely cause plovers to flush the area to an alternate site on the atoll. The impacts associated with disturbance risks for this alternative are low, the duration of the disturbance will be for the short-term, and the extent of the affect will be to the entire atoll population.

- *As many as* 62 individuals are likely to be exposed to impacts from Alternative B.

<u>Ruddy turnstone</u>

Toxicant Risk

Ruddy turnstones could be exposed to brodifacoum through both primary and secondary exposure pathways. Generally, turnstones forage in the intertidal zone for aquatic invertebrates. Additionally, turnstones eat terrestrial insects and feed on carrion when available. The primary exposure pathway is limited to turnstones that forage in the forests that consume rodenticide; whereas, the secondary exposure pathways include consumption of intertidal and terrestrial invertebrate species, carrion, and other terrestrial invertebrates that have consumed the toxicant. The bait availability will be for the short-term, the mortality risk is high, and the exposure risk is high because of the range of toxicant exposure pathways. The duration of the risk will likely be for the medium-term due to the retention time of the toxicant in the tissue of species that provide a secondary exposure pathway to turnstones, and the extent of the affect will be to the entire atoll population.

Disturbance Risk

Ruddy turnstones could be exposed to disturbances from both ground and air operations, which will likely cause turnstones to flush the area to an alternate site on the atoll. The impacts associated with disturbance risks for this alternative are low, the duration of the disturbance will be for the short-term, and the extent of the affect will be to the entire atoll population.

- *As many as* 35 individuals are likely to be exposed to impacts from Alternative B.

<u>Wandering tattler</u>

Toxicant Risk

Wandering tattlers would only be exposed to brodifacoum through secondary exposure pathways. Generally, tattlers forage in the intertidal zone for aquatic invertebrates at Palmyra. *Tattlers feed on aquatic insects, mollusks, crustaceans, and small fish.* The bait availability will be for the short-term, the mortality risk is high, and the exposure risk is *moderate* because of limited exposure to the rodenticide. The duration of the risk will likely be for the short-term due to the retention time of the toxicant in the tissue of species that provide a secondary exposure pathway to tattlers. The extent of the affect will be to individuals because of the *moderate* exposure risk.

Disturbance Risk

Wandering tattlers could be exposed to disturbances from both ground and air operations, which will likely cause tattlers to flush the area to an alternate site on the atoll. The impacts associated with disturbance risks for this alternative are low, the duration of the disturbance will be for the short-term, and the extent of the affect will be to the entire atoll population.

- *As many as* 48 individuals are likely to be exposed to impacts from Alternative B.

<u>Sanderling and pectoral sandpiper</u>

Toxicant Risk

Sanderlings and pectoral sandpipers would only be exposed to brodifacoum through secondary exposure pathways. Generally, these species forage in the intertidal zone for aquatic invertebrates. The bait availability will be for the short-term, the mortality risk is high, and the exposure risk is low because of limited exposure to the rodenticide. The duration of the risk will likely be for the medium-term due to the retention time of the toxicant in the tissue of species that provide a secondary exposure pathway to these species. The extent of the affect will only be to a few individuals because the atoll populations of both sanderlings and pectoral sandpipers are relatively low at Palmyra and the exposure risk is low.

Disturbance Risk

Sanderlings and pectoral sandpipers could be exposed to disturbances from both ground and air operations, which will likely cause sanderlings and pectoral sandpipers to flush the area to an alternate site on the atoll. The impacts associated with disturbance risks for this alternative are low, the duration of the disturbance will be for the short-term, and the extent of the affect will be to the entire atoll population.

- *As many as* five sanderling individuals are likely to be exposed to impacts from Alternative B.

- *As many as* eight pectoral sandpiper individuals are likely to be exposed to impacts from Alternative B.

<u>Laughing and Franklin's gull</u>

Toxicant Risk

Laughing and Franklin's gulls could be exposed to brodifacoum through both primary and secondary exposure pathways. Generally, gulls are omnivorous and are often found foraging in the intertidal zone for aquatic and terrestrial invertebrates, eating seeds and plants, or feeding on carrion. The primary exposure pathway is significant because gulls are known to consume bait pellets. Additionally, the secondary exposure pathways include consumption of intertidal and terrestrial invertebrate species, carrion, and other terrestrial invertebrates that have consumed the toxicant. The bait availability would be for the short-term, the mortality risk is high, and the exposure risk is high because of the range of toxicant exposure pathways. The duration of the risk will likely be for the medium-term due to the retention time of the toxicant in the tissue of species that provide a secondary exposure pathway to gulls. The extent of the affect will be to individuals because gulls are very infrequent visitors of Palmyra.

Disturbance Risk

Franklin's and laughing gulls could be exposed to disturbances from both ground and air operations, which will likely cause gulls to flush the area to an alternate site on the atoll. The impacts associated with disturbance risks for this alternative are low, the duration of the disturbance will be for the short-term, and the extent of the affect will be to the entire atoll population.

- *As many as* one laughing gull individual is likely to be exposed to impacts from Alternative B.

- *As many as* nine Franklin's gull individuals are likely to be exposed to impacts from Alternative B.

<u>Northern shoveler and northern pintail</u>

Toxicant Risk

Northern shovelers and northern pintail ducks could be exposed to brodifacoum through both primary and secondary exposure pathways. Generally, ducks forage in small, inland ponds for aquatic invertebrates, eat terrestrial insects, and consume plants and seeds. Ducks are susceptible to primary exposure of the bait because they are granivorous and would likely be attracted to the grain matrix within the bait pellet. The secondary exposure pathways include consumption of intertidal and terrestrial invertebrate species that have consumed the toxicant. The bait availability would be for the short-term, the mortality risk is high, and the exposure risk is medium because of the range of toxicant exposure pathways. The duration of the risk will likely be for the medium-term due to the retention time of the toxicant in the tissue of species that provide a secondary exposure pathway to ducks. We expect that less than ten individuals will be impacted by the eradication because ducks are highly infrequent visitors to Palmyra.

Disturbance Risk

Northern shovelers and pintail ducks could be exposed to disturbances from both ground and air operations, which will likely cause ducks to flush the area to an alternate site on the atoll. The impacts associated with disturbance risks for this alternative are low, the duration of the disturbance will be for the short-term, and the extent of the affect will be on the individual level.

- *As many as* six northern pintail individuals are likely to be exposed to impacts from Alternative B.

- *As many as* two northern shoveler individuals are likely to be exposed to impacts from Alternative B.

Breeding seabirds (masked booby, brown booby, red-footed booby, great frigatebird, sooty tern, white tern, red-tailed tropicbird, white-tailed tropicbird, black noddy, and brown noddy)

Toxicant Risk

The breeding seabirds at Palmyra are at extremely low risk of toxicant exposure because they rarely if ever feed on anything other than marine organisms. *We would minimize the potential of exposure of groun- nesting boobies to toxicant by hand-baiting the causeways where most brown and masked boobies nest and bait will not be distributed within reach of birds sitting in the nest.* We would minimize the potential for fish to be exposed to the toxicant by hand baiting near the shoreline and using an internal deflector system in the bait hopper to prevent bait from being broadcast into bodies of water; therefore, the extent of the effect is insignificant and does not require further scrutiny. Young boobies of all three species at Palmyra engage in manipulative play with sticks and small objects. They don't ingest the objects but could be exposed to very small amounts by holding the pellets in their bills.

Disturbance Risk

Breeding seabirds are at a greater risk from disturbance because they will be attending nests and caring for young. The majority of the disturbance will come from both ground and air operations, which would cause individuals to flush from roosts and nests leaving eggs and chicks vulnerable to predation or injury. Additionally, there is a risk of breeding disturbance from the listed disturbance impacts; however, there will be limited aerial operations directly above ground breeding masked or brown booby colonies. The risk level from disturbance from aerial operations would be low. This is supported from research conducted by GECI on disturbance affect to booby populations on Isla Isabel from helicopter operations, which found little to no effect on booby colonies from helicopter operations (GECI 2009). Additionally, ground operations will be minimal near breeding colonies and will result in low disturbance impacts. The duration for the disturbance affect is for the short-term and the extent is to the entire atoll population.

- 100,000 – 200,000 individuals are likely to be exposed to impacts from Alternative B.

Non-breeding seabirds (lesser frigatebird)

Toxicant Risk

Lesser frigatebirds are at a no risk of toxicant exposure because they rarely if ever feed on anything other than marine fish. We would mitigate impacts to fish by hand baiting near the shoreline and using a deflector to prevent bait from entering the waterways; therefore, the extent of the affect is insignificant and does not require further scrutiny.

Disturbance Risk

Lesser frigatebirds could be exposed to disturbances from both ground and air operations, which will likely cause them to flush the area to an alternate site on the atoll. The impacts associated with disturbance risks for this alternative are low, the duration of the disturbance will be for the short-term, and the extent of the affect will be on the individual level.

- 20 individuals are likely to be exposed to impacts from Alternative B.

Impacts on Reptiles

<u>Geckoes (native *Lepidodactylus* sp) and nonnative mourning gecko (*Lepidodactylus lugubris*))</u>

Toxicant Risk

Geckoes are at risk of secondary exposure to rodenticide through the consumption of terrestrial invertebrates; however, there is a gap in the literature on the toxicity of anticoagulant rodenticides to reptiles. Additionally, even less is known about either the native or nonnative geckoes at Palmyra. Therefore, this assessment is likely deficient at examining all of the potential toxicant exposure pathways, as well as, the fate of individuals that consume bait through secondary pathways. The bait availability would be for the short-term, the mortality risk is high, and the exposure risk is medium. The duration of the risk is for the medium-term, and the extent is to the entire atoll population.

Disturbance Risk

Geckoes are at a negligible risk of disturbance from both ground and air operations because they are fairly elusive and have many alternative areas to retreat to during eradication operations; therefore, they are only vulnerable for the short-term and only to a few individuals.

<u>Hawksbill turtle and green turtle</u>

Toxicant Risk

Turtles may face a primary risk of exposure to the toxicant through eating bait directly as it drops through the water column. These turtles' common foraging behaviors make exposure unlikely, but juvenile green turtles in particular are known to be comparatively opportunistic feeders, and marine turtles have been documented ingesting marine debris elsewhere (Carr 1987, Meylan 1988, NOAA Fisheries pers. comm., Bjorndal et al. 1994, Coyne 1994, Bugoni et al. 2001). Mitigation measures to reduce bait drift into waterways will be employed to reduce the exposure risk to turtles, including hand-baiting narrow strips of land and portions of the coconut palm canopy than cannot be safely and effectively baited by air, and using a deflector to control the direction of the bait flow from the hopper. Even if bait pellets enter the water at the full application rate, they will only be ingestible by turtles for a few hours prior to embedding in the sediment and breaking down to tiny fragments (Empson and Miskelly 1999). Thus, the duration of risk to turtles is for the very short term. The extent of risk is only to a few individuals. The risk of turtle mortality, given the low likelihood of exposure to the toxicant, is unknown but suspected to be low.

Disturbance Risk

Turtles could be exposed to disturbances from boat operations, which will likely cause turtles to flee from the immediate area. However, boat operations in association with the rat eradication would not exceed normal levels of boat use during the research season, and no negative impact to turtles has been associated with boat activities during the research season (A. Meyer pers. comm.). The impacts associated with disturbance risks for this alternative are low, the duration of the disturbance will be for the short-term, and the extent of the affect will be on the individual level.

Impacts on Fish

Fish (black-spotted sergeant (*Abudefduf sordidus*), stripe belly puffer (*Arothron hispidus*), camouflage grouper (*Epinephelus polyphekadion*), bohar (*Lutjanus bohar*), black tail snapper (*Lutjanus fulvus*), dusky farmerfish (*Stegastes nigricans*), and bonefish (*Albula vulpes*))

Toxicant Risk

Some fish species face both a primary and secondary risk of exposure to the toxicant through the consumption of aquatic invertebrates and by eating bait directly as it drops through the water column - species analyzed here either consumed or mouthed placebo bait during field trials at Palmyra Atoll in May 2010 (Alifano and Wegmann 2010) (see Appendix F). Little is known about the effect that brodifacoum has on fish; therefore, for the purposes of this analysis we are considering the mortality risk from brodifacoum to be high. Additionally, mitigation measures to reduce bait drift into waterways will be employed to further reduce the exposure risk to fish including hand baiting narrow strips of land and portions of the coconut palm canopy than cannot be safely and effectively baited by air, and using a deflector to control the direction of the bait flow from the hopper. The duration of risk is for the very short-term because bait pellets will only be available for a few hours prior to embedding in the sediment and breaking down to tiny fragments. The extent of risk is only to a few individuals.

Disturbance Risk

Fish could be exposed to disturbances from boat operations, which likely will cause fish to flush the immediate area. The impacts associated with disturbance risks for this alternative are low, the duration of the disturbance will be for the short-term, and the extent of the effect will be on the island population level.

Impacts on Invertebrates

Terrestrial crabs

Toxicant Risk

Terrestrial crabs are at both a primary and secondary risk of exposure to the brodifacoum bait from the consumption of bait pellets, carrion, invertebrates, or crab excrement. The exposure risk is high; however, crabs show not adverse response to ad-lib consumption of bait (Alifano and Wegmann 2010). We anticipate no risk of mortality to the island population for the short-term.

Disturbance Risk

Disturbance risks to terrestrial crabs include minor impacts from ground operations, as well as a disruption of their typical foraging base by providing an alternative food source through the bait pellets. The duration of this disturbance would only be for the short-term, but the extent will be to the entire atoll population.

Impacts on Vegetation

Toxicant Risk

Vegetation is at a negligible risk of toxicant impacts because brodifacoum lacks any herbicidal properties; therefore, the extent of the affect is insignificant and does not require further scrutiny.

Disturbance Risk

Vegetation is at a minor risk of disturbance by trampling from ground operations with the greatest threat from the introduction or dispersal of nonnative invasive plant species. The risk of spreading invasive plant species will be minimized by integrating biosecurity measures into the daily eradication operations. The duration of the affect will be for the very short-term.

Impacts Table for Alternative B: Biological Resources

Table 4.2. Impacts of Alternative B on Biological Resources

Species	Bait avail-ability[1]	Risk mortality - toxicant use[2]	Toxicant exposure risk level[3]	Disturbance risk[4]	Extent of risk within a population[5]		Duration of risk[6]	
					toxicant	disturbance	toxicant	disturbance
Bristle-thighed curlew	Short	High	High	Low	Island	Island	Medium	Short
Pacific Golden-plover	Short	High	High	Low	Island	Island	Medium	Short
Ruddy turnstone	Short	High	High	Low	Island	Island	Medium	Short
Wandering tattler	Short	High	*Moderate*	Low	Individ.	Island	Short	Short
Sanderling & pectoral sandpiper	Short	High	Low	Low	Individ.	Island	Medium	Short
Laughing & Franklin's gull	Short	High	High	Low	Individ.	Island	Medium	Short
Northern shoveler & pintail duck	Short	High	Medium	Low	Individ.	Individ.	Medium	Short
Breeding seabirds[7]	*Low*	*Low*	*Low*	Low	None	Island	None	Short
Non-breeding seabirds[8]	*Low*	*Low*	*Low*	Low	None	Individ.	None	Short
Geckoes[9]	Short	High	Medium	None	Island	Individ.	Medium	Short
Turtles[10]	*Low*	*Low*	*Low*	Low	*Individ.*	Individ.	*Short*	Short
Fish[11]	Short	High	Low	Low	Individ.	Island	Short	Short
Terrestrial crabs	Short	None	High	Low	Island	Island	Short	Short
Vegetation	None	None	None	Low	None	Island	None	Short

[1]None: No toxicological sensitivity; Short: Bait or rats with toxicant residue available for up to 36 days; Medium: Bait in crab excrement or animal tissue available for 37-90 days; Long: Toxicant persistent anywhere in the environment for more than 90 days. [2]None: No toxicological sensitivity; Low: Minor toxicological sensitivity; Medium: Moderate toxicological sensitivity; High: Severe toxicological sensitivity. [3]None: No exposure pathway; Low: Possible exposure pathway; Medium: One exposure pathway; High: Multiple exposure pathways. [4]None: No disturbance pathway; Low: Low sensitivity to disturbance; Medium: Moderate sensitivity to disturbance; High: Severe sensitivity to disturbance. [5]Individual (Individ.): Few individuals affected; Island population (Island): Many individuals affected with no affect to the global or regional breeding population; Global or regional population (Global): Many individuals affected with impacts on the global or regional breeding population. [6]Short: Impacts for up to 2 months; Medium: Impacts for more than 2 months and up to 6 months; Long: Impacts for more than 6 months. [7]Breeding seabirds includes: masked booby, brown booby, red-footed booby, great frigatebird, sooty tern, white tern, red-tailed tropicbird, white-tailed tropicbirds, black noddy, and brown noddy. [8]lesser frigatebird. [9]Native (*Lepidodactylu*s n. sp) and nonnative mourning gecko. [10]hawksbill turtle and green turtle. [11]black-spotted sergeant, stripe belly puffer, camouflage grouper, bohar, black tail snapper, dusky farmerfish, and bonefish.

4.4.4.5 Impacts of Alternative C- Preferred Alternative on biological resources

Impacts on Birds

Generally, birds that primarily eat plant matter such as seeds and fruits would initially be at high risk for primary exposure to brodifacoum. Predators and scavengers would in some cases be at high risk of secondary exposure to brodifacoum. Animals that feed on rats, rat carcasses, or large ground-dwelling invertebrates such as land crabs would initially be at high risk of secondary exposure to brodifacoum. Birds that have a broad, omnivorous diet would initially be at high risk for both primary and secondary exposure.

The risk of exposure (either primary or secondary) in initially high-risk animals (terrestrial herbivores, many predators and scavengers, and omnivores) would begin to decline rapidly within 30 days of the final bait application session as the rat population declines, bait pellets are consumed or disintegrated, and bait becomes less available to invertebrate consumers. The risk of exposure in these initially high-risk animals would generally be low within 30 days of the final bait application and negligible within a few months thereafter.

On the other hand, birds foraging in the intertidal zone would be at lower risk for primary exposure because pellets that drift into the water would disintegrate and become unavailable within a few hours. Similarly, birds that forage primarily in the intertidal zone and specialize in intertidal invertebrates would initially be at a low risk of secondary exposure. Also, birds that feed primarily on flying insects and "micro-invertebrates" would be at an initial, lower risk of secondary exposure due to the low likelihood that these classes of invertebrates would be carrying brodifacoum in their systems; this risk would steadily decline to negligible within a few months. The likelihood of exposure in intertidal specialists would decline even more rapidly, becoming negligible within 30 days of the final bait application.

The successful eradication would result in important benefits for migratory birds. Rats have likely contributed to the extirpation of as many as eight seabird species from Palmyra: Audubon's shearwater, Christmas Island shearwater, wedge-tailed shearwater, Phoenix petrel, white-throated storm-petrel, Bulwer's petrel, blue noddy, and gray-backed tern. While no historical or paleontological records were found for these species nesting at Palmyra, they do breed regionally at rat-free islands in the Line archipelago, such as Kiritimati Island in the Republic of Kiribati and Jarvis Island National Wildlife Refuges. Black rats would effectively prevent the establishment, or reestablishment of breeding populations of any of these species (Norman 1975). When rats are eradicated from Palmyra Atoll, we expect the number of nesting seabirds and reproductive success of these seabirds to increase. We also anticipate that several of the aforementioned ground nesting shearwaters, petrels and terns will reestablish colonies at Palmyra. The benefits of rat eradication will be greatest for nesting species. However, migratory shorebirds will also benefit, especially the bristle-thighed curlew. Predation by introduced predators, such as dogs, cats, pigs and rats, is an important source of mortality elsewhere for wintering curlews during the molt-induced flightless period (Marks et al. 1990, Marks et al. 2002). Eradication of rats will eliminate this source of mortality at Palmyra.

There is expected to be some negative effects to migratory birds associated with the eradication *program. However, the Preferred Alternative includes several measures intended to minimize these effects. Shorebirds will be the most vulnerable to direct and secondary poisoning during the eradication, so the eradication is scheduled to occur during the summer nesting season, when the number of migratory shorebirds is at its lowest (June-July). Not all shorebirds migrate to the nesting grounds and we plan to capture as many of the remaining shorebirds as possible and hold them under direct, constant veterinary care during the period when they would be vulnerable to primary or secondary poisoning. Regular surveys of the island will be conducted and all carcasses that could potentially be a source of secondary poisoning will be removed. Color and size were considered when selecting the bait formulation to minimize the attractiveness of the bait to birds and minimize the time toxicant is available to birds. To minimize exposure potential to seabirds bait will be hand broadcast along the narrow causeways where the majority of the boobies nest, and this bait will not be distributed within reach of birds sitting in the nest. Areas known to host concentrations of shorebirds roosting will be baited using bait stations to further restrict bait availability.*

The following is a breakdown of the direct toxicant and disturbance impacts to each of the identified bird species that migrate to, breed at, and overwinter at Palmyra. Additionally, we have quantified the number of individuals per species that are likely to be adversely affected by Alternative C (we have assumed the worst case scenario and consider any individuals that may be present on the atoll during the eradication operations to be vulnerable to adverse impacts from the action alternative). The take numbers for Action Alternative C are from runway and all-atoll shorebird counts conducted during the season (June-July) when breeding adults should be at their breeding grounds in Alaska, or from Depkin (2002).

<u>Bristle-thighed curlew</u>

Toxicant Risk

Bristle-thighed curlews could be exposed to brodifacoum through both primary and secondary exposure pathways. Generally, curlews forage in the intertidal zone for aquatic invertebrates and seabird eggs, and have been observed ignoring placebo (non-toxic) bait pellets when they are placed in the vicinity of more typical prey items – fiddler crabs (see Appendix F). Additionally, curlews are known to eat small fruit and insects in the forested areas of the atoll, and to a limited extent, prey on terrestrial hermit crabs (see Appendix I). The primary exposure pathway is limited to curlew's who forage in the forests and directly consume bait; whereas, the secondary exposure pathways include consumption of intertidal invertebrate species, hermit crabs, roaches, and other terrestrial invertebrates. The bait availability will be for the short-term, the mortality risk is high, and the exposure risk is high because of the range of toxicant exposure pathways. The duration of the risk will likely be for the medium-term due to the retention time of the toxicant in the tissue of species that provide a secondary exposure pathway to curlews. The extent of the affect will be to the individuals that remain on the atoll after the captive hold and to those who could not be captured.

Disturbance Risk

Bristle-thighed curlews who remain at Palmyra during the aerial broadcast could be exposed to disturbances from both ground and air operations, which will likely cause curlews to flush the area to an alternate site on the atoll. The impacts associated with disturbance risks for individuals that remain at Palmyra are low, the duration of the disturbance will be for the short-term, and the extent of the affect will be to the entire atoll population. The curlews that will be captured and held during the time that the bait is available in the environment will experience disturbance impacts from being captured, as well as, while they are in captivity. Curlews could experience increased stress, injury, risk of disease, and potential mortality from captive care operations. The risk level is high and will last for the medium-term to ensure that released birds will not be exposed to harmful concentrations of the toxicant (see Section 4.4.1.2.1). Captured individuals are at a high risk from disturbance impacts.

- *As many as* 182 individuals could be exposed to impacts from Alternative C

Pacific golden-plover

Toxicant Risk

Pacific golden-plovers could be exposed to brodifacoum through both primary and secondary exposure pathways. Generally, plovers forage in the intertidal zone for aquatic invertebrates and insects. Additionally, plovers are known to eat insects in the forested areas of the atoll. The primary exposure pathway is limited to plovers that forage in the forests and consume rodenticide; whereas, the secondary exposure pathways include consumption of terrestrial invertebrates. The bait availability would be for the short-term, the mortality risk is high, and the exposure risk is high because of the range of toxicant exposure pathways, and the duration of the risk will likely be for the medium-term due to the retention time of the toxicant in the tissue of species that provide a secondary exposure pathway to plovers. The extent of the toxicant risk will be to the individuals that remain on the atoll after the captive hold, which is intended to mitigate the impacts to plovers from toxicant exposure.

Disturbance Risk

Pacific golden-plovers that remain at Palmyra during the aerial broadcast could be exposed to disturbances from both ground and air operations, which will likely cause plovers to flush the area to an alternate site on the atoll. The impacts associated with disturbance risks for individuals that remain at Palmyra are low, the duration of the disturbance will be for the short-term, and the extent of the affect will be to the entire atoll population. The plovers that will be captured and held during the time that the bait is available in the environment will experience disturbance impacts from being captured, as well as, while they are in captivity. Plovers could experience increased stress, injury, risk of disease, and potential mortality from captive operations. The risk level is high and will last for the medium-term to ensure that there will be no residual toxicant on the atoll. Captured individuals are at a high risk from disturbance impacts.

- *As many as* 62 individuals could be exposed to impacts from Alternative C.

Ruddy turnstone

Toxicant Risk

Ruddy turnstones could be exposed to brodifacoum through both primary and secondary exposure pathways. Generally, turnstones forage in the intertidal zone for aquatic invertebrates. Additionally, turnstones eat terrestrial insects and feed on carrion when available. The primary exposure pathway is limited to turnstones who forage in the forests that consume rodenticide; whereas, the secondary exposure pathways include consumption of intertidal and terrestrial invertebrate species, carrion, and other terrestrial invertebrates that have consumed the toxicant. The bait availability would be for the short-term, the mortality risk is high, and the exposure risk is high because of the range of toxicant exposure pathways. The duration of the risk will likely be for the medium-term due to the retention time of the toxicant in the tissue of species that provide a secondary exposure pathway to turnstones. The extent of the affect will be to the entire atoll population.

Disturbance Risk

Ruddy turnstones could be exposed to disturbances from both ground and air operations, which will likely cause turnstones to flush the area to an alternate site on the atoll. The impacts associated with disturbance risks for this alternative are low, the duration of the disturbance will be for the short-term, and the extent of the affect will be to the entire atoll population.

- *As many as* 35 individuals could be exposed to impacts from Alternative C.

Wandering tattler

Toxicant Risk

We expect that wandering tattlers would only be exposed to brodifacoum through secondary exposure pathways. Generally, tattlers forage in the intertidal zone for aquatic invertebrates at Palmyra. *Tattlers feed on aquatic insects, mollusks, crustaceans, and small fish.* The bait availability would be for the short-term, the mortality risk is high, and the exposure risk is *moderate* because of limited exposure to the rodenticide. The duration of the risk will likely be for the short-term due to the retention time of the toxicant in the tissue of species that provide a secondary exposure pathway to tattlers. The extent of the affect will be to individuals only because of the *moderate* exposure risk.

Disturbance Risk

Wandering tattlers could be exposed to disturbances from both ground and air operations, which will likely cause tattlers to flush the area to an alternative site on the atoll. The impacts associated with disturbance risks for this alternative are low, the duration of the disturbance will be for the short-term, and the extent of the affect will be to the entire atoll population.

- *As many as* 48 individuals could be exposed to impacts from Alternative C.

Sanderling and pectoral sandpiper

Toxicant Risk

Sanderlings and pectoral sandpipers would only be exposed to brodifacoum through secondary exposure pathways. Generally, these species forage in the intertidal zone for aquatic invertebrates. The bait availability would be for the short-term, the mortality risk is high, and the exposure risk is low because of limited exposure to the rodenticide. The duration of the risk will likely be for the medium-term due to the retention time of the toxicant in the tissue of species that provide a secondary exposure pathway to tattlers. The extent of the affect will only be to a few individuals because the atoll populations of both sanderlings and pectoral sandpipers are relatively low at Palmyra.

Disturbance Risk

Sanderlings and pectoral sandpipers could be exposed to disturbances from both ground and air operations, which will likely cause them to flush the area to an alternate site on the atoll. The impacts associated with disturbance risks for this alternative are low, the duration of the disturbance will be for the short-term, and the extent of the affect will be to the entire atoll population.

- *As many as* five sanderling individuals are likely to be exposed to impacts from Alternative C.

- *As many as* eight pectoral sandpiper individuals are likely to be exposed to impacts from Alternative C.

<u>Laughing and Franklin's gull</u>

Toxicant Risk

Laughing and Franklin's gulls could be exposed to brodifacoum through both primary and secondary exposure pathways. Generally, gulls are omnivorous and are often found foraging in the intertidal zone for aquatic and terrestrial invertebrates, eating seeds and plants, or feeding on carrion. The primary exposure pathway is significant because gulls are known to consume bait pellets. Additionally, the secondary exposure pathways include consumption of intertidal and terrestrial invertebrate species, carrion, and other terrestrial invertebrates that have consumed the toxicant. The bait availability would be for the short-term, the mortality risk is high, and the exposure risk is high because of the range of toxicant exposure pathways. The duration of the risk will likely be for the medium-term due to the retention time of the toxicant in the tissue of species that provide a secondary exposure pathway to gulls. The extent of the affect will be to individuals because gulls are very infrequent visitors of Palmyra.

Disturbance Risk

Franklin's and laughing gulls could be exposed to disturbances from both ground and air operations, which will likely cause gulls to flush the area to an alternative site on the atoll. The impacts associated with disturbance risks for this alternative are low, the duration of the disturbance will be for the short-term, and the extent of the affect will be to the entire atoll population.

- One laughing gull individual may be exposed to impacts from Alternative C.

- *As many as* nine Franklin's gull individuals may be exposed to impacts from Alternative C.

<u>Northern shoveler and northern pintail</u>

Toxicant Risk

Northern shovelers and northern pintail ducks could be exposed to brodifacoum through both primary and secondary exposure pathways. Generally, ducks forage in small, inland ponds for aquatic invertebrates, eat terrestrial insects, and consume plants and seeds. Ducks are susceptible to primary exposure of the bait because they are granivorous and would likely be attracted to the grain matrix within the bait pellet. The secondary exposure pathways include consumption of intertidal and terrestrial invertebrate species that have consumed the toxicant. The bait availability would be for the short-term, the mortality risk is high, and the exposure risk is medium because of the range of toxicant exposure pathways. The duration of the risk will likely be for the medium-term due to the retention time of the toxicant in the tissue of species that provide a secondary exposure pathway to ducks. We expect that fewer than ten individuals will be affected by the eradication because ducks are highly infrequent visitors to Palmyra.

Disturbance Risk

Northern shovelers and pintail ducks could be exposed to disturbances from both ground and air operations, which will likely cause ducks to flush the area to an alternate site on the atoll. The impacts associated with disturbance risks for this alternative are low, the duration of the disturbance will be for the short-term, and the extent of the affect will be on the individual level.

- *As many as* six northern pintail individuals may be exposed to impacts from Alternative C.

- *As many as* two northern shoveler individuals may be exposed to impacts from Alternative C.

<u>Breeding seabirds (masked booby, brown booby, red-footed booby, great frigatebird, sooty tern, white tern, red-tailed tropicbird, white-tailed tropicbird, black noddy, and brown noddy)</u>

Toxicant Risk

The breeding seabirds at Palmyra are at *extremely low* risk of toxicant exposure because they rarely if ever feed on anything other than marine organisms. *The primary exposure pathway would be the accidental ingestion of toxicant during nest maintenance or preening. The risk of this type of exposure is extremely low, and even lower for species that do not build nests (sooty tern and white tern). We would minimize the potential of exposure of ground nesting boobies to toxicant by hand baiting the causeways where most brown and masked boobies nest and this bait will not be distributed within reach of birds sitting in the nest.* We would minimize the potential for fish to be exposed to the toxicant by hand baiting near the shoreline and using an internal deflector system in the bait hopper to prevent bait from being broadcast into bodies of water; therefore, the extent of the affect is insignificant and does not require further scrutiny.

Disturbance Risk

Breeding seabirds are at a greater risk from disturbance because they will be attending nests and caring for young. The majority of the disturbance will come from both ground and air operations, which would cause individuals to flush from roosts and nests leaving eggs and chicks vulnerable to predation or injury. Additionally, there is a risk of breeding disturbance from the listed disturbance impacts; however, there will be limited aerial operations directly above ground breeding masked or brown booby colonies. The risk level from disturbance from aerial operations would be low. This is supported from research conducted by GECI on disturbance affect to booby populations on Isla Isabel from helicopter operations, which found little to no effect on booby colonies from helicopter operations (GECI 2009). Additionally, ground operations will be minimal near breeding colonies and will result in low disturbance impacts. The duration for the disturbance affect is for the short-term and the extent is to the entire atoll population.

- 100,000 – 200,000 individuals are likely to be exposed to impacts from Alternative C.

Non-breeding seabirds (lesser frigatebird)

Toxicant Risk

Lesser frigatebirds are at *extremely low* risk of toxicant exposure because they rarely if ever feed on anything other than marine organisms. We would minimize the potential for fish to be exposed to the toxicant by hand baiting near the shoreline and using an internal deflector system in the bait hopper to prevent bait from being broadcast into bodies of water; therefore, the extent of the affect is insignificant and does not require further scrutiny.

Disturbance Risk

Lesser frigatebirds could be exposed to disturbances from both ground and air operations, which will likely cause them to flush the area to an alternate site on the atoll. The impacts associated with disturbance risks for this alternative are low, the duration of the disturbance will be for the short-term, and the extent of the affect will be on the individual level.

- 20 individuals are likely to be exposed to impacts from Alternative C.

Impacts on Reptiles

Geckoes (native and nonnative)

Toxicant Risk

Geckoes are at risk of secondary exposure to rodenticide through the consumption of terrestrial invertebrates; however, there is a gap in the literature on the toxicity of anticoagulant rodenticides to reptiles. Additionally, even less is known about either the native or nonnative geckoes at Palmyra. Therefore, this assessment is likely deficient at examining all of the potential toxicant exposure pathways, as well as, the fate of individuals that consume bait through secondary pathways. The bait availability would be for the short-term, the mortality risk is high, and the exposure risk is medium. The duration of the risk is for the medium-term, and the extent is to the entire atoll population.

Disturbance Risk

Geckoes are at a negligible risk of disturbance from both ground and air operations because they are fairly elusive and have many alternative areas to retreat to during eradication operations; therefore, they are only vulnerable for the short-term and only to a few individuals.

Hawksbill turtle and green turtle

Toxicant Risk

Turtles may face a primary risk of exposure to the toxicant through eating bait directly as it drops through the water column. These turtles' common foraging behaviors make exposure unlikely, but juvenile green turtles in particular are known to be comparatively opportunistic feeders, and marine turtles have been documented ingesting marine debris elsewhere (Carr 1987, Meylan 1988, NOAA Fisheries pers. comm., Bjorndal et al. 1994, Coyne 1994, Bugoni et al. 2001). Mitigation measures to reduce bait drift into waterways will be employed to reduce the exposure risk to turtles, including hand baiting narrow strips of land and portions of the coconut *palm canopy than cannot be safely and effectively baited by air, and using a deflector to control the direction of the bait flow from the hopper. Even if bait pellets enter the water at the full application rate, they will only be ingestible by turtles for a few hours prior to embedding in the sediment and breaking down to tiny fragments (Empson and Miskelly 1999). Thus, the duration of risk to turtles is for the very short term. The extent of risk is only to a few individuals. The risk of turtle mortality, given the low likelihood of exposure to the toxicant, is unknown but suspected to be low.*

Disturbance Risk

Turtles could be exposed to disturbances from boat operations, which will likely cause turtles to flee from the immediate area. However, boat operations in association with the rat eradication would not exceed normal levels of boat use during the research season, and no negative impact to turtles has been associated with boat activities during the research season (A. Meyer pers. comm.). The impacts associated with disturbance risks for this alternative are low, the duration of the disturbance will be for the short-term, and the extent of the affect will be on the individual level.

Impacts on Fish

<u>Fish (black-spotted sergeant, stripe belly puffer, camouflage grouper, bohar, black tail snapper, dusky farmerfish, and bonefish)</u>

Toxicant Risk

Some fish species face both a primary and secondary risk of exposure to the toxicant through the consumption of aquatic invertebrates and by eating bait directly as it drops through the water column - species analyzed here either consumed or mouthed placebo bait during field trials at Palmyra Atoll in May 2010 (Alifano and Wegmann 2010) (see Appendix F). Little is known about the effect that brodifacoum has on fish; therefore, for the purposes of this analysis we are considering the mortality risk from brodifacoum to be high. Additionally, mitigation measures to reduce bait drift into waterways will be employed to further reduce the exposure risk to fish including hand baiting narrow strips of land and portions of the coconut palm canopy than cannot be safely and effectively baited by air, and using a deflector to control the direction of the bait flow from the hopper. The duration of risk is for the very short-term because bait pellets will only be available for a few hours prior to embedding in the sediment and breaking down to tiny fragments. The extent of risk is only to a few individuals.

Disturbance Risk

Fish could be exposed to disturbances from boat operations, which likely will cause fish to flush the immediate area. The impacts associated with disturbance risks for this alternative are low, the duration of the disturbance will be for the short-term, and the extent of the affect will be on the island population level.

Impacts on Invertebrates

<u>Terrestrial crabs</u>

Toxicant Risk

Terrestrial crabs are at both a primary and secondary risk of exposure to the brodifacoum bait from the consumption of bait pellets, carrion, invertebrates, or crab excrement. The exposure risk is high; however, crabs show not adverse response to ad-lib consumption of bait (Alifano and Wegmann 2010). We anticipate no risk of mortality to the island population for the short-term.

Disturbance Risk

Disturbance risks to terrestrial crabs include minor impacts from ground operations, as well as a disruption of their typical foraging base by providing an alternative food source through the bait pellets. The duration of this disturbance would only be for the short-term, but the extent will be to the entire atoll population.

Impacts on Vegetation

Toxicant Risk

Vegetation is at a negligible risk

Disturbance Risk

Vegetation is at a minor risk of disturbance by trampling from ground operations with the greatest threat from the introduction or dispersal of nonnative invasive plant species. The risk of spreading invasive plant species will be minimized by integrating biosecurity measures into the daily eradication operations. The duration of the affect will be for the very short-term.

Impacts Table for Alternative C: Biological Resources

Table 4.3. Impacts of Alternative C on Biological Resources

Species	Bait availability[1]	Risk mortality - toxicant use[2]	Toxicant exposure risk level[3]	Disturbance risk[4]	Extent of risk within a population[5]		Duration of risk[6]	
					toxicant	disturbance	toxicant	disturbance
Bristle-thighed curlew	Short	High	High/ Low[7]	Low/ High[8]	Individ.	Island	Medium	Short
Pacific golden-plover	Short	High	High/ Low[7]	Low/ High[8]	Individ.	Island	Medium	Short
Ruddy turnstone	Short	High	High	Low	Island	Island	Medium	Short
Wandering tattler	Short	High	*Moderate*	Low	Individ.	Island	Short	Short
Sanderling & pectoral sandpiper	Short	High	Low	Low	Individ.	Island	Medium	Short
Laughing & Franklin's gull	Short	High	High	Low	Individ.	Island	Medium	Short
Northern shoveler & pintail duck	Short	High	Medium	Low	Individ.	Individ.	Medium	Short
Breeding seabirds[9]	*Low*	*Low*	*Low*	Low	None	Island	None	Short
Non-breeding seabirds[10]	*Low*	*Low*	*Low*	Low	None	Individ.	None	Short
Geckoes[11]	Short	High	Medium	Low	Island	Individ.	Medium	Short
Turtles[12]	*Low*	*Low*	*Low*	Low	*Individ*	Individ.	*Short*	Short
Fish[13]	Short	High	Low	Low	Individ.	Island	Short	Short
Terrestrial crabs	Short	None	High	Low	Island	Island	Short	Short
Vegetation	None	None	None	Low	None	Island	None	Short

[1]None: No toxicological sensitivity; Short: Bait or rats with toxicant residue available for up to 36 days; Medium: Bait in crab excrement or animal tissue available for 37-90 days; Long: Toxicant persistent anywhere in the environment for more than 90 days. [2]None: No toxicological sensitivity; Low: Minor toxicological sensitivity; Medium: Moderate toxicological sensitivity; High: Severe toxicological sensitivity. [3]None: No exposure pathway; Low: Possible exposure pathway; Medium: One exposure pathway; High: Multiple exposure pathways. [4]None: No disturbance pathway; Low: Low sensitivity to disturbance; Medium: Moderate sensitivity to disturbance; High: Severe sensitivity to disturbance. [5]Individual (Individ.): Few individuals affected; Island population (Island): Many individuals affected with no affect to the global or regional breeding population; Global or regional population (Global): Many individuals affected with impacts on the global or regional breeding population. [6]Short: Impacts for up to 2 months; Medium: Impacts for more than 2 months and up to 6 months; Long: Impacts for more than 6 months. [7]High toxicant risk for birds left at Palmyra, low toxicant risk for birds captively held. [8] Low disturbance risk for birds left at Palmyra, high disturbance risk for birds captively held. [9]Breeding seabirds includes: masked booby, brown booby, red-footed booby, great frigatebird, sooty tern, white tern, red-tailed tropicbird, white-tailed tropicbirds, black noddy, and brown noddy[10]lesser frigatebird[11.] Native (Lepidodactylus n. sp) and nonnative mourning gecko. [12]hawksbill turtle and green turtle. [13]black-spotted sergeant, stripe belly puffer, camouflage grouper, bohar, black tail snapper, dusky farmerfish, and bonefish.

Table 4.4. Estimated populations of migratory birds at Palmyra Atoll and estimated take.

Common Name	Scientific Name	Estimated Palmyra Population[1]	Estimated World Population	Estimated Take by Evaluating Risk Factors	Estimated Maximum Take (Assuming 100%)
Bristle-thighed curlew	*Numenius tahitiensis*	266	10,000[2]	140	182
Pacific golden-plover	*Pluvialis fulva*	144	185,000-250,000[2]	45	62
Ruddy turnstone	*Arenaria interpres*	112	450,000-600,000[2]	20	35
Wandering tattler	*Tringa incana*	126	10,000-25,000[3]	35	48
Sanderling	*Calidris alba*	5	590,000[2]	0	5
Pectoral sandpiper	*Calidris melanotos*	8	>500,000[3]	0	8
Solitary sandpiper	*Tringa solitaria*	1	150,000[2]	0	1
Semipalmated plover	*Charadrius semipalmatus*	1	150,000[2]	0	1
Sharp-tailed sandpiper	*Calidris acuminata*	3	160,000[2]	0	3
Buff-breasted sandpiper	*Tryngites subruficollis*	1	30,000[3]	0	1
Lesser yellowlegs	*Tringa flavipes*	1	400,000[2]	0	1
Short-billed dowitcher	*Limnodromus griseus caurinus*	5	75,000[2]	0	1
Cattle egret	*Bubulcus ibis*		>6,000,000[2]	0	5
Northern pintail	*Anas acuta*	6	>4,000,000[2]	0	6
Northern shoveler	*Anas clypeata*	2	>6,000,000[2]	0	2
Green-winged teal	*Anas crecca carolinensis*	2	>2,000,000[2]	0	2
Lesser scaup	*Aythya affinis*		2,950,000[2]	0	1
Laughing gull	*Leucophaeus atricilla*	1	817,000-837,000[2]	0	1
Franklin's gull	*Leucophaeus pipixcan*	9	470,000-1,490,000[2]	0	9
Breeding Seabirds					**(Assuming 1%)**
Black noddy	*Anous minutus*	6,500	>560,000[2]	0	65
Brown noddy	*Anous stolidus*	560	>1,000,000[2]	0	6
Sooty tern	*Onychoprion fuscatus*	219,000	>21,000,000[2]	0	2,190[5]
White tern	*Gygis alba*	500	250,000-1,000,000[2]	0	5
Great frigatebird	*Fregata minor*	400	500,000-1,000,000[4]	0	4
Lesser frigatebird	*Fregata aerial*	20	>400,000[4]	0	1
White-tailed tropicbird	*Phaethon lepturus*	10	<400,000[4]	0	1
Red-tailed tropicbird	*Phaethon rubricauda*	400	35,000-45,000[4]	0	4
Red-footed booby	*Sula sula*	12,500	<600,000[4]	0	125
Brown booby	*Sula leucogaster*	740	440,000-550,000[4]	0	8
Masked booby	*Sula dactylatra*	70	>200,000[4]	0	1

[1] Maximum recent count /estimate; [2]Wetlands International (2006); [3]Morrison et al. (2006); [4]FWS (2005); [5]Take of seabirds is extremely unlikely and the estimated maximum take is assumed to be less than 1% of the individuals present. The calculated maximums for black noddies, sooty terns, and red-footed boobies are far greater than what is expected to take even in the worst case scenario. However, high numbers of these species breed at Palmyra so the calculated estimate (1%) is a large number. If sooty terns are not breeding during the operational window, the expected maximum take will equal zero.

4.4.4.6 Impacts of Alternative D on biological resources

Impacts on Birds

Generally, birds that primarily eat plant matter such as seeds and fruits would initially be at high risk for primary exposure to brodifacoum. Predators and scavengers would in some cases be at high risk of secondary exposure to brodifacoum. Animals that feed on rats, rat carcasses, or large ground-dwelling invertebrates such as beetles would initially be at high risk of secondary exposure to brodifacoum. Birds that have a broad, omnivorous diet would initially be at high risk for both primary and secondary exposure.

Birds foraging in the intertidal zone would be at lower risk for primary exposure because pellets that enter the water would disintegrate and become unavailable within a few hours. Similarly, birds that forage primarily in the intertidal zone and specialize in intertidal invertebrates would only be at an initially low risk of secondary exposure. Also, birds that feed primarily on flying insects and "micro-invertebrates" would be at an initially low risk of secondary exposure due to the low likelihood that these classes of invertebrates would be carrying brodifacoum in their systems. The risk of exposure (secondary) in birds that feed on flying insects and "micro-invertebrates", would initially be low, and would steadily decline to negligible within a few months. The likelihood of exposure in intertidal specialists would decline even more rapidly, becoming negligible within 30 days of the final bait application.

The following is a breakdown of the direct toxicant and disturbance impacts to each of the identified bird species that migrate, breed, and overwinter at Palmyra. Additionally, we have quantified the number of individuals per species that are likely to be adversely affected by alternative D (we have assumed the worst case scenario and consider any individuals that may be present on the atoll during the eradication operations to be vulnerable to adverse impacts from the action alternative). The take numbers for bait station alternative D are from runway and all-atoll shorebird counts conducted during winter months when the atoll's entire population (breeders and non-breeders) should be present, and from Depkin (2002):

<u>Bristle-thighed curlew</u>

Toxicant Risk

Bristle-thighed curlews could be exposed to brodifacoum through both primary and secondary exposure pathways. Generally, curlews forage in the intertidal zone for aquatic invertebrates and seabird eggs, and have been observed ignoring placebo (non-toxic) bait pellets when they are placed in the vicinity of more typical prey items – fiddler crabs (see Appendix F). Additionally, curlews are known to eat small fruit and insects in the forested areas of the atoll, and to a limited extent prey on terrestrial hermit crabs (see Appendix I). The primary exposure pathway is limited to curlews that forage in the forests and directly consume bait; whereas, the secondary exposure pathways include consumption of intertidal invertebrate species, hermit crabs, roaches, and other terrestrial invertebrates. The bait availability will be for the long-term due to the length of time bait stations will be on the ground, the mortality risk is high, and the exposure risk is low. The duration of the risk will likely be for the long-term because bait stations will be on the ground for up to 2 years, and the extent of the effect will be to individuals on the atoll due to the low exposure risk.

Disturbance Risk

Bristle-thighed curlews could be exposed to disturbances from both ground operations and maintenance of bait station transects, which will likely cause curlews to flush the area to an alternate site on the atoll and potentially alter their habitat. The impacts associated with disturbance risks for this alternative are very high, the duration of the disturbance will be for the long-term, and the extent of the effect will be to the entire atoll population.

- *As many as* 226 individuals are likely to be exposed to impacts from Alternative D.

<u>Pacific golden-plover</u>

Toxicant Risk

Pacific golden-plovers could be exposed to brodifacoum through both primary and secondary exposure pathways; however, with a bait station operation the exposure risk will be much less than with an aerial broadcast operation. Generally, plovers forage in the intertidal zone for aquatic invertebrates and insects. Additionally, plovers are known to eat insects in the forested areas of the atoll. The primary exposure pathway is limited to plovers that forage in the forests that consume rodenticide pellets that have been removed from bait stations; whereas, the secondary exposure pathways include consumption of intertidal invertebrate species, roaches, and other terrestrial invertebrates. The bait availability will be for the long-term due to the length of time that bait stations will be on the ground, the mortality risk is high, and the exposure risk is low. The duration of the risk will likely be for the long-term because bait stations will be on the ground for up to 2 years, and the extent of the effect will be to individuals on the atoll.

Disturbance Risk

Pacific golden-plovers could be exposed to disturbances from both ground operations and maintenance of bait station transects, which will likely cause plovers to flush the area to an alternate site on the atoll and potentially alter their habitat. The impacts associated with disturbance risks for this alternative are very high, the duration of the disturbance will be for the long-term, and the extent of the effect will be to the entire atoll population.

- *As many as* 88 individuals are likely to be exposed to impacts from Alternative D.

<u>Ruddy turnstone</u>

Toxicant Risk

Ruddy turnstones could be exposed to brodifacoum through both primary and secondary exposure pathways; however, with a bait station operation the exposure risk will be much less than with an aerial broadcast operation. Generally, turnstones forage in the intertidal zone for aquatic invertebrates. Additionally, turnstones eat terrestrial insects and feed on carrion when available. The primary exposure pathway is limited to turnstones that forage in the forests that consume rodenticide pellets that have been removed from bait stations; whereas, the secondary exposure pathways include consumption of intertidal and terrestrial invertebrate species, carrion, and other terrestrial invertebrates that have consumed the toxicant. The bait availability would be for the long-term due to the length of time that bait stations would be on the ground, the mortality risk is high, and the exposure risk is low. The duration of the risk will likely be for the long-term because bait stations will be on the ground for up to 2 years, and the extent of the effect will be to individuals on the atoll due to the low exposure risk.

Disturbance Risk

Ruddy turnstones could be exposed to disturbances from both ground operations and maintenance of bait station transects, which will likely cause turnstones to flush the area to alternate site on the atoll and potentially alter their habitat. The impacts associated with disturbance risks for this alternative are very high, the duration of the disturbance will be for the long-term, and the extent of the affect will be to the entire atoll population.

- *As many as* 28 individuals are likely to be exposed to impacts from Alternative D.

<u>Wandering tattler, sanderling, and pectoral sandpiper</u>

Toxicant Risk

Wandering tattlers, sanderlings, and pectoral sandpipers are at no risk of toxicant exposure because they rarely if ever feed on anything other than intertidal invertebrates at Palmyra, which will not be exposed to the rodenticide through a bait station operation. Therefore, the extent of the effect is insignificant and does not require further scrutiny.

Disturbance Risk

Wandering tattlers, sanderlings, and pectoral sandpipers could be exposed to disturbances from both ground operations and maintenance of bait station transects, which will likely cause them to flush the area to an alternate site on the atoll. The impacts associated with disturbance risks for this alternative are very high, the duration of the disturbance will be for the long-term, and the extent of the effect will be to the entire atoll population.

- *As many as* 37 wandering tattler individuals are likely to be exposed to impacts from Alternative D.

- *As many as* five sanderling individuals are likely to be exposed to impacts from Alternative D.

- *As many as* eight pectoral sandpiper individuals are likely to be exposed to impacts from Alternative D.

<u>Laughing and Franklin's gull</u>

Toxicant Risk

Laughing and Franklin's gulls could be exposed to brodifacoum through primary and secondary exposure pathways; however, with a bait station operation the exposure risk will be much less than with an aerial broadcast operation. Generally, gulls are omnivorous and are often found foraging in the intertidal zone for aquatic and terrestrial invertebrates, eating seeds and plants, or feeding on carrion. The secondary exposure pathways include consumption of intertidal and terrestrial invertebrate species, carrion, and other terrestrial invertebrates that have consumed the toxicant. The bait availability would be for the long-term due to the length of time that bait stations will be on the ground, the mortality risk is high, and the exposure risk is low. The duration of the risk will likely be for the long-term because bait stations will be on the ground for up to 2 years, and the extent of the effect will be to individuals on the atoll due to the low exposure risk.

Disturbance Risk

Franklin's and laughing gulls could be exposed to disturbances from both ground operations and maintenance of bait station transects, which will likely cause gulls to flush the area to an alternate site on the atoll and potentially alter their habitat. The impacts associated with disturbance risks for this alternative are very high, the duration of the disturbance will be for the long-term, and the extent of the effect will be to the entire atoll population.

- *As many as* 10 individuals are likely to be exposed to impacts from Alternative D.

<u>Northern shoveler and pintail duck</u>

Toxicant Risk

Northern shovelers and northern pintail ducks could be exposed to brodifacoum through both primary and secondary exposure pathways. Generally, ducks forage in small, inland ponds for aquatic invertebrates, eat terrestrial insects, and consume plants and seeds. Ducks are susceptible to primary exposure of the bait because they are granivorous and would likely be attracted to the grain matrix within the bait pellet. The secondary exposure pathways include consumption of intertidal and terrestrial invertebrate species that have consumed the toxicant. With a bait station operation, it is unlikely that ducks will have access to bait, however it is possible that they could consume terrestrial invertebrates have consumed bait. The duration of the risk will likely be for the long-term because bait stations will be on the ground for up to 2 years, and the extent of the effect will be to individuals on the atoll due to the low exposure risk.

Disturbance Risk

Northern shovelers and pintail ducks could be exposed to disturbances from both ground operations and maintenance of bait station transects, which will likely cause ducks to flush the area to an alternate site on the atoll and potentially alter their habitat. The impacts associated with disturbance risks for this alternative are very high, the duration of the disturbance will be for the long-term, and the extent of the effect will be to a few individuals.

- *As many as* 10 individuals are likely to be exposed to impacts from Alternative D.

<u>Ground-nesting seabirds (brown and masked booby, red-tailed tropicbird, sooty tern)</u>

Toxicant Risk

Ground nesting seabirds are at no risk of toxicant exposure because they rarely if ever feed on anything other than fish, which will not be exposed to the rodenticide through a bait station operation. Therefore, the extent of the effect is insignificant and does not require further scrutiny.

Disturbance Risk

Ground nesting seabirds could be exposed to disturbances from ground operations, breeding disturbance, and maintenance of bait station transects, which will likely cause seabirds to flush the area to an alternate site on the atoll leaving eggs and chicks vulnerable to predation, as well as, potentially altering their habitat. The impacts associated with disturbance risks for this alternative are very high, the duration of the disturbance will be for the long-term, and the extent of the effect will be to the entire atoll population.

- 100,000 – 150,000 individuals are likely to be exposed to impacts from Alternative D.

Tree-nesting seabirds (red-footed booby, white tern, black and brown noddy, great frigatebird)

Toxicant Risk

Tree nesting seabirds are at no risk of toxicant exposure because they rarely if ever feed on anything other than fish, which will not be exposed to the rodenticide through a bait station operation. Therefore, the extent of the affect is insignificant and does not require further scrutiny.

Disturbance Risk

Tree nesting seabirds could be exposed to disturbances from ground operations, breeding disturbance, and maintenance of bait station transects, which will likely cause seabirds to flush the area to an alternate site on the atoll leaving eggs and chicks vulnerable to predation, as well as, potentially altering their habitat. The impacts associated with disturbance risks for this alternative are very high, the duration of the disturbance will be for the long-term, and the extent of the effect will be to the entire atoll population.

- 20,000-50,000 individuals are likely to be exposed to impacts from Alternative D.

Lesser frigatebird

Toxicant Risk

Lesser frigatebirds are at no risk of toxicant exposure because they rarely if ever feed on anything other than fish, which will not be exposed to the rodenticide through a bait station operation. Therefore, the extent of the effect is insignificant and does not require further scrutiny.

Disturbance Risk

Lesser frigatebirds could be exposed to disturbances from both ground operations and maintenance of bait station transects, which will likely cause frigatebirds to flush the area to an alternate location on the atoll and potentially alter their habitat. The impacts associated with disturbance risks for this alternative are very high, the duration of the disturbance will be for the long-term, and the extent of the effect will be to a few individuals.

- 20-30 individuals are likely to be exposed to impacts from Alternative D.

Impacts on Reptiles

Geckoes (native and nonnative)

Toxicant Risk

Geckoes are at risk of secondary exposure to rodenticide through the consumption of terrestrial invertebrates; however, there is a gap in the literature on the toxicity of anticoagulant rodenticides to reptiles. Additionally, even less is known about either the native or nonnative geckoes at Palmyra. Therefore, this assessment is likely deficient at examining all of the potential toxicant exposure pathways, as well as, the fate of individuals that consume bait through secondary pathways. The bait availability would be for the long-term due to the length of time that bait stations will be on the ground, the exposure risk is low, the mortality risk is high, the duration of the risk is for the long-term, and the extent is to the entire atoll population.

Disturbance Risk

Geckoes could be exposed to disturbances from both ground operations and maintenance of bait station transects, which will likely alter their habitat. The impacts associated with disturbance risks for this alternative are high, the duration of the disturbance will be for the long-term, and the extent of the effect will be to a few individuals.

<u>Hawksbill turtle and green turtle</u>

Toxicant Risk

Turtles may face a primary risk of exposure to the toxicant through eating bait directly as it drops through the water column. These turtles' common foraging behaviors make exposure unlikely, but juvenile green turtles in particular are known to be comparatively opportunistic feeders, and marine turtles have been documented ingesting marine debris elsewhere (Carr 1987, Meylan 1988, NOAA Fisheries pers. comm., Bjorndal et al. 1994, Coyne 1994, Bugoni et al. 2001). By limiting the spread of bait to bait stations placed inland of the high tide line, bait would only enter the marine environment by human error, such as spilling bait while moving from one bait station transect to the next. Any bait pellets that do enter the water will only be ingestible by turtles for a few hours prior to embedding in the sediment and breaking down to tiny fragments (Empson and Miskelly 1999). Thus, the duration of risk to turtles is for the very short term. The extent of risk is essentially negligible. The risk of turtle mortality, given the extremely low likelihood of exposure to the toxicant, is unknown but suspected to be negligible.

Disturbance Risk

Turtles could be exposed to disturbances from boat operations, which will likely cause turtles to flee from the immediate area. However, boat operations in association with the rat eradication would not exceed normal levels of boat use during the research season, and no negative impact to turtles has been associated with boat activities during the research season (A. Meyer pers. comm.). The impacts associated with disturbance risks for this alternative are low, the duration of the disturbance will be for the short-term, and the extent of the effect will be on the individual level.

Impacts Fish

<u>Fish (black-spotted sergeant, stripe belly puffer, camouflage grouper, bohar, black tail snapper, dusky farmerfish, and bonefish)</u>

Toxicant Risk

Some fish species face both a primary and secondary risk of exposure to the toxicant through the consumption of aquatic invertebrates and by eating bait directly as it drops through the water column - species analyzed here either consumed or mouthed placebo bait during field trials at Palmyra Atoll in May 2010 (Alifano and Wegmann 2010) (see Appendix F). Little is known about the effect that brodifacoum has on fish; therefore, for the purposes of this analysis we are considering the mortality risk from brodifacoum to be high. Additionally, by limiting the spread of bait to bait stations placed inland of the high tide line, bait would only enter the marine environment by human error, such as spilling bait while moving from one bait station transect to the next. The duration of risk is for the very short-term because bait pellets will only be available for a few hours prior to embedding in the sediment and breaking down to tiny fragments. The extent of the toxicant risk is only to a few individuals.

Disturbance Risk

Fish could be exposed to disturbances from boat operations, which likely will cause fish to flush the immediate area. The impacts associated with disturbance risks for this alternative are low, the duration of the disturbance will be for the short-term, and the extent of the effect will be on the island population level.

Impacts on Invertebrates

Terrestrial crabs

Toxicant Risk

Terrestrial crabs are at both a primary and secondary risk of exposure to the brodifacoum bait from the consumption of bait pellets, carrion, invertebrates, or crab excrement. The exposure risk is medium because crabs would likely attempt to break into bait stations and consume the bait; however, crabs are not susceptible to the toxicant (Alifano and Wegmann 2010) resulting in no risk of mortality to individuals for the long-term.

Disturbance Risk

Disturbance risks to terrestrial crabs include minor impacts from ground operations and maintenance of bait station transects, as well as a disruption of their typical foraging base by providing an alternative food source through the bait pellets. The disturbance risk will be very high. The duration will be for the long-term, and the extent will be to the entire atoll population.

Impacts on Vegetation

Toxicant risk

Vegetation is at no risk of toxicant impacts because brodifacoum lacks any herbicidal properties; therefore, the extent of the affect is insignificant and does not require further scrutiny

Disturbance Risk

Vegetation is at a risk of disturbance from trampling by ground operations and maintenance of bait station transects (28.5 miles of 1m transect would be established and maintained) with the greatest threat from the introduction or dispersal of nonnative invasive plant species. The risk of spreading invasive plant species will be minimized by integrating biosecurity measures into the daily eradication operations. The disturbance risk is very high; the duration of the affect will be for the long-term, and will affect the entire atoll community.

Impacts Table for Alternative D: Biological Resources

Table 4.5. Impacts of Alternative D on Biological Resources

Species	Bait avail-ability[1]	Risk mortality - toxicant use[2]	Toxicant exposure risk level[3]	Disturbance risk[4]	Extent of risk within a population[5]		Duration of risk[6]	
					toxicant	disturbance	toxicant	disturbance
-thighed curlew	Long	High	Low	High	Individ.	Island	Long	Long
Pacific golden-plover	Long	High	Low	High	Individ.	Island	Long	Long
Ruddy turnstone	Long	High	Low	High	Individ.	Island	Long	Long
Wandering tattler	None	None	None	High	None	Island	None	Long
Sanderling & pectoral sandpiper	None	None	None	High	None	Island	None	Long
Laughing & Franklin's gull	Long	High	Low	High	Individ.	Island	Long	Long
Northern shoveler & pintail duck	None	Low	Low	High	Low	Individ.	None	Long
Ground-nesting seabirds[7]	None	None	None	High	None	Island	None	Long
Tree-nesting seabirds[8]	None	None	None	High	None	Island	None	Long
Lesser frigatebird	None	None	None	High	None	Individ.	None	Long
Geckoes[9]	Long	High	Low	High	Island	Individ.	Long	Long
Turtles[10]	None	None	None	Low	None	Individ.	None	Short
Fish[11]	None	None	None	Low	None	Island	None	Short
Terrestrial crabs	Long	None	Medium	High	Individ.	Island	None	Long
Vegetation	None	None	None	High	None	Island	None	Long

[1]None: No toxicological sensitivity; Short: Bait or rats with toxicant residue available for up to 36 days; Medium: Bait in crab excrement or animal tissue available for 37-90 days; Long: Toxicant persistent anywhere in the environment for more than 90 days. [2]None: No toxicological sensitivity; Low: Minor toxicological sensitivity; Medium: Moderate toxicological sensitivity; High: Severe toxicological sensitivity. [3]None: No exposure pathway; Low: Possible exposure pathway; Medium: One exposure pathway; High: Multiple exposure pathways. [4]None: No disturbance pathway; Low: Low sensitivity to disturbance; Medium: Moderate sensitivity to disturbance; High: Severe sensitivity to disturbance. [5]Individual (Individ.): Few individuals affected; Island population (Island): Many individuals affected with no affect to the global or regional breeding population; Global or regional population (Global): Many individuals affected with impacts on the global or regional breeding population. [6]Short: Impacts for up to 2 months; Medium: Impacts for more than 2 months and up to 6 months; Long: Impacts for more than 6 months. [7]Ground-nesting seabirds includes: masked booby, brown booby, red-tailed tropicbird, sooty tern. [8]Tree-nesting Shorebirds includes: red-footed booby, white tern, black noddy, brown noddy, great frigatebird. [9]Native (Lepidodactylus n. sp) and nonnative mourning gecko. [10]hawksbill turtle and green turtle. [11]black-spotted sergeant, stripe belly puffer, camouflage grouper, bohar, black tail snapper, dusky farmerfish, and bonefish.

4.4.5 Indirect Impacts to Biological Resources

Indirect Impacts or secondary effects are not directly linked to the original action and are removed from it by distance or time. Indirect effects often include socioeconomic impacts such as community growth or changes in population patterns as a result of implementation of a proposed action. Additionally, indirect impacts often far exceed those of direct impacts and include both positive outcomes and long-term negative impacts. The following is an analysis of the indirect impacts from each of the three alternatives.

4.4.5.1 Indirect effects under Alternative A

Alternative A, the no action alternative, would leave rats at Palmyra. Rats will continue to impact the atoll by altering vegetation communities (Wegmann 2009), reduce the breeding success of seabirds (Norman 1975), and impact important ecosystem processes (Young et al. 2010). Specifically, rats will continue to depress the recruitment of native tree species through seed and seedling predation. Furthermore, rats create breeding habitat for invasive mosquitoes that could be vectors West Nile virus, avian malaria, and dengue.

4.4.5.2 Indirect effects under common to all action alternatives

The three action alternatives are designed to remove invasive rats from Palmyra. By removing rats from the atoll, some seabirds should experience higher reproductive success, and seabird species that are conspicuously absent from the atoll may reestablish. Native vegetation would be released from rat-related recruitment limitations, which would lead to a long term increase in preferred nesting habitat for tree-nesting seabirds. *Nonnative vegetation could likewise be released. Vegetation communities would be monitored for responses to rat removal.*

4.5 Impacts to the Social and Economic Environment

4.5.1 Eradication Personnel

4.5.1.1 Alternative A – No Action

Eradication personnel will not be on the island, and therefore, would experience no impacts. However, the personnel that maintain and utilize the research station would continue to experience rat-related loss of food stores, damage to supplies and equipment, and rat-related degradation of the natural environment.

4.5.1.2 Alternative B

Eradication personnel would experience minor noise impacts from helicopter operations during the aerial baiting process. This impact would only impact personnel for a very short period of time and would not be likely to result in any long-term impacts.

4.5.1.3 Alternative C – Preferred Alternative

Eradication personnel would experience minor noise impacts from helicopter operations during the aerial baiting process. This impact would only impact personnel for a very short period of time and will not be likely to result in any long-term impacts.

4.5.1.4 Alternative D

Eradication personnel would be subject to the physical stress of establishing and maintaining an extensive network of bait stations in difficult working conditions.

4.5.2 Refuge Visitors and Recreation

The CEQ guidelines at 40 CFR 1508.14 include the human relationship with the natural environment as a category of potential impacts that must be considered in a National Environmental Policy Act (NEPA) analysis. This is interpreted to mean that a NEPA analysis needs to examine the potential effects of an action on any economic and/or social values that are related to the natural environment.

4.5.2.1 Analysis framework for refuge visitors and recreation

Public access to Palmyra is limited due to the remoteness of the atoll, and is by permit only. This analysis will examine the likely changes to visitor experience as a result of all the action alternatives. The Service would consider any major, long-term changes to the visitor experience to be significant.

Alternative A – No Action

There will be no effect to refuge visitors under the no action alternative. During the eradication and for 2 years afterwards, signs that inform visitors about the potential risks inherent to toxicant-based rodent eradication projects would be posted, along with signs that described the anticipated benefit that would come to Palmyra's terrestrial ecosystem due to rat removal.

Alternative B

The area immediately surrounding Palmyra Atoll will be closed to recreational boater access during aerial bait application operations, which would be a minor short-term inconvenience to the few refuge visitors that are likely to frequent Palmyra. During the eradication and for 2 years afterwards, signs that inform visitors about the potential risks inherent to toxicant-based rodent eradication projects would be posted, along with signs that described the anticipated benefit that would come to Palmyra's terrestrial ecosystem due to rat removal.

Alternative C – Preferred Alternative

The area immediately surrounding Palmyra Atoll will be closed to recreational boater access during aerial bait application operations, which would be a minor short-term inconvenience to the few refuge visitors that are likely to frequent Palmyra. During the eradication and for 2 years afterwards, signs that inform visitors about the potential risks inherent to toxicant-based rodent eradication projects would be posted, along with signs that described the anticipated benefit that would come to Palmyra's terrestrial ecosystem due to rat removal.

Alternative D

There will be no effect to refuge visitors during the implementation of alternative D. During the eradication and for 2 years afterwards, signs that inform visitors about the potential risks inherent to toxicant-based rodent eradication projects would be posted, along with signs that described the anticipated benefit that would come to Palmyra's terrestrial ecosystem due to rat removal.

4.5.3 Historical and Cultural Resources

4.5.3.1 Analysis framework for historical and cultural resources

The National Historic Preservation Act (NHPA) defines the concept of an "adverse affect" to historical resources, but the regulations make it clear that "a finding of adverse effect on a historic property does not necessarily require an EIS under NEPA" (36 CFR 800.8(a)(1)). Section 106 of the NHPA requires agencies to consult with the appointed regional Historic Preservation Officer(s) if adverse impacts to historical or cultural resources are possible. This analysis will describe the potential impacts to historical and cultural resources at Palmyra Atoll as a reference for consultation with the appropriate Historic Preservation Officers. The majority of the cultural and historical artifacts are remnants of World War II era activities at Palmyra including: bunkers, pill boxes, concrete buildings, concrete foundations, bottles, silverware, barbed wire, and unexploded ordinances.

Alternative A – No Action

The Service has no evidence that rat activities affect historical and cultural resources on the atoll. Rats are burrowing animals, a behavior that has the potential to damage buried artifacts, but there are crab species that burrow on the atoll as well, which makes the preservation of buried artifacts at Palmyra difficult, whether or not rats are present. Rats may continue to cause damage to the historical buildings at Palmyra, but this damage would likely be minor and would not likely be irreversible.

Alternative B

Alternative B would not involve activities that would require soil disruption or any other actions that would affect the historical or cultural resources at Palmyra.

Alternative C– Preferred Alternative

Alternative C would not involve activities that would require soil disruption or any other actions that would affect the historical or cultural resources at Palmyra.

Alternative D

Because the bait stations would be placed over the entire atoll, there is high likelihood that some of the excavations would uncover artifacts related to WWII. Therefore, installing the bait stations throughout the entire atoll would be considered an undertaking with the potential to affect a historic property and would require compliance with Section 106 of the National Historic Preservation Act including identification, evaluation, and assessment of effects for Alternative D.

4.6 Consequences: Cumulative Impacts

4.6.1 Assessing Cumulative Impacts

The NEPA regulations require Federal agencies to consider not just the direct and indirect impacts of an action but also the cumulative impacts to which an action would contribute. Analyzing cumulative impacts at Palmyra Atoll requires consideration of other, unrelated impacts that are occurring simultaneously to those resources, impacts that have occurred in the past, or impacts that are likely to occur in the foreseeable future. The continued presence of rats is likely affecting many of the species on the atoll and the biogeochemical cycles that those species drive, but there are no other clear localized impacts known to be occurring today. Furthermore, there are no foreseeable future human actions on the atoll that are likely to negatively affect the atoll's environment, because the land is being managed in perpetuity as a National Wildlife Refuge. However, many of the species at Palmyra may still be recovering from severe past impacts. Also, many of the species that use Palmyra Atoll have large ranges. These far-ranging populations may have been affected in the past, may be currently experiencing unrelated impacts, or may be at risk of impacts from foreseeable consequences elsewhere in their ranges.

The following is a breakdown of the past, present, and foreseeable future actions that will likely contribute to the cumulative impacts associated with the three identified alternatives. Direct and indirect impacts from each alternative will be analyzed with the following list of activities to determine the cumulative impacts for the given alternative.

4.6.1.1 Past actions

Past actions are actions that occurred in the past but have lasting impacts that could contribute to the impacts associated with the proposed action.

- <u>Failed rat eradication</u> – In 2002 there was an attempt to eradicate rats from Palmyra with the use of bait stations and brodifacoum bait. The eradication failed and resulted in the continued presence of rats; however, the currently proposed eradication would counter this impact from the previous eradication attempt and would not negatively contribute to the impacts from the proposed action.

- <u>Military occupation since World War II</u> – Likely introduction of nonnative rats and ants, both of which have negative impacts on almost all facets of the terrestrial ecosystem.

- <u>Construction of a fish processing facility</u> – A facility was built in the late 1990s with no lasting impacts that would contribute to the impacts from the proposed action.

- <u>Construction of TNC camp</u> – In the early 2000s a camp was built with no lasting impacts that would contribute to the impacts from the proposed action.

- <u>TNC camp upgrade</u> – In 2005 TNC updated the camp with no lasting impacts that would contribute to the impacts from the proposed action.

4.6.1.2 Current actions

Current actions are actions that are occurring within the same timeframe as the proposed action, or within the planning and compliance phase of the proposed action, and could contribute to the impacts from the proposed action.

- Runway maintenance – The runway at Palmyra Atoll is regularly graded and maintained by TNC. This process does not have a direct negative impact on native species, and could be seen as a benefit to shorebirds – the runway is the most commonly used roosting site for all of Palmyra's shorebird species.

- Anthropogenic climate change - The four areas of impact linked to global climate change that may have the greatest potential effect at Palmyra Atoll are sea level rise, weather changes, coral bleaching, and oceanic chemical composition change (often called ocean acidification). Of these, sea level rise is most applicable to this terrestrial analysis. Insert in line 5, page 148. ….temperature of 0.5 to 1.0 "degrees" C by 2090. Regional predictions (IPCC 2007) for the North Central Pacific Gyre area are for increases of surface temperature of 0.5 to 1.0 °C by 2090. More recently, New et al. (2011) indicate the likelihood of temperature rises of 3 or 4 "degrees" C within this century. Palmyra's terrestrial ecology will be affected by increasing rainfall and it is likely that future tropical cyclones (typhoons and hurricanes will become more intense, with larger peak wind speeds and more heavy precipitation associated with ongoing increases of tropical sea surface temperatures at all sites. Localized variations in subsidence and emergence of the sea floor and plate-tectonics activity prevent extrapolations in sea level fluctuations and trends between different regions. Thus, it may not be possible to discuss uniform changes in sea level on a global scale, or the magnitude of greenhouse gas-forced changes as these changes may vary regionally (Michener et al. 1997) but it is certain that sea level will rise and contribute to shoreline erosion and salt water intrusion into subsurface freshwater aquifers as have already been noted throughout the Pacific (Shae et al. 2001). Coral bleaching and oceanic chemical composition changes will likely affect structure and ecosystem services of the coral reef atoll.

- Scientific research - The combination of its location, isolation, rich biological systems, and lack of persistent human pressures make Palmyra an exceptional and unique location for a wide range of research pertaining to biodiversity, conservation, natural history, ecosystem restoration, marine ecosystem dynamics, biogeochemistry, climate dynamics, and atmospheric processes. Scientists and institutions interested in studying the natural systems of Palmyra Atoll and its surrounding region have united to form a partnership, the Palmyra Atoll Research Consortium (PARC). The current research projects that may contribute to the cumulative impacts of the proposed action include (each project will be evaluated for impacts separately):

    - Biodiversity research - Biodiversity research at Palmyra focuses on the characterization of compositions, distributions, and interactions in the marine environment. This effort includes comprehensive biological surveys along with biophysical, biogeochemical, and ecological analyses designed to understand the importance of organisms, ranging from microbes to top predators, to ecosystem function. All of these projects are focused on marine biodiversity and would not contribute to the cumulative impacts from the proposed action.

- Top predator research – The reefs and lagoons of Palmyra are home to abundant predator populations proving great opportunities for researchers to study the importance of predators in the marine environment. These projects aim at increasing our understanding of the roles that predators play in shaping marine ecosystems by documenting, in detail, the ecological linkages and dynamics affected by predators. These projects are focused on marine predators and would not contribute to the cumulative impacts from the proposed action.

- Lagoon research – Lagoon research at Palmyra Atoll is focused on characterizing and quantifying the dynamics of lagoon ecosystems in terms of hydrology, sediment supply and transportation, and biology. The majority of the impacts from U.S. military occupation stem from lagoon modification and long term occupation during World War II. These alterations are in the process of breaking down, which causes sediment to redistribute via natural processes. These projects would not contribute to the cumulative impacts from the proposed action.

- Conservation research – Conservation research is focused on understanding the current invasive species problems at Palmyra and instigating mitigation and restoration efforts, as well as, monitoring ongoing physical and biological changes to the atoll ecosystem. These projects could positively contribute to the cumulative impacts of the proposed action and will likely decrease the overall impacts that invasive species have on the atoll.

- Climate and biogeography research – Climate and biogeography research will help explain the changing climate and oceanographic regime in a key region of the global ocean. It is hoped that the researchers will develop a greater understanding of the affect that changing ocean temperatures and ocean chemistry has on atoll ecology and assess the short-term and long-term effects for similar atoll systems. These projects would not add to the cumulative impacts of the proposed action.

Future Actions – actions that are reasonably foreseeable in the future that could contribute to the cumulative impacts from the proposed action.

- Invasive palm removal – The FWS and U.S. Geological Survey (USGS) may coordinate efforts to remove invasive palms *(Cocos nucifera*) from Palmyra. This action will positively affect the atoll by removing a prevalent invasive plant and, in doing so, free up limiting resources (e.g., light and soil nutrients) for native plants. This project could positively contribute to the cumulative impacts of the proposed action by improving habitat for native species and contributing to the overall restoration of the atoll.

- Bird translocation project – The FWS may coordinate efforts to translocate two endangered tropical land birds, the Christmas Island warbler (*Acrocephalus aequinoctialis*) and the Tuamotu sandpiper (*Prosobonia cancellata*), to Palmyra should the rat eradication be successful. Both species were historically found in the Line Islands (BirdLife International 2008, IUCN 2010) but have both been severely affected by invasive predators. Palmyra Atoll will provide predator-free habitat for both birds. This project could positively contribute to the cumulative impacts of the proposed action by improving the overall biodiversity of the atoll.

4.6.1.3 Cumulative impacts under Alternative A – No Action

Under the no action alternative, the negative impacts that rats have on Palmyra's terrestrial system would continue in perpetuity. These impacts could be additive to other, unrelated future impacts on Palmyra's resources. The minor impacts that ongoing projects (primarily research related) would have on the biological, physical, and cultural resources of Palmyra are not likely to contribute to rat-related impacts. If rats persist at Palmyra, the biological resources of the atoll would continue to be negatively affected.

4.6.1.4 Cumulative impacts under Alternative B

There would be no major negative impacts to the biological, physical, or cultural resources of Palmyra Atoll under Alternative B. The minor negative impacts to biological, physical, and cultural resources as a result of Alternative B would not contribute to the impacts related to any separate, current or future projects. Similarly, the expected positive impacts of Alternative B to Palmyra's biological resources could contribute to the cumulative, positive impacts from separate, current or future projects.

4.6.1.5 Cumulative impacts under Alternative C– Preferred Alternative

There would be no major negative impacts to the biological, physical, or cultural resources of Palmyra Atoll under Alternative C. The minor negative impacts to biological, physical, and cultural resources as a result of Alternative C would not contribute to the impacts related to any separate, current or future projects. Similarly, the expected positive impacts of Alternative BC to Palmyra's biological resources could contribute to the cumulative, positive impacts from separate, current or future projects.

4.6.1.6 Cumulative impacts under Alternative D

There would be no major negative impacts to the biological, physical, or cultural resources of Palmyra Atoll under Alternative D. The minor negative impacts to biological, physical, and cultural resources as a result of Alternative D would not contribute to the impacts related to any separate, current or future projects. Similarly, the expected positive impacts of Alternative BD to Palmyra's biological resources could contribute to the cumulative, positive impacts from separate, current or future projects.

4.7 Irreversible and Irretrievable Impacts

4.7.1 Alternative A – No Action

The no action alternative does not require the commitment of any resources that are considered to be irreversible or irretrievable. The majority of the impacts associated with this alternative will only result in short term impacts and do not require the use of any non-renewable resources.

4.7.2 Alternative B

This alternative does not require the commitment of any resources that are considered to be irreversible or irretrievable except for the use of fuel for the helicopter and boat operations. The majority of the impacts associated with this alternative will only result in short term impacts and do not require the use of any non-renewable resources. Furthermore, there will be no construction or development of any permanent structures, divergence of any waterways, or extraction of gas or oil resources during the project implementation period.

Project activities would require a commitment of funds that would then be unavailable for use on other Service projects. At some point, commitment of funds (for purchase of supplies, payments to contractors, etc.) would be irreversible; once used, these funds would be irretrievable. Non-renewable or non-recyclable resources committed to the project (such as helicopter fuel and bait) would also represent an irreversible or irretrievable commitment of resources.

4.7.3 Alternative C– *Preferred Alternative*

This alternative does not require the commitment of any resources that are considered to be irreversible or irretrievable except for the use of fuel for the helicopter and boat operations. The majority of the impacts associated with this alternative will only result in short term impacts and do not require the use of any non-renewable resources. Furthermore, there will be no construction or development of any permanent structures, divergence of any waterways, or extraction of gas or oil resources during the project implementation period.

Project activities would require a commitment of funds that would then be unavailable for use on other Service projects. At some point, commitment of funds (for purchase of supplies, payments to contractors, etc.) would be irreversible; once used, these funds would be irretrievable. Non-renewable or non-recyclable resources committed to the project (such as helicopter fuel and bait) would also represent an irreversible or irretrievable commitment of resources.

4.7.4 Alternative D

This alternative does not require the commitment of any resources that are considered to be irreversible or irretrievable except for the use of fuel for boat operations. The majority of the impacts associated with this alternative will only result in short term impacts and do not require the use of any nonrenewable resources. Furthermore, there will be no construction or development of any permanent structures.

Project activities would require a commitment of funds that would then be unavailable for use on other Service projects. At some point, commitment of funds (for purchase of supplies, payments to contractors, etc.) would be irreversible; once used, these funds would be irretrievable. Non-renewable or non-recyclable resources committed to the project (such as bait and bait stations) would also represent an irreversible or irretrievable commitment of resources.

4.8 Short-term Uses and Long-term Productivity

An important goal of the Service is to maintain the long-term ecological productivity and integrity of the biological resources on the Refuge. The action alternatives are designed to contribute to the long-term ecological productivity of Palmyra and would not result in short-term uses of the resources that would counteract this long-term productivity. Any short-term, negative impacts to the atolls biological resources would be outweighed by the ecosystem's long-term restoration-based benefits caused by the eradication of rats.

5 Consultation and Coordination

5.1 Introduction

The NEPA scoping process (40CFR 1501.7) was used to determine the scope of the analysis and to identify potential issues and opportunities related to the Proposed Action. A summary of the scoping and public involvement process for the proposed project is as follows:

The NEPA scoping process for the eradication of black rats from Palmyra Atoll involved both internal and external scoping. The internal scoping process included review of the biological, physical, and social issues associated with eradicating rats from Palmyra Atoll, as well as a review of the 2001 and 2002 rat eradication project that failed to removal all of the rats from Palmyra. The Refuge, TNC, PARC, and IC coordinated on scientific experiments to identify the ecological factors that are affected by the presence of rats, as well as the potential benefits to ecological services, including species recovery, from rat removal. The external scoping process involved consultation with cooperative and regulatory agencies that have a specialized expertise or stake in the outcome of the project, and a 45-day public scoping period prior to preparation of the Draft EIS.

5.2 Regulatory Framework

The following federal laws, proclamations, executive orders are the most relevant to eradicating rats at Palmyra atoll:

Antiquities Act (16 U.S.C. § 431, et seq.), provides statutory authority for the establishment of national monuments and Proclamation 8336, January 6, 2009, establishing Palmyra Atoll as a part of the Pacific Remote Islands Marine National Monument;

Clean Water Act of 1972, as amended (33 U.S.C. §1251 et seq.);

Endangered Species Act of 1973, as amended (16 USC. § 1531 et seq.);

Executive Order 13186 of 2001 Responsibilities of Federal Agencies to Protect Migratory Birds;

Executive Order 13112 of February 3, 1999 - Invasive Species;

Federal Insecticide, Fungicide, and Rodenticide Act of 1947, as amended (7 U.S.C. §136 et seq.)

Fish and Wildlife Act of 1956 (16 U.S.C. § 742f);

Fish and Wildlife Improvement Act of 1978 (16 U.S.C. § 742l);

Marine Mammal Protection Act of 1972 (16 U.S.C. § 1361 et seq.);

Migratory Bird Treaty Act of 1918, as amended (16 U.S.C. §§ 703-712, July 3, 1918);

National Environmental Policy Act of 1969 (42 U.S.C.A. § 4331 et seq.)

National Historic Preservation Act of 1966, as amended through 2000, (16 U.S.C. § 470 et seq.);

National Wildlife Refuge System Administration Act of 1966, as amended, (16 U.S.C. §§ 668dd-ee); and

Refuge Recreation Act (16 U.S.C. § 460k-3).

5.3 Agency Scoping and Review

A planning and work team consisting of Refuge, TNC, and IC staff held quarterly meetings to prepare the draft plan. The team involved and consulted with the National Wildlife Research Center USDA-APHIS, EPA, NMFS, The New Zealand Department of Conservation, and the Service's Ecological Services offices throughout the process and provided drafts of all documents prepared during the process. Team members met with scientists from the Insecticide and Rodenticide branch of the registration division of the Office of Pesticide Programs at EPA in Washington D.C. in April 2010 and with scientists at the National Wildlife Research Center in Fort Collins, CO in June 2010 to discuss pesticide label issues.

5.4 Public Participation

On January 14, 2010, FWS issued a Federal Register notice of intent to prepare an EIS (FR Doc. 2010-579). The notice stated the Service "intend[s] to prepare an environmental impact statement to evaluate eradication of nonnative rats on Palmyra Atoll National Wildlife Refuge (Refuge). We provide this notice to advise the public and other agencies of our intent, and obtain public comments, suggestions, and information on the scope of issues to consider in the EIS and the important issues to be considered during NEPA analysis." This scoping period closed March 1, 2010. Substantive comments were received from three individuals or organizations (Attached below). All substantive comments were taken into consideration in the preparation of this Final EIS.

The Draft EIS was made available for review by the public during a 45-day comment period between February 25 and April 11, 2011 (76 FR 10621). The Service sought public to provide input on its content. Direct mail was sent to known interested parties. Twenty-one reviewers provided comments via email and letters. The comments and the Service's responses to them are in Appendix M.

This Final EIS will be released to the public. Availability of the Final EIS will be advertised in the Federal Register, by mail to all interested parties who have requested information, and in local media as appropriate. A Record of Decision on the action will be made no sooner than 30-days after the Federal Register publication.

Comments Received During the Public Scoping Review

The following three comments represent the sum total of all comments received during the public scoping review period.

Comment 1:

From Elizabeth Tymkiw liztymkiw@hotmail.com
02/05/2010 09:43 AM

To: US Fish and Wildlife Service <palmyra@fws.gov>

Subject: EIS for rat removal from Palmyra island

I fully support any effort towards the removal of any invasive, exotic species, including rats, from this island. Rats can be very harmful to native wildlife, especially birds, that have no defenses against these introduced predators.
Liz Tymkiw

Comment 2:

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, CA 94105-3901

March 1, 2010

Beth Flint, Acting Project Leader
Pacific Reefs National Wildlife Refuge Complex
300 Ala Moana Blvd. Suite 5-231
Honolulu, HI 96850

Subject: Scoping Comments for Eradication of Nonnative Rats on Palmyra Atoll National Wildlife Refuge

Dear Ms. Flint:

The U.S. Environmental Protection Agency (EPA) has reviewed the Federal Register Notice published on January 14, 2010 requesting comments on the U.S. Fish and Wildlife Service's (FWS) Notice of Intent (NOI) to prepare an Environmental Impact Statement. Our comments are provided pursuant to the National Environmental Policy Act (NEPA), Council on Environmental Quality (CEQ) regulations (40 CFR Parts 1500-1508), and our NEPA review authority under Section 309 of the Clean Air Act.

The FWS proposes to eradicate non-native rats on Palmyra Atoll National Wildlife Refuge to help restore this important center of biodiversity and species abundance in the Central Pacific. EPA has the following comments for your consideration in preparing the Draft EIS (DEIS).

The DEIS should clearly identify the underlying purpose and need to which FWS is responding (40 CFR 1502.13). A clear purpose and need statement provides the framework for a complete project description and for identifying project alternatives. For example, the NOI identifies the problem of the invasive coconut palm, likely aided by rat-related recruitment. The purpose and need statement should clarify whether the coconut palm will be directly addressed through this project.

The DEIS should evaluate a reasonable range of alternatives, and present the environmental impacts in comparative form, sharply defining the issues, and providing a clear basis for choice among options by the decision maker and the public (40 CFR 1502.14). We find tables comparing alternatives and impacts to be helpful. If rodenticide use will be proposed, potential alternatives could include the use of different rodenticide products, possible use of different application rates[1], different or combined application methods (bait stations, aerial broadcast, etc.) and combinations of the above. For alternatives that would utilize bait stations, FWS may want to consider option(s) that place them very densely, due to the arboreal nature of

[1] Note that if FWS proposes different application rates than are higher than that allowed on the pesticide label, it must apply to EPA for an emergency exemption.

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the rat's home range and their limited coverage on a land-area basis, although this would add to cost and logistical difficulty. If non-pesticide alternatives (or components) exist that are viable, they should be included. When alternatives are eliminated from detailed study, the DEIS should briefly discuss the reasons for their elimination (40 CFR 1504.14 a).

We recommend that the affected environment section of the DEIS describe the history of non-native rat introduction and the current activities that occur on the island. A biosecurity component should be included in all project alternatives to prevent rat reintroduction. To our knowledge, Palmyra receives one supply shipment and one fuel shipment via barge per year, and barges are held flush with the dock during loading and unloading, allowing opportunities for reintroduction. Additionally, private boats can anchor in the harbor area of Cooper Island, and while those boats do not dock, they are anchored within easy swimming distance for rats. The DEIS should describe how these potential pathways for reintroduction will be addressed.

Pre- and post-operation monitoring plans should be documented in the project description. Biological monitoring includes indexing target and non-target species for abundance before and after treatment. Such activities should be continued for some time post-treatment as eradications typically are not considered successful until two years have passed with no evidence of the targeted species being detected. Other monitoring efforts, if needed, should also be described in the project description.

If rodenticides will be used, there is the likelihood for significant environmental exposure. In research conducted in 2008 using marker-treated placebo bait on Palmyra, evidence of bait ingestion was found in every potential primary consumer organism sampled, suggesting that rodenticide would likely contaminate every terrestrial food chain. The EIS should explore the issues of non-target impacts and the longer-term ecological improvements that might reasonably be expected to result from a successful eradication. The DEIS should identify each non-target species that are currently present on the atoll and identify the types of organisms expected to populate the atoll once rats are eliminated. Experiences from past efforts on Palmyra, as well as successful eradications, should be summarized to support the various assessments and predictions. Readers of the DEIS should be provided a realistic picture of the consequences of a no-action alternative versus various rat eradication options.

The DEIS should predict impacts from rodenticide use to ground, surface, and coastal waters. Identify the source of drinking water for island visitors and researchers and evaluate potential impacts to these water sources from the project. Describe safety measures that will avoid contamination of water sources and marine food sources. Identify impacts to surface/coastal waters from stormwater runoff of rodenticides. Measures should be incorporated to prevent rodenticide from spreading into the marine environment, however, the DEIS should address the likelihood that these measures might not be 100% effective if aerial broadcast is used, and because of high tides and the frequency of significant rains[2].

[2] If rodenticide cannot be completely prevented from directly entering waters during the course of application, a National Pollutant Discharge Elimination System (NPDES) permit would be required effective April 9, 2011.

The DEIS should also identify the procedures for the recovery and ultimate disposition of spilled bait. Finally, the DEIS should identify the monitoring, collection and disposal plan for dead animals and assess impacts to environmental resources from the method of disposal.

EPA appreciates the opportunity to comment on the preparation of the DEIS. When the DEIS is released for public review, please send one hard copy and 2 electronic copies to this office at the same time it is officially filed with our Washington D.C. Office. If you have any questions, please contact me at (415) 947-4178 or vitulano.karen@epa.gov.

Sincerely,

Karen Vitulano
Environmental Review Office
Communities and Ecosystems Division

cc: William W. Jacobs, Registration Division, EPA HQ, Office of Pesticide Programs
Patti TenBrook, EPA Region 9 Pesticides Office

Comment 3:

From: Mark Rauzon mjrauz@aol.com

03/01/2010 06:30 PM

To: US Fish and Wildlife Service Barbara_maxfield@fws.gov

Subject: palmyra

Mar. 1, 2010
Dear Mr. Pawawski:
I am writing to support the EIS to evaluate the eradication of ship rats from Palmyra Atoll National Wildlife Refuge. After the attempted eradication attempt in 2002 that failed, I have been interested in how the follow-up would be accomplished. That failure was attributed to insufficient manpower to deliver baits to all the rats, especially the arboreal individuals. I hope this next attempt succeeds and it can if baits are distributed into the canopy. This is best done aerially, via helicopter, and supplements with baits sling into the treetops from the ground.
The three-dimension landscape, the amount of precipitation and the presence of abundant land crabs make this the first of its kind of eradication attempt and therefore a risky proposition.
This project therefore must have the highest level of planning and best equipment if it is to succeed where the other failed. One thing is paramount, the right choice of bait. The second-generation rodenticide Brodficoum is recommended, as was used in the first attempt.

I have just returned from the Second Island Invasive Species Eradication conference held Feb.7-12, 2010 in Auckland, NZ. Few if any eradication programs did not feature Brodificoum; control projects did, but no eradications, especially those involved high-density bait competition. I also went out of my way to seek the opinion of many New Zealand rodent eradication specialists, and the all advised Brodificoum for use in this complicated project. The recent rat eradication failure at Lehua is a demonstration of poor planning and was a set back to the field as a whole. Diphasinone was used in a dry island situation, and it failed. Palmyra, a wet island, with one failure already cannot risk another.
If you have any further questions please don't hesitate to contact me.
Sincerely,

Mark Rauzon
Laney College
Geography Dept. Chair
900 Fallon St.
Oakland, CA 94704

5.5 Preparers and Primary Contributors

- Jim Breeden – Assistant Refuge Manager, Palmyra Atoll National Wildlife Refuge, FWS
- Dr. Beth Flint – Supervisory Wildlife Biologist Pacific, Pacific Reefs National Wildlife Refuge Complex, FWS
-
- Dr. Amanda Meyer – Refuge Manager, Palmyra Atoll National Wildlife Refuge, FWS
- Susan White – Project Leader, Pacific Reefs National Wildlife Refuge Complex, , FWS
- Dr. Lee Ann Woodward – Ecotoxicologist, Pacific Reefs National Wildlife Refuge Complex, FWS

- Mark Fox –Director of External Affairs, The Nature Conservancy
- Jordan Jokiel – Palmyra Program Director, The Nature Conservancy
- Evelyn White – Senior Communications Manager, The Nature Conservancy
-
- Aurora Alifano – Island Restoration Specialist, Island Conservation
- Amy Carter, Philanthropy & Communications Manager, Island Conservation
- Dr. Gabrielle Feldman – Environmental Compliance Specialist, Island Conservation
- Dr. Gregg Howald – North American Regional Director/Ecotoxicologist, Island Conservation
- Bradford Keitt, Director of Conservation, Island Conservation
- Lillie Langlois – Assistant Environmental Compliance Specialist, Island Conservation
- Jacob Sheppard – Environmental Compliance Specialist, Island Conservation
- Dr. Alex Wegmann – Palmyra Rat Eradication Project Manager, Island Conservation

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APPENDIX A

PALMYRA ATOLL RAINFOREST RESTORATION PROJECT: RAT ERADICATION MONITORING PLAN FOR ALTERNATIVES B AND C (AERIAL BROADCAST OF 25W) [DRAFT]

PALMYRA ATOLL RAINFOREST RESTORATION PROJECT: RAT ERADICATION MONITORING PLAN FOR ALTERNATIVES B AND C (AERIAL BROADCAST OF 25W) [DRAFT]

By the US Department of Agriculture, APHIS, Wildlife Services, National Wildlife Research Center and Island Conservation

For

The Palmyra Atoll Rainforest Restoration Project Partnership

16 April 2011

Contact: William Pitt, USDA, APHIS, Wildlife Services, National Wildlife Research Center, PO Box 10880, Hilo, HI 96721; 808 961-4482 ext 22, will.pitt@aphis.usda.gov: John Eisemann, USDA, APHIS, Wildlife Services, National Wildlife Research Center, 4101 Laporte Avenue, Fort Collins, CO 80521, John.D.Eisemann@aphis.usda.gov.

Contents

1 Introduction

1.1 Background

Palmyra Atoll (Palmyra), co-managed by the US Fish & Wildlife Service and The Nature Conservancy, is an important center of biodiversity and species abundance in the Central Pacific region. No baseline record of Palmyra's terrestrial ecosystem prior to the 19th century exists; however, it is possible that Polynesian voyagers altered Palmyra's environment prior to European exploration of the Pacific by introducing coconut palms. Anthropogenic impacts accelerated during and after WWII with introductions of other plants, terrestrial arthropods, and mammals. Rats were likely introduced to the atoll during this period.

Introduced non-native species are a leading cause of extinctions in island communities worldwide. Removing rats from Palmyra will result in biodiversity benefits for seabirds, plants, terrestrial invertebrates, and other components of the atoll's terrestrial ecosystem; however, the removal process is complicated and could cause short- or even long-term damage to some of Palmyra's animal populations. If the removal of rats from Palmyra does cause harm to local individual animals or animal populations, we anticipate that this impact will be short-lived and overshadowed by the large restoration benefit achieved through the removal of rats.

1.2 Conservation action

In June of 2011, the Palmyra Atoll Rainforest Restoration Project (PARRP) partnership will treat the entire atoll with rodenticide to remove the alien rat (*Rattus rattus*) population. The eradication will involve both aerial and ground application of bait containing the second generation anticoagulant rodenticide brodifacoum at a concentration of 25 ppm (Brodifacoum 25 W Conservation Bait registered with the US EPA, sold by USDA - APHIS, and manufactured by Bell Labs, Madison WI). All emergent land areas will be treated, and measures will be employed to prevent intentional and minimize accidental bait drift into the marine environment.

Bait will be applied to the atoll according to a strategic plan that will minimize the risk of bait drift into the marine environment while ensuring that a sufficient amount of bait is delivered to every potential rat territory. Two applications of bait over the entire atoll will be conducted during the eradication, and each application will employ three methods of aerial broadcast baiting (full swath - 40m, directional swath - 20m, and narrow swath - 10 m), and hand baiting. Bait will be slung into the crowns of coconut palms (*Cocos nucifera*) that overhang near-shore waters as this habitat will not be baited during the aerial application, and bait stations will be placed and maintained around the camp area and on select small islands that are thought to be rat-free.

The operation is scheduled to coincide with the summer migration of shorebird species that are at risk of exposure to the rodenticide. The implementation team will include 4-5 personnel who are dedicated to monitoring the parameters of the eradication, such as bait application rate and bait fait, and environmental factors, such as rodenticide residue in water and non-target species exposure to the rodenticide. All sampling devices, including location markers, such as flagging tape, will be recovered once the monitoring goals have been met.

This conservation action, including the monitoring component, will be a cooperative effort by the US Department of Agriculture, US Fish and Wildlife Service, The Nature Conservancy, and Island Conservation.

1.3 Scope

This monitoring plan details the ecotoxicology and efficacy monitoring that will be undertaken in conjunction with the implementation of the rat removal project at Palmyra. The five objectives of the monitoring plan are:

1. Verification of the application rate on the ground and in the coconut palm canopy

2. Document adverse impacts, or lack thereof, to Palmyra's biota caused by the rat removal action.

3. Document long term negative impacts, or lack thereof, to Palmyra's biota caused by the rat removal action

4. Establish clear pathways by which non-target species could be exposed to the rodenticide employed to remove rats from Palmyra, and measure rodenticide exposure levels for key non-target species

5. Document that the rat removal action has successfully removed all rats from Palmyra.

The monitoring actions described in this plan will occur prior to, during, and after the implementation of the eradication. This plan builds on prior studies of Palmyra's eradication environment (Howald et al. 2004, Buckelew et al. 2005, USDA-APHIS 2006, Wegmann et al. 2008, Alifano and Wegmann 2010, Alifano et al. 2010), rodent eradication studies conducted in similar environments (Wegmann et al. 2006, Wegmann et al. 2007, Wegmann 2008), and decades of research on the management of invasive species (Witmer et al. 2007). The monitoring activities, number of samples that will be collected, and the effort (number of personnel) that will be required for each sampling activity are presented in Tables 1 and 2.

2 Monitoring Actions

2.1 Bait Application Rate Monitoring

2.1.1 Terrestrial Environment

During each bait application, the amount of bait that will be available to ground-foraging rats and other consumers will be measured within 30 minutes of the bait landing on the ground. The monitoring team will use plastic hoops ("sampling hoops") that are 91.44 cm diameter to quantify the bait application rate on the ground.

2.1.1.1 Monitoring Procedure

Thirteen areas will be monitored for bait application rate (figure 1). These areas represent the four habitat types on the atoll. At least 192 independent measurements will be taken during each of the two bait applications across these 13 sampling areas. Each measure will consist of counting bait pellets within a sampling hoop. Approximate locations of sampling points will be determined by GPS location prior to application. Monitoring will occur within 1 hour after bait has been applied to these areas.

2.1.2 Lagoon Environment

Despite the measure employed to prevent bait drift into the marine environment, a small amount of bait may enter near-shore waters due to wind, ricochet off of vegetation, or human error. The monitoring team will use sampling hoops placed in the near-shore marine environment to measure the amount of bait that accidentally enters the water.

2.1.2.1 Monitoring Procedure

The sampling hoops will be placed at sample sites throughout the atoll. At each sample site (10sites), five transects of three sampling hoops that run perpendicular to the shoreline will be established with 5 m between each transect. The three hoops in each transect will be secured at 3m, 6m, and 9m from the high-tide line, which will be identified as the highest reach of the last high tide cycle. Each sampling hoop will be secured to weights placed on the bottom or stakes driven into the marine sediment. Transects at a minimum of five sites will be sampled directly after bait is aerially broadcast onto the adjacent land area, and only at low tide or when the sampling hoops are not submerged. To account for the chance that the aerial baiting schedule may not coincide with a tide that is low enough to allow for sampling, ten sites will be established (Figure 2).

2.2 Bait Pellet Fate

2.2.1 Palm Canopy

An assessment of the presence of bait pellets and pellet fate in coconut palm crowns will occur directly after the first and second bait applications.

2.2.1.1 Monitoring Procedure

Fifteen coconut palms that can be easily accessed with a 40' extension ladder and located on Cooper Island (Figure 3) will be selected prior to the first bait application. Each palm will be checked for the presence of bait pellets within four hours of bait being broadcast over the surrounding canopy. During this initial assessment, the location of five bait pellets (the bait pellets will be found in the tree or placed there if less than five are found) will be indicated by using a permanent marker to draw an arrow that points to the pellet on an adjacent frond. Each of the five study pellets in each study tree will be given a unique, two digit identifier ("1-1" will mean that this is pellet 1 in tree 1) and checked daily until the pellet disappears or is undetectable. While the pellets remain in the crowns, pellet fate will be recorded according to the following bait pellet condition scale:

1. Bait hard, intact, whole
2. Bait hard, intact, partially gone
3. Bait soft, intact, whole
4. Bait soft, intact, partially gone
5. Bait mushy, disintegrated
6. Bait dry, disintegrated
7. Bait pellet gone

2.2.2 Ground

The fate of bait pellets on the ground will be measured after each of the two bait applications.

2.2.2.1 Monitoring Procedure

PVC sampling hoops will be fixed in place within representative patches of Palmyra's four main terrestrial habitat types: Coconut Palm Forest, *Scaevola/Heliotropium* shrubland, *Pisonia* forest, and *Lepturus* meadow (Figure 4). The four study patches will be located on Cooper Island. Ten sampling hoops will be placed in each study patch. Directly following the treatment of the surrounding area, pellets will be added to or removed from the sampling hoops so that the bait density within the hoop equals the target application rate. Each sampling hoop within each study patch will be visited every day until all pellets are gone from within the hoop; the number of pellets remaining and general pellet condition (see the bait pellet condition scale above) will be recorded during each visit.

2.2.3 Crab burrows

Consumption of bait by land crabs is a well documented occurrence during rodent eradication operations. While Land crabs readily consume bait brodifacoum and diphacinone (Pain et al. 2000, Tanner et al. 2004, Alifano and Wegmann 2010), and presumably other anticoagulant rodenticides do not appear to harm the crabs. However, it is possible that Gecarcinid land crabs, such as the *Cardisoma* species occurring at Palmyra, cache bait in their burrows. If bait caching occurs (this behavior has not been documented), then such caches may facilitate the eradication effort by acting as bait stations, or increase the potential risk of harmful exposure of non-target species to the applied rodenticide by creating pockets of bait that are not readily consumed. A bait caching study will be conducted prior to the eradication.

2.2.3.1 Monitoring Procedure
Prior to the eradication, non-toxic (placebo) 25W bait pellets will be broadcast by hand around an area containing shallow *Cardisoma sp.* burrows. Following the bait application, up to 10 burrows will be checked for evidence of bait caching by crabs. If bait caching is observed (if pellets are brought into the burrow by the crab(s) and are not directly consumed), the fate of the cached pellets will be monitored daily and pellet condition will be assessed according the aforementioned bait pellet condition scale.

2.3 Impacts to Target and Non-Target Organisms (Rats, Fish, Geckos, Crabs, Birds)

2.3.1 Carcass searching and shorebird counts
The Palmyra rat eradication project has been designed to specifically target rats and avoid harm to non-target species; however, with a broadcast bait application, the potential for exposing non-target individuals to the applied rodenticide exists. To document harm caused to non-target organisms due to exposure to rodenticide, the Monitoring Team will conduct directed carcass searches, and will sample terrestrial and marine organisms for evidence of exposure. In addition, all carcasses located opportunistically during all eradication operations will be collected for necropsy and residue analysis.

2.3.1.1 Directed Searches
Organized searches for dead or moribund target (rat) and non-target individuals (fish, geckos, crabs, and birds) will occur during and after the eradication.

2.3.1.1.1 Monitoring Procedure
Starting three days prior to the first bait application and continuing until 30 days after the second bait application, organized carcass searches will occur on the runway and on North Beach – both are prominent, easily accessed shorebird roosting sites (Figure 5). In addition to this search effort, an all atoll shorebird count and carcass search (Figure 6) will occur at the following intervals after the first bait application: days 5, 8, 15, and 18. Furthermore, all project staff will be instructed on proper collection and tagging protocols should they come across a carcass during other project activities – this will allow for opportunistic documentation of non-target species response to the eradication action. All dead or moribund target and non-target individuals found during and up to 2 months after the operation will be properly collected and necropsied, and the resulting samples will be labeled for lab-based detection and quantification of rodenticide residue.

2.3.1.2 Terrestrial Non-Target sampling: hermit crabs, geckos, ants, cockroaches
To further assess non-target species exposure to the applied rodenticide, small samples of select terrestrial non-target species will be collected and analyzed for rodenticide residue.

2.3.1.2.1 Monitoring Procedure
A minimum of 5 pooled samples (2-5g per sample) will be collected at four intervals after the first bait application: 1-4 days, 11-14 days, day 24, and day 56. In addition, one pre-eradication sample will be collected for method development. Geckos will be haphazardly

collected at night from the trunks of coconut palms, ants will be collected with guarded bait cards (sugar and protein bait placed on 5cm x 5cm paperboard cards that are secured inside crab-proof cages that are anchored to the ground), and cockroaches will be haphazardly collected at night in and around unused manmade structures, on the trunks of coconut palms, and via leaf-litter sifting. All collection will occur on Cooper Island, and all specimens will be properly collected, preserved, and labeled for lab-based assessment of exposure to rodenticide.

2.3.1.3 Marine Non-Target sampling: Black-spot Sergeant, fiddler crabs

To further assess non-target species exposure to the applied rodenticide, small samples of select marine non-target species will be collected and analyzed for rodenticide residue. Because of their foraging strategies, abundance, and, in the case of the fiddler crab, foodweb-based connection to target and other non-target species, the Black-Spot Sergeant (*Abudefduf sordidus*), and the fiddler crab *Uca tetragonon* were selected as indicator vertebrate and invertebrate marine organisms.

2.3.1.3.1 Monitoring Procedure

Samples comprising three Black-Spot Sergeants will be collected from ten different locations before the eradication and 1-2 days after the second bait application. For fiddler crabs, a minimum of 5 pooled samples (2-5g per sample), plus one sample for method development will be collected prior to the eradication, and at four intervals after the first bait application: 1-4 days, 11-14 days, day 24, and day 56.

2.4 Environmental Sampling

2.4.1 Water sampling

As mentioned, sincere effort will be taken during the eradication to prevent bait drift into the near-shore waters. However, it is possible that rodenticide could enter aquatic water bodies through accidental, direct spread of pellets into water, or through the flushing of land-based sediment during heavy rain events. To assess both marine and inland waters for rodenticide residue, the Monitoring Team will collect water samples after each bait application and at the end of the operation.

2.4.1.1 Monitoring Procedure

Within 24 hours of each application and on the last day of the operation (after the second application), the monitoring team will collect 12 one-liter water samples (in chemically cleaned jars) from 12 sites (Figure 7):

- 3 sites outside lagoon (western terrace)
- 6 sites inside adjacent to baited area in deep water
- 1 site in the brackish eel pond adjacent to Cooper Island
- 1 site in the runway pond
- 1 site in a groundwater well on Eastern Island

2.5 Efficacy

2.5.1 Direct - Radio Collars

During the eradication, the efficacy of the operation will be assessed by following rats that were fitted with radio transmitters prior to the first bait application

2.5.1.1 Monitoring Procedure

Starting the night after the first bait application, the monitoring team will follow 30 rats fitted with radio collars. Fifteen rats will be trapped within the camp area (preferably inside or around buildings), ten rats will trapped and followed on Aviation Island, and five rats will be trapped and followed on Strawn Island. All collared rats will be found every other night until mortality is confirmed by observation of the carcass or retrieval of the collar.

2.5.2 Indirect - Monitoring Stations (Chew Blocks, Tracking Tunnels, Motion-Sensing Cameras)

Following the eradication operation, rat detection stations will be established throughout the atoll; the stations will be frequently checked and serviced over a two week period. At this time, Rat detection stations will also be established in the camp area and these stations will become part of the ongoing biosecurity program.

2.5.2.1 Monitoring Procedure

Four to six weeks after the second bait application, a small team will return to Palmyra to establish rat detection stations throughout the atoll (Figure 8). Every station will have a corrugated plastic indicator block, and tracking tunnels and motion sensing camera traps will be spaced intermittently throughout the detection station network. The stations will be checked and serviced every three days over a fifteen day period. If rat sign is encountered on an isolated land mass that is small enough to effectively retreat by hand, the monitoring team will consult with the PARRP management team about conducting a follow-up bait application on this land mass.

Detection stations that are placed in the camp area will be monitored and serviced by trained TNC station staff according to this schedule: once per week for six months following the eradication, once per month after six months.

At one year and two years after the eradication, a monitoring team will return to Palmyra and re-establish the rat detection stations. During these monitoring efforts, live traps will be added to the detection station network, and stations will be monitored/serviced every three days for fifteen days.

As part of the atoll's biosecurity program, all station staff will be trained in the detection of rat sign. If sign is observed, indicator blocks will be placed in the surrounding area and any blocks with potential rat chew marks will be sent to rodent identification experts for verification.

3 Tables and Figures

Table 1. Sample collection schedule for the Palmyra Atoll Rat Eradication monitoring tasks – the numbers in the cells represent the number of samples that will be collected for the given monitoring activity on the given day.

PALMYRA ATOLL RAT ERADICATION	DAYS AFTER 1ST BROADCAST																											
MONITORING ACTIVITIES	Pre	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Post	TOTAL
Application Rate Ground: Hoops		96	96													96	96											384
Application Rate Lagoon: Hoops		75	75													75	75											300
Bait Fate Ground: Hoops[1]		40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40		960
Bait Fate Canopy: Palm Crowns[2]		15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15		360
Bait Fate Crab Burrows: Burrows	10																											10
Focused Carcass Search: Days (N-Beach, Runway)	6		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2		56
Atoll Carcass Search: Samples							1			1								1			1							4
Shorebird Count Runway: Samples							1			1								1			1							4
Shorebird Count Atoll: Samples							1			1								1			1							4
Non-Target Sampling- Geckos: Pooled Samples[3]	2				2		3					2		3										2	3		5	22
Non-Target Sampling- Ants: Pooled Sample[3]	2				2		3					2		3										2	3		5	22
Non-Target Sampling- Cockroaches: Pooled Samples[3]	2				2		3					2		3										2	3		5	22
Non-Target Sampling- Fish: Individuals	30																	15	15									60
Non-Target Sampling- Fiddler Crabs[3]	2				2		3					2		3										2	3		5	22
Non-Target Sampling- Hermit Crabs [3]																				5			5					10
Environmental Sampling- Water- Outside:	3			3														3								3		12
Environmental Sampling- Water- Inside Lagoon:	6			6														6								6		24
Environmental Sampling- Water- Brackish Eel Pond:	1			1														1								1		4
Environmental Sampling- Water- Runway Pond:	1			1														1								1		4
Environmental Sampling- Water- Fresh Water Well:	1			1														1								1		4
Efficacy Monitoring- Radio Collars- Strawn: Locations	5			5		5		5		5		5		5		5		5		5		5		5				60
Efficacy Monitoring- Radio Collars- Cooper: Locations	15			15		15		15		15		15		15		15		15		15		15		15				175
Efficacy Monitoring- Radio Collars- Aviation: Locations	10			10		10		10		10		10		10		10		10		10		10		10				120
Efficacy Monitoring- Stations- Chew Blocks: Stations																											215	215
Efficacy Monitoring- Stations- Tracking Tunnels: Stations																											43	43
Efficacy Monitoring- Stations - Camera Traps: Stations																											24	24

1 Each hoop should include approximately 15 pellets (if application rate is 90 kg/ha and each pellet weight about 6 grams), consequently, ~600 pellets per app. or 1,200 pellets over both apps.

2 Each palm crown will contain 5 pellets (15 palms x 5 pellets/palmx 2 applications = 150 pellets monitored each day until gone)

3 Each Non-target sample consists of a minimum of 5 individuals ($\geq$ 10 grams total).

Table 2. Staffing schedule for the Palmyra Atoll rat eradication monitoring tasks – the numbers in the cells represent the number of personnel that will be needed to complete the given task on the given day.

PALMYRA ATOLL RAT ERADICAITON	DAYS AFTER 1ST BROADCAST																										
MONITORING ACTIVITIES	**Pre**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**Post**
Application Rate Ground: Hoops		4														4											
Application Rate Lagoon: Hoops		4														4											
Bait Fate Ground: Hoops			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
Bait Fate Canopy: Palm Crowns			2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
Bait Fate Crab Burrows: Burrows	1																										
Focused Carcass Search: Days (N-Beach, Runway)	2		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
Atoll Carcass Search: Samples							12			12								12			12						
Shorebird Count Runway: Samples							1			1								1			1						
Shorebird Count Atoll: Samples							12			12								12			12						
Non-Target Sampling- Geckos: Pooled Samples	2		2	2	2	2							2	2	2	2										2	2
Non-Target Sampling- Ants: Pooled Samples	2		2	2	2	2							2	2	2	2										2	2
Non-Target Sampling- Cockroaches: Pooled Samples	2		2	2	2	2							2	2	2	2										2	2
Non-Target Sampling- Fish: Individuals	2																2	2									
Non-Target Sampling- Fiddler Crabs:	2		2	2	2	2							2	2	2	2										2	2
Environmental Sampling- Water- Outside:	2		2														2									2	
Environmental Sampling- Water- Inside Lagoon:	2		2														2									2	
Environmental Sampling- Water- Brackish Eel Pond:	2		2														2									2	
Environmental Sampling- Water- Runway Pond:	2		2														2									2	
Environmental Sampling- Water- Fresh Water Well:	2		2														2									2	
Efficacy Monitoring- Radio Collars- Strawn: Locations	2		1		1		1		1		1		1		1		1		1		1		1				
Efficacy Monitoring- Radio Collars- Cooper: Locations	2		1		1		1		1		1		1		1		1		1		1		1				
Efficacy Monitoring- Radio Collars- Aviation: Locations	2		1		1		1		1		1		1		1		1		1		1		1				
Efficacy Monitoring- Stations- Chew Blocks: Stations																											2
Efficacy Monitoring- Stations- Tracking Tunnels: Stations																											2
Efficacy Monitoring- Stations - Camera Traps: Stations																											2

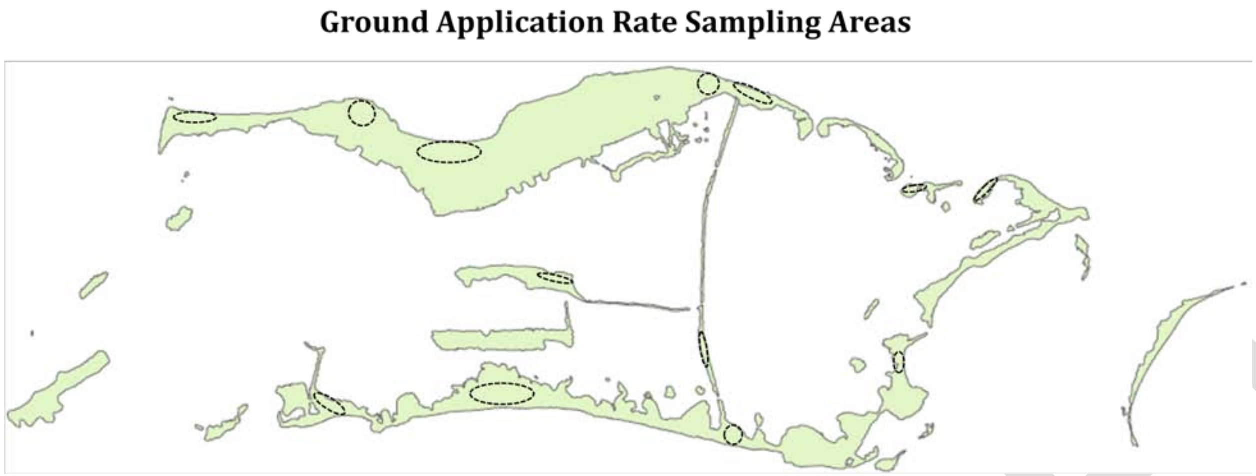

Figure 1. A map of the thirteen sampling locations that will be used to measure the bait application rate on the ground during each of the two aerial broadcasts that will occur during the Palmyra Atoll rat eradication.

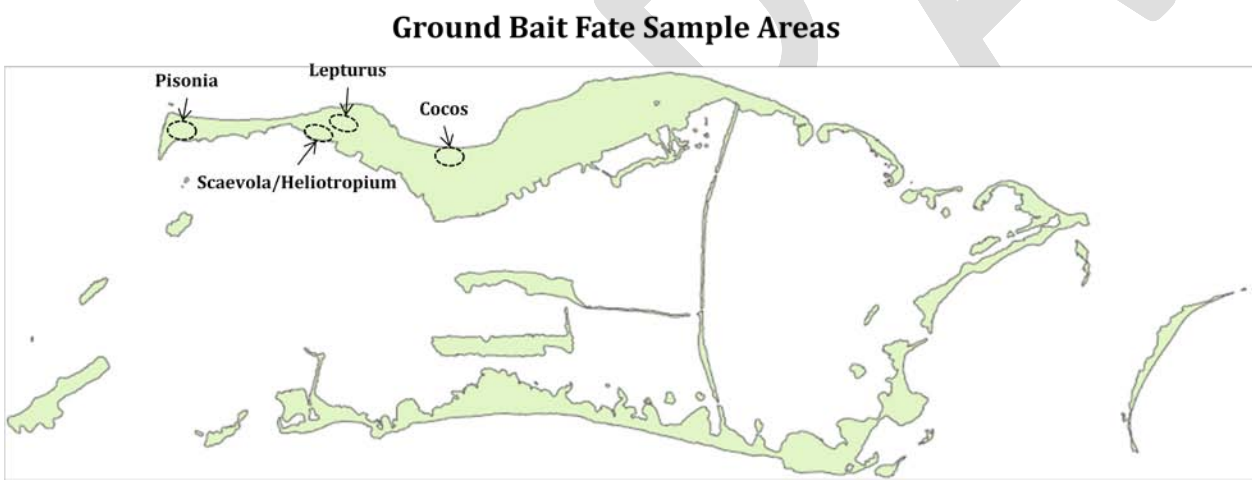

Figure 2. A map of the four sampling locations that will be used to measure the fate of bait pellets after each of the two aerial broadcasts that will occur during the Palmyra Atoll rat eradication.

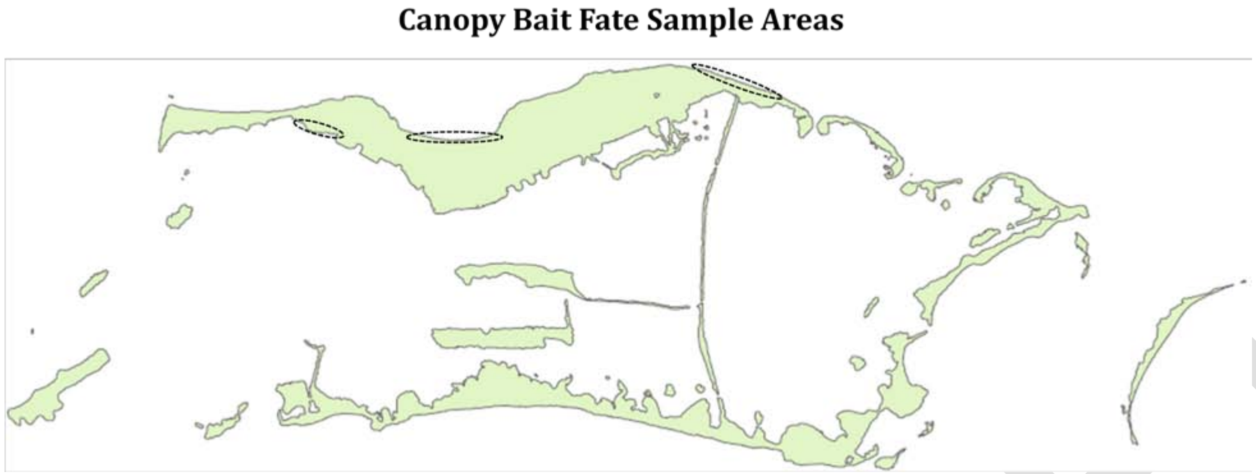

Figure 3. A map of the three sampling locations that will be used to measure the fate of bait pellets lodged in the crowns of palm trees after each of the two aerial broadcasts that will occur during the Palmyra Atoll rat eradication.

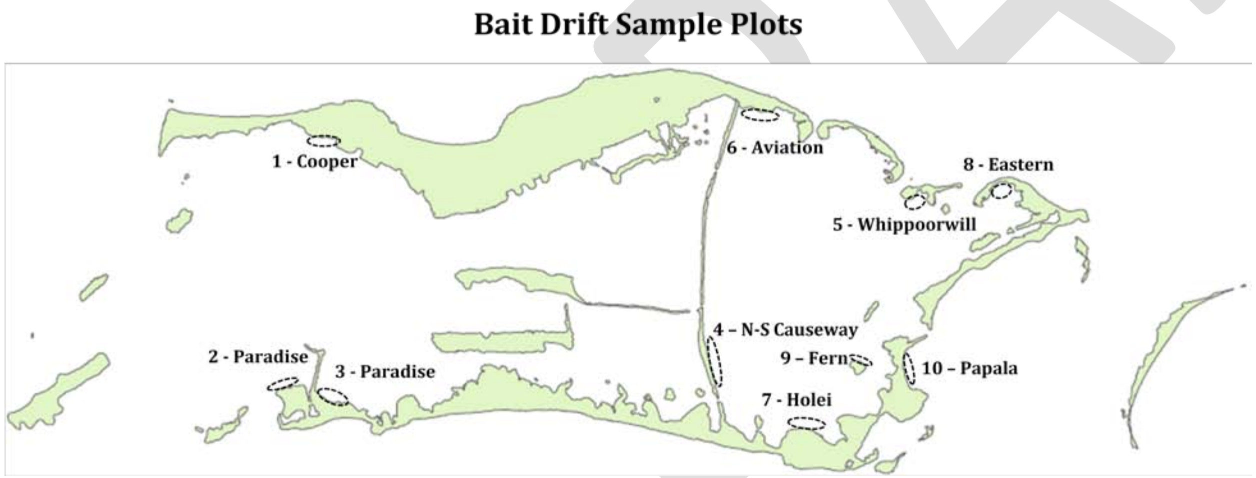

Figure 4. A map of the ten sampling locations that will be used to measure the rate at which bait drifts into the near-shore marine environment during each of the two aerial broadcasts that will occur during the Palmyra Atoll rat eradication.

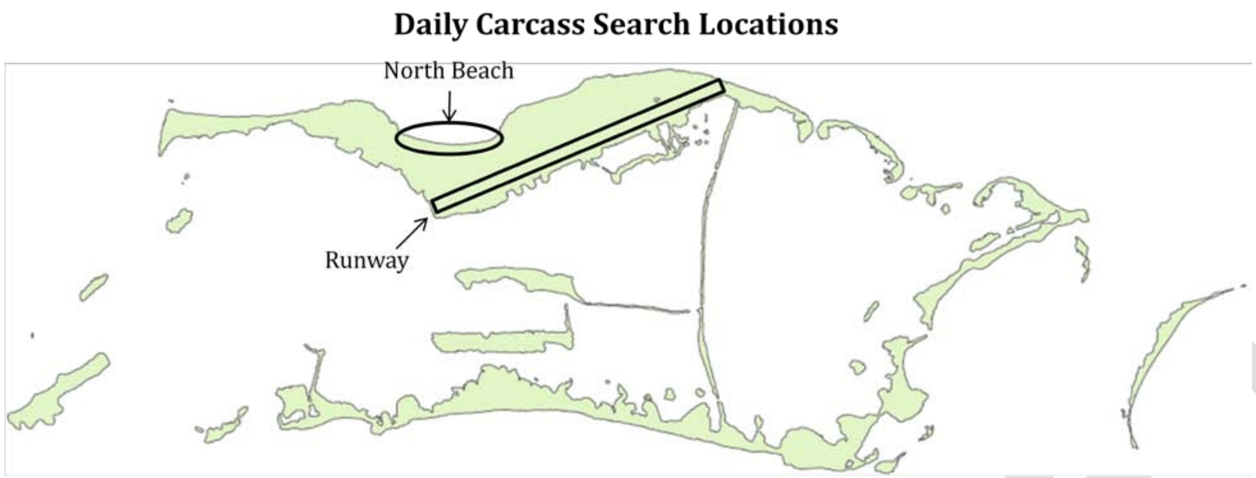

Figure 5. The locations where daily carcass searching will occur during the Palmyra Atoll rat eradication.

Figure 6. A depiction of the routs followed during an “All-Atoll” shorebird count and carcass search.

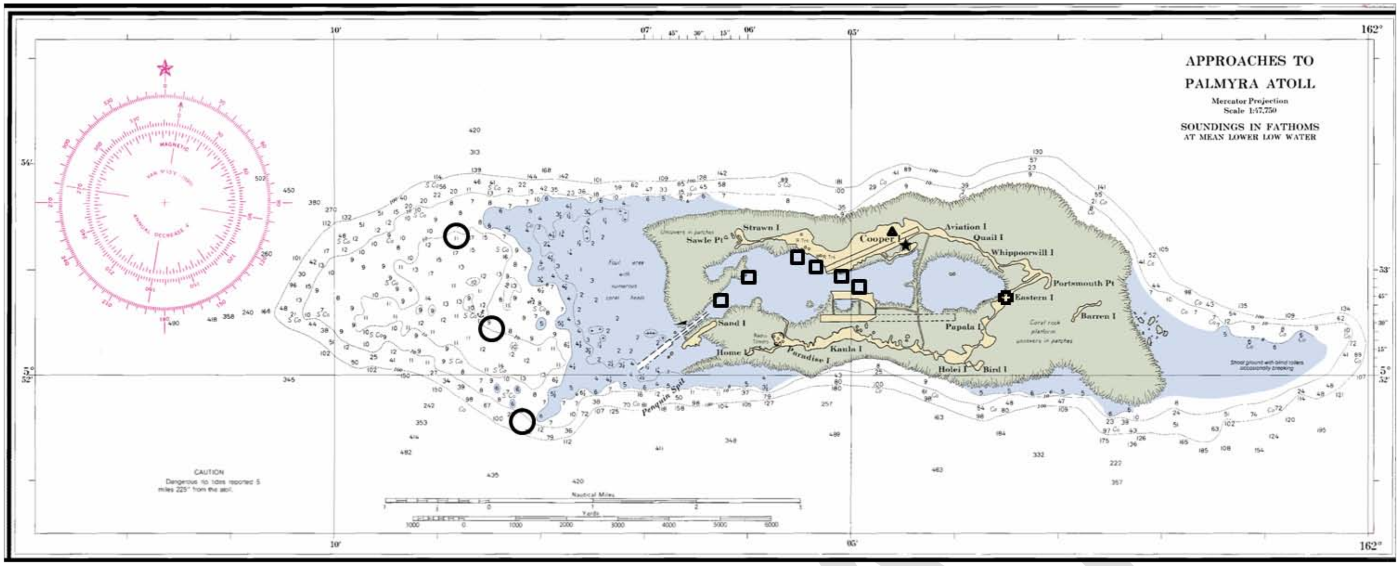

Figure 7. A map of the twelve sampling locations that will be used to test water for brodifacoum residue after the bait application associated with the Palmyra Atoll rat eradication. Circles represent the three sites that are outside of the lagoon. Squares represent the six sampling sites that are inside the lagoon. The star is the brackish "Eel Pond" on Cooper Island. The triangle is the "Runway Pond" on Cooper Island. And, the cross is the fresh water well on Eastern Island.

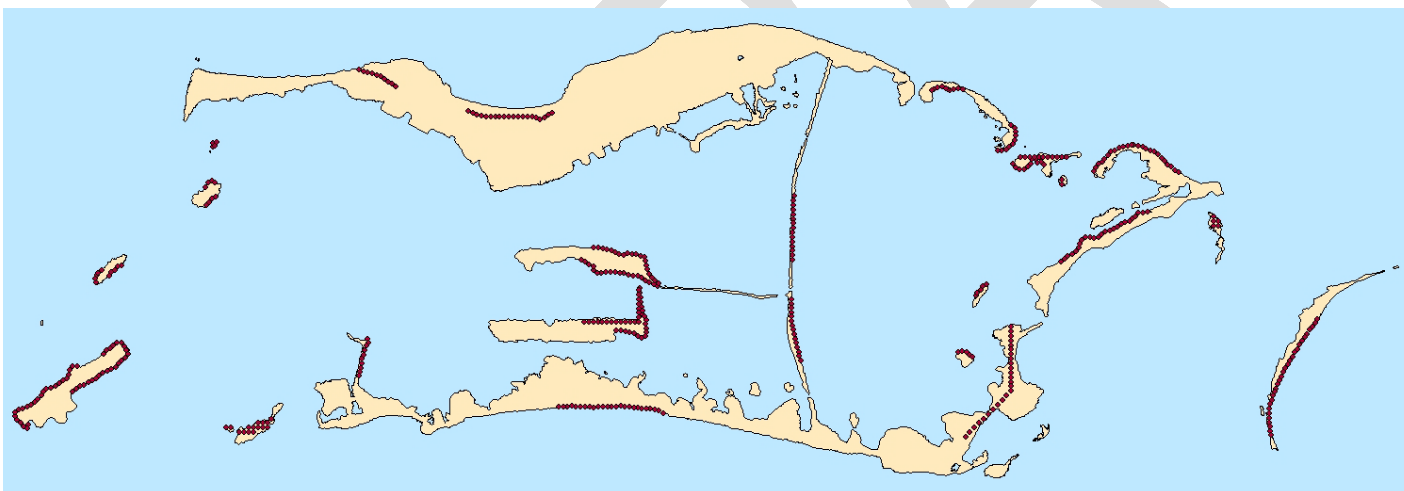

Figure 8. A map of the approximate locations of rat monitoring stations that will be established four to six weeks after the second bait application. Three detection devices will be employed during this monitoring effort: chew blocks, tracking tunnels, and camera traps. The monitoring stations will be activated and monitored for two weeks at this time, and then again for two weeks at one year and two years post eradication.

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APPENDIX B

WORKING DRAFT PALMYRA ATOLL BIOSECURITY PLAN: PREVENTION OF RODENT INCURSION AND RODENT DETECTION RESPONSE

WORKING DRAFT PALMYRA ATOLL BIOSECURITY PLAN: PREVENTION OF RODENT INCURSION AND RODENT DETECTION RESPONSE

PREPARED BY THE NATURE CONSERVANCY*

April 15, 2011

*Contact: Jordan Jokiel, The Nature Conservancy, 923 Nuuanu Ave., Honolulu, HI 96817, 808-587-6282

INTRODUCTION

The conservation and socio-economic benefits of eradicating rats from Palmyra Atoll ("Palmyra") will only be fully realized if rodent reinvasion is prevented. Pest reinvasion mitigation or biosecurity plans are critical components of successful eradication campaigns. Because The Nature Conservancy (TNC), United States Fish and Wildlife Service (FWS) and Palmyra Atoll Research Consortium (PARC) collectively maintain and operate a Nature Preserve, a research station, and National Wildlife Refuge there is a steady influx of supplies, equipment, and personnel which regularly arrive at Palmyra via airplane and ocean going vessel from many ports of call. As such, the risk of rat-reintroduction is high.

To mitigate the risk of a post eradication rodent reinvasion, a biosecurity plan must be put into action prior to the eradication and continued indefinitely. The biosecurity measures identified in this plan were developed with the guidance of the Department of Conservation (New Zealand), The Island Eradication Advisory Group (New Zealand) and a review of the document entitled, "Review of Rat Invasion Biology; Implications for Island Biosecurity" (J.C. Russel, D.R. Towns and M.N. Clout).

The three basic units of biosecurity are quarantine, surveillance and contingency response. Implementation, oversight and funding responsibility for biosecurity actions for Palmyra are the responsibility of TNC and FWS. TNC will be the primary lead for managing biosecurity measures in Honolulu and on Cooper Island, and FWS will be the primary lead for actions in the Refuge.

Potential pathways for rodent introduction to Palmyra include: airplanes, marine vessels, and their associated cargo. Biosecurity measures for each of these pathways are described below.

BIOSECURITY MEASURES

PATHWAY	*BIOSECURITY* MEASURE
PLANE	PRE-DEPARTURE QUARANTINE: • Maintain permanent control devices* in Honolulu hangar area. • Place detection** and control devices on plane 3 days prior to departure to Palmyra. Check prior to departure. • Ensure plane is secured (doors closed) on the runway in Honolulu. POST-ARRIVAL QUARANTINE: • Ensure plane is secured (doors closed) on runway.

PATHWAY	*BIOSECURITY* MEASURE
	• Maintain permanent control devices at Palmyra runway area. SURVEILLANCE: • Place detection and control devices on plane 3 days prior to departure to Palmyra. Check prior to departure. CONTINGENCY RESPONSE: • Maintain control and detection devices at a density of one device per hectare in a one kilometer radius around the runway at Palmyra.

PATHWAY	***BIOSECURITY* MEASURE**
CARGO TRANSPORTED ON PLANE	PRE-DEPARTURE QUARANTINE: • Develop a secure, dedicated staging area for Palmyra provisioning operations which will allow for better inspection, decontamination and storage of all Palmyra-bound cargo • Maintain permanent control and detection devices in provisioning area. • Visually inspect all cargo, especially produce and large equipment before loading on plane. • Reduce packaging and re-pack in rodent-proof containers. • Reduce the threat of this pathway by producing more food locally at the atoll. POST ARRIVAL QUARANTINE: • Visually inspect all cargo as it is being unloaded. SURVEILLANCE: • Require rodent free certification inspection for provisioning staging area once per year CONTINGENCY RESPONSE: • Maintain control and detection devices at a density of *4* devices per hectare in *200 m* radius around the *portion of the runway where the plan stops to load and unload passengers and cargo*.

PATHWAY	***BIOSECURITY* MEASURE**
VESSELS THAT DOCK AT PALMYRA (ANNUAL PROVISIONING SHIP, RESEARCH VESSELS, OTHER)	PRE-DEPARTURE QUARANTINE: • Maintain permanent control devices* in wharf area in Honolulu. • Require rodent free certification inspection for vessel 2 weeks prior to departing for Palmyra. • Visually inspect interior and exterior of vessel for evidence of rodents three days prior to departure to Palmyra. • Deploy rodent control and detection devices on vessel one week prior to departure. Maintain and check every two days prior to and during duration of operation. POST-ARRIVAL QUARANTINE: • Ensure vessel is secured when docked at Palmyra (minimize physical vectoring pathways between vessel and dock) SURVEILLANCE: • Deploy rodent control and detection devices on vessel one week prior to departure. Maintain and check every two days prior to and during duration of *stay at Palmyra*. CONTINGENCY RESPONSE: • Maintain control and detection devices at a density of one device per hectare in a one kilometer radius around the wharf at Palmyra.

<table>
<tr><th>PATHWAY</th><th>BIOSECURITY MEASURE</th></tr>
<tr><td>VESSELS THAT DOCK AT PALMYRA (ANNUAL PROVISIONING SHIP, RESEARCH VESSELS, OTHER)</td><td>PRE-DEPARTURE QUARANTINE:
Develop a secure, dedicated staging area for Palmyra provisioning operations which will allow for better inspection, decontamination and storage of all Palmyra-bound cargo.
Maintain permanent control and detection devices in provisioning area.
Visually inspect all cargo, especially produce and large equipment before loading.
Reduce packaging and re-pack in rodent-proof containers.
Place cargo in shipping containers.
Implement rodent control and detection measures inside shipping containers.
Reduce the threat of this pathway by producing more food locally at the atoll.
POST ARRIVAL QUARANTINE:
Visually inspect all cargo as it is being unloaded.
SURVEILLANCE:
Require rodent free certification inspection for provisioning staging area once per year.
CONTINGENCY RESPONSE:
Maintain control and detection devices at a density of 4 devices per hectare in 200 m radius around the wharf.</td></tr>
</table>

PATHWAY	***BIOSECURITY* MEASURE**
VISITING VESSELS (ARRIVAL OF VESSEL HAS BEEN COORDIANTED AND OPERATION HAS GONE THROUGH THE PERMITTING PROCESS GOVERNED BY FWS AND TNC)	QUARANTINE: • Ensure bio-security information is provided via the permitting process and on website. • No visiting vessels are permitted to dock (except for emergencies or with prior approval and protocols) and must moor at designated areas in the lagoon. • Ensure ship is moored properly. SURVEILLANCE: • Implement rat control and detection measures on vessel while moored. CONTINGENCY RESPONSE: • Maintain control and detection devices at a density of *4* devices per hectare in a one kilometer radius on the land area adjacent to the mooring site.

PATHWAY	***BIOSECURITY* MEASURE**
VISITING VESSELS (UNEXPECTED ARRIVAL AND/OR OPERATOR HAS NOT GONE THROUGH THE PERMITTING PROCESS GOVERNED BY FWS AND TNC)	QUARANTINE: • Provide bio-security information to visiting vessel. • Assess the likelihood that the vessel may harbor rodents before granting access to moor in the lagoon. • No visiting vessels are permitted to dock (except for emergencies or with prior approval and protocols) and must moor at designated areas in the lagoon. • Ensure ship is moored properly. SURVEILLANCE: • Implement rodent control and detection measures on vessel while moored. CONTINGENCY RESPONSE: • Maintain control and detection devices at a density of *4* devices per hectare in a one kilometer radius on the land area adjacent to the mooring site.

PATHWAY	*BIOSECURITY* MEASURE
VISITING VESSELS THAT NEED TO DOCK FOR EMERGENCY PURPOSES	QUARANTINE: • Assess the likelihood that the vessel may harbor rodents before granting access to dock. • Ensure vessel is secured when docked (minimize physical vectoring pathways between vessel and dock) SURVEILLANCE: • Deploy rodent control and detection devices on vessel. Maintain and check every two days. • Visually inspect all cargo before it is unloaded. CONTINGENCY RESPONSE: • Maintain control and detection devices at a density of *4* devices per hectare in a one kilometer radius around the wharf.

PATHWAY	***BIOSECURITY* MEASURE**
VESSEL (ATTENDED OR UNATTENDED) RUNS AGROUND	SURVEILLANCE: • Inspect vessel and assess the likelihood that the vessel may harbor rodents. CONTINGENCY RESPONSE: • Deploy rodent control and detection measures at a density of *eight* devices per hectare in a one kilometer radius on adjacent emergent land.

BIOSECURITY CONSIDERATIONS

BIOSECURITY ISSUE	**BIOSECURITY MEASURE**
Ensure that biosecurity measures continue to be maintained and refined as needed by all staff and stakeholders in perpetuity.	Disseminate information describing the importance of keeping Palmyra rat free as well as indentifying specific measures which reduce the possibility for vectoring rodents to Palmyra. Information can be disseminated via SUP process, PARC pre-trip information packet, PARC meetings*, and new employee briefings.*
Visiting vessels may not take adequate steps to reduce likelihood of vectoring rodents to Palmyra.	Disseminate information via FWS and TNC permit process and websites.

FWS and TNC may not be trained in techniques to readily detect and rapidly respond to rodent infestations.	Provide rat detection/rapid response training *to existing employees, and make such training compulsory when staffing pertinent positions.*

*Control devices include bait stations, live traps, sticky traps, and snap traps, as well as an integrated approach that includes a combination of these devices.

**Detection devices include, tracking tunnels, and chew blocks, as well as an integrated approach that includes a combination of these devices.

RODENT DETECTION RESPONSE

The conservation and socioeconomic benefits of eradicating rats from Palmyra would only be fully realized if it is successful and any rodent reinvasion is prevented. Rat detection response and pest reinvasion mitigation or biosecurity plans are critical components of successful eradication campaigns. A quantity of a FIFRA registered bait product (not to exceed ≤ 2000 lbs or 907 kg) would be stored at the PARC field station. TNC and FWS would appropriately secure, label, and store all bait left at Palmyra in a dry location, ready for use should rats be detected after the rat eradication. All use of bait would be in accordance with the bait product's label.

If rat sign were encountered or a rat sighting occurred, rat detection devices (as described above) would be established in the area surrounding the sign or sighting and on adjacent islands. Confirmed rat presence would initiate a rat removal response to eradicate a residual population or an incursion. The area surrounding the confirmed rat detection would be treated with rodenticide applied by hand broadcast or bait station, or by live trapping, or by a combination of the three control methods. Detection devices placed in and beyond the treatment area would be monitored as frequently as possible during the control period, and until the point at which rats have not been detected for 30 consecutive days. Control of the invading or residual rat population would be adaptively managed to minimize risk to non target species while maximizing the probability of removing all target individuals.

APPENDIX C

PALMYRA ATOLL RAT ERADICATION ASSESSMENT TRIP REPORT 2004



PALMYRA ATOLL RAT
ERADICATION ASSESSMENT
TRIP REPORT
AUGUST 2004

PREPARED BY:

GREGG HOWALD*
ISLAND CONSERVATION NW, BRITISH COLUMBIA

ARACELI SAMANIEGO
CONSERVACIÓN DE ISLAS, MEXICO

STACEY BUCKELEW
ISLAND CONSERVATION, USA

PETE MCCLELLAND
NEW ZEALAND DEPARTMENT OF CONSERVATION

BRADFORD KEITT
ISLAND CONSERVATION, USA

ALEX WEGMANN
UNIVERSITY OF HAWAI`I AND USFWS

WILLIAM C. PITT
USDA- WILDLIFE SERVICES, NATIONAL WILDLIFE RESEARCH CENTER

DANIEL S. VICE
USDA-WILDLIFE SERVICES, GUAM

EARL CAMPBELL
US FISH AND WILDLIFE SERVICE, ECOLOGICAL SERVICES, HAWAI`I

KATIE SWIFT
US FISH AND WILDLIFE SERVICE, ECOLOGICAL SERVICES, HAWAI`I

STEVE BARCLAY
US FISH AND WILDLIFE SERVICE, REFUGES, HAWAI`I

CORRESPONDENCE: ghowald@islandconservation.org
PHONE: (604) 628-0250



SUMMARY

With funding from Mr. Ian Cumming, we studied the feasibility of rat eradication on Palmyra Atoll in August - September 2004. In August 2004, a team of nine people with representatives from Island Conservation, three US government agencies (USDA-NWRC, USDA-WS, USFWS-ES and USFWS Refuges) and the Department of Conservation New Zealand visited the atoll for eight days to initiate detailed research. Two Island Conservation staff remained on the atoll for one additional month to complete the planned research. The main goals of this expedition were to:

1) Assess the previous effort to eradicate rats from Palmyra Atoll both to learn why it was not successful and what experiences from that effort can be used to develop methods for a follow-up rat eradication.
2) Conduct site-specific research needed to develop a plan for a successful rat eradication.

Research was conducted on-island to answer questions critical to successful rat eradication. To determine if all rats would have access to rodenticide bait we asked:

- Do rats spend multiple days in trees without coming to the ground (will ground baiting suffice or must bait be available above ground as well)?
- What is the two dimensional (*planar*) movements of rats over a period of several days (how does bait need to be spatially distributed)?
- How much bait needs to be put out given bait loss to weather, land crabs and other invertebrates?
- Because land crabs are the main source of competition for bait, what is their distribution and density, and are there effective crab-proof bait station designs?

To make sure the rodenticide of choice, brodifacoum, was effective against the rats on Palmyra, we ran a small toxicity study in the field. Finally, to make sure the eradication could be conducted without harming other components of Palmyra's ecosystem, we identified potential non-target species that might require special mitigation.

We found that Palmyra's abundant rainfall and aseasonal environment were obstacles to successful rat eradication. They make it difficult to develop a bait that maintains its palatability over time and is more attractive to all rats than the abundant natural food resources. The abundant landcrabs compete with rats for the bait and make it difficult to ensure enough bait is available to all rats for an adequate time period.

Our rat range data indicate that the standard bait station spacing of 50 x 50 m may have been insufficient to get bait into every rat's ranging territory because the animals live in a three-dimensional habitat that includes the forest canopy. We recommend any bait station-based efforts require a distribution of stations with a maximum separation of 25 m to increase the proportion of rats coming into contact with bait stations, which still might not be adequate to intercept all rats.

Our initial estimates suggest that a broadcast application will require an application of 60-80 kg/ha to ensure that enough bait is available to the rats on the ground for four days, to overcome competition from landcrabs that are attracted to and consume the bait (but are not affected by the anticoagulant rodenticide). We were unable to precisely determine an effective broadcast application rate because of the high density of crabs and limited availability of placebo bait. We estimated the rate of bait application required to overcome crab consumption using measured crab densities multiplied by the mean and highest rate of bait consumption for each species of crab (measured in cage trials). We estimate that for the highest density of crabs in coconut palm forests, we would need to apply from as little as 3.34 kg/ha to as much as 47.74 kg/ha to overcome bait loss to crabs. Additional bait would be applied to ensure enough bait is available to rats. Further field testing to determine an appropriate application rate will be required.

Our resistance trials demonstrated that there is some tolerance or resistance to brodifacoum in the rat population, likely developed after long-term, chronic rat control. The build-up of resistance or tolerance may have contributed to the compromised original rat eradication effort and may suggest a need for an alternate toxin in addition to brodifacoum in future eradication efforts.

We tested six different bait types on Palmyra – CI-25, CI-25 Waxed, Ramik (8 g), Ramik (2 g), Weatherblock XT, and Final Blox. CI-25 proved to be the most palatable bait; however, it was unable to endure the wet climate on Palmyra. Ramik (8 g) retained its shape and firmness in Palmyra's climate for long enough, but the bait was not (relative to the other bait) palatable to the rats. Weatherblock XT and Final Blox survived well in Palmyra's environment; however, they contain Bitrex, a bittering agent that reduces palatability of the bait which may limit the success of the eradication. We identified the characteristics of the bait we need to deliver to the rats on Palmyra. We are currently working with Bell Laboratories of Madison, WI, to develop a bait for us to further test on Palmyra in 2005.

We believe that the most effective means to eradicate rats from Palmyra will be the use of baits containing brodifacoum and perhaps an additional bait containing a non-anticoagulant (such as bromethalin) rodenticide, either aerially broadcast or with an approach combining aerial broadcast and bait stations spaced at 25 m intervals. Because of the stringent regulatory environment in the US, which makes the approval of an aerial rodenticide broadcast a complex process, and the need to assure availability of bait both to rats in the canopy and on the forest floor, we believe that the combined use of bait stations (spaced at 25 m) and aerial broadcast may be the most effective method of eradication, but also the most logistically complex and costly. Rats with small territories, which may not encounter bait stations during foraging, should encounter the bait broadcast into the canopy and thus will not escape bait exposure. Bait station eradication can be implemented at any time during the year. Timing of the broadcast could be closely linked to the migratory patterns of non-target birds on the island, with little impact on the eradication.

We identified non-resident migratory shorebirds at risk of both primary and/or secondary exposure to the rodenticide. The primary species of concern are the Bristle-thighed Curlew *Numenius tahitiensis* and the Pacific Golden Plover *Pluvaialis fulva*. Both species are identified as species of high conservation concern in the US Pacific Islands Regional Shorebird Conservation Plan (2004) and the US Shorebird Conservation Plan (2000). Both species overwinter on the atoll, with some individual juvenile birds present throughout the year. The most effective mitigation for these species is to conduct the eradication when there are the smallest numbers of birds present on the atoll.

With $120,000 in funding from the USFWS, we recommend conducting a trial hand broadcast (to mimic an aerial application) application into representative habitat to test the efficacy, risks and logistics of eradicating rats from Palmyra Atoll coincident with the lowest numbers of migratory shorebirds.

Table of Contents

INTRODUCTION

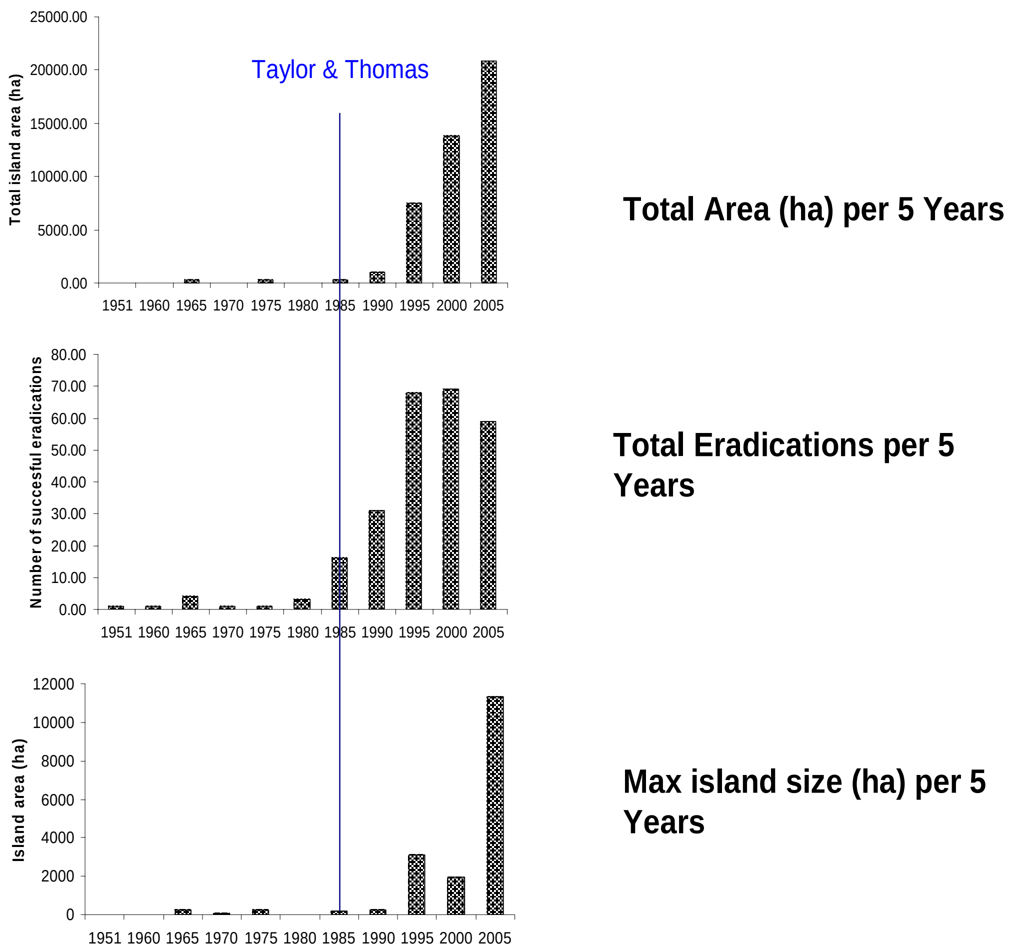
Island ecosystems, such as Palmyra Atoll, are key areas for conservation because they are essential habitat for seabirds, pinnipeds and sea turtles that range over thousands of square kilometers of open ocean, but depend on islands for breeding, raising young, and resting. In addition, islands tend to be rich in endemic species and are home to 15-20% of all plant, reptile and bird species, even though they make up only about 3% of the Earth's area (Whittaker 1998).

Unfortunately islands have been disproportionately affected by humans. More than 80% of all of recorded extinctions (excluding fish) have occurred on islands, and most of these were caused, at least in part, by invasive species (Island Conservation analysis of data from IUCN Global Red List and World Conservation Monitoring Center 1992).

One of the most significant invasive species on islands are rats in the genus *Rattus*. They have been introduced onto about 82% of the world's islands and/or island chains (Atkinson 1985), where they frequently have a quantifiable negative impact on the distribution and abundance of native flora and fauna. This is most pronounced on oceanic islands where native species have evolved in the absence of mammalian predators and thus have limited behavioral, morphological, and life-history defenses against rats (Brown 1997). Consequently, rats have been implicated in 40-60% of recorded bird and reptile extinctions since 1600 (Groombridge 1992). Fortunately, it is possible to eradicate rats from many islands, and in the last 20 years there has been a series of technological innovations in the field of rat eradication that have dramatically increased the power of this important conservation tool (Figure 1, Galvan *et al.* 2005). Briefly, rats are eradicated by distributing a bait containing a rodenticide, usually brodifacoum, into all rat territories. Bait can be placed in bait stations spaced on a grid of 25 x 25 m to 100 x 100 m, or can be broadcast evenly at a known density either by hand on small islands or with a helicopter using a bait-spreading bucket on larger islands.

Palmyra Atoll National Wildlife Refuge, located in the Line Islands of the central Pacific Ocean, approximately 1760 km south of the main Hawai`ian Islands, likely never supported native mammals because of its remoteness. However, non-native black rats (*Rattus rattus*) were introduced to Palmyra, likely during the US military occupation of the atoll in the 1940s. The establishment of rats on Palmyra is believed to have had a major negative impact on the ecosystem, especially on seabirds, invertebrates, and vegetation.

Figure 1. Total area, number and maximum island size of global rat eradications per five years (1951-2005). Taylor and Thomas (1989) developed a systematic bait station approach which facilitated a dramatic increase in successful eradications. The application of aerial broadcast by the early 1990's allowed much bigger and complex island rat eradications (Source: ***Unpub. data:*** *Island Conservation, IUCN, University of California Santa Cruz, Auckland University)*



The Nature Conservancy (TNC), in conjunction with the US Department of Agriculture's Wildlife Services and the US Fish and Wildlife Service initiated a rat eradication on Palmyra Atoll in 2001 in an attempt to restore the island ecosystem. However, the eradication effort was suspended in August 2003 after it became apparent that the rats could not be eradicated using the methods employed despite the ongoing efforts of island staff and volunteers.

In the spring 2004, Island Conservation and TNC secured funding from Mr. Ian Cumming to conduct a site assessment on Palmyra and develop specific recommendations, techniques and options to complete the eradication. In August 2004, a team of nine people with experience in island rodent eradication or control (Table 1) visited Palmyra Atoll to gather enough information to plan a trial eradication and begin planning eradication of rats from Palmyra Atoll.

Table 1. Eradication assessment team

Name	Organization	Expertise
Gregg Howald	Director, Island Conservation	Ecotoxicology/Eradication/Compliance
Brad Keitt	NW Project Director, Island Conservation	Avian Ecology/Eradication
Araceli Samaniego	Project Director, Island Conservation	Rodent Ecology/Eradication
Stacey Buckelew	Biologist, Island Conservation	Island Ecology/Conservation
Dan Vice	USDA-WS, Guam	Wildlife Biology/Control
Earl Campbell	USFWS-ES, Hawai`i	Wildlife Biology/Control
Will Pitt	USDA-NWRC, Hawai`i	Wildlife Biology/Control
Pete McClelland	New Zealand Dept. of Conservation	Island Mgmt/Rodent Eradication/Endangered Species Mgmt.
Alex Wegmann	PhD student, U. of Hawai`i	USFWS Palmyra Refuge Support

An initial eight-day site assessment was held to conduct basic studies and define site-specific research to be continued by two Island Conservation staff who remained on the island for an additional four weeks.

OBJECTIVES OF SITE VISIT

1. Evaluate the constraints of eradicating rats from Palmyra Atoll.
2. Review past eradication efforts.
3. Conduct site-specific research to aid in design of an eradication project, specifically:
    a. Evaluate the arboreal nature of rats and their *planar* movements, to determine if bait application into trees would be necessary.
    b. Determine an effective broadcast application rate that would deliver enough bait to the rats.
    c. Evaluate the presence of brodifacoum resistance in the local rat population from chronic control during past eradication efforts.
    d. Compare palatability of baits to natural foods and various alternative baits.
    e. Evaluate degradation rates of different types of bait in the Palmyra environment.
4. Assess presence of and risks to potential non-target species, and develop any necessary mitigation measures.

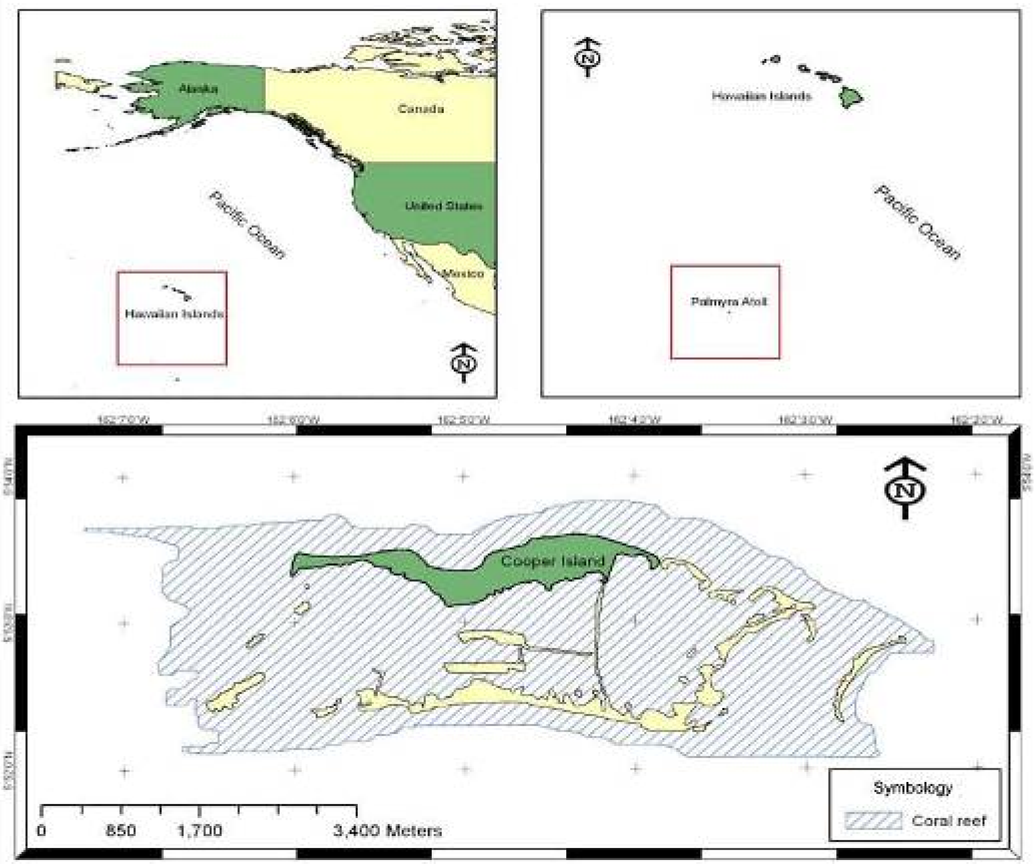
Field work was conducted from August 7 - September 11, 2004.

CONSTRAINTS

Access

Palmyra is approximately 1760 km south of Honolulu, in the Line Islands (Figure 2). Visitors to Palmyra can reach the atoll by either charter aircraft or by ship or boat. The atoll has a one-mile long coral rubble runway that is maintained by TNC staff. There is no regular air service to Palmyra, but TNC and USFWS regularly charter a small Gulfstream II twin turbo prop from Air Services Hawai`i, based on the south side of Honolulu International Airport. The aircraft can carry a maximum payload of 3300 pounds (both supplies and people). Maximum seating is for 18 persons. The cost for air charter is $20,000 for one round trip, typically with no overnight layovers.

Fig. 2. Location of Palmyra Atoll, Line Islands.



Ships and smaller pleasure craft visit the atoll regularly. The deepwater lagoon provides a safe, protected anchorage and can accommodate larger tugs and barges for deliveries of materials and supplies. TNC hires a tug/barge out of Honolulu to service the atoll yearly. The barge is able to tie up to Cooper Island near the old fish processing plant west of the main camp area. The cost of the barge/tug combination is a very expensive $150,000 per run.

Additional bareboat charters are available from the mainland and Honolulu, and the costs range from $2800 – $5500 per day, with some boats offering a maximum payload of 500,000 pounds.

Infrastructure

The developed portion of the atoll is on Cooper Island, and is owned and operated by TNC. TNC currently operates a full service tent camp capable of supporting 28 persons, with a generator for power and a rainwater collection system for drinking and wash water. Additional infrastructure includes old copra plantation buildings which provide shelter from the rain, a recreation facility, small dock, concrete bunkers, a well-maintained one mile long coral rubble runway for small aircraft and large propeller planes such as C-130s, and small boats to move personnel and gear between the islets. TNC charges users an access fee to fund the maintenance of these facilities.

Staff and guests are housed in groups of two in small weatherports. Two large weatherports support the communal kitchen/eating area, and shower/laundry facilities. The old fish plant and copra plantation buildings, and some additional weatherports, provide a workshop and ample storage space for equipment and supplies. Since the 2004 field work described in this report, TNC and a consortium of universities have completed construction of a new field research station on Palmyra.

Two small (about 18' long), plastic, open runabout boats are available to shuttle gear and people between islets as necessary. The shallow lagoon limits access to only a few landing points on the islets.

Weather

Palmyra lies within the Inter-Tropical Convergence Zone (ITCZ), the band of low pressure along the equator formed by the upward convection of warm, moist air from the Earth's surface. The climate of Palmyra is characterized by high humidity (>90%), warm temperatures (75 – 85 degrees Fahrenheit) with almost daily copious rainfall events associated with thunderstorms. Mean annual rainfall on Palmyra is 4.06 m.

Island Size and Topography

Palmyra Atoll is comprised of 54 islets encompassing 228 ha, rising to a maximum elevation of 2 m. The atoll is well within the size range of successful rat eradications (Figure 1). All of the land area can be accessed on foot, however, there are areas of thick vegetation, especially the *Scaevola* habitat, which precludes access without trail cutting. Although most of the islets are not connected, they can be reached by wading or swimming across the narrow channels that separate individual islets, or by boat.

There are potential safety concerns to eradication staff from unexploded ordnance, contaminated dump sites, hidden bunkers and marine wildlife (e.g. sharks), which could limit the successful implementation of a ground-based operation. Barrier and Quail Islands are inaccessible due to unexploded ordnance concerns. All areas of concern should be identified prior to implementation of the eradication.

Plants and Animals

The aseasonal climate on Palmyra supports dense vegetation of native and non-native trees and shrubs. A large portion of the atoll (approximately 48%) lies under a canopy of non-native coconut palm (*Cocos nucifer*a). Other habitat types include broadleaf forest composed of *Terminalia catappa,* the native *Pisonia grandi*s, and the shrub-like *Scaevola sericea* and *Tournefortia argenatea*. The *Pisonia* forest was once regarded as the best example of a pristine *Pisonia* forest in the American Pacific, but the trees are now dying due to stress response from introduced scale insects whose populations are inflated due to their symbiotic relationship with the introduced ant *Pheidole megacephala*. The decline of the *Pisonia* forest has caused dramatic changes in the Palmyra ecosystem.

The terrestrial habitats on Palmyra support 10 species of breeding seabirds. There are no breeding landbirds on Palmyra, but the island supports overwintering populations of Bristle-thighed Curlews (*Numenius tahitiensis*) and other shorebird including Wandering Tattlers (*Heterscelus incanus*), Pacific Golden Plovers (*Pluvialis fulva*) and Ruddy Turnstones (*Arenaria interpres*). The curlew and Pacific Golden Plover are designated by the US and Region 1 Shorebird Conservation plans as Species of High Conservation Concern because of limited breeding and non-breeding distributions, low relative abundance, and a decline in populations.

Palmyra supports a notably diverse assemblage of six landcrab species, including the large coconut crab (*Birgus latro*). The most abundant landcrab is the red hermit crab (*Coenobita* *perlatus*). Additional species include the purple hermit crab (*Coenobita brevimanus*), orange land crab (*Cardisoma carnifex*) and purple land crab (*Cardisoma rotundum*). These crabs compete with rats for access to the bait.

There are two terrestrial reptile species on Palmyra, an introduced house gecko (*Hemidactylus frenatus*) and a native mourning gecko (*Lepidodactylus lugubris*).

Palmyra supports a diverse collection of both native and non-native insects, including cockroaches and ants that are known to compete with rats for access to bait. During the first eradication attempt, it was noted that ants overwhelmed some bait stations, completely consuming the bait present in the stations within 24 hours.

Two domestic cats and a domestic dog are present as pets on the atoll, as well as one cat that is confined to a boat moored in the lagoon. We recommend that the pets be removed from the atoll prior to any eradication attempt. These animals would be at risk of exposure to any rodenticides used during an eradication effort.

REVIEW OF PAST ERADICATION EFFORTS

A review of the past eradication efforts was conducted in an attempt to identify why the eradication failed, so that some benefit can come from the time, energy and financial resources put into that project, and to ensure that any mistakes are not repeated in future efforts. This section summarizes the observations made by the crew that visited the island in August 2004. The review was designed to identify the processes or systems that failed.

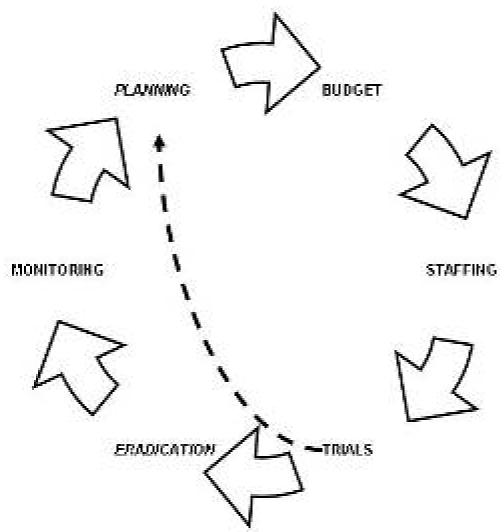
The three fundamental, and interrelated, parts of a successful rat eradication are:

1. exhaustive planning,
2. ongoing and effective communication between and among participants, and
3. adequate funding to implement the plan, including a contingency for unexpected costs or needed modifications to the eradication plan.

Planning

Based on the information that was provided, there appears to have been a lack of detailed planning, with only an Environmental Assessment that functioned as a written plan. No detailed plan was peer reviewed for potential problems, or shared with all participants to ensure continuity. Insufficient planning resulted in the use of techniques that proved inadequate to eradicate the rats. There was an ineffective management structure, use of volunteers and other staff with no expertise in rat eradication, poor communication between the involved parties and an inadequate budget to complete the eradication. The lack of a monitoring and communication plan led to poor data feedback to management and technical support that resulted in the continued use of inappropriate techniques and eventually contributing to a failed eradication (Figure 3).

Figure 3. A conceptual model of constant evaluation needed for a successful eradication project.



Communication

Initiating the eradication with an inappropriate approach or technique does not have to result in a failed eradication if there are adequately trained staff collecting data and making observations that are delivered to management and technical support staff, to troubleshoot and make modifications to the program as necessary.

There were many parties involved in the eradication, including USDA-Wildlife Services, US Fish and Wildlife Service, The Nature Conservancy management, TNC island managers and staff, a range of bait station technicians from previous projects and a series of inexperienced volunteers. There was no written communication plan that outlined either individuals' role or lines of communication for various aspects of the eradication. There appears to have been periodic communication breakdowns between the parties that led to strained relations between individuals and reluctance to share data or information. A detailed plan with an effective communication structure could have facilitated the relaying of information to appropriate support staff, who could have identified and rectified the problems with the eradication early and made the necessary changes.

Funding

The initial budget submitted to the National Fish and Wildlife Foundation was grossly inadequate to complete the project. The project appeared to be supply-driven, i.e., the project was constructed within the confines of the available funds. The project relied on the use of unpaid, inexperienced volunteer bait station technicians who were unable to identify subtle problems. Similarly, there was no contingency to modify the project as unanticipated problems arose.

The attempted eradication should not have been started given the inadequate funding. It is extremely important that eradication projects are adequately budgeted, with an appropriate contingency to respond to unexpected, unpredictable challenges. If only partial funding can be found, the project should be delayed until adequate funding is secured.

Eradication Technique

Successful eradication of rats from islands requires the use of techniques that:

1. Put every individual rat at risk from the proposed technique(s),
2. Remove/kill rats faster than they can replace themselves (breed), and
3. Prevent the in-migration by other rats.

Because of Palmyra's isolation, and the basic quarantine measures for ships and barges that regularly visit the atoll, the risk of rats immigrating to Palmyra is very low. Thus, the eradication efforts focus on steps 1 and 2.

The aseasonal, warm, humid climate and abundance of natural foods on Palmyra enable a sustained high density of rats that likely breed year round. Rats are capable of producing and weaning a litter every month. Thus, any technique that is used on Palmyra requires that the eradication be carried out intensively and as quickly as possible. The eradication attempt between 2001 and 2003 delivered bait in bait stations and could have killed the rats faster than they were breeding, assuming they had access to the bait stations, there was enough bait in the stations, and rats consumed the bait and were susceptible to the rodenticide.

Our assessment of the technique used in the previous eradication attempt focused on:

- **Bait availability** – Did all rats have access to bait stations and bait within the bait stations?
- **Bait palatability** – Did rats eat the bait?
- **Bait susceptibility** – Did all rats die after eating the bait?

Bait Station Design

The eradication of rats from Palmyra was initiated in 2001 initially with the placement of PVC tube bait stations placed on the ground. The stations certainly allowed rat access to the baits, but stations were readily overwhelmed by the abundant landcrabs and hermit crabs that were attracted to and consumed the bait. The stations were modified to elevated platforms with a small PVC tube that excluded some but not all landcrabs and hermit crabs from the stations. The final bait station design was made of empty 15 liter bait buckets modified to exclude crabs using a raised access hole (4.4 cm diameter, about 20 cm above ground) with bait suspended by wire near the bottom of the bucket. A baffle was put in place to prevent the large coconut crabs (which could not feasibly be excluded from the buckets) from "sweeping" the station, with a claw, for the bait. For rats to gain access to the bait, rats had to jump up to the hole, climb through the hole, jump down into the bucket and/or over the baffle. Bait blocks had to be chewed off a wire, which required rats to either consume part of the block in the station, or only remove part of the block from the station. To exit the station, rats had to jump over or onto the baffle edge, then jump up or over to the access/exit hole. The stations were secured in place with a large piece of coral rubble found in the vicinity of the station. Landcrabs, cockroaches, and ants competed with the rats for access to the bait in all bait station designs.

The third and final bait station design was successful in excluding the majority of landcrabs from gaining access to the bait within the stations (see Vice 2004,Appendix 1). However, there is a possibility, unconfirmed, that the modified bait stations design either physically or behaviorally excluded rats from the stations. Later in the project, personnel reported that rats routinely were observed to walk past armed bait stations, apparently ignoring the station. Similarly, there were reports of numerous bait stations that had no bait removed, yet live traps placed nearby or on top of the stations routinely captured rats. This indicates that some rats could not, or would not, enter the bait stations. It is unclear if it was a problem with the bait station design physically excluding the rats, or if the attractiveness of the bait was not high enough compared to the abundant natural foods. In other words, it is unknown if some of the rats simply chose not to enter the stations.

Bait Station Spacing

The stations were placed at approximately 50 m intervals laid along transects that were cut perpendicular to the axis of each islet. It appeared from the map of bait stations, and from a general walk around on the atoll, that the spacing was accurate, and all peninsulas and small islets had bait stations. The use of 50 m spacing of bait stations was based on the successful use of 50 m spacing of stations at Kure and Midway Atolls, and is typically the standard applied to island *Rattus rattus* eradication in the more temperate climates. (*Rattus exulans* were removed from Rose Atoll (6 ha) using bait station spacing at 30 m, in addition to live traps and snap traps at 10 m intervals.) The 50 m spacing was established to ensure that there are at least two or more bait stations in each and every adult rat home range or territory. An individual rat would require a minimum ranging area of 2500 m^2 to encounter at least one station within its territory.

Our radio telemetry data comparing the movements of rats live-trapped in coconut palms with rats trapped on the ground demonstrated that rats on Palmyra live in a three-dimensional environment, and regularly move between the tree canopy and the ground. The trees on the atoll, especially the abundant coconut palm, provide abundant food and shelter for rats. The ranging or *planar* movements of rats captured in coconut palms on Palmyra was particularly small, with a mean of 693 m^2 and a maximum of 1215 m^2. The *planar* ranging area of rats on Palmyra was measured to be smaller than typically measured elsewhere in more temperate climates, including Hawai`i. *R. rattus* in Hawai`ian forests were reported to have a mean home range of 3.6 ha (36,000 m^2) (range: 1.57-4.45 ha) (Lindsey *et al*. 1999) and *R. rattus* in New Zealand forests were noted as having home ranges as small as 0.3 ha (3,000 m^2) (Hooker and Innes 1995). The smaller *planar* movement measured on Palmyra is likely due to both the three-dimensional environment available and the abundance of natural foods. Thus, the rats could live in high densities and not have to move great distances to meet their life needs – food, water, shelter and mates to reproduce. Thus, we hypothesize that the rats, especially those with small territories, could have likely survived and either never encountered or infrequently encountered bait stations spaced at 50 m intervals. Some of these rats which did not encounter or avoided contact with the bait stations likely formed part of the residual population that repopulated the island after the eradication efforts were suspended.

Rat home ranges seem largely dependent on site-specific topography, rat density, habitat type, and food availability. Thus, to ensure a successful eradication, site-specific data must be relied upon as an indication of rat home ranges. Spacing of bait stations at 25 m intervals would ensure rats with territories as small as 625 m^2 would encounter at least one bait station within their territories.

Bait

For a successful eradication of introduced rats from an island, the fundamental requirement is that every last rat is removed or killed. Leaving even one pregnant female alive on the island, or failing to prevent future re-introductions, can negate the financial and time commitment devoted to eradicating rats initially. Thus, every effort must be made to get the last rat. The use of rodenticides for restoring islands is a powerful conservation tool. Used effectively, removal of the last rat is possible and rat eradications have been carried out over 250 times worldwide (Island Conservation, unpub. database).

To be an effective eradication tool, bait must:

- contain an active ingredient that is known to be highly toxic to the target population,
- be palatable and induce low or no bait shyness from the target population,
- be consumed in sufficient amounts by each rat to receive a lethal dose.

Of all known rat eradications worldwide, the vast majority have used the anticoagulant rodenticides, mainly brodifacoum (a second-generation anticoagulant), as the primary method of removal. The mode of action for brodifacoum is to prevent the production of active clotting factors by blocking the vitamin K-reductase enzyme in liver microsomes. The lack of active clotting factors leads to the inability of clot formation at sites of hemorrhage. The lack of clot formation leads to fatal hemorrhaging usually from a single point or multiple locations. Death typically results from complications due to hypovolemic shock. The major advantage of the anticoagulants is that the onset of poisoning symptoms is delayed until after consumption of a lethal dose. Thus, rats do not associate the symptoms of poisoning with the bait and bait shyness is avoided.

Over half of known rat eradications worldwide have used brodifacoum exclusively; the remaining projects used additional rodenticides or trapping as a secondary or tertiary means of removing rats (Figure 4). The introduction of an alternate rodenticide is used as a strategy to deal with individual rats that may have avoided the primary rodenticide through taste or behavioral aversion (e.g. USDA 2002). On other tropical islands (Rose Atoll, Kure Atoll, Sand Island, East Island, Midway Atoll), brodifacoum has been used as the primary rodenticide and occasionally bromethalin (an acute rodenticide) has been used as the secondary rodenticide. The mode of action for bromethalin is to uncouple oxidative phosphorylation in the mitochondria in cells of the central nervous system leading to a decreased production of ATP. Low levels of ATP inhibit the activity of the Na/K ATPase and lead to a subsequent buildup of cerebral spinal fluid. The increased cerebral spinal fluid results in high intracranial pressure, causing damage to nerve axons, inhibiting neural transmission and leading to paralysis, convulsions and death.

In the first rat eradication attempt on Palmyra, two baits containing two active ingredients were used. The bait used most extensively was Weather Block XT (Syngenta Crop Protection Inc.) containing 50 ppm brodifacoum. The bait was a 20 g blue wax block with a small hole in the center. The USDA (2002) reported 1,764.5 kg of Weatherblock XT had been applied on Palmyra by June 11, 2002. The total amount used after June 11, 2002 through August 2003 (end of eradication attempt) is not reported.

The second bait type was Fastrac All Weather Blox (Bell Laboratories, Inc.), containing 100 ppm bromethalin. The bait was a 20 g green wax block, tubular-shaped, with a small hole running through the longitudinal center of the block. The USDA (2002) reported that very little Fastrac bait containing bromethalin was used during the eradication attempt (25.3 kg) on "several islands" by June 11, 2002 during the first year of the eradication attempt. The amount of bromethalin used through the entire duration of the eradication attempt (through August 2003) was not reported.

When applied correctly, the use of bait containing brodifacoum and bromethalin has a high probability of successfully eradicating rats from islands. The rodenticide choice for Palmyra was appropriate and had a high probability of facilitating a successful eradication had the rats consumed lethal amounts of bait. However, Weatherblock XT contains Bitrex (a brand name for the bittering agent known as denatonium benzoate). The intent of the addition of Bitrex into rodenticide baits is to prevent the accidental consumption of rodent baits by children when used in urban settings. However, it is also known to reduce the acceptance of the bait to rats under laboratory conditions (Veitch 2002) and it is generally accepted that bait uptake declines with the addition of Bitrex into baits. Bait containing Bitrex is not recommended for use in island eradications due to the increased risk of bait shyness in individual rats potentially leading to eradication failure. On Palmyra, Bitrex may have caused some rats to avoid the bait (bait shyness) and not consume a lethal dose. Thus, Bitrex is another factor that may have compromised the success of the first eradication attempt.

The ongoing, chronic use of brodifacoum to control the rats on Palmyra may have led to the selection for individual rats that were physiologically more tolerant or resistant to the rodenticide. Over time, this can lead to the development of a resistant population, which makes it more and more difficult to control rats using that particular rodenticide. Although brodifacoum is highly toxic to rats, resistance to the second generation anticoagulants has been shown to develop in rodent populations in the United Kingdom (Cowan *et al.* 2004). Intensive baiting on Palmyra took place for a number of years (three years during the failed eradication attempt alone) around the camp complex on Cooper Island, primarily with brodifacoum, but also occasionally with diphacinone. The intensive rodent control may have been selecting for rats that are more tolerant of the rodenticides, either through the ability to metabolize and excrete the compound, or tolerance to higher doses. The investigation into resistance in August 2004 suggested that the early stages of brodifacoum resistance were present in the Cooper Island rat population (Pitt 2004, Appendix 2). Thus, ongoing baiting with brodifacoum alone could have led to the failure of eradication on Palmyra, even if all the additional biological problems were rectified. Ongoing use of 4-hydroxycoumarin anticoagulants may result in a population of rats that are resistant to the entire suite of anticoagulant rodenticides (Macnicoll 1986). Thus, to overcome resistance, a non-anticoagulant, possibly bromethalin, would have to be used.

CONCLUSIONS ON PAST ERADICATION EFFORTS

The benefit of looking back on a failed eradication attempt is that the problems identified can be rectified in a new eradication plan for Palmyra and raise awareness for other tropical and non-tropical island ecosystems in which rat eradication is desired. The eradication attempt on Palmyra Atoll between 2001 and 2003 violated the first two rules for eradication: all individuals were not at risk from the eradication technique, and the rats were repopulating the island at least as quickly as they were removed from the ecosystem in the latter stages of the baiting operation. There were problems with the planning, communication, and funding that were complicated by the local biological conditions, especially the competition from landcrabs and the small ranging territories of rats on the island. There was an assumption that the same management and eradication techniques applied successfully elsewhere could be applied on Palmyra without any background research or trials. A small scale trial would have revealed that the technique of eradication would not have been successful and could have allowed for research into new techniques, such as the effective bucket bait station that was ultimately designed and used. However, the bait buckets designed to exclude crabs could have excluded rats, the spacing of the bait stations physically excluded some rats from gaining access to the bait, the presence of Bitrex in the bait likely caused bait shyness in some individual rats, and the chronic baiting apparently resulted in slight brodifacoum resistance. Cumulatively, these problems presented insurmountable challenges to the eradication because there was no research/monitoring program built in to identify and then rectify problems. Had a project manager with expertise in rat eradication been involved with the project throughout, these problems could have been identified early, saving money, time, effort and frustration. Unfortunately it is unclear to what extent each of these problems alone or in combination caused the failure of the eradication.

The adaptive management approach is necessary in all eradication attempts, as each project presents its own unique set of challenges. Although Palmyra's ecosystem presents new challenges to rat eradication, they are not insurmountable and with the data collected during the site assessment in August 2004, an effective eradication plan can be developed. The eradication plan will need to be tested in a trial to identify potential problem areas and develop solutions to be implemented prior to the successful completion of an eradication on the atoll.

STUDIES CONDUCTED ON PRE-ERADICATION TRIP ASSESSMENT

We conducted the following research during the site visit and assessment in August 2004 to support the development of a rat eradication plan.

Evaluate Arboreal Nature and Planar Movements of Rats on Palmyra Atoll

Methods

Since the movement, behavior, and canopy use by rats on Palmyra Atoll was unknown, we monitored a group of radio-collared rats within a palm forest (5 ha) on Cooper Island. Live traps baited with fresh coconut were set both on the ground (25 m apart) and in coconut trees (20-50 m apart). Traps were checked and reset daily for one week. Radio collars were put on nine rats captured on the ground and 12 rats captured in the tree traps. We only put collars on rats that weighed >100 g (collar weight approximately 5g). All rats were fitted with radio collars, observed over a 24-hour period, and released on their respective capture site. Directional Yagi antennas and digital receivers were used to monitor rat activity daily. The study area was visited nightly (2100-0000) and alternately in the dawn (0430-0700) and afternoon hours (1300-1500) to assess movement and refuge behaviors. Individuals were tracked an average of 12.9 days (s.d.=6.4). Data recorded for each individual included active/inactive status, specific spatial location (bearing and distance from a fixed marker location), and whether the animal was on the ground or in a tree. Signals determined to be inactive for >1 week were excluded from analysis. Daytime and nighttime locations for each individual were georeferenced from fixed marker locations using Garmin MapSource software and imported to ArcView for further analysis. Range areas were determined using a maximum-area calculation from peripheral locations encompassing the majority of central locations (assumed or confirmed refuge locations) including any stray or outlying positions. We believe this to be an adequate measure of ranging area for the purpose of determining an adequate spacing of bait stations to ensure that all rats have access to stations.

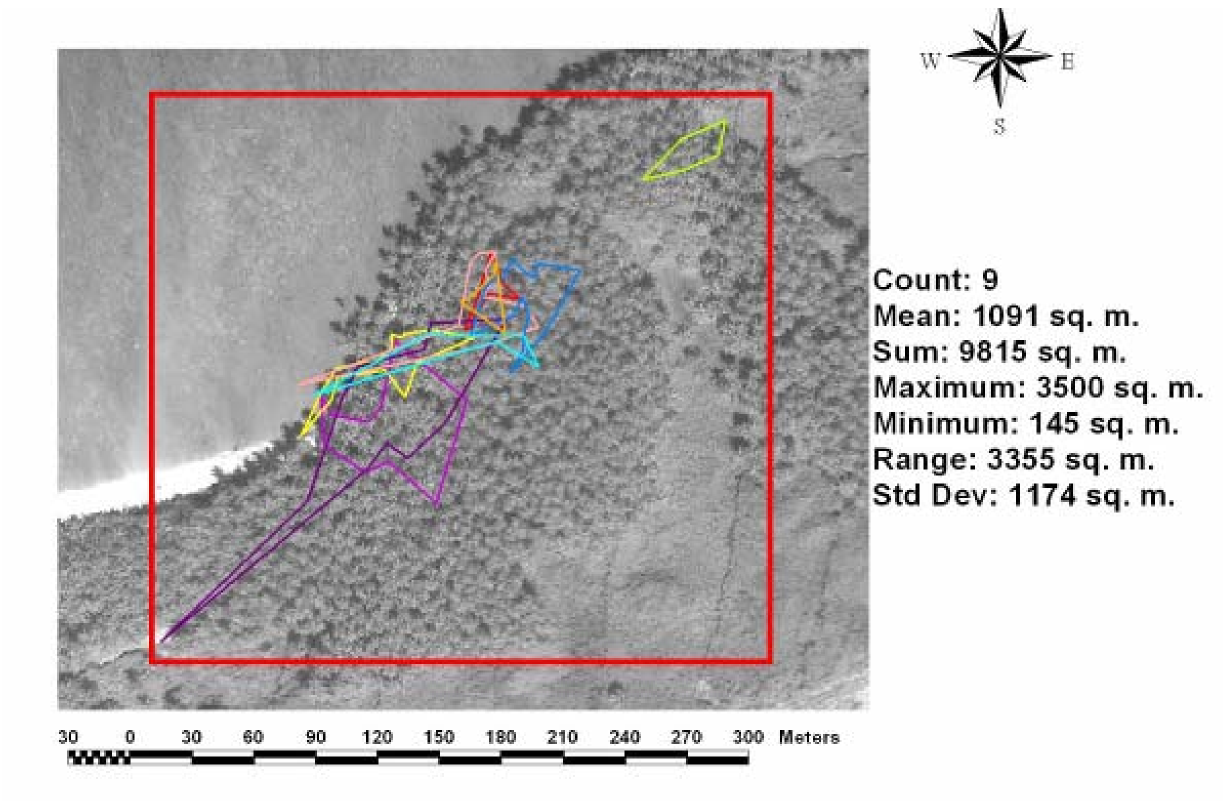
Results and Discussion

Mean ranging area for rats trapped in trees was 693 m^2 (s.d.=334) and 1091 m^2 (s.d.=1174) for ground-trapped rats (Figs. 5 and 6). Males, in general, covered a larger home range area (mean = 1317 m^2) than females (mean = 424 m^2), which is typical for this species (Table 2). Our results indicate that ranging areas were surprisingly small, but may be explained by the year-round availability of nesting and food resources. Small home range areas are also consistent with observations of high rodent abundances, which usually result in each rat having a smaller ranging territory (H. Gellerman, pers. Comm..) The information about rat movement therefore suggests that the distance between bait stations in previous eradication effort was likely too great to put all rats at risk of exposure.

All tree-trapped individuals ventured down and spent nearly 51% of the measured time on the forest floor. Inversely, ground trapped rats were observed in the canopy 29% of the measured time. This result suggests no rats are strictly arboreal, which is particularly favorable if a bait station eradication approach is implemented.

Although rats were more active during the evening hours, the Palmyra population showed a high level of diurnal activity compared to other populations. This may be related to the high

Figure 5. Ranging areas of 9 ground captured radio collared rats, Palmyra Atoll, August 2005.



percentage of foliage cover (both canopy and understory) and lack of predators, and/or the high density of rats competing for resources.

Figure 6. Ranging areas of 11 tree captured, radio collared rats, Palmyra Atoll, August 2005.

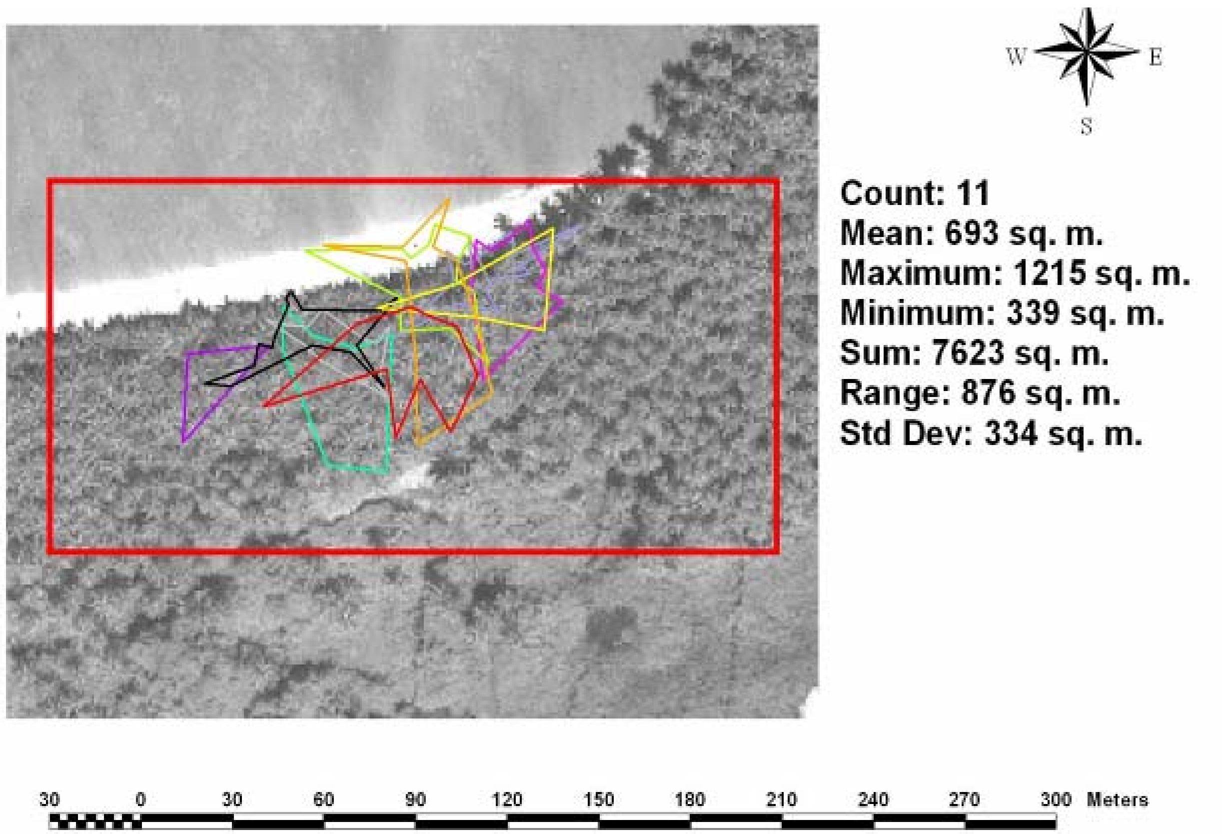


Table 2. Mean, minimum, maximum and median ranging areas (m^2) of rats on Palmyra Atoll (2004). Median home ranges represent territory sizes.

	Mean	Min	Max	Median
Male (10)	1317	429	3500	1008
Female (11)	424	145	744	367

Assuming that the ranging area data collected in August, 2004, is representative of rat ranging distances, it is clear that a very tight bait station spacing would be required to ensure delivery of bait to all rats. Using the lowest ranging territory measured, approximately 68 bait stations per hectare would be required to capture every rat territory, or about 15,436 stations atoll-wide. Installation of 15,000 bait stations may not be feasible because it would likely be expensive to install and maintain.

Calibration of a Broadcast Application Rate

If an aerial or hand bait application is used it is essential to apply enough bait so that it is available to rats for about four days. To calculate the appropriate bait application rate, one must consider both the uptake of bait by rats and by other species. In tropical systems such as Palmyra, land and hermit crabs would play a significant role in removing bait from the environment. Although crabs and other invertebrates are not susceptible to anticoagulant rodenticides, they are attracted to and compete with rats for bait. Thus, the total estimated uptake of bait by both rats and crabs must be considered for accurate bait application rate estimates.

During the field assessment, bait uptake at various application rates was initially measured using placebo bait (bait without brodifacoum added) in a plot with an unmonitored buffer zone. The buffer zone was intended to reduce the attraction of crabs to the bait in the uptake plot. This method was abandoned after initial results demonstrated artificially high crab densities even with large buffer zones. Although there was an obvious edge effect to the measured bait uptake, the required bait application rate using this method was approximated to be in excess of 60 kg/ha.

Because of the complications associated with the uptake plots, we estimated the potential uptake of bait loss by crabs using daily bait consumption rates of crabs in large cage trials multiplied by the density of crabs measured in the field. We acknowledge that this is a limited estimate and may not reflect true bait loss. It does, however, allow for "ballparking" a broadcast application rate. To estimate crab uptake across the atoll two factors were measured: 1) bait consumption for each species, and 2) number of individuals by species per unit area (crab density). Individual consumption rates for the four most abundant land crab species (*Coenobita perlatus* (N=3), *Coenobita brevimanus* (N=3), *Cardisoma carniferex* (n=5), *Cardisoma rugosa* (n=5)) were measured in captivity. All crabs were fed CI-25 placebo bait and consumption was measured using a digital balance every 12 hours over a four-day period. In collaboration with Alex Wegmann (University of Hawaii), an atoll-wide crab density survey for all five species was conducted. Five percent of the emergent land area across the major habitat types was surveyed and 250 m transects (2.5 m x 50 m) were randomly chosen from a geo-referenced Palmyra Atoll 25 m survey grid. All *Coenobita*, *Cardisoma,* and *Birgus* crabs encountered on the transects were counted with tally-counters to ensure accuracy. Prominent habitat type was recorded for each transect, and for transects that spanned more than one habitat type the habitat composing the majority of the transect was recorded. In addition, the time of day and weather conditions were recorded at the start of each transect. The survey results for each habitat type were used to extrapolate an atoll-wide population estimate for each species.

Crab density data were not normal (left-skewed) when tested with normal probability plots. Square root transformation of the data solved this issue. Thus, density estimates were square-root-transformed to perform descriptive statistic analyses of the mean, standard deviation, upper and lower confidence intervals. Once descriptive statistics were performed, data were back-transformed to yield corrected density mean, standard deviation, and upper and lower confidence intervals.

Major habitat types and their extension on Palmyra Atoll are described in Table 3, below:

Table 3. Area (ha) of major habitat types on Palmyra					
Palm forest	**Open ground**	***Pisonia* forest**	***Scaevola* forest**	***Terminalia* forest**	**ATOLL**
98.2	20.8	23.8	65.5	19.2	**227.6**

Results and Discussion

The statistical estimates of the crab densities on the atoll are presented in Table 4. Red hermit crabs (*Coenobita perlatus)* were measured as the most abundant crab species on the atoll.

Using the captive crab consumption/density approach to bait application estimate, we estimate the highest bait application required to overcome crab consumption over four days to be between 3.34 and 47.74 kg/ha, in addition to the application required to deliver bait to rats (Tables 5 and 6).

Our results indicate both land and hermit crabs are important competitors with rats for bait. Hermit crabs consume less than land crabs, but are more abundant on the atoll. Due to logistical difficulties during the experiments (such as potential captive stress-level effects and weather conditions) the consumption rates by crabs may be underestimated.

Table 4. Estimated crab densities per hectare. Means, standard deviation, upper confidence intervals (Upper CI), and lower confidence intervals (Lower CI) for Palmyra Atoll, 2004.

	Purple hermit crab	Red hermit crab	Orange land crab	Purple land crab	All crabs
Forest Type	***Terminalia* forest (19.2 ha)**				
Mean (crabs/ha)	139	185	18	26	368
Standard Dev	19	68	1	0	88
Upper CI	205	296	33	40	574
Lower CI	87	99	7	15	209
Forest Type	***Scaevola* forest (65.5 ha)**				
Mean (crabs/ha)	14	179	46	9	248
Standard Dev	0	113	7	2	122
Upper CI	24	312	77	15	428
Lower CI	7	82	23	4	116
Forest Type	***Pisonia* forest (23.8 ha)**				
Mean (crabs/ha)	7	116	55	54	231
Standard Dev	8	39	17	13	76
Upper CI	9	190	97	93	390
Lower CI	4	60	25	26	115
Forest Type	**Open (20.8 ha)**				
Mean (crabs/ha)	5	15	4	5	30
Standard Dev	6	0	13	4	23
Upper CI	8	29	5	9	51
Lower CI	3	6	3	3	14
Forest Type	**Coconut palm forest (98.2 ha)**				
Mean (crabs/ha)	67	416	44	47	574
Standard Dev	6	182	4	5	197
Upper CI	100	631	69	75	874
Lower CI	40	246	24	26	336
Grand Total Means	**232**	**910**	**166**	**142**	**1450**

Table 5. Predicted crab bait consumption (kg/ha) (mean, std. dev, upper and lower confidence intervals) by species and habitat type over four days assuming mean consumption rate, Palmyra Atoll, 2004. Value highlighted in yellow indicates highest probabl application rate to overcome crab bait loss.

	Purple hermit crab	Red hermit crab	Orange land crab	Purple land crab	Pooled
Forest Type			***Terminalia* forest**		
Mean	0.53	0.71	0.07	0.1	1.41
Standard Dev	0.07	0.26	0	0	
Upper CI	0.78	1.13	0.13	0.15	2.19
Lower CI	0.33	0.38	0.03	0.06	0.8
Forest Type			***Scaevola* forest**		
Mean	0.05	0.68	0.18	0.03	0.95
Standard Dev	0	0.43	0.03	0.01	
Upper CI	0.09	1.19	0.3	0.06	1.64
Lower CI	0.03	0.31	0.09	0.02	0.44
Forest Type			***Pisonia* forest**		
Mean	0.03	0.44	0.21	0.21	0.88
Standard Dev	0.03	0.15	0.06	0.05	
Upper CI	0.04	0.73	0.37	0.36	1.49
Lower CI	0.02	0.23	0.09	0.1	0.44
Forest Type			**Open**		
Mean	0.02	0.06	0.02	0.02	0.11
Standard Dev	0.02	0	0.05	0.02	
Upper CI	0.03	0.11	0.02	0.03	0.19
Lower CI	0.01	0.02	0.01	0.01	0.05
Forest Type			**Coconut palm forest**		
Mean	0.25	1.59	0.17	0.18	2.19
Standard Dev	0.02	0.7	0.01	0.02	
Upper CI	0.38	2.41	0.26	0.29	**3.34**
Lower CI	0.15	0.94	0.09	0.1	1.29

Table 6. Predicted crab bait consumption (kg/ha) (mean, std. dev, upper and lower confidence intervals) by species and habitat type over four days *assuming maximum consumption rate,* Palmyra Atoll, 2004. Value highlighted in yellow indicates application rate to overcome crab bait loss.

	Purple hermit crab	Red hermit crab	Orange land crab	Purple land crab	Pooled
Forest Type	***Terminalia* forest**				
Mean	1.03	12.19	0.71	0.92	14.85
Standard Dev	0.14	4.5	0.03	0	
Upper CI	1.51	19.54	1.31	1.41	23.77
Lower CI	0.64	6.57	0.29	0.53	8.03
Forest Type	***Scaevola* forest**				
Mean	0.11	11.8	1.81	0.31	14.03
Standard Dev	0	7.5	0.27	0.06	
Upper CI	0.18	20.62	3.05	0.53	24.37
Lower CI	0.05	5.43	0.89	0.15	6.53
Forest Type	***Pisonia* forest**				
Mean	0.05	7.65	2.15	1.89	11.74
Standard Dev	0.06	2.55	0.66	0.44	
Upper CI	0.07	12.58	3.81	3.25	19.71
Lower CI	0.03	3.95	0.97	0.9	5.85
Forest Type	**Open**				
Mean	0.04	1	0.16	0.18	1.38
Standard Dev	0.04	0.03	0.5	0.15	
Upper CI	0.06	1.89	0.21	0.31	2.46
Lower CI	0.02	0.39	0.12	0.09	0.62
Forest Type	**Coconut palm forest**				
Mean	0.49	27.47	1.72	1.65	31.34
Standard Dev	0.04	12.02	0.14	0.18	
Upper CI	0.74	41.67	2.71	2.62	**47.74**
Lower CI	0.3	16.22	0.96	0.91	18.39

Brodifacoum Resistance

We conducted two trials evaluating the susceptibility and potential resistance of rats to brodifacoum from long-term use on Cooper Island. The details of the study and results can be found in Pitt 2004 (attached).

In summary, one of the rats, dosed at four times the LD50, died 21 days post-dosing and showed no symptoms characteristic of anticoagulant poisoning. This situation suggests that slight resistance to brodifacoum may occur within the population, and/or vitamin K (an antidote to brodifacoum) is abundantly available and consumed on the atoll. Vitamin K is contained in coconut fruit, particularly in young green coconuts, but its relative importance in the diet of the rats on Palmyra is unclear.

Rat Bait Preference

Methods

Potential baits for use during an eradication on Palmyra were tested for palatability in paired trials against other bait types or natural foods. Individual rats were live-trapped and held a minimum of 24 hours pre-trial. Trials consisted of 10 individuals each presented with paired food types. Food types were presented in random locations within the cage to reduce spatial selectivity. Trial results were determined by observation of first bait/food type selected. Thus, the first bait tasted by a rat was considered preferred. Each rat was observed for an additional period after the animal made its first choice to see if the rat switched and consumed the alternative bait/food type. The time to selection was recorded for each individual in addition to any switches made to the alternate bait/food choice during the trial. Three main trial types were conducted: 1) commercial bait vs. competing commercial bait to assess bait preference; 2) bait vs. bait of the same type at various stages of degradation to determine if bait exposed to environmental conditions was palatable; and 3) bait vs. natural foods known to be consumed by rats on Palmyra.

Results and Discussion

The results (Table 7) indicate that CI-25 (the bait developed by Bell Labs and Island Conservation for use on Anacapa Island, Channel Islands National Park, California) was the most preferred bait when compared to both natural foods and other baits. Ramik (2 g) was preferred to Ramik (8 g) and natural *Terminalia* fruit but not Weatherblock XT. As has been found in other studies (Howald *et al.*2005), bait exposed to environmental conditions and lightly covered with mold was preferred to fresh bait.

Table 7. Results of rat preference trials, Palmyra Atoll, 2004.

Baits in Trial	Preferred	Preference (%)
Paired Bait Trials		
CI-25/Ramik (8g)	CI-25	90
CI-25/Ramik(broken 8 g)	-	50
CI-25/Ramik (2 g)	CI-25	60
CI-25/CI-25 (wax coat)	CI-25	60
Ramik (8 g)/Ramik (2 g)	Ramik (2 g)	100
Ramik (8 g)/Weatherblock	Weatherblock	100
Degraded Bait Trials		
Wblk/ Wblk (mold – 1 wk)	Moldy Wblk	70
Wblk/ Wblk (mold – 2 wk)	Moldy Wblk	60
Natural Food Trials		
CI-25/Coconut	CI-25	100
Ramik (2 g) /*Terminalia* fruit	Ramik (2 g)	60

Bait Degradation

In order to ensure effective bait delivery to rats on the island, the bait must be able to withstand the island's climate and retain its size, shape and consistency. The rate of bait degradation is related to weather conditions, and is more rapid under the hot, humid, and wet climate of Palmyra.

Methods

To determine how well different types of bait retain their consistency in the Palmyra environment, degradation trials were conducted in natural conditions and in bait stations. Details of the degradation trial can be found in McClelland (2004) (Appendix 2).

Results and Discussion

The degradation rate for each type of bait in natural conditions was very similar among habitat types, indicating that type of bait is more important than microhabitat (Tables 8 and 9). The most preferred bait, CI-25, could not withstand the humid conditions and disintegrated rapidly (mean = 3 days). In addition we observed that insects, especially ants, proved to be moderate consumers of all baits when .the bait was on the ground for more than 10 days.

In bait stations, Weatherblock withstood environmental conditions similarly among habitat types and resisted mold for one week longer than when fully exposed to the environmnent (Tables 8 and 9).

Our results demonstrate that the Weatherblock bait and the large (8 g) Ramik placebo broadcast baits proved to be effective in withstanding degradation (mold/moisture).

Table 8. Results of degradation trial by habitat type and fully exposed to the environment, Palmyra Atoll, 2004.

Bait type	Days to mold/crack	Days to disintegration
	Scaevola	
CI-25	1	3
Ramik (2 g)	2	5
Fastrac	4	>20
Generation block	4	>20
Weatherblock	7	>20
	Grassland	
CI-25	1	3
Ramik (2 g)	3	4
Fastrac	3	>20

Generation block	6	>20
Weatherblock	6	>20
Terminalia		
CI-25	1	3
Ramik (2 g)	2	5
Fastrac	3	>20
Generation block	7	>20
Weatherblock	6	>20
Pisonia		
CI-25	1	3
Ramik (2 g)	2	3
Fastrac	3	>20
Generation block	7	>20
Weatherblock	7	>20
Cocos		
CI-25	1	3
Ramik (2 g)	2	4
Fastrac	3	>20
Generation block	5	>20
Weatherblock	5	>20
Mean degradation		
CI-25	1.0 (s.d.=0.0)	3.0 (s=0.0)
Ramik (2 g)	2.2 (s.d.=.71)	4.2 (s=.84)
Fastrac	3.6 (s.d.=.89)	>20
Generation block	5.8 (s.d.=1.3)	>20
Weatherblock	6.2 (s.d.=.84)	>20

Table 9. Results of Weatherblok XT degradation trial in bait stations by habitat type, Palmyra Atoll, 2004.

Bait type	Days to mold/crack	Days to disintegration
	Scaevola	
Weatherblock	13	> 20
	Grassland	
Weatherblock	15	> 20
	Terminalia	
Weatherblock	13	> 20
	Cocos	
Weatherblock	13	> 20
	Pisonia	
Weatherblock	20	> 20
	Mean degradation (days)	
Weatherblock	14.8 (s.d.=3.03)	> 20

Non-Target Species and Mitigation Measures

Palmyra supports several species that may be at risk of disturbance or exposure to rodenticide if basic mitigation measures are not adopted. The range of species includes landcrabs (if bromethalin is used), breeding seabirds, migratory shorebirds, two species of sea turtles and possibly the Hawai`ian Monk Seal (*Monachus schauinslandi*). In addition, the two domestic cats and a dog on the island will require specific mitigation to prevent exposure to the rodenticides used.

Specific mitigation measures will need to be developed for each species to minimize the impact of disturbance and/or rodenticide exposure. The primary mitigation is the timing of the bait operation to minimize the numbers of individuals of each species of concern on the island during baiting operation. Specific mitigation measures adopted are dependent on the eradication strategy used and will be developed further in a separate recommendation report.

CONCLUSIONS FROM PRE-ERADICATION STUDIES

- Eradication of rats from Palmyra Atoll is quite feasible, however it is by no means trivial and there are several technical challenges.
- No rats are exclusively arboreal
- The *planar* movements of rats were relatively small, indicating that the distance between bait stations in previous work was too great for eradication.
- Broadcast application rates may need to be in excess of 60 kg/ha to compensate for loss of bait to the high density of crabs found in various habitats throughout the atoll.
- Possible mild resistance to brodifacoum exists within the rat population.
- Palmyra rats prefer CI-25 bait over both other available baits and key, naturally abundant and available foods.
- CI-25 bait degrades rapidly on Palmyra and does not last more than a few days.

MANAGEMENT IMPLICATIONS FOR FUTURE ERADICATION EFFORT

- Both bait station and aerial application approaches could be used (and/or required) on Palmyra Atoll.
- Broadcast application in excess of 60 kg/ha may be needed to compensate for crab uptake and competition for the bait, ensuring enough bait on the ground for 3-4 days.
- Both brodifacoum and a secondary rodenticide, such as bromethalin, could be used in the eradication attempt. Bromethalin should overcome any brodifacoum-resistant individual rats, but landcrabs are susceptible to bromethalin and would require specific mitigation if bromethalin is used, to prevent population level exposure.
- A bait should be developed that is as palatable as CI-25 and that can withstand the Palmyra climate.

- A bait is in development currently and will be in degradation/palatability tests on Palmyra in February 2005.

RECOMMENDATIONS

1. Carry out specific research to conduct a trial eradication and refine a plan for eradication of rats from Palmyra Atoll, including:
    - Confirming broadcast application rate.
    - Developing a broadcast bait that can withstand the climate on Palmyra.
    - Testing rat use of elevated bait stations.
2. Conduct a trial broadcast eradication on Palmyra Atoll, with two rodenticides.
3. Review results and modify the approach to eradication as necessary; then begin planning the eradication of rats from Palmyra Atoll.

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Toxicant Delivery Stations and Terrestrial Crab Exclusion

Project Summary – Palmyra Atoll
August 2004

Prepared by:

Daniel Vice
Assistant State Director
USDA, Wildlife Services
1060 Route 16, Suite 103C
Barrigada Heights, Guam 96913

INTRODUCTION

Successful delivery of anticoagulant poisons to every animal is the fundamental premise behind complete eradication of rats (*Rattus* spp.) from islands. In the absence of non-target species, bait delivered via aerial or hand broadcast can be made available to every animal in a defined time frame. However, non-target species often prevent the use of broadcast techniques, as primary and secondary uptake may adversely impact unintended targets and/or may limit bait availability to rats. On many tropical islands, terrestrial crabs occur in great abundance, and may consume bait directly, competing with rats and subsequently reducing bait availability. Additionally, crabs that have ingested toxicants become secondary hazards to migratory shorebirds, other native wildlife, and potentially, humans. To mitigate such hazards, anticoagulant toxicants are frequently delivered in secure bait stations. An ideal delivery device excludes all non-target hazards and allows free access to all sizes and species of rats.

Beginning in 2000, Palmyra Atoll, the northern most island in the Line Island chain, was the site of a black rat (*R. rattus*) eradication attempt, utilizing brodifacoum delivered in bait stations. Initially delivered in 12" long, 1 ½" diameter PVC pipes, hermit crabs (*Coenobita* spp.), land crabs (*Cardasoma* spp.) and coconut crabs (*Birgus latro*) consumed large volumes of toxicant. To further exclude crabs, several modifications were made to the delivery device, including anchoring the pipe to the ground or a raised platform, as well as capping one end of the pipe. These modifications were not successful at eliminating bait take by crabs. Following approximately 6 months of use, these devices were abandoned. The use of an alternative design, consisting of a covered 4-gallon plastic pail, with a 1 ½" diameter hole cut into the side approximately 8" up from the bottom of the pail, was implemented. This device provided some degree of exclusion for hermit crabs, land crabs, and coconut crabs. During this effort, at least one bristle-thighed curlew (*Numenius tahitiensis*), a species of concern, was killed through secondary toxicant uptake after eating hermit crabs that had ingested anticoagulant bait. Despite intensive poisoning over a 24 month period, the eradication effort at Palmyra was unsuccessful.

Future eradication attempts on Palmyra may require the development and use of delivery devices that provide complete crab exclusion as well as accessibility to all rats. In support of this need, a series of *in situ* and *in vitro* bait station experiments were initiated on Palmyra. The primary objective of this project was to assess the ability of different bait delivery stations to exclude terrestrial crabs.

METHODS

Prototype toxicant delivery stations were constructed of materials available on Palmyra Atoll. Three general station types were developed. The first, a platform station, consisted of 2" outside diameter PVC pipe, fitted with a 12" x 12" x3/8" plywood square on top of the pipe. Affixed to the plywood was a Protecta© toxicant delivery box (11 ½" x 12" x 6 ½", 2 entry box). The PVC pipe was cut to provide an above-ground height of both 24" and 18". This device will be referred to as the "box" station.

The second station type was constructed of ½" inside diameter electrical magnetic tubing (EMT; steel pipe) with a lid from a 5 gallon bucket firmly affixed to the pipe via a ½" hole drilled in the center of the lid. A second lid, to provide some protection from environmental conditions, was affixed approximately 10" above the first lid. The lower lid was set to provide an above-ground platform height of both 24" and 18". This device will be referred to as the "pipe" station.

The third station type consisted of a 4 gallon plastic bucket, fitted with a lid. A 1 ½" diameter hole was cut in the side of the bucket, approximately 8" from the bottom of the bucket. To further facilitate rat entrances and reduce crab damage to the bucket, a variation on this design was constructed, which included a 2" outside diameter, 4" length PVC pipe sleeve, inserted into the hole on the side of the bucket. This device will be referred to as the "bucket" station.

Evaluations of bait station crab exclusion were conducted inside a warehouse formerly utilized by a commercial fishing enterprise on Palmyra. Crabs were housed in 4' x 4' x 2.5' rigid plastic "totes" which are widely used in the commercial fishing industry. The smooth inner surface of the bins prevented crabs from climbing out. A single trial was defined by the same population of crabs in the same tote with a single bait station design (Table 2). Any change in crab number, individuals, or bait station design constituted a new trial. The number of exposure hours represents the total hours of individual crab exposure to a given bait station (e.g., 5 crabs in a single trial for 24 hours = 120 crab exposure hours).

Terrestrial crabs were grouped in three taxonomic categories for evaluation: 1) Hermit crabs (*Coenobita perlatus* and *C. brevimanus*), 2) Coconut crabs, and 3) Land crabs (*Cardasoma carnifex* and *C. rugos*). Live crabs were hand captured on Palmyra, placed inside totes, and exposed to bait stations. Hermit crabs were initially placed in groups of 55, with 35 adults and 20 sub-adults in each tote. Hermit crab densities were doubled to 110 individuals (70 adult and 40 sub-adults) following 2 full days of trials. These densities were established to mimic the "piling" behavior that hermit crabs exhibit when a valuable food source is found. Hermit crabs were considered adults if they were using a Hawai`ian turban shell *(Turbo sandwicenis)*; sub-adults were smaller crabs in any other shell. Land crabs were placed in groups of 5, and coconut crabs were held individually (this was done to reduce the probability of competitive interactions and subsequent injuries while in captivity). A single bait station was placed inside each tote. Stations were baited with placebo Ramik© bait (20 gram pellets) and roasted coconut mixed with peanut butter. Bait in each station was captivated with steel rods or tie wire to prevent removal. Entries into the pipe and box bait stations were documented through bait consumption. Entries into the bucket station were documented through bait consumption and crabs stuck inside the bait station. Because the number of nightly entry events could not be established through bait consumption, total entries were not documented. Exclusion capabilities are reported as "yes" or "no". Crabs were provided *ad lib* water and alternate natural food items during the duration of the trials.

Following the initial lab trials, a small number of field trials using the three bait station types were initiated. Seven bait stations (2 – 24" box stations, 1 – 18" box station, 2 - bucket stations without a PVC insert, 1 - bucket station with a PVC insert, and 1 – 18" pipe station) were placed in field use for three days, to assess crab exclusion and rat accessibility. Devices were baited in the same manner as in the lab trials. Crab and rat entrances were assessed using bait consumption and ink tracking boards.

RESULTS

Lab Trials

Thirty five separate lab trials were initiated during this effort, with a total crab exposure time of 41,175 hours (Table 1). Of the three primary stations evaluated, only the pipe station was accessed by crabs, and coconut crabs were the only group that entered the station and consumed bait. The bucket stations excluded all crab entries across each taxonomic group, although coconut crabs easily accessed the top of the bucket station. As well, the box station excluded all crab entries across each taxonomic group. Coconut crabs were able to climb the PVC pipe that supported the box and reach the delivery device, but were unable to access the secured bait inside the box.

Hermit crabs were able to climb the support pipe for both the pipe and box stations, but were unable to access bait as the platforms on both stations precluded entry. Only large adult hermit crabs were observed climbing the PVC pipe supporting the box station. Both adult and larger sub-adult hermit crabs were able to climb the ½" EMT supporting the pipe station. In several instances, sub-adult hermit crabs were observed clinging to the shell of adult crabs as they climbed, and were therefore capable of reaching higher on the stations than if climbing unaided.

Land crabs were not observed making any entry attempts into any of the bait stations. It is apparent that land crabs will be a greater impact to eradication efforts if broadcast methodologies are incorporated.

Field Trials

Given the small number of stations available and the short duration of testing, field evaluations provided limited information on crab exclusion and rat accessibility. In three nights of field use, only a single bucket station, without the PVC insert, received a rat visit. All stations were free of any indication of crab entries.

TRIAL	CRAB TYPE	# CRABS /TRIAL	# TRIALS	# EXPOSURE HOURS	CRAB ENTRIES
Bucket	Land Crab	5	2	1195	No
Bucket	Coconut Crab	1	4	101	No
Bucket	Hermit Crab	55	3	8629.5	No
Bucket	Hermit Crab	110	1	5170	No
24" Pipe	Coconut Crab	1	2	36	Yes
18" Pipe	Hermit Crab	55	2	2585	No
24" Pipe	Hermit Crab	55	2	2585	No
18" Pipe	Land Crab	5	2	115	No
24" Pipe	Land Crab	5	2	120	No
18" Pipe	Hermit Crab	110	1	5170	No
24" Box	Coconut Crab	1	4	101	No
18" Box	Land Crab	5	2	495	No
24" Box	Land Crab	5	2	500	No
18" Box	Hermit Crab	55	2	2585	No
24" Box	Hermit Crab	55	3	6617.5	No
18" Box	Hermit Crab	110	1	5170	No

Table 1. Exposure time and crab entrances for toxicant bait stations evaluated on Palmyra Atoll, August 2004.

DISCUSSION

The ideal toxicant bait station for use on Palmyra would have 100% crab exclusion, 100% accessibility to all rats, be cheap to build/purchase, and be simple to apply in the field. The three different bait station types evaluated here all appear to have significant crab exclusion qualities, and were constructed of readily available materials. The pipe and bucket stations would be easier to apply in field use than the box station, as the box station would require the use of rebar or some other support material for attachment to the ground. However, given the apparent repellency to coconut crabs offered by the box station, it may be the device of choice on islands with substantial coconut crab populations (i.e., Sand Island).

Prior to implementing wide-scale use of any delivery device, the accessibility of the station to rats must be assessed. Each of these devices appears to have complete accessibility to rats, but this has not been verified. An important next step will be to complete lab trials using captive rats exposed to the delivery devices, to assess accessibility.

A challenge for the application of any large-scale eradication attempt using bait stations will be quality control in field use. Any vegetation, litter, or other materials around a station may enhance the ability of non-targets to enter the station. Both hermit crabs and coconut crabs are extremely adept climbers, and small hermit crabs can support themselves on extremely thin branches or leaves. In addition, bait stations that are not well supported or anchored can be knocked over by coconut crabs, making bait subsequently available to non-target species. Mitigation for these potential hazards must be developed and implemented at the outset of any eradication attempt and frequent quality assurance reviews should be conducted at regular intervals to ensure field application techniques are meeting the prescribed use patterns.

APPENDIX 2. BRODIFACOUM RESISTANCE STUDY, W. PITT.

Study Title:

Resistance in roof rats (Rattus rattus) from Palmyra Atoll

Prepared by:

William C. Pitt, PhD
USDA APHIS, WS, NWRC, Hawai`i Field Station

Sponsor:

Name: Island Conservation Northwest
1485 Crawford Road
Kelowna, British Columbia, Canada

Name: U.S. Fish and Wildlife Service
Address: Pacific Islands Office
P.O. Box 50088
Honolulu, HI 96850

Introduction

This field study is one component of continuing research to evaluate the reasons for an unsuccessful rodent eradication program and to determine the feasibility of future eradication efforts on Palmyra Atoll. Previously, the Nature Conservancy attempted an island eradication effort using bait stations with brodifacoum based baits. Baiting continued for more than two years and not all the rats were removed. Further, baiting around the housing complex has continued for 4 or more years with brodifacoum primarily but also with diphacinone baits. One possibility for the failed eradication effort is that a segment of the rat population was resistant to brodifacoum and thus not susceptible to control. The purpose of the current study was to evaluate if any portion of the rat population is resistant to brodifacoum due to previous baiting efforts. The rats most likely to show signs of resistance would be rats near the housing complex on Cooper Island where baiting with brodifacoum has been ongoing for the longest period of time.

Methods and Results

General Methods:

Black rats (Rattus rattus) were captured on Cooper Island near the base camp between August 7-14 2004. This area has had the longest history of brodifacoum use and if rats had developed resistance it would likely come from this population. All rats were sexed, weighed, and housed in individual cages. Rats were maintained under outdoor ambient conditions, but under a roofed structure to prevent wetting by precipitation or overheating by direct sunlight. Water was available ad libitum. CI-25 placebo bait was used as food and was always available for control animals and available to treatment animals after all treatment bait had been consumed.

For treatment animals, an LD 50 of 0.7 mg/kg was used as the LD 50 based on the published range of 0.65 – 0.73 mg/kg for black rats.

All rats were examined daily and the condition of the rats and any mortalities were recorded. Dead rats were weighed, sexed, and necropsied for signs of anticoagulant poisoning as described by Stone et al. (1999). The bait would be submitted for analysis if < 50% of the treatment rats are dead or appear moribund by the end of the feeding trial. This chemical analysis of the % active ingredient would have been done to assure that the low mortality rate was not a result of insufficient concentration of active ingredient.

<u>Resistance Trial A:</u>

Twenty rats were used in resistance Trial A with equal numbers of males and females randomly placed into control and treatment groups (Table 1). Each treatment rat was fed 1 Final block (50 ppm Brodifacoum) on two consecutive days (2 Final blocks total). The LD 50 dose varied according to weight of rats (0.014 g Final block per gram of animal).

The rats were initially dosed on 8 August 2004 (1200 hrs) with 1 Final Block and again on 9 August 2004 with a second Final Block. All treatment rats died 5-10 days after initial exposure to bait (13 – 18 August, 2004).

Resistance Trial B:

Twenty-eight rats (14 males, 14 females) were used in resistance Trial B (Table 2). Rats were captured 8 - 10 August 2004 on Cooper Island near the research complex. Each rat was randomly placed into one of four treatment groups limited by having at least 3 of each sex in each treatment group. The treatment groups were control, LD 50 dose, twice LD 50 dose, and four times LD 50 dose. Each LD 50 dose was normalized based on mass of the rat. Each treatment rat was fed a single dose of CI -25 (25 ppm brodifacoum).

The rats were initially dosed on 11 August 2004 (1300 hrs). All treatment rats died 5-21 days (mean = 8.7 days) after initial exposure to bait (16 August – 1 September, 2004). Four treatment rats persisted after 10 of the initial dose with death occurring on days 11, 11, 13, and 21 after initial dose.

Necropsy

Two control rats (#13, 17) and one treatment rat (#32) were necropsied to document signs of bleeding or other abnormalities (Table 3). The control rats had been euthanized on 3 September and the treatment rat had been found dead on 1 September, 2004. Necropsies included a gross physical examination, removal of the fascia, and internal examination of the organs to detect signs of bleeding.

No obvious signs of bleeding were observed in any of the rats. Rat #32 had a small hematoma on the right front leg but this appeared to be a minor injury that had previously healed. Rat #32 had external trauma to its head but it was unclear if this happened pre or post mortem. The injuries to the head were sufficient to cause death.

Discussion

The eventual death of all rats suggests the majority of black rats on Palmyra Atoll are susceptible to the effects of brodifacoum. Seven rats died with a single dose at the LD 50 level for black rats. Further, 28 of 29 rats died within 2 weeks of the initial dose (one rat escaped). These results indicate that there is not a large portion of the population resistant to the effects of brodifacoum. Further, it is likely that there is not a significant source of Vitamin K in their diet to counteract the effects of the rodenticide.

The length of time between initial dose and death of at least one rat suggests that a portion of the population may be resistant to effects of brodifacoum. This conclusion is further supported by the lack of hemorrhaging observed during the necropsy of a rat that persisted 21 days after the initial dose. The rat received 4 times the LD 50 dose and did not show obvious signs of hemorrhaging.

Rats survived an average of 7 days and 8.1 days (removing rat #32) after receiving the initial dose in resistance trials A and B respectively. Although rats did not die quickly from the high doses of brodifacoum provided, the survival duration after the initial dose is similar to other studies of brodifacoum (Gill and Redfern 1980). This length of survival after initial dosage is unremarkable.

Recommendations

1. A second baiting with another anticoagulant would be necessary to ensure complete eradication, if brodifacoum based bait is used to remove rats from Palmyra Atoll.
2. Another anticoagulant could be used instead of brodifacoum due to little chance of cross-resistance among anticoagulants (Apperson et al. 1981).
3. Continued haphazard baiting around the research station with brodifacoum should be terminated as soon as possible, if brodifacoum based baits will be used in an Atoll wide eradication effort.
4. An intensive evaluation of the efficacy will be necessary to ensure complete eradication, if brodifacoum based baits are used.
5. The brodifacoum LD 50 suggested for roof rats (0.65 – 0.73 mg/kg) appears to be adequate for rat eradication efforts on Palmyra Atoll.

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Table 1. Black rats (Rattus rattus) mass, sex, treatment, and fate in resistance trial A on Palmyra Atoll. August 2004.

Rat #	Mass (g)	Sex	Treatment	8Aug bait Mass (g)	9Aug bait Mass (g)	Total Bait (g)	LD 50 bait mass normalized	Multiple of LD50	Date of death
2	150	Female	Control	NA	NA	NA	NA	NA	NA
3	105	Female	Control	NA	NA	NA	NA	NA	NA
4	200	Female	Control	NA	NA	NA	NA	NA	NA
7	200	Female	Control	NA	NA	NA	NA	NA	NA
8	215	Female	Brodifacoum	20	20	40	3.01	13.3	8/14/2004
9	155	Female	Brodifacoum	21	20	41	2.17	18.9	8/14/2004
10	220	Female	Brodifacoum	20	20	40	3.08	13.0	8/15/2004
12	190	Female	Brodifacoum	20	21	41	2.66	15.4	8/13/2004
13	205	Female	Brodifacoum	21	20	41	2.87	14.3	8/15/2004
15	165	Female	Brodifacoum	NA	NA	NA	NA	NA	NA
16	115	Female	Control	NA	NA	NA	NA	NA	8/18/2004
20	230	Male	Control	NA	NA	NA	NA	NA	NA
21	210	Male	Brodifacoum	20	20	40	2.94	13.6	8/16/2004
22	155	Male	Brodifacoum	20	20	40	2.17	18.4	8/18/2004
24	190	Male	Control	NA	NA	NA	NA	NA	NA
25	200	Male	Brodifacoum	19	20	39	2.8	13.9	8/16/2004
26	170	Male	Brodifacoum	20	20	40	2.38	16.8	8/15/2004
27	210	Male	Control	NA	NA	NA	NA	NA	NA
28	140	Male	Brodifacoum	20	20	40	1.96	20.4	8/14/2004
30	275	Male	Control	NA	NA	NA	NA	NA	NA
31	200	Male	Control	NA	NA	NA	NA	NA	NA

Table 2. Black rats (Rattus rattus) mass, sex, treatment, and fate in resistance trial B on Palmyra Atoll. August 2004.

Rat Mass (g)	Sex	Treatment Group	LD 50 multiple	Brodifacoum (mg)	Bait (g)	Date of death
245	Male	3	2	0.343	13.72	8/21/2004
195	Male	4	4	0.546	21.84	8/20/2004
195	Male	2	1	0.1365	5.46	8/20/2004
155	Female	2	1	0.1085	4.34	8/19/2004
155	Female	4	4	0.434	17.36	8/16/2004
160	Female	2	1	0.112	4.48	8/16/2004
140	Female	4	4	0.392	15.68	8/18/2004
220	Female	3	2	0.308	12.32	8/20/2004
160	Male	2	1	0.112	4.48	8/19/2004
195	Male	3	2	4	10.92	8/22/2004
195	Male	1	NA	0	10	NA
230	Male	1	NA	0	10	NA
140	Male	1	NA	0	10	NA
100	Female	3	2	0.14	5.6	8/23/2004
130	Female	1	NA	0	10	NA
155	Female	1	NA	0	10	NA
145	Female	4	4	0.406	16.24	8/20/2004
170	Female	1	NA	0	10	NA
145	Female	3	2	0.203	8.12	Escaped
170	Female	2	1	0.119	4.76	8/16/2004
155	Female	3	2	0.217	8.68	8/19/2004
160	Male	2	1	0.112	4.48	8/20/2004
225	Male	3	2	0.315	12.6	8/18/2004
190	Male	4	4	0.532	21.28	8/18/2004
225	Male	1	NA	0	10	NA
175	Male	3	2	0.245	9.8	8/17/2004
135	Female	2	1	0.0945	3.78	8/19/2004
225	Male	4	4	0.63	25.2	8/22/2004
175	Male	4	4	0.49	19.6	9/1/2004

Table 3. Necropsy results of rodents captured on Palmyra Atoll, August 2004.

ID Number	Sex	Date dead	Body weight (g)	Head-Body length (mm)	Tail length (mm)	Right hind foot length (mm)	Right ear length (mm)	Dorsal pelage color	Ventral pelage color	Reproductive status
Control (13)	Male	9/3/2004	214.30	196.3	223.3	36	24.3	Long black guard hairs & grayish hairs with orange tips	Grayish color with white cream tips	descended testes
Control (17)	Female	9/3/2004	129.85	172	203.7	34.2	22	Long black guard hairs & grayish hairs with orange tips	Grayish color with white cream tips	Vagina perforate
LD50X4 (32)	Male	9/1/2004	154	147	219.7	34.3	Not taken	Long black guard hairs & grayish hairs with orange tips	Grayish color with white cream tips	descended testes

Necropsy Notes:

All the rats were classified as *Rattus rattus* by their morphological characteristics.

When peeling of the entire fascia from the three rats, rat # 32 had signs of previous bleeding on the right front forelimb.

The remaining muscle color throughout the rats' bodies was pink and healthy.

Rat # 17 had green color stains on its paws, tail, and near the anus.

Rat # 32 had both its ears torn apart, missing both its eyes, and the left side of its rostrum had been scraped away.

Rat # 32 had green color stains on its ventral pelage, paws, tail, and in the anus region.

Overall, no obvious signs of hemorrhaging were seen.

BAIT WEATHERING TRIAL

Prepared by: Pete McClelland, New Zealand Department of Conservation

September 2004

Summary

In order to ensure that bait is available for rats for the desired three nights following a broadcast operation the two available bait types were placed under rat and crab proof exclosures and their degradation monitored for four days. The small (1-2g) CI-25 baits broke down rapidly while the 8g Ramik bait was still in good condition at the completion of the trial.

Methodology

The trial used five exclosures – approximately 50cm square with 15cm high sides, a 15cm foot coming out from the base to try and prevent rats or crabs digging under and 1cm square wielded wire mesh on the top to five the bait full access to the weather. These were placed in the 5 major habitat types found on the Island namely,

a) Pisonia – tall forest with an open understorey, approximately 80% canopy cover and with a well drained storey substrate.
b) Coconut Palms – tall forest, open understorey, approximately 80% canopy. Moderately drained sandy substrate.
c) Terminalia – tall forest, approximately 95% canopy heavy fern ground cover, approximately 1m high. Leaf litter substrate.
d) Open grass – no canopy, 100 % ground cover, compacted substrate
e) Pandonas – low "forest" 100% canopy and heavy understorey of same vegetation. Fine gravel substrate and leaf litter.

The sites were checked every 24 hours within 3 hours (after) of the rainfall being record for that period, and the condition of the bait recorded. Specifically the physical shape of the bait i.e. solid → soft → crumbly , retaining shape, degree of water absorption. Also, amount of mould on the bait, likely palatable (very subjective) and ant activity.

Results

Rainfall

11 August

12 August

13 August

14 August

Bait Condition

11 August

Plot A) **CI-25** - swollen and crumbly, 100% moisture penetration, moderate ant activity

Ramik – outer layer flaking 50% moisture penetration, no ant activity

Plot B) **CI-25** - swollen and crumbly, 100% moisture penetration, moderate ant activity.

Ramik - outer layer flaking – 50% moisture penetration, no ant activity

Plot C) **CI-25 -** all bait eaten by crabs

Ramik – 100% moisture penetration, outer layers flaking

Plot D) **CI-25** – swollen and mushy, just holding shape, moderate ant activity

Ramik – 100% moisture penetration, outer layer flaking (can crush with two fingers) still palatable.

12 August

Plot A) **CI-25** – disintegrating but still in general shape

Ramik – continued flaking – 2 layers

Plot B) **CI-25** – all eaten by crabs

Ramik – 1st layer flaking – 100% moisture penetration

Plot C) **CI-25** – all bait eaten by crabs

Ramik – all bait eaten by crabs

Plot D) **CI-25** – disintegrating – wet mush

Ramik – 1st layer flaking

Plot E) **CI-25** – (new yesterday) 100% moisture penetration, bait swollen and crumbly

Ramik – flaky 1st layer

13 August

Plot A) **CI-25** – most bait eaten by crabs , rest mush
Ramik – no change

Plot B) All bait eaten by crabs

Plot C) All bait eaten by crabs

Plot D) **CI-25** – 50% bait gone, not whole pallets – wet mushy – high ant numbers

Ramik – still holding shape but 50% flaking

Plot E) **CI-25 –** disintegrating but still holding shape

Ramik – flaked 1st layer

14 August

Plot A) All bait eaten

Plot B) No bait

Plot C) No bait

Plot D) **CI-25** – 75% bait gone (ants?)

Ramik – no change

Plot E) All bait gone

DISCUSSION

Keeping crabs out of the exclosures was more difficult than predicted as they tunnelled under the foot. In some cases 50+ crabs would be inside the enclosure overnight. There was no evidence of rats taking the bait so when bait was missing and crabs present it is assumed the crabs ate the bait. When bait was missing but no crab activity was found it was always when the CI-25 bait had gone mushy and its loss was attributed to ants.

Even when the CI-25 bait was replaced it was always wet through and starting to breakdown by the next day. It is very unlikely, given the rainfall on Palmyra, that 1gm CI-25 baits would last three nights in a presentable state, even if the crabs/ants didn't eat it. A large bait would have a reduced surface area: volume ratio and is likely to last better. The Ramik bait weathered well, even though it started flaking after one day it appeared to still hold its shape after three nights and may in fact have become more palatable as it got softer.

CONCLUSION

The 1gm CI-25 bait is not suitable for use on Palmyra. The 8 gm Ramik bait does have the desirable weathering properties, but does have issues with sowing rate and possibly palatability. Therefore other bait types need to be explored and tested.

RECOMMENDATION

That as many different bait types/sizes be tested for weathering as well as palatability etc to see if one that meets the tight requirements of Palmya can be found. If a suitable bait can be found – field trials should be carried out.

APPENDIX D

PROGRESS IN PALMYRA ATOLL RESTORATION: RAT ERADICATION TRIAL 2005

PROGRESS IN PALMYRA ATOLL RESTORATION: RAT ERADICATION TRIAL 2005

Stacey Buckelew [1]
Gregg R. Howald [2*]
Alex Wegmann [3]
Jacob Sheppard [1]
Jennifer Curl[1]
Pete McClelland [4]
Bernie Tershy [1]
Katie Swift [5]
Earl Campbell [5]
and
Beth Flint [6]

1 - Island Conservation
Center for Ocean Health, University of California
100 Shaffer Rd, Santa Cruz, CA 95060
Telephone: (831) 459-1476
Fax: (831) 459-3383
www.islandconservation.org

2 – Island Conservation Canada

3 – University of Hawaii, Honolulu, Hawaii

4 – New Zealand Department of Conservation

5 – US Fish and Wildlife Service – Ecological Services, Honolulu, Hawaii

6 – US Fish and Wildlife Service – Pacific Islands National Wildlife Refuges, Honolulu, Hawaii

* Correspondence:
Phone: (604) 628-0250
Gregg.Howald@islandconservation.org

Summary

In July 2005, a team of 6 people returned to Palmyra Atoll to conduct a trial rat eradication building on the feasibility assessment. The main goals of this expedition were to:

1. Evaluate the preference and efficacy of newly formulated bait (PI-25, containing 25 ppm brodifacoum, Bell Laboratories, Inc.) on the local rat population under laboratory and field conditions.
2. Conduct a broadcast trial rat eradication using PI-25.
3. Evaluate rodenticide exposure risks to non-target species.

Palmyra's abundant rainfall and aseasonal environment are obstacles to successful rat eradication. They make it difficult to develop a bait that maintains its palatability over time and is more attractive to all rats than the abundant natural food resources. We found that PI-25 bait was preferred over natural food items in both laboratory and field conditions. The bait maintained its shape and integrity despite the high rainfall and was preferred over natural food items, even after absorbing moisture and the onset of mold growth, in both laboratory and field conditions.

We conducted a trial eradication on a subset of 5 islands in Palmyra, totaling 4.08 ha. Each island was treated with PI-25 broadcast by hand to the ground, and delivered by slingshot, pole or broadcast into every coconut palm tree on each island. We targeted a bait application rate necessary to have enough bait available in every potential rat territory for a minimum of 4 days. A calibration trial indicated that between 60-90 kg/ha may be required, however, due to uncertainty in the data we initially applied high on the first treated island, and reduced the rate based on bait uptake monitoring. We broadcast bait at 60 (Little East Island), 70 (Bunker Island), 80 (Fern Island), 85 (Home Island) and 95 kg/ha (Whippoorwill Island) and monitored bait uptake and impact on the local rat population.

We determined that bait application of 80 kg/ha or less would be inadequate to ensure bait would be available in every potential rat territory for at least 4 days, on islands with a high abundance of landcrabs (*Cardisoma* spp.) and hermit crabs (*Coenobita* spp.) that consume the bait (but are not affected by the rodenticide). Our monitoring indicates that an application rate of 85 - 95 kg/ha would be adequate to overcome competition from landcrabs, with 99.9% bait removed from the islands by 7 days post broadcast.

Our direct (radio collared rats and live traps) and indirect (wax chew blocks) monitoring of efficacy of the bait application on the rat population indicates that we were successful in eradicating rats from all the treated islets at all application rates. However, the islands with low application rates (<80 kg/ha) had no established hermit crab populations that were important consumers of bait and we believe the successful removal of rats from those islands with lower application rates was due, at least in part, to the absence of hermit crabs. A small juvenile, weanling rat was detected live on day 8 post broadcast on the 95 kg/ha treated island but was found moribund on day 10. The discovery of a live weanling rat strongly suggests that a second bait application is necessary to ensure bait is available to all weanling rats that had not yet left the nest and could escape exposure to bait after the first application. Therefore, for the rat eradication to have a high probability of succeeding by broadcast with PI-25, we recommend that bait be applied twice at 90 kg/ha, 10-14 days apart, to overcome competition by the abundant landcrabs and hermit crabs and ensure enough bait is available to the entire rat population for a minimum of 4 days.

To evaluate the risk of rodenticide exposure to non-target species we monitored the local shorebird population and collected landcrabs to monitor for brodifacoum residues on days 2, 6, 10, 21 and 56 days post broadcast. For the four species of shorebirds that are known to use Palmyra, *Numenius tahitiensis* (Bristle-thighed Curlew), *Heteroscelus incanus* (Wandering Tattler), *Pluvialis fulva* (Pacific Golden-plover) and *Arenaria interpres* (Ruddy Turnstone), the curlew and plovers were believed to be at the greatest risk of secondary exposure to the rodenticide from feeding on hermit and landcrabs that consume the bait under the forest canopy. The frequency of detection of these shorebirds were consistently higher post broadcast and was likely due to migratory influx. We did not detect any dead or moribund birds in the treated areas. Thus, the timing of the eradication prior to the arrival, or after the departure, of migratory shorebirds is effective at minimizing the risk of short term rodenticide exposure. A risk assessment is to be done for shorebirds based on the pending landcrab and hermit crab brodifacoum residue data.

We conclude that rats can be eradicated from Palmyra Atoll with a high probability by broadcasting PI-25 bait containing 25 ppm brodifacoum. The relative long term risk of rodenticide exposure to non-target shorebirds is currently under evaluation.

Table of Contents

Introduction

Island ecosystems, such as Palmyra Atoll, are key areas for conservation because they are essential habitat for seabirds, pinnipeds and sea turtles that use thousands of square kilometers of open ocean, but depend on islands for breeding, raising young, and resting. In addition, islands tend to be rich in endemic species and are home to 15-20% of all plant, reptile and bird species, even though they make up only about 3% of the earth's area (Whittaker 1998).

Unfortunately islands have been disproportionately affected by humans. More than 80% of all of recorded extinctions (excluding fish) have occurred on islands, and most of these were caused, at least in part, by invasive species (Island Conservation analysis of IUCN Global Red List data and Groombridge 1992).

One of the most successful invasive species on islands are rats in the genus *Rattus.* They have been introduced onto about 82% of the world's islands and/or island chains (Atkinson 1985), where they frequently have a quantifiable negative impact on the distribution and abundance of native flora and fauna. This is most pronounced on oceanic islands where native species have evolved in the absence of mammalian predators and thus have limited behavioral, morphological, and life-history defenses against rats (Brown 1997). Consequently, rats have been implicated in 40-60% of recorded bird and reptile extinctions since 1600 (Groombridge 1992). Fortunately, it is possible to eradicate all rats from many islands, and in the last 20 years there have been a series of technological innovations in the field of rat eradication that have dramatically increased the power of this important conservation tool (Galvan et al. 2005). Briefly, rats are eradicated by distributing a bait containing a rodenticide, usually brodifacoum, into all rat territories. Bait can be placed in bait stations spaced on a grid of 25x25m to 100x100m, or can be broadcast evenly at a known density either by hand on small islands or with a helicopter using a bait spreading bucket on larger islands.

Palmyra Atoll National Wildlife Refuge, located in the Line Islands, Pacific Ocean, approximately 1760 km south of the main Hawaiian Islands, likely never supported native mammals because of its remoteness. However, non-native black rats (*Rattus rattus*) were introduced to Palmyra, likely during the US military occupation of the atoll in the 1940's. The establishment of rats on Palmyra is believed to have had a major negative impact on the ecosystem, especially on seabirds, invertebrates, and vegetation.

Modeling successful projects carried out in New Zealand and those conducted in North America by Island Conservation and others, we initiated a trial eradication on Palmyra Atoll, Pacific Remote Islands National Wildlife Refuge Complex, USA. The trial eradication and associated research and monitoring was conducted on a subset of five islets within the atoll, comprising a total emergent land area equal to 4.08 ha, from June 28 through August 14, 2005.

The trial eradication built upon the feasibility study on Palmyra Atoll in 2004(Howald *et al.* 2004). The feasibility study evaluated rat susceptibility and attraction to various baits, monitored rat movement and habitat use via radio telemetry, conducted an atoll wide land crab density survey, and measured the rate of bait loss in the Palmyra environment. In addition the potential risks to other non-target species were assessed on the island and the operational logistics considered for an atoll wide eradication. The results from this preliminary phase indicated that a trial eradication of rats was necessary to assess the probability of success for an atoll-wide eradication (Howald *et al*. 2004).

The objective of the June-August 2005 Palmyra visit was to perform a trial rat eradication on a subset of islets at Palmyra Atoll. The methodologies detailed below for the Palmyra Atoll trial eradication were designed to mimic an aerial broadcast of bait, which was identified as the preferred method during the 2004 feasibility study. The results of the trial eradication will be used to structure future eradication plans on the atoll.

Research and Monitoring Goals

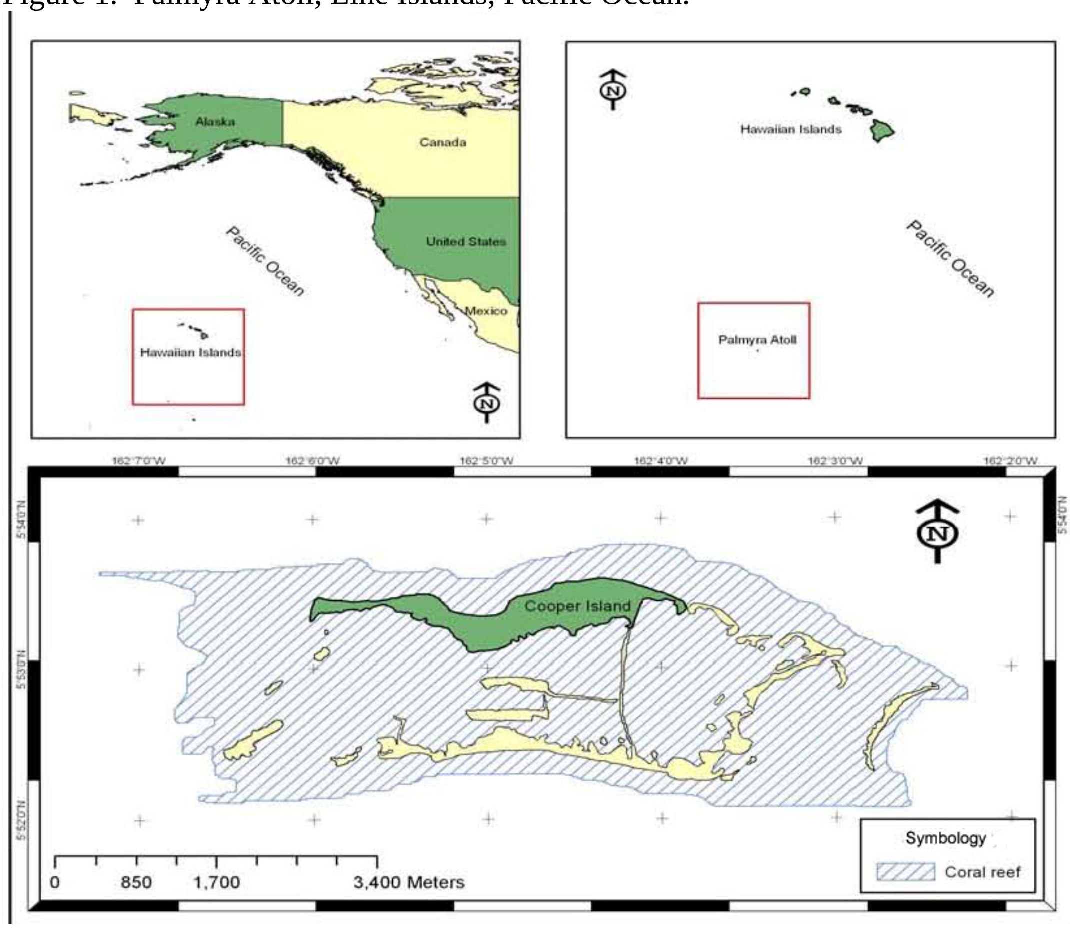
The goals of the research and monitoring during the eradication trial were to:

1. *Study rat preference and susceptibility to the proposed bait;*
2. *Validate the bait application rate;*
3. *Evaluate efficacy of bait application on the rat population;*
4. *Evaluate potential rodenticide exposure risks to non-target species.*

Study Area

Location: In the Line Islands, 1760 km south of Honolulu, Hawaii (Figure 1 and Appendix A).

Figure 1. Palmyra Atoll, Line Islands, Pacific Ocean.



Size and Topography: Palmyra Atoll is comprised of 54 islets encompassing 228 ha, rising to a maximum elevation of 2 m. The atoll is well within the size range of successful rat eradications (Figure 1). All of the land area can be accessed on foot, however, there are areas of thick vegetation, especially the *Scaevola* habitat, which precludes access without trail cutting. Although most of the islets are not connected, they can be reached by wading or swimming across the narrow channels that separate individual islets, or by boat.

There are potential safety concerns to eradication staff from unexploded ordnance, contaminated dump sites, hidden bunkers and marine wildlife (e.g. sharks), which could limit the successful implementation of a ground-based operation. Barrier and Quail Islands are inaccessible due to unexploded ordnance concerns.

Plants and Animals: The aseasonal climate on Palmyra supports dense vegetation of native and non-native trees and shrubs. A large portion of the atoll (approximately 48%) lies under a canopy of non-native coconut palm (*Cocos nucifer*a). Other habitat types include broadleaf forest composed of *Terminalia catappa,* the native *Pisonia grandi*s, and the shrub-like *Scaevola sericea* and *Tournefortia argenatea*. The *Pisonia* forest was once regarded as the best example of a pristine *Pisonia* forest in the American Pacific, but the trees are now dying due to stress response from introduced scale insects whose populations are inflated due to their symbiotic relationship with the introduced ant *Pheidole megacephala*. The decline of the *Pisonia* forest has caused dramatic changes in the Palmyra ecosystem.

The terrestrial habitats on Palmyra support 10 species of breeding seabirds. There are no breeding landbirds on Palmyra, but the island supports overwintering populations of Bristle-thighed Curlews (*Numenius tahitiensis*) and other shorebird including Wandering Tattlers (*Heterscelus incanus*), Pacific Golden Plovers (*Pluvialis fulva*) and Ruddy Turnstones (*Arenaria interpres*). The curlew and Pacific Golden Plover are designated by the US and Region 1 Shorebird Conservation plans as Species of High Conservation

Concern because of limited breeding and non-breeding distributions in the Pacific, low relative abundance, and a decline in global populations.

Palmyra supports a notably diverse assemblage of six landcrab species, including the large coconut crab (*Birgus latro*). The most abundant landcrab is the red hermit crab (*Coenobita perlatus*). Additional species include the purple hermit crab (*Coenobita brevimanus*), orange land crab (*Cardisoma carnifex*) and purple land crab (*Cardisoma rotundum*). Landcrabs are the primary competitors of rats for access to the bait.

There are two terrestrial reptile species on Palmyra, an introduced house gecko (*Hemidactylus frenatus*) and a native mourning gecko (*Lepidodactylus lugubris*).

Palmyra supports a diverse collection of both native and non-native insects, including cockroaches and ants that are known to compete with rats for access to bait. During the first eradication attempt, it was noted that ants overwhelmed some bait stations, completely consuming the bait present in the stations within 24 hours.

Two domestic cats and a domestic dog are present as pets on the atoll, as well as one cat that is confined to a boat moored in the lagoon. Tropical vegetation including a mix of native and non-native plants and trees.

Climate: Palmyra lies within the Inter-Tropical Convergence Zone (ITCZ), the band of low pressure along the equator formed by the upward convection of warm, moist air from the Earth’s surface. The climate of Palmyra is characterized by high humidity (>90%), warm temperatures (75 – 85 degrees Fahrenheit) with almost daily copious rainfall events. Mean annual rainfall on Palmyra is 4.06 m.

Pre- Eradication Trials

Prior to initiating the trial eradication we:

1) Reconfirmed the effectiveness of the PI-25 bait (25 ppm brodifacoum, Bell Laboratories, Inc.).
2) Reconfirmed the preference of bait in various stages of degradation (fresh vs. four days of weathering) versus naturally occurring foods in laboratory and field conditions.
3) Calibrated an appropriate application rate using a non-toxic placebo bait in a 1.5 ha plot.

Laboratory Bait Efficacy

Methods

Prior to commencement of the trial eradication on the five treatment islets we conducted an on-island effectiveness trial with wild captive rats to confirm efficacy of the bait. A grain-based bait containing the rodenticide brodifacoum (currently named PI-25) was formulated by Bell Laboratories, Inc. to withstand the moist weather conditions encountered on Palmyra Atoll. The formulated bait is a 1/2” diameter, blue colored, highly compressed grain pellet (mean weight of 2.3 g) (Figure 2).

The efficacy trial used 10 rats live-captured on Cooper Island. The rats were randomly assigned five each to an experimental and control group. The rats were sexed, weighed, and housed in individual cages inside a facility where conditions were darker, drier, and cooler than ambient conditions to prevent exposure to precipitation or direct sunlight. The five rats

Figure 2. PI-25 bait (Bell Laboratories, Inc) used on Palmyra Atoll National Wildlife Refuge, July 2005.

in the experimental group were given, no choice, PI-25 bait, equivalent to four times the LD_{50} (LD_{50} = 0.7 mg/kg, based on published range of 0.65- 0.73 mg/kg for *Rattus rattus*)of brodifacoum (calculated based on each individual's body mass) until all bait was consumed. After the toxic bait consumption, experimental rats were maintained on coconut, a non-toxic natural food source, until mortality or study end. The five rats in the control group were maintained on coconut for the duration of the trial. Water was available to all rats *ad libitum.* Rats were examined daily and the condition of each rat – whether active, lethargic, bleeding, moribund, or dead – was recorded.

Results and Discussion

Mortality of all rats in the experimental group occurred between Day Six and Day Nine post-treatment, with average mortality occurring on Day Seven post-treatment (n=5, s=1.2) (Table 2). Two of the five experimental rats were necropsied after death and hemorrhaging was detected at the base of the cerebrum for both specimens, symptomatic of brodifacoum toxicosis. No mortalities occurred for the five rats in the control group, their general condition remained healthy and active until euthanized.

All of the rats died within the expected mortality window between 3-10 days typical after brodifacoum exposure. Although the sample size is low, the mortality of all 5 individuals exposed to brodifacoum is concurrent with the data from 2004 (Pitt 2004 in Howald *et al.* 2004) suggesting that brodifacoum has a high probability of removing 100% of the local rat population.

Bait Preference

Methods

We conducted both (a) laboratory based preference trial and (b) a field bait preference trials using motion sensing cameras on Cooper Island. Both trials consisted of five identical choice tests in which bait in different states of weathering was paired against naturally occurring food sources.

Table 2. Efficacy trial results and day of mortality post-treatment of experimental rats, Palmyra Atoll, July 2005.

Treatment	Rat #	Sex	Day of Visual Poisoning Symptoms	Day of Mortality
Experimental	1	M	6	6
	2	M	4	9
	3	M	5	6
	4	F	5	7
	5	M	5	7
	Mean		5	7
	Std. Dev.		-	1.2
Control	6	M	NA	NA
	7	M	NA	NA
	8	J	NA	NA
	9	M	NA	NA
	10	M	NA	NA
	Mean		-	-
	Std. Dev.		-	-

The choice preferences tested were:

1. Fresh bait vs. green coconut *(Cocos nucifera)*
2. Fresh bait vs. *Pandanus* seeds (*Pandanus tectorius*)
3. Fresh bait vs. weathered bait*
4. Weathered bait* vs. green coconut
5. Weathered bait* vs. *Pandanus* seeds

*Bait was weathered four days by covering with a wire mesh cage, exposed to ambient weather conditions. General bait condition displayed <50% surface area mold and discoloration.

<u>Laboratory Preference Trials</u> – Rats were initially sexed and weighed for choice preference trials conducted in a laboratory setting, then housed in individual cages before the trial began. Twenty-four hours prior to the start of the trial rats were fasted and given water only. Rats were maintained in conditions identical to bait validation trials – a dark,

dry, cool location sheltered from exposure to precipitation or overheating by direct sunlight.

Each choice test was conducted using four individual rats. For each test, the two food choices were placed side by side in each cage with random placement of food orientation (i.e. left-right, or right-left). Food choice was determined as the first item to be wholly consumed by the rat. For each test using bait as a choice item, 3-5 pellets were placed in a small plastic cup inside the cage. For natural foods, one coconut or Pandanus seed was placed directly onto the floor of the cage. Food items were presented to each rat in the test and the time recorded. Observations of food choices were made from a distance of 3-5 m from the cages. Time elapsed between presentation and when a food item was chosen was recorded for each rat.

Motion Sensing Cameras – Motion sensing cameras were used to examine the food preferences of rats within their natural ecological setting, and to evaluate the effect that competitive interactions with other species may have to preference choices.

Three motion-sensing cameras (Bushnell Trailscout 2.1 MP Digital Motion-Sensing Camera, Model # 11-9800) were randomly placed on Cooper Island over the duration of the seven weeks. Five food choice tests (mentioned in the above Laboratory Trial section) were performed of a total of six times each, three times in daylight and three times at night. Each choice test consisted of placing the two food items in front of a camera with a visible divider set in between. An identical control test (no camera) was placed >1m distance from each camera to control for any potential camera effect. Cameras were set to collect images at a rate of one image per 30 seconds. Food preference was determined only from images in which a clear choice was evident.

Results and Discussion

Laboratory Trials – The results from the lab trial suggest that both fresh and weathered bait were preferred over green coconut seeds, and that rats had an equal preference for fresh and weathered bait when presented with both at the same time (Table 3). The results suggest that rats preferred Pandanus to both fresh and weathered bait. However, though six rats chose Pandanus seeds initially, all but two rats consumed some fresh or weathered bait later in the trial. This would suggest that some rats may avoid the bait in favor of Pandanus fruit in some situations. We believe that overall, the results from this laboratory study strongly suggest that rats prefer PI-25 bait pellets over coconut when given a choice between the two. The preference for PI-25 vs. Pandanus fruit remains equivocal under laboratory conditions.

Table 3. Rat preference between natural food sources and grain-based bait pellets in a laboratory trial.

# Rats	Sex Ratio (F:M)	Trial	Preference	% Preference
4	3:1	Coconut vs. fresh bait	Fresh bait	100
4	2:2	*Pandanus* vs. fresh bait	*Pandanus*	75
4	2:2	*Pandanus* vs. weathered bait	*Pandanus*	75
4	1:3	Fresh bait vs. weathered bait	No preference	50
4	3:1	Coconut vs. weathered bait	Weathered bait	100

Motion Sensing Cameras – In tests between fresh bait and natural food sources, on average, rats chose bait 91% of the time. In trials testing the choice of weathered (moldy) bait versus natural foods, rats chose weathered bait on average 93% of the time. The results also show that fresh bait is greatly desired (89%) over weathered bait, and that weathered bait is still preferred over natural food sources. The results suggest that in natural environments rats prefer grain-based bait to alternate food sources (Table 4). The evidence from the cameras would suggest that rats prefer fresh and degrading PI-25 to natural foods when given the choice on Palmyra Atoll.

Table 4. Palatability trials with motion sensing cameras showing the percent of images demonstrating rat preference for a specific food option

Trial	Choice	Number of Photos	% images showing rat choice
Fresh bait vs. *Pandanus*	Bait	9	83
Fresh bait vs. green coconut	Bait	18	100
Fresh bait vs. weathered bait	Fresh bait	12	89
Weathered bait vs. *Pandanus*	Weathered bait	8	86
Weathered bait vs. green coconut	Weathered bait	7	100

Validation of Application Rate

Methods

Prior to the distribution of PI-25 for the trial eradication, we calibrated the application rate using placebo compressed-grain bait pellets. Results from measured bait consumption (uptake) in fixed-area plots were used to calculate the rate of bait uptake into the environment and thus, translated into an application rate required to ensure enough bait was available on the ground, and in each potential rat territory, for four (4) days post application.

The placebo bait pellets were similar in size and shape to the PI-25 bait, a 1/2" diameter, undyed, 2.3 g (mean weight) highly compressed grain pellet (Bell Laboratories, Inc.). Bait was applied by hand broadcast to a 1.5 ha ground area on Aviation Island at a rate of 90 kg/ha. A crew of four persons, each spaced three meters apart, broadcast bait in consecutive cross-islet transects. Each person was responsible for applying bait at the target application rate to the 1.5 m radial area around him or her at each 1 m pace traveled along the transect. To best ensure uniform bait distribution all members of the team applied baited in unison across the width of the islets, each individual distributing bait to his or her respective transect.

Consumption of bait pellets was measured over a four-day period in 20 1x5 m uptake plots. Pellets were individually placed and marked with a pin flag in the uptake plots at the concentration of four pellets/ m^2, an extrapolation from the application rate of 90kg/ha. Plots were visited daily and the number of pellets remaining was recorded, and pin flags removed from where bait pellets were consumed.

Results and Discussion

Bait consumption calculated from uptake plots is presented as both mean rate of daily uptake (Table 5) and cumulative uptake (Table 6 and Figure 3). Bait loss (likely attributable mostly to uptake by landcrabs and rats) averaged 45.5% (39.86 kg/ha) during the initial 24 hour period and continued at a rate of approximately 8% for the remaining 3 days (Tables 5, 6). By Day Four post-application an average 30% (27.14 kg/ha) of the applied bait remained in the study area (Table 6). Consumption however varied significantly among individual uptake plots within the study area. At Day Four post-application six plots experienced complete consumption of pellets initially applied whereas in seven plots ≥ 10 pellets (50% initial application) persisted.

Based on the methods we used to measure bait loss in the validation trial, we conservatively estimated an application rate > 90 kg/ha would be necessary to ensure availability of bait to 100% of the rat population over a 4-day period. The wide variance in the data, likely due to the small measurement plots and variation in the distribution and abundance of crabs, precluded us from making a conclusive statement about application rate.

Table 5. Mean placebo bait removed as measured daily in uptake plots (n= 20). Palmyra Atoll, July 2005.

Day	**# Pellets Removed ($/m^2$)**	***Std Dev***	**Equivalent Uptake (kg/ha)**	***Std Dev***
1	1.82	*1.07*	41.86	*32.50*
2	2.21	*1.08*	8.97	*7.53*
3	2.51	*1.09*	6.90	*8.11*
4	2.82	*1.07*	7.13	*11.12*

Figure 3. Mean cumulative uptake of placebo bait, by weight measured in daily uptake plots (n=20), Palmyra Atoll, July 2005.

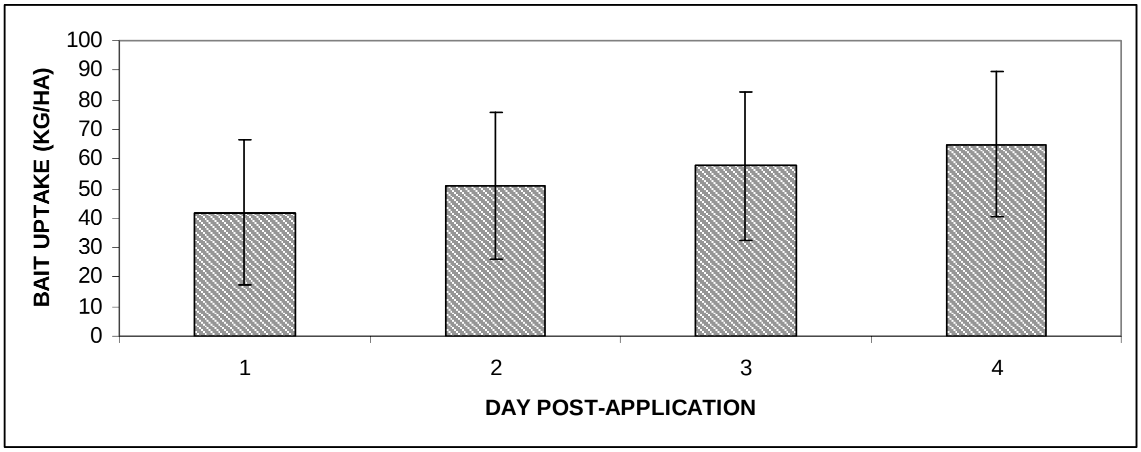


Table 6. Mean percent consumption of placebo PI-25, measured cumulatively in daily uptake plots (n= 20), Palmyra Atoll, July 2005.

Day	Uptake (kg/ha)	*Std Dev*	% Uptake
1	41.86	*24.52*	46.50
2	50.83	*24.82*	56.48
3	57.73	*25.08*	64.14
4	64.86	*24.56*	72.07

Trial Rat Eradication

Island Selection

The trial eradication was conducted on a subset of five islets within Palmyra Atoll comprising a total emergent land area of 4.08 ha (Appendix A). Islets were selected based on their size, relative rat and crab densities, and predominant forest structure, and isolation (reduced probability of reinvasion during monitoring phase). Crab densities varied across islets from low to mean-high abundance (assessed during the 2004 feasibility phase – see Howald et al. 2004) for both hermit and land crab species and rat populations were abundant on all treatment islets. To mimic aerial dispersal by helicopter, bait was applied to both the ground and palm tree canopy on all treatment islets using a hand broadcast method. The trial eradication proceeded with a sequential approach to baiting islets (see Table 7 and map in Appendix A).

The application rate between the islets was deliberately varied because of the uncertainty in the calibration experiment and we could adjust the rates on the other islands based on the bait uptake data from the previously treated islets. Bait was applied at a high application rate on Whippoorwill Island. Little East was applied at the lowest application rate because it had a low density of crabs and was believed to have a high probability of reinvasion due to its connection at low tide to the adjacent islands.

Table 7. Treated islands and emergent land area, Palmyra Atoll, July 2005.

ISLAND	APPLICATION DATE	LAND AREA (ha)	Application Rate (kg/ha)
Whippoorwill	15-Jul 2005	1.45	95
Bunker	16-Jul 2005	0.16	70
Fern	21-Jul 2005	0.40	80
Little East	21-Jul 2005	0.67	60
Home	24-Jul 2005	1.40	85

Methods

Bait Application

Figure 4. Hand broadcast calibration on the Palmyra Atoll airstrip using placebo PI-25, July 2005.

Calibration – The success of a rat eradication by broadcasting bait is largely dependent on the availability of bait to all rats within their respective territories over a minimum of three to four days. Thus even bait distribution across the islets during the trial was paramount. We calibrated bait application to refine hand broadcast methods on the airstrip on Palmyra prior to bait application on the trial islets (Figure 4). The calibration was designed to ensure that bait was applied in as evenly as possible during the bait application on the islets.

Ground Application – Using a team of four to five persons spaced three meters apart, bait was applied in consecutive cross-islet transects. Each member of the team was responsible for applying bait at the target application rate, calculated to a set number of pellets to be dropped in the 1.5 m radial area around him or her at each 1 m pace traveled along the transect. To best ensure uniform bait distribution all members of the team applied baited in unison across the width of the islets, each individual distributing bait to his or her respective transect (Figure 5).

We actively verified the bait application rate by sampling randomly placed three-meter radius circular plots continuously during the application process. A three meter long piece of flagging tied to a pole marking the plot's center was stretched out and moved to define the plot's perimeter. All pellets within the circle were marked with a pin flag and the pin flags counted and removed. The total number of bait pellets, mean, and the variance were calculated on-site and application rate was adjusted accordingly when necessary.

Figure 5. Hand broadcast application, Palmyra Atoll, July 2005.

Based on the target bait application rate (kg/ha) for each island, the total mass of bait to be applied on each islet was calculated using remotely measured islet surface areas. Polygon shapefiles were layered over Palmyra satellite imagery and the surface area calculated for non-tidal islet areas. After the entire islet was walked in transects, any bait remaining from the pre-determined total amount was applied uniformly throughout the islet.

During the application one sample of bait per 10 kg bucket applied was collected for confirmation of the concentration of brodifacoum by HPLC analysis.

Canopy application – Bait was applied to every coconut palm on each trial islet to:

1. Best mimic a helicopter bait broadcast, and
2. Provide additional insurance that bait is readily available to rats that are primarily arboreal.

Each palm tree was baited with at least 6-12 bait pellets distributed into the palm crown. Trees were marked when they had been successfully treated to ensure that no trees were omitted. Bait was delivered into the canopy using several methods:

1) "Bolos". Bait pellets joined together by paraffin wax to make conglomerates of 6-12 pellets, connected in pairs by a length of string. These "bolos" were shot into the canopy using a slingshot. A bolo delivery was considered successful if it lodged within 0.5 m of the core of the tree's crown (Figure 5).
2) Bait blocks. Bait pellets were embedded into paraffin wax to form conglomerates of 6-12 pellets, which were delivered into a palm crown using a long extension pole (Figure 5).
3) Hand placement. Bait was placed directly by hand into palm crowns either from the ground or at canopy level by climbing an adjacent tree.
4) Trunk placement. When bait could not be effectively delivered into a palm crown using any of the above methods, a bait conglomerate was secured to the trunk 2-3 m above ground level.

Figure 5. Slingshot and Pole Application of PI-25 into Coconut palm canopies, Palmyra Atoll, July 2005.

Measurement of Bait Uptake

Uptake was measured using randomly placed three meter radius circular plots on one, two, three and four days post application on Home (n=30) and Whippoorwill (n=35) Islands, and due to logistical constraints on 1,2, and 3 days post application on Bunker Island (n=6). Remaining bait pellets within each circular plot were tallied and recorded. Uptake was not measured on Little East or Fern because of the extensive fern ground cover that made it impossible to establish and accurately find and count bait pellets. A general walk through on Little East and Fern islands on days 2 and day 3, respectively, post bait application were used to estimate bait availability/uptake.

Results

Bait application rates were achieved during each application but bait was unevenly distributed due to thick vegetation in some parts of the islands, and irregular uptake, in part due to the variation in distribution and abundance of Cardisoma landcrabs. The first two tables include the extreme outliers (Table 8, 9), and the later two tables reject the outliers (Table 10, 11). Figure 2 graphically depicts mean bait consumption, without outliers, by weight. By removing extreme outliers from the data set, there is a regular decline in percentage uptake of remaining bait from Day One to Day Four.

Table 8. Mean consumption rate (w/ outliers) measured daily in uptake plots, Palmyra Atoll, July 2005.

Island	Day	# Pellets (m^2)	*Std Dev*	Uptake (kg/ha)	*Std Dev*	*N Plots*
Whippoorwill (95 kg/ha)	1	3.13	*1.15*	26.24	*26.49*	*35*
	2	2.92	*1.22*	4.86	*28.02*	*35*
	3	1.69	*0.85*	28.35	*19.48*	*35*
	4	1.44	*0.89*	5.65	*20.44*	*35*
Home (85 kg/ha)	1	3.21	*1.09*	14.90	*25.17*	*30*
	2	2.56	*1.13*	16.67	*25.89*	*30*
	3	2.75	*1.53*	-4.87	*35.17*	*30*
	4	1.84	*1.29*	17.96	*29.62*	*30*
Bunker (70 kg/ha)	1	1.67	*0.50*	31.59	*11.46*	*6*
	2	1.72	*1.10*	-1.06	*25.40*	*6*
	3	1.30	*0.97*	9.52	*22.29*	*6*

Table 9. Mean consumption (w/ outliers) measured cumulatively in uptake plots, Palmyra Atoll, July 2005.

Island	Day	Uptake (kg/ha)	*Std Dev*	% Uptake
Whippoorwill	1	26.24	*26.49*	26.70
	2	31.10	*28.02*	31.64
	3	59.44	*19.48*	60.49
	4	65.09	*20.44*	66.24
Home	1	14.90	*25.17*	16.85
	2	31.56	*25.89*	35.68
	3	26.69	*35.17*	30.17
	4	44.65	*29.62*	50.47
Bunker	1	31.59	*11.46*	45.12
	2	30.53	*25.40*	43.61
	3	40.05	*22.29*	57.21

Table 10. Average consumption rate (w/o outliers) measured in uptake plots, Palmyra Atoll, July 2005.

Island	Day	# Pellets (m^2)	*Std Dev*	Uptake (kg/ha)	*Std Dev*	*N*
Whippoorwill	1	2.97	*0.96*	29.86	*22.11*	*19*
	2	2.21	*0.71*	17.62	*16.31*	*21*
	3	1.54	*0.76*	15.43	*17.47*	*14*
	4	0.95	*0.58*	13.42	*13.26*	*21*
Home	1	2.96	*0.94*	20.32	*21.69*	*33*
	2	2.37	*0.90*	13.60	*20.61*	*22*
	3	2.29	*0.99*	1.97	*22.74*	*31*
	4	1.64	*1.06*	14.95	*24.39*	*23*
Bunker	1	1.67	*0.50*	31.59	*11.46*	*5*
	2	0.97	*0.48*	16.17	*11.11*	*3*
	3	0.73	*0.46*	5.56	*10.60*	*4*

Table 11. Mean percent consumption (w/ outliers) measured in uptake plots, Palmyra Atoll, July 2005.

Island	Day	Uptake (kg/ha)	*Std Dev*	% Uptake
Whippoorwill	1	29.86	*22.11*	26.70
	2	47.48	*16.31*	31.64
	3	62.91	*17.47*	60.49
	4	76.34	*13.26*	66.24
Home	1	20.32	*21.69*	16.85
	2	33.90	*20.61*	35.68
	3	35.87	*22.74*	30.17
	4	50.83	*24.39*	50.47
Bunker	1	31.59	*11.46*	45.12
	2	47.75	*11.11*	43.61
	3	53.32	*10.60*	57.21

The general walk through on day 2 post broadcast on Little East Island, an estimated 60-70% of bait had been taken up, however, there was uneven distribution of bait availability. We estimated that 99.9% of the bait had been removed in prime rat and landcrab habitat above the shoreline leaving potential rat territory size areas free of bait. Further, Little East had no established hermit crab population which were an important driver of bait uptake on the remaining treated islands in the atoll. Thus, 60 kg/ha is too low an application rate to ensure bait is available to the entire rat population for a minimum of 4 days.

By day 3 post broadcast on Fern Island (baited at 80 kg/ha), an estimated 60-70% of bait had been taken up. Bait was relatively evenly distributed across the island, which from observations of personnel experienced in aerial drops was as consistent as that spread from a helicopter, with bait available in even small rat territories. However, in areas of high density *Cardisoma* landcrab burrows, all the bait had been taken up. Further, Fern Island has no established hermit crab population that competes with landcrabs and rats for the bait. Therefore, it appears that 80 kg/ha may not be adequate to ensure bait is available to the entire rat population across the atoll for a minimum of 4 days.

Our monitoring of uptake data from Whippoorwill and Home islands indicates on average 30% of applied bait still available to rats four days post application (Figure 6). On a walk through on Whippoorwill on day 7 post application we estimated that >99% of the bait pellets had been removed. Calculation of the 99.99% confidence interval indicates the relative probability of bait applied at different densities available to 100% of the rat population four days post application (Table 12). Results from Bunker Island indicate bait would not be detected in monitoring plots by day 3 post application when baited at 70 kg/ha. Bait would be detected in monitoring plots with an application rate of 85-95 kg/ha to rats at 4 days post application.

In evaluating the bait uptake data, and the subjective evaluation of bait spread across the treated islands, we believe an application rate of 90 kg/ha is appropriate to ensure enough bait is available to every rat across the atoll for a minimum of 4 days.

Figure 6. Cumulative bait consumption (w/o outliers) measured in uptake plots for a) Home Island (n=109); b) Whippoorwill Island (n=75); and c) Bunker Island (n=12).

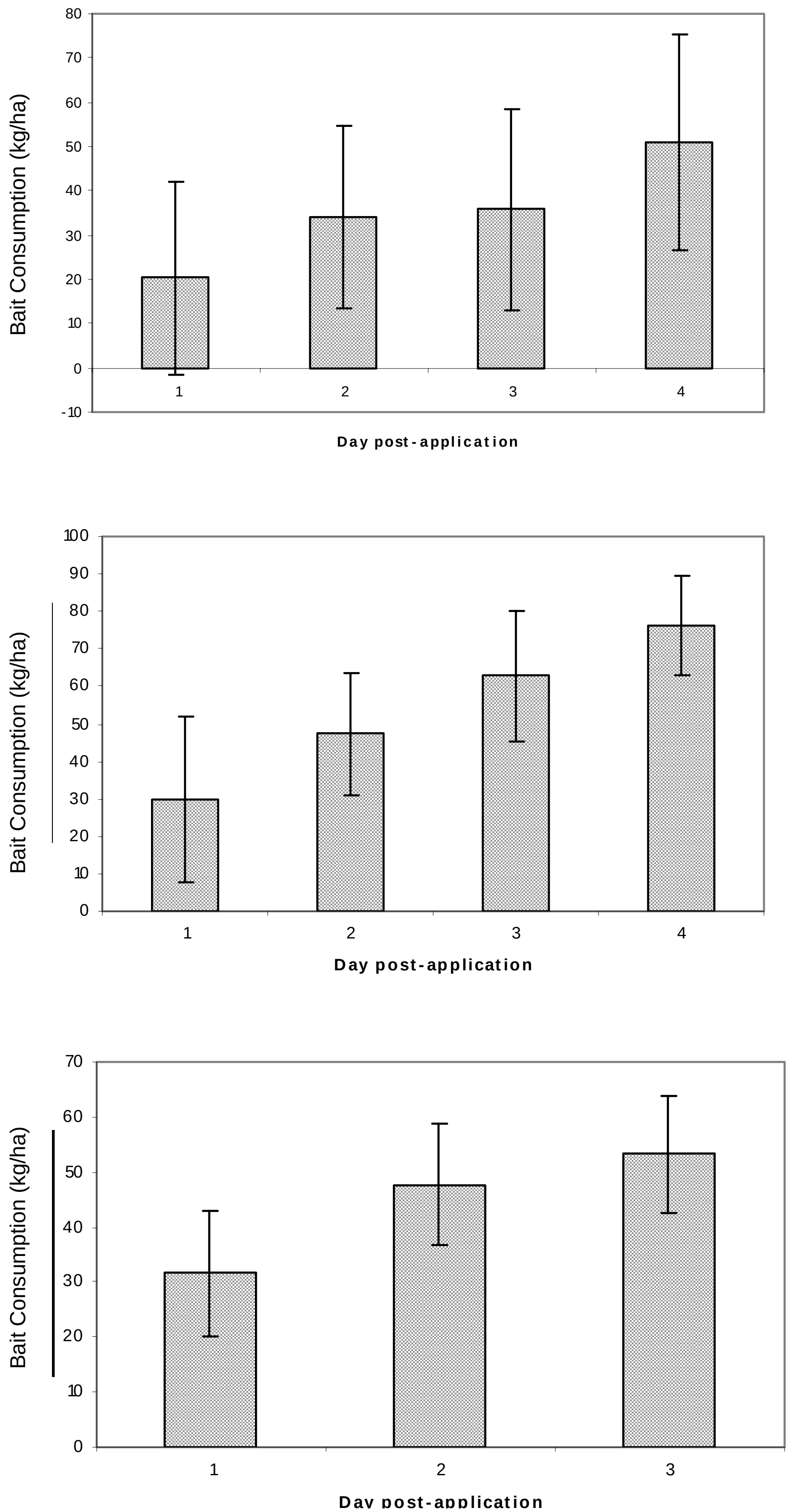


Table 12. Bait remaining four days post application. Data are $\chi \pm$ 99.99% confidence limits of pellets per m^2. Palmyra Atoll, July 2005.

Island	Bait Application Rate (kg/ha)	*99.99% Confidence Limits*	Min # Pellets L_1	Max # Pellets L_2
Whippoorwill	95.00	*1.44 ± 0.49*	0.95	1.94
Home	85.00	*1.65 ± 0.67*	0.98	2.32
Bunker	70.00	*1.30 ± 1.30*	0.00	2.60

Efficacy

Methods

We used direct and indirect methods to monitor the effectiveness of the bait application in eradicating rats. The following techniques were used to measure efficacy : (1) pre and post bait broadcast live trapping on ground and in the coconut palm canopy, (2) pre and post bait broadcast wax indicator chew blocks, and (3) monitoring of radio collared rats.

Live Trapping

One week prior to the bait application one three-night trap session was conducted on each of the islets to assess rat presence and compare relative densities between islets. Haguruma brand live traps were armed with coconut and set both on the ground and in the coconut palm canopy (Table 13). Ground traps were set on overturned five-gallon buckets to minimize disturbance by land crabs and spaced 15-25 m apart. Traps set in 8-20 m tall coconut palm trees were mounted with nails beneath the crown base and secured around the trunk with thin-gauged wire (Figure 7).

Table 13. Number of ground traps and traps mounted in coconut palms for each treated island, Palmyra Atoll, July 2005.

Island	# of ground traps	# of tree traps
Whippoorwill/Bunker	55	10
Home	35	10
Little East	40	4
Fern	25	10

Figure 7. Haguruma brand live rat traps mounted on buckets and in coconut palms, Palmyra Atoll, July 2005.

Both ground and tree traps were checked daily and the condition or contents of each trap, whether rat, crab, or no catch, was recorded. All rats captured were marked with a uniquely numbered ear tag, and in some cases, a radio collar (see below), and the sex, weight and apparent reproductive condition were noted. Each rat was released at the point of capture. All traps were rearmed for each successive trap night and placed in the same location.

Live trapping on the ground and trees resumed on all treatment islets one week post bait application. All traps were armed with fresh coconut, and checked daily for condition and contents. Trap effort was sustained for a total of 21, 16, 15, and 13 days on Whippoorwill/Bunker, Fern, Little East, and Home islands respectively.

Ground based live trapping was conducted on untreated Cooper Island before and after the bait application for reference. No tree trapping was conducted on Cooper Island due to logistical constraints.

Chew Blocks

Figure 8. Wax chew block with peanut butter. Note ants feeding on peanut butter, Palmyra Atoll, July 2005.

Peanut butter flavored paraffin wax chew blocks were used as an indirect method of detecting rat presence. Rats chewing on blocks left distinct incisor marks indicative of rat activity (Table 14 and Figure 8).

Chew blocks were nailed to a tree two to three meters above the ground to minimize crab access. Prior to the application blocks were set in tandem with the three-night live trapping session on all treatment islets. Blocks were inspected daily for signsa of rat incisor marks, crab claws, or insects. Each chewed or marked block was replaced with a fresh block for the successive evening.

Table 14. Number of chew blocks on each islet, Palmyra Atoll, July 2005.

Island	# of blocks
Whippoorwill/Bunker	55
Home	35
Little East	40
Fern	25

Beginning one week post application blocks were set and inspected daily or bi-daily until August 13, 2005, after which blocks were checked at two-week intervals. Blocks were set and checked at the same interval as live traps for a total of 21, 16, 15, and 13 days on Whippoorwill, Fern, Little East, and Home islands respectively.

Radio Telemetry

Radio-collared rats were used as a direct indicator of efficacy.   During the pre-application trapping sessions a total of 45 adult rats (Table 15) captured on the ground and in the trees (with exception of Little East island) were anaesthetized and fitted with radio collars programmed to a unique frequency (ATS, Minnesota) (Figure 9). Each rat fitted with a radio collar was also marked with a uniquely numbered ear tag and the sex and weight recorded. Collared rats were held in cages and observed over a 24-hour period until released on their respective capture site.

Figure 9. Radio collaring rats, Palmyra Atoll, July 2005.

Directional Yagi antennas and digital receivers were used to track rats at daily and/or nightly intervals to confirm movement of the radio signal (indicating that the rat was alive) prior to the bait application. All collared rats were determined to be active by direct visual observation, dynamic signal at the time of tracking (indicating that the rat was moving), or multiple refuge/nest locations between consecutive fixes.

Radio-collared rats were tracked and monitored on all treatment islets until mortality was detected or the radio signal was lost likely as a result of irreparable damage by crabs. Mortality was determined through carcass recovery or when the signal was located repeatedly in the same location over a period of seven days. At the time of recovery the location of death, whether ground, arboreal, or underground, and the condition of each carcass, whether scavenged or whole, was recorded.

Table 15. Number of rats fitted with radio collars captured in Ground and Tree placed live traps on treatment islets (Ratio= male:female:juvenile).

ISLAND	GROUND	TREE	TOTAL
Whippoorwill	4 (1:3)	5 (1:4)	9 (2:7)
Home	13 (5:7:1)	3 (2:1)	16 (7:8:1)
Little East	13 (6:7)	0 (0:0)	13 (6:7)
Fern	4 (1:3)	3 (1:2)	7 (2:5)
TOTAL	**34** **(13:20:1)**	**11** **(2:3)**	**45** **(17:27:1)**

Results and Discussion

Trapping

Rats were detected on the ground prior to the bait application on all treatment islets, and in the palm canopy on all treatment islets except Little East which had only a few coconut palms. On the treatment islets pre-application ground trapping success for rats ranged between 19.7% and 46.3% (n= 533.5 trap nights) with a mean trap success of 29.4 % (s = 11.5) (Table 16). The pre-application trap success at the reference location was 33.3% (n=45), a rate comparable to mean success on trial islets. Rats were captured in the palm canopy at a rate of 7.5% to 13.3 % (n= 155) (Table 17). No rats were trapped in the palm canopy on Little East, likely attributable to significantly lower palm tree density.

After the bait application, no rats were captured after 1542.5 trap nights across the treated islets. Rat trap success during the reference trapping effort on an untreated islet (Cooper) was 46.4% (n= 36.5 trap nights).

Table 16. Pre- and post-bait application ground trap success on trial islets and Cooper Island (reference site), Palmyra Atoll, July 2005.

SESSION	ISLAND	TRAP NIGHTS *TN= #traps –(0.5 xTNC*)*	TRAP SUCCESS	
			RAT	CRAB
Pre-application	Whippoorwill/ Bunker	141.0	27.6	5.7
	Home	93.0	32.3	2.2
	Little East	232.5	19.7	5.1
	Fern	67.0	46.3	0.0
	TOTAL =	**533.5**	**29.4**	**2.9**
	Std. Dev.	-	11.5	2.3
Reference (pre)	*Cooper*	*45.0*	*33.3*	*0.0*
Post-application	Whippoorwill/ Bunker	653.5	0.0	1.5
	Home	264.0	0.0	1.9
	Little East	378.5	0.0	4.0
	Fern	246.5	0.0	0.4
	TOTAL =	**1542.5**	**0.0**	**2.0**
	Std. Dev.	-	0.0	1.5
Reference (post)	*Cooper*	*36.5*	*46.6*	*0.0*

* TNC = Tripped no catch.

Table 17. Pre and post bait application tree trap success, Palmyra Atoll, July 2005.

SESSION	ISLAND	TRAP NIGHTS *n= #traps – (0.5 x TNC*)*	% RAT SUCCESS
Pre-application	Whippoorwill/ Bunker	45.0	13.3
	Home	40.0	7.5
	Little East	20.0	0.0
	Fern	50.0	12.0
	TOTAL=	**155.0**	**8.2**
	Std. Dev.	**-**	**6.0**
Post-application	Whippoorwill/ Bunker	130.0	0.0
	Home	80.0	0.0
	Little East	40.0	0.0
	Fern	100.0	0.0
	TOTAL =	**350.0**	**0.0**
	Std. Dev.	**-**	**0.0**

* TNC= Tripped no catch

Chew Blocks

Prior to the bait application on all treatment islets rat activity was detected using chew blocks. Rat activity ranged from 35.4 to 100.0%, with a mean rat activity of 74.3% (n=638, s= 24.2) (Table 18). Ants and crabs were responsible for less than 2% of activity and only 6.8% (s= 7.0) of blocks completely disappeared.

No rat incisor maks were detected post bait application (n= 1686 block nights) (Table 18). On average crabs and ants were responsible for 8% (s= 5.4) and 38.4% (s= 9.5) of activity respectively. Blocks completely disappeared at a mean of 7.8% (s=5.8) of the time.

Table 18. Chew block activity pre- and post-bait application on trial islets, July 2005, Palmyra Atoll.

SESSION	ISLAND	BLOCKS (n)	% CHEWED			
			RAT	CRAB	ANT	Block Gone
Pre-application	Whippoorwill	164	81.7	0.0	0.0	17.1
	Bunker	16	100.0	0.0	0.0	0.0
	Home	277	35.4	0.0	0.7	5.4
	Little East	106	84.0	0.0	0.9	10.4
	Fern	75	70.7	0.0	8.0	1.3
	Total	638	74.3	0.0	1.9	6.8
	Std. Dev.	-	24.2	0.0	3.4	7.0
Post-application	Whippoorwill	676	0.0	15.4	40.1	12.7
	Bunker	88	0.0	6.8	29.5	2.3
	Home	400	0.0	4.3	52.0	12.8
	Little East	272	0.0	11.4	29.0	10.7
	Fern	250	0.0	2.0	41.2	0.8
	Total	1686	0.0	8.0	38.4	7.8
	Std. Dev.	-	0.0	5.4	9.5	5.8

Measures of activity on chew blocks four to five weeks post bait application (monitored at 14-day intervals) have indicated no rat presence on any treatment islet (Table 19).

The two week interval between checks was due to logistical complications and lack of staffing. We recognize that the missing blocks complicate the data because it is impossible to conclude what removed the blocks. However, we hypothesize that hermit

Table 19. Percent chew block activity measured post eradication on 5 trial islets, Palmyra Atoll, July 2005. Chew blocks were set 14 days prior to the sample date (n= 10 blocks per sample date).

ISLAND	DATE	Day post-application	% SUCCESS			
			RAT	CRAB	ANT	Block Gone
Whippoorwill/ Bunker	24-August	40	0.0	30.0	50.0	50.0
	7-September	54	0.0	10.0	10.0	90.0
	21-September	68	0.0	10.0	10.0	90.0
	Total	-	0.0	16.7	23.3	76.7
	Std. Dev.	-	0.0	11.5	23.1	23.1
Home	24-August	31	0.0	30.0	40.0	60.0
	7-September	45	0.0	0.0	30.0	70.0
	21-September	59	0.0	40.0	40.0	60.0
	Total	-	0.0	23.3	36.7	63.3
	Std. Dev.	-	0.0	20.8	5.8	5.8
Little East	24-August	34	0.0	0.0	0.0	100.0
	7-September	48	0.0	10.0	10.0	90.0
	21-September	62	0.0	30.0	30.0	70.0
	Total	-	0.0	13.3	13.3	86.7
	Std. Dev.	-	0.0	15.3	15.3	15.3
Fern	24-August	34	0.0	0.0	70.0	30.0
	7-September	48	0.0	0.0	80.0	20.0
	21-September	62	0.0	0.0	90.0	10.0
	Total	-	0.0	0.0	80.0	20.0
	Std. Dev.	-	0.0	0.0	10.0	10.0

crabs were likely responsible for the majority if not all the block removal because the removed blocks were on trees and vegetation that hermit crabs were routinely found and could easily climb. Further, the blocks were typically coated with a small layer of peanut butter and was not permeated through the block so as to discourage rats from consuming all of the wax and prior to the baiting, rats did not consume the entire wax block when given the opportunity.   From the blocks that were remaining on trees, combined with the trap data, we conclude that the data would strongly suggest that the rats had successfully been removed from all of the treated islands.

Radio Telemetry

Recovery of collared rats began five days post bait application on all treatment islets and continued until collar status was determined for all rats. Of radio collared rats, 27 were actively recovered (carcasses) and 9 were presumed dead (signal located repeatedly in the same location over a seven-day period). Four radio collar signals were lost and not recovered after the bait application, presumably damaged by crabs. Five radio-collared rats were omitted from analysis due to improperly functioning collars prior to the bait application. Mean day of carcass recovery was 7.2 days post bait application (n=40 rats, s= 2.3) (Table 20).

A sub-sample of radio-collared carcasses in the most optimal condition were collected and submitted for brodifacoum residue analysis to National Wildlife Research Center, Fort Collins, Colorado (n=5).

Table 20. a) Number and location of radio collared rats recovered or presumed dead: Ground (exposed or beneath foliage location), within burrow, or palm tree (presumed dead). b) Condition percentage of radio collared rats recovered or presumed dead: whole (fresh carcass, death <24 hr), decomposed (skeleton and sinew, death >48 hr), scavenged (collar only recovered), and unknown (collar not recovered)., Palmyra Atoll, July 2005

ISLAND	a) LOCATION of DEATH (%)				b) CONDITION (%)				
	GROUND	BURROW	TREE	N	WHOLE	DECOM	SCAVN	UNK	N
Whippoorwill	87.5	12.5	0.0	8	37.5	50.0	12.5	0.0	8
Home	66.7	22.2	11.1	9	0.0	55.6	22.2	22.2	9
Little East	37.5	62.5	0.0	8	25.0	62.5	0.0	12.5	8
Fern	66.7	0.0	16.7	6	16.7	50.0	0.0	16.7	6
Total	64.5	25.8	6.5	31	19.4	54.8	9.7	16.1	31
Std. Dev.	20.6	27.0	8.3	-	15.7	5.9	10.8	14.2	-

The radio collar, live trap and chew block data together strongly suggest that the rats had been successfully removed from the treated islets. However, on day 8 post broadcast on Whippoorwill, a small, live juvenile rat was discovered in a rat nest with 2 adult sized, and dead, rats. The rat escaped and ran off quickly with no behavioral signs of anticoagulant poisoning. Two days later, during a check on the island, a similar sized rat was found alive in the same rat nest, but clearly lethargic, and was euthanized. The legs showed signs of hemorrhaging including the top and bottom of the feet. The lethargy and hemorrhaging were likely signs of exposure to brodifacoum, however, residue analysis is pending to confirm.

We conclude that the bait application was effective in removing all of the rats from the treated islets, however, it is unclear how long the islets remained rat free. The discovery of the small, young rat at day 8 on Whippoorwill Is. was troubling as it confirms that rat eradications should take place at a time of year when there is no breeding so as to prevent young weanling rats escaping exposure to the bait when in the burrow, and surviving to repopulate the island causing the eradication to fail. Palmyra Atoll is an aseasonal environment and it is likely that rats are breeding year round making it difficult to ensure bait is delivered to all rats including weanlings. Thus, to ensure bait availability to all rats including weanlings, we are recommending that bait be applied twice at the full application rate, 10-14 days apart, to ensure a high probability of successfully removing rats from Palmyra Atoll.

Evaluation of Primary and Secondary Exposure Risks to Non-Target Species

We monitored the movement of brodifacoum and/or its associated impact within the terrestrial ecosystems on all treatment islets. Within the terrestrial environment we:

1. performed shorebird surveys to assess potential impact to migratory population,
2. collected land and hermit crabs, which are known prey items of shorebirds, to measure brodifacoum residues over time,
3. indexed crab populations pre- and post-application to measure potential impact,
4. monitored in the environmental fate of bait over time, and
5. searched for carcasses of non-target species to assess potential impact to non-target species.

Shorebirds

Methods

Informal shorebird surveys were conducted for the duration of the trial during most visits to the trial islets. Surveys were conducted by walking the perimeter of the islet and recording the number of each species of shorebird encountered on or in the immediate vicinity of the islet. The time, weather conditions, and tidal position were recorded.

Results

Four species (*Numenius tahitiensis*, Bristle-thighed Curlew *[BRCU]; Heterscelus incanus*, Wandering Tattler *[WATA]; Pluvialis fulva*, Pacific Golden Plover *[GOPL]* and

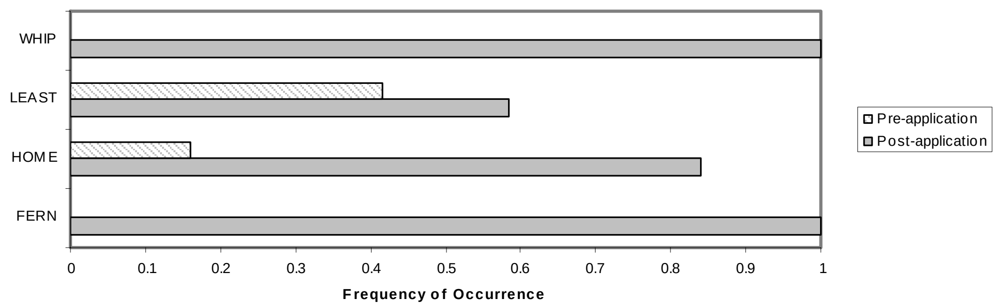
Arenaria interpres, Ruddy Turnstone *[RUTU]*) of shorebirds were encountered on each trial islet both previous to and up to three weeks post bait application (Figure 10).

Shorebirds seen during the surveys were frequently observed traveling between islets and over the central lagoon, indicating a lack of site-specific fidelity   Therefore, based on the broad utilization of habitat it is impossible to infer any effects of the trial eradication on Palmyra's shorebird populations. However, the numbers of individuals observed during the surveys were higher post bait application than pre application for all species except Ruddy Turnstones on Little East islet and Wandering Tattlers on Whippoorwill, Home, and Little East islets (Table 21). The increased abundance of shorebirds sightings post application was more likely a result of migratory influx, which generally begins in the late summer months on the atoll, rather than an artifact of the trial itself. At a minimum the surveys conducted confirm the presence of shorebird species on each trial islet during the summer of 2005. This data, although unable to detect any direct impacts to the local population associated with the trial eradication, will prove useful for the logistical and operational planning of an atoll-wide rat eradication.

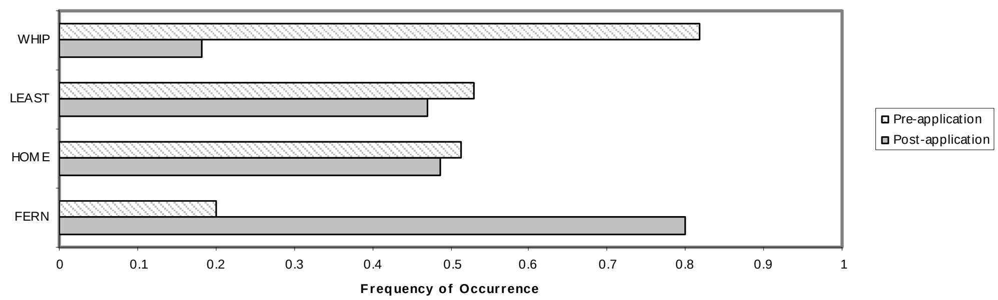
Bristle-thighed Curlews, though generally observed along the shorelines and above open water, were occasionally sighted beneath the forest canopy in the interior of the islets. Although no foraging activity was observed, numerous husking stations attributed to the curlews were found beneath the canopy, containing fragments of the turbo snail shells used by hermit crabs. This evidence suggests that hermit crabs compose at least a portion of the curlew's diet, confirming their potential risk of secondary exposure to the rodenticide.

Figure 10. Frequency of sighting during pre and post-appIlcation shorebird surveys for species: a) Bristle-thighed Curlew, b) Wandering Tattler, c) Pacific Golden Plover, and d) Ruddy Turnstone.

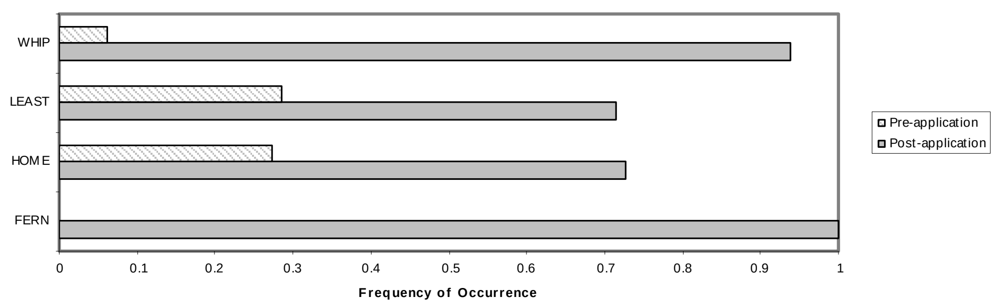
a. Bristle-thighed Curlew



b. Wandering Tattler



c. Pacific Golden Plover



d. Ruddy Turnstone

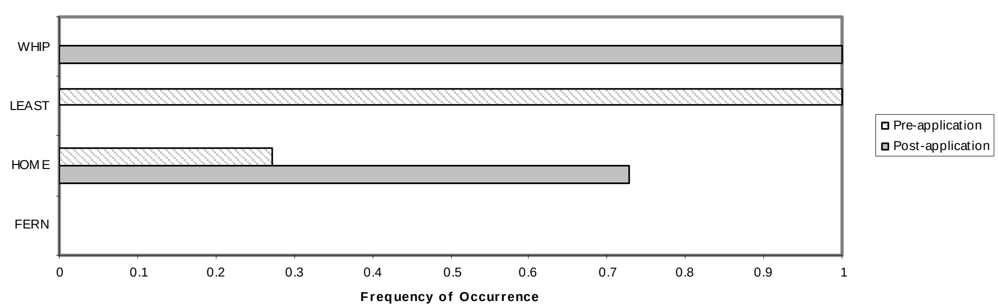


Table 21. Mean species sighting per survey conducted for 5 trial islets. a) Pre-application surveys: Whippoorwill/Bunker (n=3); Little East (n=5); Home (n=5); and Fern (n=5). b) Post-application surveys: Whippoorwill/Bunker (n=13); Little East (n=6); Home (n=10); and Fern (n=8), Palmyra Atoll July-August 2005.

Species	Island	Pre-application	Post-application	% Difference
BRCU	Whippoorwill/Bunker	0.00	0.13	100.00
	Little East	1.40	3.70	62.16
	Home	1.00	1.17	14.29
	Fern	0.00	0.85	100.00
	Mean	**0.60**	**1.46**	**55.95**
	Std. Dev.	**0.71**	**1.56**	**40.67**
WATA	Whippoorwill/Bunker	0.80	0.13	-84.38
	Little East	3.80	2.00	-47.37
	Home	1.60	1.50	-6.25
	Fern	2.67	2.77	3.70
	Mean	**2.22**	**1.60**	**-33.57**
	Std. Dev.	**1.30**	**1.11**	**40.44**
GOPL	Whippoorwill/Bunker	0.00	0.13	100.00
	Little East	1.20	1.60	25.00
	Home	0.40	0.83	52.00
	Fern	0.67	2.38	72.04
	Mean	**0.57**	**1.24**	**62.26**
	Std. Dev.	**0.50**	**0.97**	**31.69**
RUTU	Whippoorwill/Bunker	0.00	0.00	0.00
	Little East	0.60	0.80	25.00
	Home	0.40	0.00	-100.00
	Fern	0.00	0.15	100.00
	Mean	**0.25**	**0.24**	**6.25**
	Std. Dev.	**0.30**	**0.38**	**82.60**

Land Crab Residue Analysis

Palmyra hosts a diverse and abundant land crab community with six land crab species present throughout the atoll. The most abundant land crab is the red hermit crab (*Coenobita perlatus*). Additional species include the purple hermit crab (*Coenobita brevimanus*), orange land crab (*Cardisoma carnifex*) and purple land crab (*Cardisoma rotundum*), the large coconut crab (*Birgus latro*), and *Geograpsis crinipes*, which is present at low numbers on the atoll.

Although crabs and other invertebrates are not known to be susceptible to anticoagulant rodenticides, they readily consume bait. Crabs were collected from each trial islet for analysis of tissue residues, including brodifacoum from bait ingestion, at 2, 6, 10 and 21 days post bait application (Table 22). Five crabs from each of the two most abundant genera (*Cardisoma* spp. and *Coenobita* spp.) were collected on each sample day at Whippoorwill and Home islets. Due to low initial population sizes of *Coenobita* spp. on Little East and Fern islets, this genus was excluded from the collections made on these two trial islets. One *B. latro* individual was discovered dead in a live rat trap 21 days post application on Little East was submitted for tissue analysis. With the exception of the one dead *B. latro* specimen, all crabs sampled were collected live, euthanized by freezing, and submitted whole to the National Wildlife Research Center Analytical Lab for analysis. Results from the tissue analysis will be reported elsewhere.

Table 22. Land crab collections from trial islets for brodifacoum residue analysis, Palmyra Atoll, July-August 2005.

Island	Day Post-application	*Cardisoma* spp.	*Coenobita* spp.
Whippoorwill	2	5	5
	6	5	5
	10	5	5
	21	5	5
	Total	*20*	*20*
Little East	2	5	-
	6	5	-
	10	5	-
	21	5	-
	Total	*20*	-
Fern	3	5	-
	6	5	-
	10	5	-
	21	5	-
	Total	*20*	-
Home	2	5	5
	6	5	5
	10	5	5
	19	5	5
	Total	*20*	*20*
Grand Total		80	40

* The day 21 samples will be analyzed first to determine if the day 56 collection is needed. Collection will be needed at day 56 if any of the samples on day 21 come back positive for brodifacoum residue. No samples will be collected after day 21 if no brodifacoum is detected.

Landcrab Population Index Monitoring

Methods

All five trial islands host multi-species land crab communities, though community composition varies between islands. Brodifacoum functions as an anticoagulant in mammalian and avian circulatory systems, but is believed to be innocuous to arthropods. We tested this hypothesis by indexing land crab populations before bait application, and 15 days after bait application on four trial islets: Home, Whippoorwill, Little East, and Fern.

Land crab population indices were achieved by sampling randomly placed 25 m x 5 m fixed-width transects; individual land crabs within the transect swath were identified by species and counted. A sample was collected by walking 25 m in a randomly chosen direction from a random start point, counting only crabs within the transect swath and in front of the researcher. *Cocos* frond midribs fashioned to 2.5 m in length were carried and swung horizontally to delineate swath width while sampling transects. The number of samples per trial island is approximately equivalent to ¼ (25%) of each island's emergent land area.

Data were corrected for non-normality using a square root transformation $X' = \sqrt{X + 0.5}$ (Bartlett 1936). A two-tailed t-test was used to evaluate differences in mean density, measured per $100m^2$ (α =0.05).

Results

Results from the land crab population index study suggest that ground baiting with the brodifacoum-loaded rodenticide (PI-25) does not have a significant influence on Palmyra's land crab populations. Results indicated a non-significant difference in crab density for all islands except Home Island, where a difference in *Coenbita perlatus* density pre and post application was detected (Table 23). Difference in density, although significant, are not believed to suggest population impact from brodifacoum consumption. Crab densities have been observed to vary in correlation with weather conditions (A. Wegmann, pers. comm.). During periods of foul weather (high winds and rainfall) and extreme sun exposure in the afternoon hours, crabs take refuge beneath foliage for protection from environmental elements making census of crab populations challenging. To minimize weather effect during crab index studies the majority of censuses were performed during the morning hours on days of non-extreme weather conditions. However, based on the unpredictable weather patterns and logitisical constraints often encountered on the atoll, the post application transects on Home Island were conducted in light rainfall during the afternoon hours. It is believed the difference in density can be better attributed to weather condition than rodenticide impact. Further, the predominant forest type on Home Island of *Cocos nucifera* and *Pandanus tectorious* provide a dense understory of fronds and root structures used by non-burrowing crabs as refuge during extreme weather events. This “hiding” or refuge behavior results in extremely observer error or bias when censuses are performed. If difference in mean density were attributed to rodenticide impact it is expected that *Coenbita perlatus* carcasses would have been detected during formal and informal carcass searches performed, especially as this is a non-burrowing species. However, during the 43 hours of carcass search effort on Home Island no hermit crab carcasses were encountered.

Table 23. Land crab index pre- and post-bait application. Data are mean crab density per 100m^2 ± 95% confidence limits, Palmyra Atoll, July-August 2005.

		Fern Island	Home Island	Little East Island	Whippoorwill Island
Coenobita perlatus	Pre	0.00 ± 0.00 (8)	22.9 ± 3.73 (26)	0.00 ± 0.00 (14)	7.86 ± 3.50 (29)
	Post	0.00 ± 0.00 (8)	9.32 ± 2.77 (26)	0.00 ± 0.00 (14)	11.2 ± 4.24 (29)
	T-test	n/a	*P < 0.01**	n/a	*N.S.*
Coenobita brevimanus	Pre	0.00 ± 0.00 (8)	0.06 ± 0.08 (26)	0.23 ± 0.29 (14)	1.60 ± 0.93 (29)
	Post	0.00 ± 0.00 (8)	0.03 ± 0.06 (26)	0.34 ± 0.67 (14)	0.72 ± 0.49 (29)
	T-test	n/a	*N.S.*	*N.S.*	*N.S.*
Cardisoma carnifex*	Pre	1.20 ± 0.78 (8)	0.12 ± 0.19 (26)	2.63 ± 1.96 (14)	0.58 ± 0.42 (29)
	Post	0.70 ± 0.55 (8)	0.06 ± 0.08 (26)	0.40 ± 0.28 (14)	0.39 ± 0.26 (29)
	T-test	*N.S.*	*N.S.*	*N.S.*	*N.S.*
Cardisoma rotundum*	Pre	0.20 ± 0.39 (8)	0.12 ± 0.11 (26)	0.00 ± 0.00 (14)	0.05 ± 0.05 (29)
	Post	0.00 ± 0.00 (8)	0.00 ± 0.00 (26)	0.06 ± 0.11 (14)	0.03 ± 0.05 (29)
	T-test	n/a	n/a	n/a	*N.S.*
Birgus latro	Pre	0.10 ± 0.20 (8)	0.00 ± 0.00 (26)	0.00 ± 0.00 (14)	0.00 ± 0.00 (29)
	Post	0.00 ± 0.00 (8)	0.03 ± 0.06 (26)	0.11 ± 0.15 (14)	0.00 ± 0.00 (29)
	T-test	n/a	n/a	n/a	n/a

* Post bait application values for *Cardisoma* sp. might be biased by land crab sampling – 15 *Cardisomas* were removed from each island for toxin loading analysis prior to the post application index sampling.

Environmental Fate of Bait

The rate and characteristics of bait decomposition on each trial islet were monitored over time to better understand how bait withstands ambient environmental conditions on the atoll. Bait pellets were enclosed in cages to prevent consumption by crabs or rats, and left exposed to the ambient environment. Invertebrates were readily able to access the bait. A sub-sample of bait pellets was collected from each cage for brodifacoum residue analysis in a laboratory and the condition of bait noted at 3, 6, and 21 days post bait application.

In general the condition of bait at Day Three was swollen and tacky in texture while still relatively firm. By Day Six all bait pellets were swollen with moisture and soft to touch, but the pellets retained their original shape. The pellets could be molded but would not break into pieces under pressure. For two of the four treatment islets mold was noted growing on most pellets in the bait enclosures. By Day 21 crabs had effectively burrowed into the enclosures on Little East and Fern islets and consumed the bait within. For the remaining bait at Day 21 pellets were swollen to approximately 2-3 times the original, compressed size. Pellets had changed color from the dyed blue to a gray, greenish shade, and all pellets were entirely encased in mold. Bait pellets were well deteriorated, with texture spongy and would disintegrate with light pressure.

Non-Target Species Carcass Searching

Both formal (organized timed searches) and informal (opportunistic finds) carcass searches were conducted on all trial islets. Formal carcass searches were conducted at seven, 10, and 14 days post-application in which a team of two to three observers thoroughly covered all land area on the trial islets visually scanning for carcasses. Informal searches occurred opportunistically whenever field personnel visited trial islets for other scientific purposes. Carcasses found during both formal and informal searches were collected, and the general condition and location of recovery recorded, whether “exposed,” “under foliage,” or “in burrow.” All carcasses collected were bagged and frozen for potential residue analysis.

A total of 169 person-hours were devoted to carcass searches. Forty-five rat carcasses were found. In addition, three land crab (*Cardisoma carnifex*) carcasses were found on Whippoorwill Islet and were submitted for brodifacoum residue analysis.

Conclusions on Trial Eradication

We conclude that:

1. The PI-25 bait containing 25 ppm brodifacoum was effective in removing all of the rats on the trial islands.
2. PI-25 bait is an appropriate formulation to maintain its integrity in the wet, humid environment on Palmyra.
3. PI-25 is preferred by the rats over natural food items, even after absorbing moisture and molding.
4. Brodifacoum is an appropriate rodenticide to remove rats from Palmyra.
5. Landcrabs are not negatively impacted by brodifacoum.
6. No migrant shorebirds were detected dead or moribund in the study area.

Recommendations for Eradication of Rats from Palmyra Atoll

1. Rats can be removed from Palmyra Atoll with a high probability using a broadcast of PI-25 bait containing 25 ppm brodifacoum.

2. Two applications of PI-25 at 90 kg/ha/application of the bait may be needed to overcome landcrab competition and to ensure bait is available to all rats, especially weanlings, for a minimum of 4 days.

3. Applying bait prior to the arrival, or after departure, of migrant shorebirds is effective at minimizing risk of primary rodenticide exposure to non-target species.

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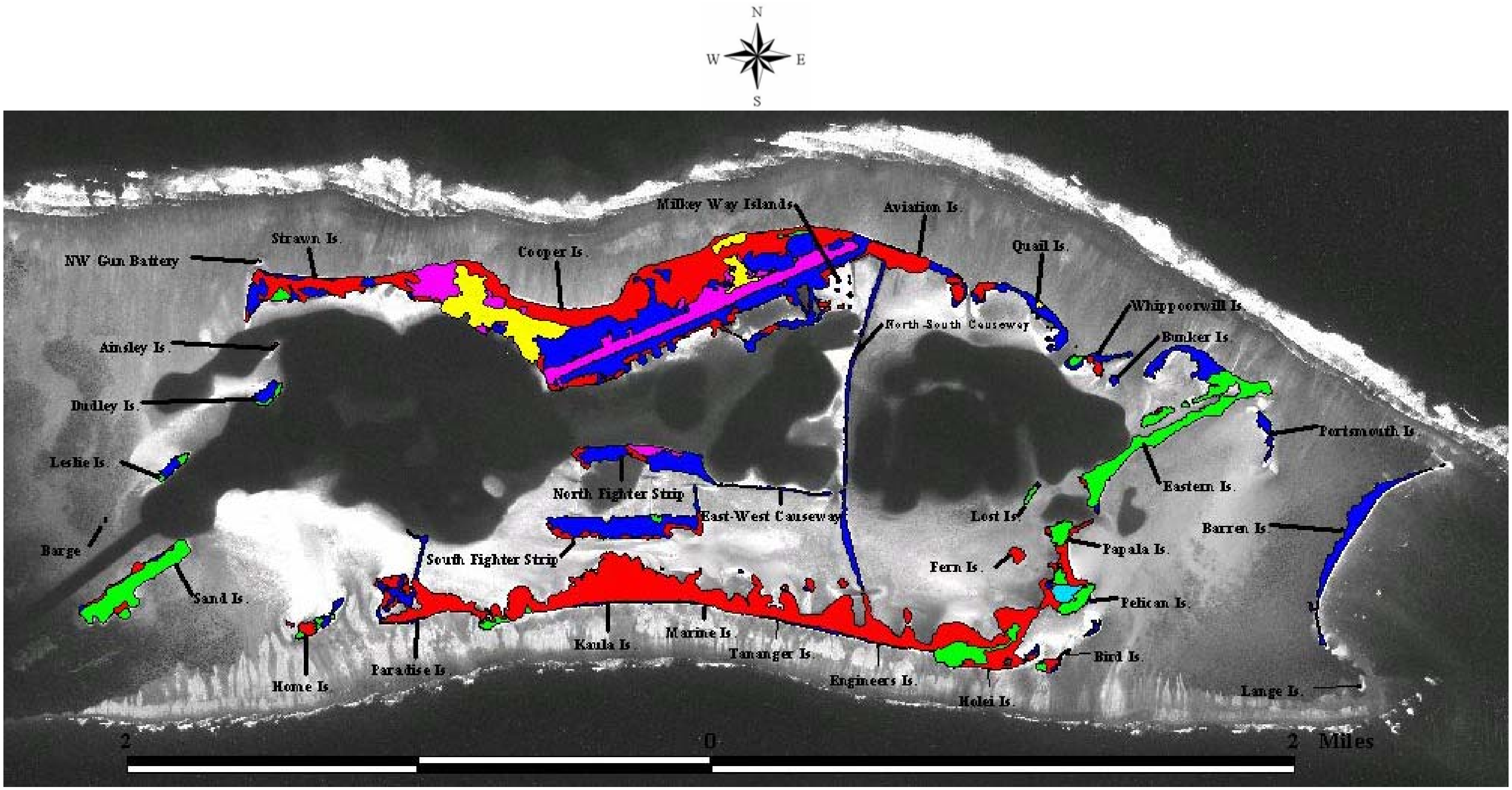
Appendix A. Trial Eradication Islands and Habitat Composition

Figure A. Palmyra Atoll National Wildlife Refuge: Primary Forest Type Map



Forest Type	% coverage	sq meters	hectares
Cocos	42.67	975970	97.6
Scaevola	29.50	674796	67.5
Pisonia	11.94	273140	27.3
Terminalia	6.24	142750	14.2
Bare ground	9.10	208050	20.8
Hibiscus	0.56	12730	1.3

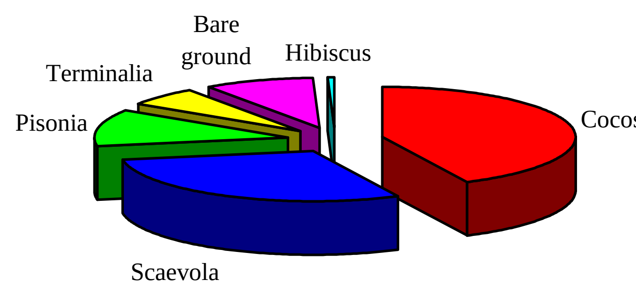


Figure B. Land area measurements and predominant forest structure for treatment islets: Fern and Home

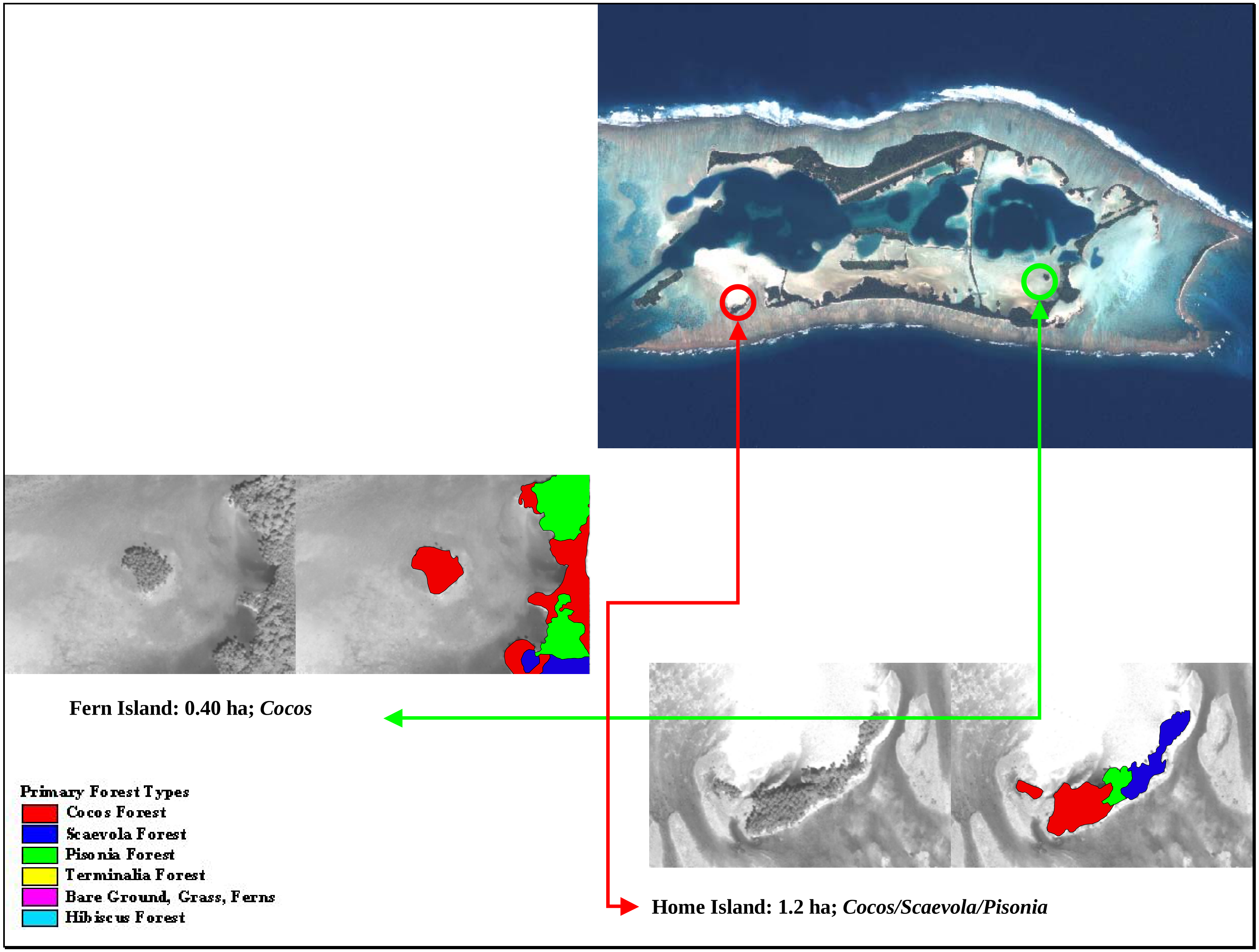
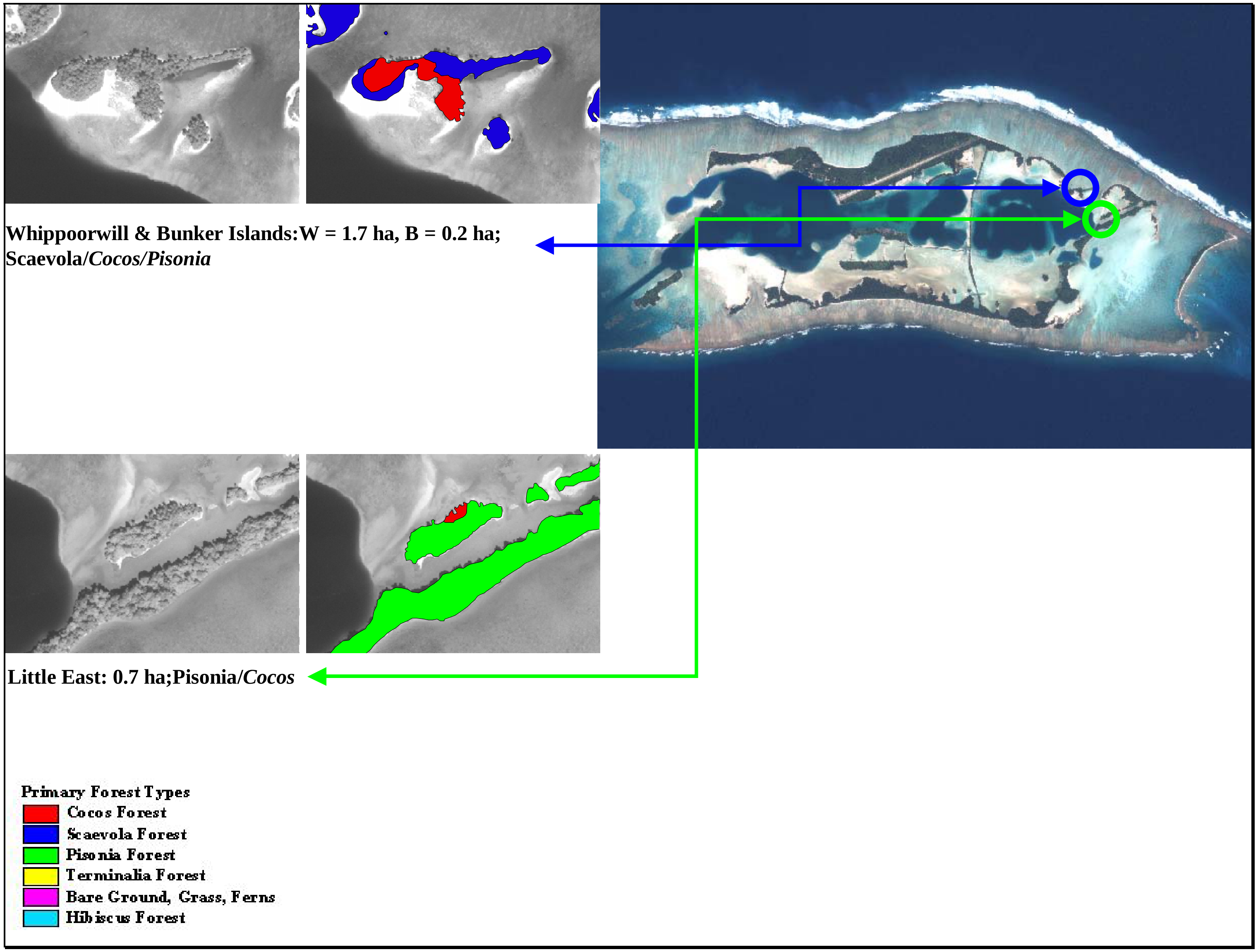


Figure C. Land area measurements and predominant forest structure for treatment islets: Whippoorwill/Bunker and Little East.



APPENDIX E

PALMYRA ATOLL RAT ERADICATION: BIOMARKER VALIDATION OF AN EFFECTIVE BAIT APPLICATION RATE, 19 JUNE TO 5 JULY, 2008

PALMYRA ATOLL RAT ERADICATION: BIOMARKER VALIDATION OF AN EFFECTIVE BAIT APPLICATION RATE 19 JUNE TO 5 JULY, 2008

PREPARED BY: ISLAND CONSERVATION

Alexander Wegmann[1], Joel Helm[1], Araceli Samaniego[1], William Smith[2], Bill Jacobs[3], Don Drake[4], Joanna Smith[5], Matthew McKown[6], Adonia Henry[2], Robert Fisher[7], Stacie Hathaway[7]

[1]Island Conservation, [2]USFWS, [3]EPA, [4]University of Hawaii, [5]University of Washington, [6]University of North Carolina, [7]USGS

Correspondence: Alexander Wegmann - 1925 Kirscher Rd #3, Kelowna BC, V1Y 4N7 Canada / alex.wegmann@islandconservation.org, / 250-870-1673

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1. EXECUTIVE SUMMARY

Pilot black rat eradication trials conducted in 2004 and 2005 by the US Fish and Wildlife Service (USFWS), Island Conservation (IC), US Department of Agriculture, and NZ Dept. of Conservation indicated that a bait application rate (60 – 95 kg/ha) might be necessary to successfully eradicate rats from Palmyra Atoll. The 2004-2005 work indicated that these bait application rates would likely be needed but did not set or confirm the rates. Rather, they provided a range of possibly suitable rates. The 2008 project attempted to determine whether lower applications rates might reach all rats sufficiently. However, the product label for Brodifacoum 25W (a bait product specially formulated for Palmyra's wet, warm conditions) was approved with a maximum bait application rate of 18 kg/ha followed five to seven days later by a second application of 9 kg/ha. The purpose of the 2008 Palmyra rat eradication biomarker study was to assess the feasibility of using the maximum (18 kg/ha and 9 kg/ha) application rate for 25W within Palmyra's challenging environment, and to monitor non-target species exposure to broadcast bait pellets.

From 19 June to 5 July 2008, eleven USFWS, IC, US Environmental Protection Agency (EPA), and volunteer personnel evaluated rat and non-target species exposure to placebo biomarker bait hand-broadcast to the ground and forest canopy at the label-specified maximum application rate (18 kg/ha followed by 9 kg/ha five days later) on 2 study islands, and at more than twice the maximum application rate (36 kg/ha followed by 36 kg/ha 5 days later) on a third study island. Study islands were chosen based on their similarities with regards to vegetation and rat and crab community composition. The following actions occurred in conjunction with the biomarker bait applications:

- Bait uptake plots to determine bait consumption rates:
    - 2,510 bait pellets in 47 plots were followed to determine bait consumption rates for both application regimes
- Live trapping effort to determine rat exposure to biomarker bait:
    - At total of 196 live traps used at the three study sites were opened for six nights of post bait application rat sampling; total effort equaled 1,132 trap nights
- Rat sampling to determine exposure to the applied biomarker bait:
    - 141 rats were captured and assessed for biomarker sign
    - 60 rat stomachs (20 from each study site) were analyzed for food content and parasite load
- Captive rat biomarker detection study:
    - 36 rats were assigned to one of three biomarker bait consumption treatments (1 pellet, 3 pellets, no pellets) for three post consumption intervals (3 days, 6 days, and 9 days). Results from this study were used to estimate the levels of bait consumption by rats in the biomarker field study.
- Hermit crab sampling to determine exposure to the applied biomarker bait:
    - For eleven days after the initial bait application, hermit crabs (*Coenobita perlatus*; n = 310) in all three study sites were assessed for exposure to biomarker bait
- Captive hermit crab biomarker detection study:
    - 27 hermit crabs were assigned to the same bait consumption and duration treatments as described above in the captive rat biomarker detection study. The results from this study corroborate the land crab field sampling results.
- Non-target species bait exposure study:
    - During two nighttime sampling efforts (both 2 days after the second bait application) we assessed biomarker bait exposure for the following non-target

species (amphipods (n=8), ants (n=52 ant trails), blister beetles (n = 2), cockroaches (n=59), geckos (n=53), katydids (n=49), and spiders (n=1)

Neither the current maximum application rate, nor twice the current maxim application rate for 25W successfully exposed all rats on each of the study islands. 32% (29/91) of the rats captured on one of the islands treated with 18 kg/ha + 9 kg/ha (the maximum application rate for 25W) showed no biomarker sign. 5% (1/21) of the rats captured on the island treated with twice the allowable application rate for 25W (36 kg/ha + 36 kg/ha) showed no biomarker sign while 29% (6/21) of the rats that tested positive for exposure to the biomarker bait in this study site may not have been exposed to an amount of bait that would equal a lethal dose of 25W – based on a comparative biomarker sign ranking system advised by the captive rat biomarker detection study. Nearly all pellets monitored within the bait uptake plots were removed (consumed) within 48 hours of bait application, and in some cases within 24 hours of bait application. Because the label-specified application rate did not expose 100% of the sampled rats within each of the three study sites, and the bait did not remain uniformly available to rats for four days post bait application, 25W's current maximum application rate is too low to provide sufficient probability of eradication success for implementation at Palmyra. If the Brodifacoum 25W bait is to be broadcast on Palmyra Atoll to eradicate roof rats, use of an application rate higher than the label's current limit will have to be authorized, perhaps via an emergency exemption or a label amendment.

2. TABLE OF CONTENTS

3. INTRODUCTION

3. 1. Project setting

Tropical oceanic islands represent some of Earth's most biologically unique ecosystems, yet the very remoteness that fuels high levels of endemicity and species radiations on islands also renders such systems vulnerable to invasive species. Invasive mammal eradications are a proven, effective method of restoring damaged ecosystems and preserving biodiversity on Islands. The presence of indigenous land crabs on most tropical islands poses a novel challenge to eradication projects, and especially eradications targeting rodents (Wegmann 2008). Land crab consumption of rodenticide bait complicates rodent eradication programs by requiring inflated bait application rates, which increases the risk of non-target species exposure to rodenticide. Because current rodent eradication practices are based on successful temperate or Subantarctic campaigns, the conservation community does not sufficient experience methods managing for land crab interference. Eradicating alien rats form Palmyra Atoll National Wildlife Refuge (Palmyra) would achieve a monumental conservation milestone for the Refuge, and would establish a benchmark for subsequent eradication campaigns on other tropical islands.

Palmyra Atoll's native flora and fauna have been marginalized greatly due to WWII-era restructuring and introductions of non-native species, notably coconut palms, ants, scale insects, and black rats (*Rattus rattus*). Nevertheless, Palmyra is an important center of biodiversity and species abundance in the Central Pacific region. Now protected within the US Fish and Wildlife Service's NWR system, Palmyra sharply contrasts with other moist Central Pacific island groups where the degradation of terrestrial and marine ecosystems keeps pace with increased anthropogenic resource exploitation. However, the continued presence of omnivorous black rats on the atoll will not allow recruitment or population establishment of those species which are vulnerable to black rats.

Palmyra is a breeding refuge for 11 seabird species; but, rat related egg and chick predation has likely led to the extirpation of four additional species (Table 1). Without the consumptive pressure of an established human population, Palmyra's land crab community is among the richest and most robust in the Central Pacific region. Palmyra is home to six species of terrestrial crabs (excluding the intertidal families Grapsidae and Ocypodidae), 4 of which are super abundant (Table 2).

Table 1. Breeding seabirds of Palmyra Atoll; * = Declining population trend

Family	***Common Name***	***Scientific Name***	***Breeding Pairs***	***IUCN***
Procellariidae	Audubon's Shearwater	*Puffinus lherminieri*	Believed extirpated	LC
	Wedge-tailed Shearwater	*Puffinus pacifica*	Extirpated	LC
	Phoenix Petrel	*Pterodroma alba*	Believed extirpated	EN*
Hydrobatidae	White-throated Storm Petrel	*Nesofregetta fuliginosa*	Believed extirpated	VU*
Sternidae	Black Noddy	*Anous minutus*	2,500	LC
	Blue Noddy	*Procelsterna cerulean*	Believed extirpated	LC
	Brown Noddy	*Anous stolidus*	1000	LC
	Sooty Tern	*Sterna fuscata*	10,000	LC
	Gray-backed Tern	*Sterna lunata*	Believed extirpated	LC
	White Tern	*Gygis alba*	150	LC
Fregatidae	Great Frigatebird	*Fregata minor*	500	LC

	Lesser Frigatebird	*Fregata aerial*	100	LC
Phaethontidae	White-tailed Tropicbird	*Phaethon lepturus*	15	LC
	Red-tailed Tropicbird	*Phaethon rubricauda*	20	LC
Sulidae	Red-footed Booby	*Sula sula*	5,000	LC
	Brown Booby	*Sula leucogaster*	150	LC
	Masked Booby	*Sula dactylatra*	20	LC

Table 2. Land crab abundance survey results, Palmyra Atoll (Howald et al. 2004). Units represent #/hectare estimates. Five of Palmyra's six land crab species were sampled; the sixth species (*Geograpsus grayi*) is rarely observed.

Land crab species	*Mean*	*Standard dev.*	*Mass (g)*[2]
Birgus latro	7	38[1]	1000
Cardisoma carnifex	46	8	300
Cardisoma rotundum	182	80	200
Coenobita. brevimanus	33	8	50
Coenobita perlatus	28	5	50

[1] Large variance probably due to low frequency of encounter and patchy distribution.
[2] Approximate adult mass

3. 2. Project background

From 2001 to 2003, The Nature Conservancy (TNC) and the US Fish and Wildlife Service (USFWS) maintained a bait-station based rat eradication effort at Palmyra. The campaign failed to remove all rats from the atoll, and the rat population has since re-established to a density that exceeds the population measured prior to the eradication attempt (Flint et al. 1992, Wegmann and Middleton 2008). In 2004, IC, USFWS, and the US Department of Agriculture initiated the construction of a second rat eradication program for Palmyra. Field studies associated with this action led to the following pertinent discoveries (Howald et al. 2004):

1) The rat population on Cooper Island showed tolerance to brodifacoum – one rat tested in a bait efficacy trial, dosed with brodifacoum at four times the LD_{50}, died 21 days post-dosing and showed no symptoms characteristic of anticoagulant poisoning.

2) *R. rattus* exploits the arboreal habitat created by monodominant *Cocos nucifera* stands

3) The *R. rattus* mean home range size at Palmyra ($693m^2$) is smaller than the bait-availability gaps in the first eradication attempt's 50m x 50m bait-station grid.

4) Palmyra's wet, tropical climate calls for a bait pellet matrix that withstands frequent saturation by rain and contact with moist soil.

5) Land crabs – unaffected by anticoagulant rodenticides – consume large volumes of bait – up to 47 kg/ha over a four day period.

6) At-risk non-target species - Bristle-thighed Curlew (*Numenius tahitiensis*), and Pacific Golden Plover (*Pluvialis fulva*) are least common at Palmyra during the months of June and July

With the lessons learned from the failed eradication attempt (utilizing a bait station approach), and the new information on hand, the joint USFWS-IC-USDA team concluded that a subsequent eradication attempt will need to meet the following requirements:

1) The eradication will employ aerial broadcast as the primary bait delivery method to ensure that all rats have access to bait, including rats frequenting or residing in the forest canopy and because of the presence of unexploded ordnance from historical military activity on the atoll.

2) Because of the possibility of toxicant resistance from chronic, sub-lethal exposure to anticoagulant rodenticides during the previous rat eradication attempt, the toxicant used in the eradication will be a second generation anticoagulant.

3) The bait matrix must be able to maintain form for at least four days of exposure in Palmyra's moist tropical climate.

4) The bait application rate will need to account for bait consumption by land crabs while maintaining enough bait on the ground to ensure that all rats have access to a lethal dose for approximately four days post bait application.

5) In order to minimize non-target species risk of exposure to rodenticide, the eradication will coincide with the low-abundance period (June-July) of migratory shorebirds, notably *N. tahitiensis* and *P. fulva.*

In 2005, IC and the USFWS conducted trial broadcast-based eradications on five islets totaling 4.08 ha (Buckelew et al. 2005). A concurrent bait consumption trial indicated that an application rate within 60-90 kg/ha will be necessary to ensure that, given land crab competition for broadcast bait pellets, all rats have access to a lethal amount of bait for four days post application. The five trial islets were each treated with moisture resistant compressed-grain pellets containing 25ppm brodifacoum, "25W" - manufactured by Bell Laboratories, Inc. - hand-broadcast to the ground and forest canopy at application rates ranging from 60 to 95 kg/ha. Subsequent post-treatment monitoring (telemetry, trapping, and indicator blocks) revealed a lack of rat presence on all 5 treatment islands.

The biomarker agent, pyranine, is a hydrophilic, pH-sensitive fluorescent dye from the group of chemicals known as arylsulfonates. Pyranine is soluble in water and has commercial application as a coloring agent, biological stain, optical detecting reagent, and a pH indicator. Pyranine is non-toxic, odorless and tasteless, and is fluorescent green when exposed to UV light. The use of pyranine as a biomarker agent within an eradication scenario is a fairly new convention (Towns and Broome 2003, Greene and Dilks 2004); therefore, this study provides an early assessment of this conservation tool.

3. 4. Study sites

Three islands were selected as study sites: Home (1.7 ha), Whippoorwill Island (1.9 ha), and Portsmouth Island (0.8 ha) (Figure 1). Home and Whippoorwill Islands were used for the 2005 trial broadcast-based eradications (Buckelew et al. 2005), and were sampled for rat density in 2008 (Table 3) (Wegmann and Middleton 2008). Prior to the initiation of this study, Portsmouth Island was surveyed for rat presence, land crab community composition. These islands met the following selection criteria: 1) islands must be isolated by water that does not go "dry" drying low tide cycles 2) islands should host land crab and plant communities that are representative of the entire atoll in composition and structure, and 3) islands must be free of known WWII era unexploded ordinance.

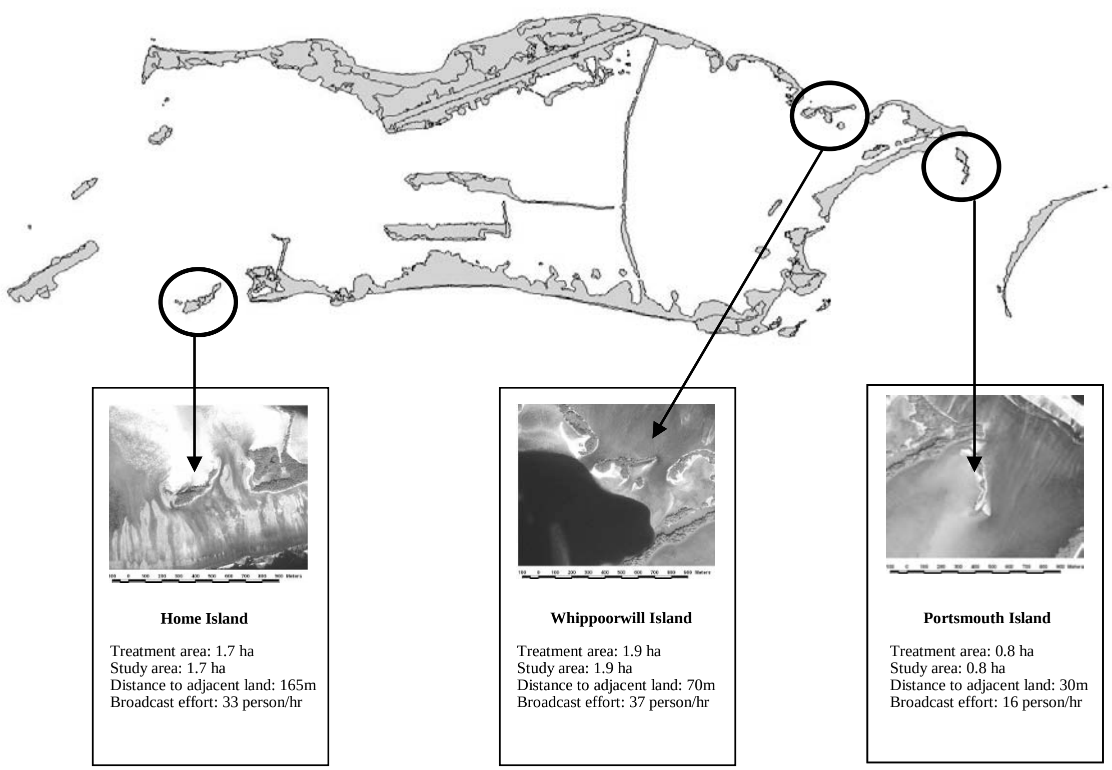

Fig. 1. Biomarker study site map. Distance to adjacent land is the shortest measure from the periphery of the study area to untreated land.

3. 5. Study questions

1) Will sequential application rates of 18 kg/ha + 9 kg/ha be enough to ensure rodenticide

exposure to all rats within the study sites (Portsmouth and Whippoorwill Island)?

2) Will sequential treatments at the application rate of 36 kg/ha deliver bait to all rats within the study site (Home Island)?

3) Which types of non-target organisms are at risk of exposure to the rodenticide during a broadcast operation?

Table 3. Rat densities on three islands within Palmyra Atoll; values are from Wegmann and Middleton (2008). "Trap nights" equal the total number of active traps multiplied by the number of nights that the traps were active minus 0.5 trap nights for each trap that was tripped without capture. "Trap success" is the quotient of the total number of rat captures divided by trap nights for a given study site.

Island	***Fern Island***	***Home Island***	***Whippoorwill Island***	***Cooper Island (reference)***	***Combined***
Island area (ha)	0.5	1.7	1.9	-	4.1
Rats captured	31	15	27	21	94
Rats recaptured	13	5	2	-	20
Abundance estimate	150	42.5	176	-	123
Density estimate (rats/ha)	300	25	93	-	139
Trap nights	68.0	53.0	85.5	54.5	261
Trap success	65%	38%	34%	39%	44%
Trap nights 2005**	67	93	141	45	346
Trap success 2005**	46%	32%	28%	40%	37%
Male mean weight (g)	165	181.1	149.7	-	165.3
Female mean weight (g)	154.6	170	162.8	-	162.5
Female / male ratio	0.9	1.2	0.9	-	1.0

Table 4. Palmyra rat eradication biomarker study timeline and activity record

	H = Home Island, **P** = Portsmouth Island, **W** = Whippoorwill-Bunker Island																	
Project Activity	**June**													**July**					
		Th	**F**	**S**	**Su**	**M**	**T**	**W**	**Th**	**F**	**S**	**Su**	**M**	**T**	**W**	**Th**	**F**	**S**	**Su**
	1-18	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**1**	**2**	**3**	**4**	**5**	**6**
Transit PA/HNL		X																X	
Assemble/season traps		X																	
Make coconut bait		X		X				X						X					
Open reference trapline		X																	
Sample reference trapline		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
Practice hand braodcast				X															
Collect crabs from reference trial			X																
Crab biomarker detection trial			X	X	X	X	X	X	X	X	X	X	X	X	X	X			
Rat biomarker detection trial			X	X	X	X	X	X	X	X	X	X	X	X	X	X			
Establish ground traps			W	HP															
Establish tree traps								WH	P										
Stage bait			HW P																
Establish uptake plots			W	HP															
Establish non-target plots			W	HP															
Crab IOA sampling														HWP					
Bait Application 18 kg/ha						WP													
Bait Application 9 kg/ha											WP								
Bait Application 36 kg.ha					H					H									
Monitor uptake plots						H	HWP	HWP	HW P	HW P	HW P	HW P	HWP	HWP					
Monitor non-target plots						H	HWP	HWP	HW P	HW P	HW P	HW P	HWP	HWP					
Open traplines								H	WP				H	WP					
Close traplines										H	WP								
Sample rats									H	HW P	WP			H	HW P	HW P	HW P	WP	
Sample night inverts / geckos												H	WP						
Remove traplines																	H	WP	

4. METHODS

The day-to-day operations of this project are summarized in Gantt chart form (Table 4).

4. 1. Hand Broadcast Baiting

4. 1. 1. Practice

Personnel practiced baiting protocols prior to applying bait in the study sites. The Cooper Island runway was used for this exercise. Pacing to 5 meters (distance between each bait line stop) was counted, and a baiting line was constructed (5 meters between each point) with obstacles (ladders, chairs, coconuts) for people to maneuver around while applying bait. A line boss controlled the movement and spacing of the baiting line. People applying bait wore “baiting bags” (JIM-GEM Tree Planting Bags, Forestry Suppliers Inc.). This exercise gave applicators the opportunity to practice applying the prescribed number of pellets to 25m^2 areas (e.g. spread bait 2.5m from the center in four cardinal directions).

4. 1. 2. Accuracy

In order to quantify the amount of bait released into the environment, several steps were taken to assure appropriate application rates (18 kg/ha + 9 kg/ha and 36 kg/ha + 36 kg/ha) were correctly applied to the three treatment islands. Prior to bait application activities, island area was derived from GIS layers. An island’s perimeter was defined as the outer vegetation line, since bait was not applied to coral rubble or sand beaches if the area in question was devoid of vegetation.

Bait application rates were based on the maximum rates for sequential broadcast baiting that are indicated on the label for the Brodifacoum 25W product (18kg/ha + 9kg/ha). The following equations describe how we determined how many pellets needed to be applied to a 25m^2 area to achieve the desired bait application rates.

$$\left[\frac{(\text{application rate (g)} / 1\,\text{hectare})}{\text{pellet weight (g)}}\right] \times \text{plot size } (\text{m}^2) \longrightarrow \#\text{ of pellets needed}$$

Portsmouth and Whippoorwill Islands

$$\frac{[(18{,}000g)/(\ 10{,}000m^2\ )]}{[(2.3g)]} \times 25\ \text{m}^2 = \ 19.56 \text{ or } 20 \text{ pellets}$$

Home Island

$$\frac{[(36{,}000g)/(\ 10{,}000m^2\ )]}{[(2.3g)]} \times 25\ \text{m}^2 = \ 39.13 \text{ or } 40 \text{ pellets}$$

To mimic an aerial bait broadcast, and to expose canopy dwelling rats (Howald et al. 2004, Wegmann et al. 2007), bait was applied to both the ground and forest canopy (*Cocos nucifera* trees only) (Table 5). The canopy was baited with “bait bolos” – bait pellets with holes drilled through the center and tied to 30-50cm of biodegradable twine. Bait bolos were carried around the island on branches and shot into the canopy using slingshots (Fig. 2). The total amount of bait needed to finish the trial was 195.3 kg, which is the combined amount of each application in each study site (Table 6)

Table 5. Bait application schedule, including application to ground and canopy areas; canopy baiting was restricted to *Cocos nucifera* trees

Study site	***Bait application rate***	***Bait applied to ground (kg/ha)***	***% trees treated***	***# trees treated***	***Bait applied to canopy (kg/ha)***	***Pellets per 25m2 uptake plot***	***Pellets per 25m^2 applied to ground (adjusted)***
Whippoorwill	18	16.6338	0.33	99	1.3662	20	18
	9	8.2962	0.17	51	0.7038	10	9
Portsmouth	18	17.7723	0.33	17	0.2277	20	19
	9	8.8827	0.17	9	0.1173	10	10
Home	36	34.8615	0.33	83	1.1385	40	38
	36	34.8615	0.33	83	1.1385	40	38

Table 6. Total amount of bait applied to the study sites

Study site	***Application rate (kg/ha)***	***Island area (ha)***	***Total bait applied (kg)***
Whipporwill	18	1.9	34.2
	9	1.9	17.1
Portsmouth	18	0.8	14.4
	9	0.8	7.2
Home	36	1.7	61.2
	36	1.7	61.2

Fig. 2. Canopy baits (bait bolos) ready for delivery into *Cocos nucifera* crowns; each bait contained 6 x 2.3 g pellets.

4. 1. 3. Baiting

We broadcast placebo (non-toxic) 25W biomarker bait pellets to the ground and forest canopy at the label-specified maximum application rate (18 kg/ha followed by 9 kg/ha five days later) on 2 study islands, and at more than twice the maximum application rate (36 kg/ha followed by 36 kg/ha five days later) on a third study island.

Baiting began on 22 June, with a minimum of five nights between applications. Placebo 25W bait laced with a food-grade biomarker (pyranine or "Solvent Green 7") was applied with a six-person baiting line in which broadcasters were spaced 5 m apart. Broadcasters counted the number of pellets to be applied to each successive 25m^2 area. Each bait application was directed by a line boss who maintained the pace of the exercise and gave instructions when line orientation or spacing went askew. Broadcasters with end positions on the line flagged their baiting position at each 5m stop; this allowed the line to reference what had been treated already. Each applicator carried up to 10kg in a bait bag.

4. 1. 4. 2.8 m radius circle plots

During the bait applications, a two-person team sampled the amount (kg/ha) of bait being applied by counting pellets within randomly selected 2.8 m radius circle plots (area = 25m^2). The 2.8 m radius plots were sampled with one person standing in the center of the plot holding onto the beginning of a 2.8 m piece of string or tape; the other person held the distal end and walked a complete circle around the person in the center. All bait pellets passing under the string were counted and vegetation and leaf-litter were moved to find hidden pellets. Major deviations from the target application rate were reported to the line boss, who then told the baiting line to either tighten or relax the spacing between broadcasters, which would result in heavier or lighter bait application. Due to Palmyra's high abundance of hermit crabs, many pellets were “captured” by crabs prior to sampling the circle plots. To account for the captured bait, hermit crabs carrying bait pellets within the circle plots were counted as 1 pellet each.

4. 2. Bait Consumption

4. 2. 1. Bait consumption plot design and placement

Bait consumption data were collected to describe the amount of bait consumed by both target species as well as non target species. On June 20th and 2first, bait consumption plots were established within each study site: Whippoorwill (n = 18), Home (n = 22), and Portsmouth (n = 7). Plots were 25 m long X 1 m wide. Wire flags were scatter-planted in each plot, and a single bait pellet was placed at the base of each flag. Plots were calibrated to the different application rates: 9 kg/ha = 10 flags, 18kg/ha = 20 flags and 36 kg/ha = 40 flags. Plots were placed parallel to the trajectory of the baiting line to capture the bait application rate error from at least 4 broadcasters. After the bait line passed over the bait consumption plot, pellets near the plot were picked up and moved to the flags within the plot.

Figure 2. Bait consumption plot; pin flags marked bait pellet location. Bait consumption rates were estimated by counting the number of pellets removed from each plot within 24 hr sample periods, and then averaging consumption rates across all plots within a study site.

4. 2. 2. Bait consumption plot sampling

Bait consumption plot sampling began the day after bait application and continued until 100% of the bait was removed from each plot. Observers walked the length of every plot stopping at each flag to inspect the immediate area (5cm) for the presence or absence of a pellet. Flags without pellets were pulled and tallied. The total number of flags pulled from each plot (total number of pellets removed) was recorded. Bait consumption plot locations were maintained and plots were reset for the second round of bait applications.

4. 3. Land Crab Index of Abundance (IOA)

Land crab index of abundance (IOA) sampling took place on 3 and 4 July. Twenty crab IOA transects were surveyed on Whippoorwill and Home, and 10 transects were surveyed on Portsmouth. Transect start points and bearings were randomly selected. The 5 meter transect width was maintained by a 2.5 m pole swung in a 180º arc pivoted from the center of the transect. All crabs detected within a distance of 2.5m from the central transect axis were identified to species (*Coenobita brevimanus*, *Coenobita perlatus*, *Cardisoma carnifex*, *Cardisoma rotundum*, and *Birgus latro*). Only crabs within the transect boundary were counted. The total number of crabs per transect was averaged within study sites.

4. 4. Rat biomarker detection assay

4. 4. 1. Sampling

Because the biomarker agent, pyranine, has only been employed once prior to this project to assess rat eradication bait application rates (Griffiths et al. 2008), we conducted a biomarker detection assay to define how long, at different bait consumption amounts, rats show biomarker sign. We trapped rats on Cooper Island with seasoned (vegetable oil and coconut milk) Hagaruma® and Tomahawk® traps baited with coconut covered with peanut butter. Captured rats were weighed, sexed, and then transferred into Tomahawk® traps (455 cm^2 bottom) or wire cages (855-1400 cm^2 bottom) placed on tables inside the North Road storage bunker (large WWII era cement bunker). The rat holding cages were placed on metal trays, and were elevated with wood strips so that urine and droppings would not collect in the cage bottoms. Trays were cleaned regularly, and all rats were provided ample food and water. Rats within the same treatment group shared pans.

4. 4. 2. Treatments

The rat biomarker detection assay involved nine biomarker exposure-duration treatments. Captured rats were assigned to the following biomarker bait exposure groups: 1 pellet (1P), 3 pellets (3P), no pellets (coconut). Rats in each exposure group were then assigned to one of three sampling periods: three days post bait consumption, six days post bait consumption, and 9 days post bait consumption. Each pellet-fed treatment group contained five rats; coconut-fed treatment groups contained only one rat. The 1P treatments replicate a sub-lethal dose of the active 25W (25 ppm brodifacoum) bait, and the 3P groups replicate a lethal dosage; 1 pellet < LD_{50} (0.5 x LD_{50}), 3 pellets > LD_{50} (1.4 x LD_{50}) for the average (164 g) male rat at Palmyra (Table 3). The LD_{50} value used for these calculations is 0.65-0.73 mg/kg for Brodifacoum vs. balck rats (Dubock and Kaukeinen 1978, Wegmann and Middleton 2008).

After transfer to caging, rats were offered bait pellets or a chunk of coconut meat, depending on treatment group. After that was consumed, they were fed a mixture of peanut butter and StoveTop® stuffing until they were euthanized and sampled for external and internal biomarker sign. Separately, one adult female was offered 10 Inert Pellets/day, no-choice, for 4 consecutive days. Another female was offered 10 Inert Pellets/day for 2 consecutive days, and a juvenile male was offered half of a typical sized Inert Pellet for one day. These last 3 subjects were euthanized and examined at the end of their exposure regimes.

The control group consisted of 2 males and a female. The males weighed 138 and 168 g at the time of transfer to caging. The control female weighed 192 g. There were 10 males (158-214 g) and 5 females (102-215 g) in the 1P group and 9 males (130-202 g) and 6 females (109-171 g) in the 3P group. The heaviest female in the 1P group delivered a litter of 7 pups 4 days after capture and 3 days after consuming the bait pellet offered.

The rat offered 10 pellets/day for 4 consecutive days was a female that weighed 158 g at capture. The initial weight for the female rat offered 10 pellets/day for 2 consecutive days was 195 g. Neither of these rats consumed all of the pellets offered on any day. The rat offered half of a pellet for one day was a juvenile male that weighed 54 g at capture. This rat initially was fed coconut and then was maintained on the same feed mixture that was fed to all subjects after their bait or coconut exposure regimen was completed. Eight days after its capture, this rat was offered ½ a pellet, which it consumed overnight. The following day it was euthanized and assessed for fluorescence.

4. 4. 3. Biomarker detection scoring system

Rats were examined for fluorescence using handheld ultraviolet flashlights. After sacrifice, rats were examined externally for evidence of bright green fluorescence at the anus and elsewhere. Subsequently, rats were examined internally for evidence of fluorescence. Digestive organs (stomach, small intestine, ceacum and large intestine) were routinely assessed. Intensity of fluorescence was assessed qualitatively according to the rating scale shown below.

Score	Description
-	No fluorescence evident
+	Fluorescence detected but limited in intensity and/or area covered
++	Fluorescence moderate in intensity and/or area covered
+++	Fluorescence glowing in intensity and pervasive

Red hermit crabs were scored for fluorescence based on a negative or positive basis. Internal sign was classified as either positive or negative. Females with eggs were not part of the sample.

4. 5. Hermit crab biomarker detection assay

4. 5. 1. Sampling

27 red hermit crabs (*Coenobita perlatus*) were collected from Cooper Island and housed, in buckets, in the North Road storage bunker. The hermit crabs were fed either pellets or coconut, according to treatment group directly after placement in the holding buckets. Crabs that received pellets were fed coconut after the pellets were consumed. All crabs were given ample food and water throughout the study.

4. 5. 2. Treatments

Hermit crabs were assigned to the same treatment groups established for the rat biomarker detection assay, except that only three crabs were assigned to each exposure-duration grouping. To assess the presence or absence of biomarker sign, hermit crabs were chilled in a refrigerator at 5° C for 45 minutes. Chilling the crabs allowed us to extract the crabs from their gastropod shells in order to examine their abdomens with low risk of causing harm. Hermit crabs were scored as positive (+) or negative (-) for internal biomarker sign. Under UV light, biomarker could be detected through the translucent epidermis of the crabs' abdomens (Fig. 4).

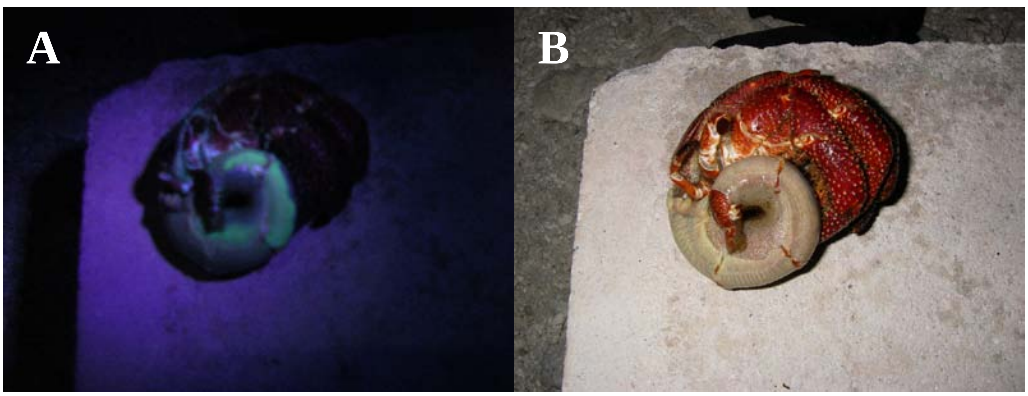

Fig. 4. A Hermit Crab (*Coenobita perlatus*) that tested positive for biomarker sign; "A" is under UV light, "B" is the same crab under full spectrum light.

4. 6. Field-based biomarker detection in rats

4. 6. 1. Sampling

Hagaruma traps that had been seasoned by dipping them in cooking oil were placed atop plastic 5 gallon buckets and baited with coconut and peanut butter. Traps were placed at a distance of approximately 10m from each other in transect(s) traveling the length of each treatment site. Tree traps were deployed in 5 coconut palms on each island in an attempt to detect biomarker presence in rats frequenting canopy habitat. A total of 1132 trap nights were logged over the course of the study: Home (n = 441.5), Whippoorwill (n = 489); Portsmouth (n = 201.5). Half trap-nights were counted when traps either caught an animal or were sprung without a capture. Traps were opened on all islands for 2 nights after the first baiting regime, and 4 nights after the second baiting regime.

4. 6. 2. Scoring System

Captured rats were brought to a central processing location established at each study site. Rats were first inspected for external biomarker sign using handheld UV flashlights. If a rat showed external biomarker sign (paws, anus, tail, mouth), it was euthanized and inspected for internal biomarker sign. Internal and external fluorescence was scored according to the scoring system described above. Rats without external sign were marked with black sharpie on their tails and released at their point of capture.

4. 7. Field-based biomarker detection in hermit crabs

4. 7. 1. Sampling

Hermit crabs were collected from each study site every day for 11 days following the initial bait application. Ten hermit crab collection plots (PVC piping driven into the ground) were established on Home and Whippoorwill, and seven were established on Portsmouth. Each sample day, the crab closest to each plot pole was collected for biomarker presence assessment. External biomarker sign was assessed in the field, and internal biomarker sign was assessed several hours later, at the field camp, using the refrigeration method discussed above.
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4. 7. 2. Scoring system

Field scoring consisted of positive or negative sign for biomarker on the claw, mouth and shell. In camp, crabs were chilled in a refrigerator until they were relaxed enough for observers to remove them from the shell. All portions of the body were examined at this point and positive-negative scoring took place for the presence or absence of biomarker sign. Hermit crab bodies then were returned to their shells. In some instances, bodies would not come free from the shell easily. Such crabs were not assessed. Crabs were released back to their collection sites on the morning following the day of capture. Of the 330 crabs sampled, 4 died during captivity.

4. 8. Field-based biomarker detection in subdominant bait consumers

4. 8. 1. Sampling

Night surveys were conducted during the evenings of June 29 and 30. Five locations were chosen on each island in order to sample the following types of non-target organisms: amphipods, ants (ant trails), cockroaches, geckos, and katydids. Specimens were collected in plastic bags and taken back to camp for biomarker evaluation. Ant trails were evaluated on site. Ant observations consisted of watching a single ant trail for up to 5 minutes to determine if the ants were transporting biomarker bait particles.

4. 9. Rat carcass consumption

4. 9. 1. Placement and Sampling

Land crabs are capable scavengers and will readily consume carrion. In a toxin-based rat eradication scenario, rats that die from rodenticide exposure present a rodenticide exposure risk for non-target species. To determine the timeframe for the dead rat rodenticide exposure pathway, rat carcasses (captured rats that tested positive for external biomarker sign and had been euthanized and examined for internal biomarker sign) were placed at their point of capture and marked with a numbered flag. Carcasses were reassessed 24 hours after placement. The percent of each carcass remaining was recorded.

5. RESULTS

5. 1. Bait consumption

Bait consumption rates for each application regime were estimated by following bait pellets marked by wire flags (n = 2,510) in 47 plots: Home = 22 plots, Portsmouth = 7 plots, Whippoorwill = 18 plots. Rats were removed from the study sites following bait applications (see section 5.3 Rat Capture). Lower application rates (9 kg/ha and 18 kg/ha) resulted in rapid bait consumption. Following the 9 kg/ha application on Whippoorwill, only 2 of 180 pellets (4.6g of 414g of bait) remained in 18 bait consumption plots (plots were loaded with 10 pellets each during the bait application) after a 24 hour period; the two remaining pellets were consumed by day 2 (Fig. 5). Bait consumption on Portsmouth showed a similar trend as nearly all of the 9 kg/ha application was consumed within 24 hrs, and all pellets within bait consumption plots were consumed within 3 days. The 18 kg/ha baiting regimes on Portsmouth and Whippoorwill resulted in more bait remaining after the initial 24 hours; however 100% bait consumption occurred in all plots on both islands within 3 days of the bait application. The 36 kg/ha baiting regimes at the Home study site resulted in 60% bait consumption within 24 hours, and small amounts of bait persisting through day 5 in the first application, and day 6 in the second application. A one-way ANOVA test, with Tukey's pairwise comparisons (MINITAB 2007), of daily mean bait consumption between all three study sites shows that Portsmouth and Whippoorwill experienced similar bait consumption patterns for both the 18 kg/ha and 9 kg/ha bait application regimes; however, mean bait consumption at the Home site was significantly higher than recorded at Portsmouth or Whippoorwill for days 1 through 3 after the first bait application, and days 1 through 4 after the second bait application (Table 7).

No bait remained on Portsmouth and Whippoorwill 2-3 days after the initial treatment at 18 kg/ha, and essentially no bait remained 2 days after the second treatment at 9 kg/ha (Fig. 5). Bait lasted longer on Home; factors likely influencing this included the higher application rate and the lower initial and post-trapping rat densities on Home.

Table 7. One-way ANOVA results for a between-site comparison of mean number of pellets removed from bait consumption plots by days post bait application for both the first and second bait application.

Bait application	*Days post bait application*	*F-statistic*	*P-value*
first	1	4.18	0.013
	2	11.84	< 0.001

	3	8.4	0.001
	4	2.8	0.072
	5	1.61	0.211
second	1	30.39	< 0.001
	2	26.7	< 0.001
	3	11.71	< 0.001
	4	3.77	0.031
	5	2.74	0.076
	6	1.81	0.176

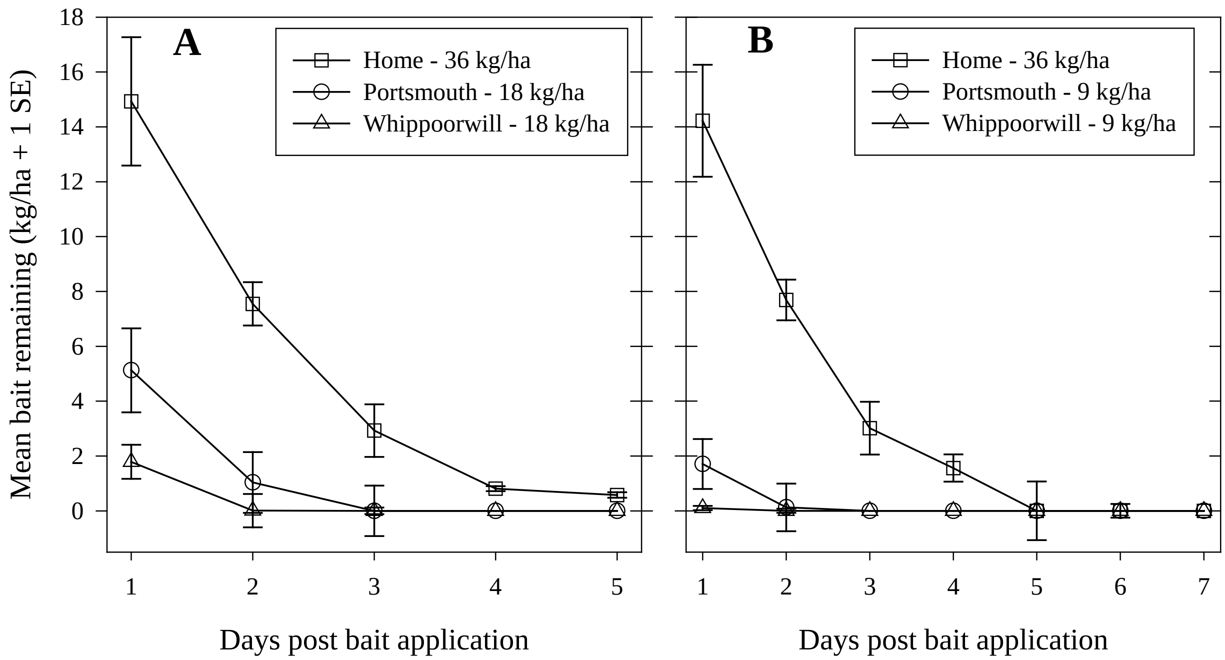

Fig. 5. Daily bait consumption estimates for the first "A" and second "B" bait applications on Home, Portsmouth, and Whippoorwill. Mean bait consumption was measured by observing bait pellet removal from fixed 25 m x 1 m plots: Home = 22 plots, Portsmouth = 7 plots, Whippoorwill = 18 plots. Error bars represent ± 1 standard error of the sample mean.

5. 2. Land Crab IOA

Land crab abundance rankings varied between study sites (Table 8). Home had relatively fewer land crabs than Portsmouth or Whippoorwill, and Whippoorwill had the highest crab density ranking.

Table 8. Index of Abundance (IOA) ranking for land crab species at the three study sites; 1 = lowest density, 3 = highest density. If the species densities are similar between study sites, the study sites received the same ranking.

Study site	***Coenobita perlatus***	***Coenobita brevimanus***	***Cardisoma carnifex***	***Cardisoma rotundum***
Home	1	1	1	1
Portsmouth	2	1	1	2

Whippoorwill	3	2	1	1

5. 3. Rat capture

For two nights after the first round of bait applications, and 4 nights after the second round of applications, live-capture rat traps were opened on all three study sites: Home = 78 traps, Portsmouth = 34 traps, Whippoorwill = 84 traps. The total trapping effort equaled 1,132 trap nights. Trap success (captures / trap-nights; trap-nights = traps / island / night) was highest at Whippoorwill for all sample nights, and lowest at Home (Table 9).

Table 9. *Rattus rattus* trap success (captures / trap nights; trap nights = traps/island/night) proceeding first and second biomarker bait applications.

	First application		Second application			
Sample	1	2	3	4	5	6
36 kg/ha + 36 kg/ha (Home)	15%	8%	0%	5%	0%	3%
18 kg/ha + 9 kg/ha (Portsmouth)	38%	29%	6%	9%	9%	3%
19 kg/ha + 9 kg/ha (Whippoorwill)	41%	30%	12%	12%	13%	5%

5. 4. Rat biomarker detection assay

External and internal biomarker sign was still noticeable nine days after bait consumption for two rats in the 3P group. Internal biomarker was found in one of these rats (Table 10). Biomarker detection results for the 3P rats at 6 days post bait consumption were similar to the 3P – 9 day group. All 3P rats sampled 3 days post bait consumption showed external and internal biomarker sign. One 1P rat showed external biomarker sign at 6 days post bait consumption, and no 1P rats showed external or internal biomarker sign at 9 days post bait consumption. Four of five 1P rats showed external biomarker sign at 3 days; two of these rats also showed internal sign. Of significance, 1 rat in the 1P-3 day group and 4 rats in the 1P-6 day group showed no biomarker sign, while all 3P-3 day rats and four of five 3P-6 day rats showed both or either external and internal biomarker sign. The difference in time-related biomarker detection between the 1P and 3P groups suggests that biomarker detection is a function of amount of bait consumed as well as time since bait consumption.

We used a multiple linear regression model to assess the strength of the relationships between biomarker detection scores, amount of bait consumed, and time since bait consumption. Neither sex nor weight significantly influenced the biomarker detection score, while the number of pellets consumed and the exposure period (time since bait consumption) did influence the biomarker detection score (Table 11). The regression models for external and internal biomarker scores are: [(external score = 2.21 + 0.620(Pellets consumed) - 0.379(Exposure period)], and [(internal score = 2.81 + 0.989(Pellets consumed) - 0.561(Exposure period)].

Table 10. Lab-based biomarker detection results for three pellet consumption variables (0 pellets, 1 pellet, 3 pellets) and three exposure variables (3 days, 6 days, 9 days); internal and external scores represent the sums of all internal or external detection factors.

Pellets consumed	***Exposure Period (days)***	***Sex***	***Weight (g)***	***Total external score***	**Total internal score**
0	3	M	138	0	**0**
	6	M	168	0	**0**
	9	F	192	0	**0**
1	3	F	215	0	**0**
		M	168	1	**2**
		M	173	1	**2**
		M	182	2	**0**
		M	158	3	**0**
	6	F	102	0	**0**
		F	180	0	**0**
		F	158	0	**0**
		M	208	0	**0**
		M	214	1	**0**
	9	F	134	0	**0**
		M	196	0	**0**
		M	215	0	**0**
		M	169	0	**0**
		M	188	0	**0**
3	3	F	150	4	**8**
		F	169	6	**7**
		M	168	3	**8**
		M	173	3	**4**
		M	130	4	**7**
	6	F	109	1	**0**
		F	171	2	**1**
		M	178	1	**0**
		M	198	0	**0**
		M	202	1	**1**
	9	F	148	1	**0**
		F	167	1	**1**
		M	150	0	**0**
		M	164	0	**0**
		M	202	0	**0**

Table 11. Summary of linear regression analysis for variables predicting internal or external detection of biomarker (pyranine) residue in rats (*R. rattus*) fed 1 biomarker bait pellet (2.3g), 3 pellets, or 0 pellets (Pellets consumed) and sampled at 3 days, 6 days, or 9 days; External and Internal (n = 5 for each pellet-exposure treatment group). * P < 0.01, ** P = 0.001, *** P < 0.001

Predictor	External		Internal	
	B	SE (B)	B	SE (B)
Intercept	1.94	1.508	3.089	2.791
Pellets consumed	0.6071**	0.1603	0.9676*	0.2968
Post-exposure interval	-0.38257***	0.07337	-0.5591***	0.1358
Sex	0.3366	0.3949	0.2702	0.731
Weight	-0.000859	0.006876	-0.00363	0.01273

5. 5. Biomarker detection in field-caught rats

141 rats were captured and assessed for biomarker sign. Rats without external or internal biomarker sign were captured at all three study sites: 5% (1/21) at Home, 32% (29/91) at Whippoorwill, and 3% (1/31) at Portsmouth (Appendix A).

Rats with external or internal biomarker scores lower than 2 (equated with rats that would have consumed Sub-Lethal quantities of brodifacoum had the 25W brodifacoum bait been used, or "SLrats") might have consumed amounts of biomarker bait that would have been insufficient to cause death had a toxic bait been used. We used the linear regression equations described above to back solve for the amount of bait consumed by rats based on internal or external inflorescence scores, and then compared brodifacoum exposure values - brodifacoum (mg) / rat (kg) - to sex-specific *Rattus* LD_{50} values (Dubock and Kaukeinen 1978) to obtain rough estimates of the LD_{50} exposure ratios for SLrats (Table 12). We found two Home SLrats, five Portsmouth SLrats, and nine Whippoorwill SLrats with estimated brodifacoum exposure values lower than 1 *Rattus*-brodifacoum LD_{50}.

Table 12. LD-50 exposure ratios for field-captured rats showing low (< 2) external or internal biomarker detection scores. Total brodifacoum exposure for the Home-21 rat was based on the internal biomarker score; total brodifacoum exposure estimates for the remaining rats were based on external biomarker score. An LD_{50} is the estimated brodifacoum exposure level that will produce 50% mortality in a given *Rattus* population. Rats marked by an asterisk (*) are those that were estimated, according to their weights and biomarker indices, to have consumed amounts of bait equal to less than the equivalent of an acute oral LD_{50} dosage of a 0.0025% Brodifacoum bait.

Study site	***Rat ID***	***Weight (g) and sex***	***Estimated # of pellets consumed***	***Approximate brodifacoum exposure (mg)***	***Approximate brodifacoum (mg) per Rat (kg)***	***Approximate brodifacoum exposure estimate (x / 1 LD-50)***
Home	1	180 F	0.5	0.03	0.67	**1**
Home	2	205 M	2.1	0.12	0.31	**0.4 ***
Home	21	212 F	2.1	0.12	0.14	**0.2 ***
Portsmouth	10	185 M	3.7	0.21	0.17	**0.3 ***
Portsmouth	14	160 F	1.1	0.06	0.16	**0.2 ***
Portsmouth	17	180 M	2.7	0.16	1.19	**1.8**
Portsmouth	25	119 M	1.1	0.06	0.16	**0.2 ***
Portsmouth	30	141 M	3.3	0.19	0.53	**0.7 ***

Portsmouth	4	165 F	2.1	0.12	0.69	**0.9 ***
Whippoorwill	2	130 F	0.5	0.03	1.19	**1.8**
Whippoorwill	35	55 M	1.1	0.06	0.41	**0.6 ***
Whippoorwill	36	180 M	1.1	0.06	0.82	**1.3**
Whippoorwill	37	180 M	1.1	0.06	2.20	**3**
Whippoorwill	38	130 F	1.1	0.06	0.16	**0.2 ***
Whippoorwill	40	150 F	1.1	0.06	1.18	**1.6**
Whippoorwill	42	150 F	2.7	0.16	0.49	**0.8 ***
Whippoorwill	44	140 M	2.7	0.16	0.42	**0.7 ***
Whippoorwill	47	160 F	2.7	0.16	0.42	**0.7 ***
Whippoorwill	5	155 F	1.1	0.06	0.70	**0.9 ***
Whippoorwill	6	148 F	0.5	0.03	1.08	**1.7**
Whippoorwill	61	150 M	0.5	0.03	0.42	**0.6 ***
Whippoorwill	62	95 M	0.5	0.03	0.67	**0.9 ***
Whippoorwill	76	144 F	1.1	0.06	0.44	**0.7 ***
Whippoorwill	84	78 M	1.7	0.10	1.99	**2.7**
Whippoorwill	85	72 F	1.7	0.10	2.16	**3.3**
Whippoorwill	86	50 F	1.7	0.10	3.11	**4.8**
Whippoorwill	91	50 F	3.9	0.22	4.49	**6.9**

5. 6. Land crab biomarker exposure

5. 6. 1. Hermit crab biomarker detection assay

Twenty-seven hermit crabs *(Coenobita perlatus*) were also assigned to the same bait consumption and duration treatments as described above in the rat biomarker detection assay. However, hermit crab biomarker sign was simply noted as present or absent rather than scored. The probability of detecting biomarker sign in hermit crabs is likely a function of time and amount of bait consumed. All crabs in the 1P group showed internal biomarker sign up to day six, and only one crab showed sign at day nine. Two of three crabs in the both the 3P-6 day and 3P-9 day groups showed biomarker sign (Table 13). The hermit crab biomarker detection assay results suggest that hermit crabs retain internal biomarker sign longer than rats, which is probably a function of the crabs' lower basal metabolic rate.

Table 13. Hermit crab biomarker detection assay results; each pellet-exposure treatment group contained 3 crabs.

Pellets consumed	***Exposure period***	***Internal biomarker sign***	
		Absent	Present
1 pellet	3	0	3
	6	0	3
	9	2	1
3 pellet	3	0	3
	6	1	2
	9	1	2
Reference (coconut)	3	3	0
	6	3	0

	9	3	0

5. 6. 2. Biomarker detection in field-captured hermit crabs

Table 14. The proportion (1-100) of hermit crabs that were positive for biomarker sign by study site and number of days after the first bait application, and number of gravid crabs (females) that were not inspected for internal biomarker sign. The second bait application occurred on the 6th day after the first bait application. Each day after the first bait application, ten crabs were sampled in each study site.

Island	***Days after first bait application***	***Biomarker detection***		***No. female crabs w/eggs***
		External	**Internal**	
Home	1	0.9	1	0
	2	1	0.6	1
	3	0.6	0.7	2
	4	0.2	0.6	4
	5	1	0.8	2
	6	1	1	0
	7	0.6	0.8	0
	8	0.8	1	0
	9	0.1	0.7	3
	10	0.2	0.6	2
	11	0.1	0.9	1
Portsmouth	1	0.9	0.6	1
	2	0.7	0.4	2
	3	0.8	0.6	2
	4	0	0.6	1
	5	0.8	0.5	1
	6	0.9	0.5	2
	7	1	0.8	0
	8	0.7	0.7	2
	9	0.6	0.6	2
	10	0	0.3	1
	11	0	0.8	0
Whippoorwill	1	1	0.3	3
	2	0.5	0.1	4
	3	0.4	0.7	0
	5	1	0.5	5
	6	0.8	0.8	2
	7	0.3	0.8	0
	8	0.1	0.5	3
	9	0.2	0.3	6
	10	0	0.4	3
	11	0.1	0.7	2

Hermit crabs (*Coenobita perlatus*; n = 310) were collected from the study sites each day after the initial bait application, and were assessed for external and internal exposure to biomarker bait (Table 14). We used one-way ANOVA tests with Tukey's pairwise comparisons to compare the mean number of crabs with and without internal or external biomarker sign between the sample sites. We found no significant between-site difference in the number of crabs without external ($F = 0.6$, $P = 0.554$) or internal ($F = 0.51$, $P = 0.606$) biomarker sign. Furthermore, We did not detect a significant difference in the number of biomarker-positive and biomarker-negative crabs between Portsmouth and Whippoorwill.

5. 7. Subdominant consumer exposure to biomarker bait

Several non target species (excluding land crabs) were assessed for biomarker sign two nights after the second bait application at each study site: amphipods (n=8), ants (n=52 ant trails), blister beetles (n = 2), cockroaches (n=59), geckos (n=53), katydids (n=49), and spiders (n=1) (Table 15). We found external or internal biomarker sign with ants, amphipods, cockroaches, and katydids. There does not appear to be a difference in subdominant consumer exposure patterns between high (Home) and low (Whippoorwill and Portsmouth) bait application rates; however, larger sample sizes are needed to support this notion.

Table 15. Assessment of subdominant consumer exposure to biomarker bait by study site. Biomarker presence is presented as the proportion of the total sample, by species and study site, that showed external or internal biomarker sign.

Study site	***Species***	***No. sampled***	***Biomarker presence (proportion)***	
			External	**Internal**
Home	Amphipods	3	0.0	0.0
	Ant	21	0.6	-
	blister beetles	2	0.0	0.0
	cockroach	19	0.5	0.6
	gecko	25	0.0	0.0
	katydid	25	0.0	0.0
	spider	1	0.0	-
Portsmouth	Amphipods	5	0.4	0.4
	Ant	5	0.0	-
	cockroach	15	0.1	0.3
	gecko	20	0.0	0.0
	katydid	20	0.1	0.1
Whippoorwill	Ant	26	0.4	-
	cockroach	25	0.4	0.4
	gecko	8	0.0	0.0
	katydid	4	0.0	0.3

5. 8. Rat carcass consumption

Rat carcasses were almost completely consumed within 24 hours of placement (Fig. 6). Hermit crabs, apparently, were the primary consumers of rat carcass. A series of images, taken at 15 minute intervals by a motion sensing camera recorded only hermit crabs attending (and completely consuming) a rat carcass 15 hrs after placement.

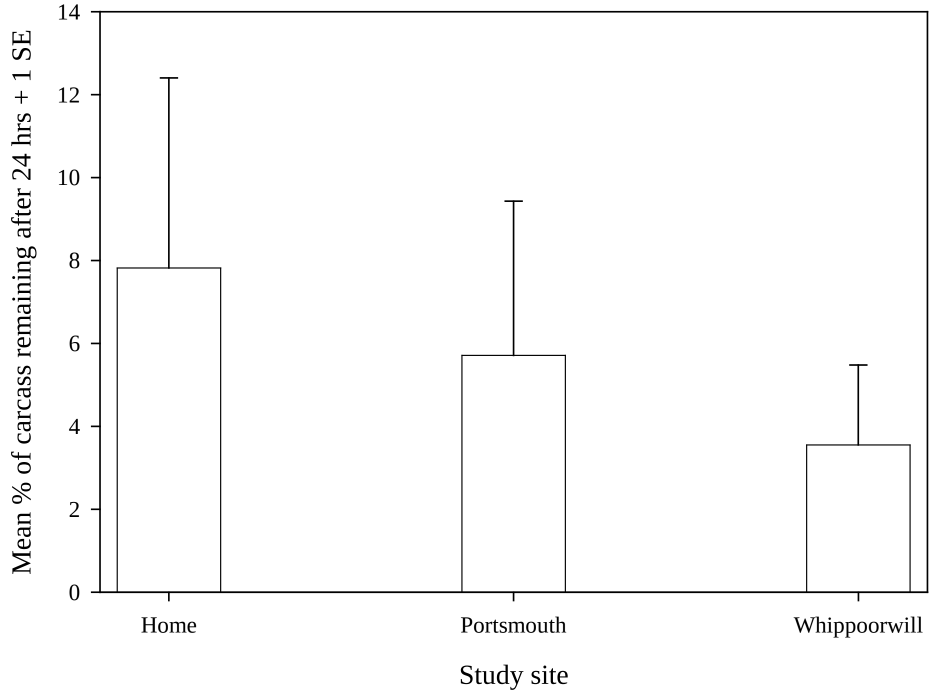

Fig. 6. Rat carcass consumption. Mean % of rat carcasses remaining after 24 hour exposure periods; hermit crabs were the primary carcass consumers.

6. DISCUSSION

6. 1. Will sequential application rates of 18 kg/ha + 9 kg/ha be enough to ensure rodenticide exposure to all rats within the study sites (Portsmouth and Whippoorwill Island)?

No. We captured rats lacking external or internal biomarker sign at both Portsmouth and Whippoorwill (Appendix A) within a post-bait application timeframe in which the biomarker is detectable in ≥ 75% of rats exposed to 3 pellets (Table 10). Furthermore, several rats captured at Portsmouth and Whippoorwill consumed, by our estimates, amounts of bait that translates to sub-lethal exposure in a 25W brodifacoum baiting scenario (Table 12).

Bait consumption results from Portsmouth and Whippoorwill show that the 18 kg + 9 kg baiting regime does not ensure that rats will have access to bait for four days (Fig. 5). Applying enough bait to ensure four days of rat exposure is a convention employed in many successful eradication campaigns (Wegmann 2008). The bait consumption trends at Portsmouth and Whippoorwill corroborate our biomarker-based assertion that an eradication program constrained by the maximum allowed application rate for 25W would have little chance of succeeding at Palmyra.

6. 2. Will sequential treatments at the application rate of 36 kg/ha deliver bait to all rats within the study site (Home Island)?

No. We captured one rat at five days after the first bait application to Home Island with no external or internal biomarker sign (Appendix A), and two rats that consumed, by our estimates, amounts of bait that translate to sub-lethal exposure in a 25W brodifacoum baiting scenario (Table 12). It is unlikely that the unmarked rat had invaded from Paradise Island – the nearest point of land 200 m across water. While some bait remained on the ground longer than four days after each 36 kg/ha application at Home, approximately 65% of the applied bait was consumed within the first 24 hr period, and 78% was consumed after 48 hrs. If rats (15 removed from Home during biomarker detection sampling between the first and second bait applications) were accessing a sizeable percentage of the bait, we would expect a reduction in the bait consumption rate for the second application. However, we observed an increase in bait consumption during the second application (Fig. 5), which suggests that crab related bait consumption (crabs were not removed during the biomarker detection sampling) prevents repeat bait applications ≥ 5 days apart from having a cumulative effect on the amount of bait remaining on the ground. Because three rats at the Home site were not exposed to enough bait to incur a lethal response in a brodifacoum-based operation, it is improbable that the 36 kg/ha + 36 kg/ha baiting regime would lead to eradication success at Palmyra.

6. 3. Which types of non-target organisms are at risk of exposure to the rodenticide during a broadcast operation?

We documented direct bait take (bait consumption or bait possession) by land crabs and other invertebrates (Table 15). All five of Palmyra's land crab species (Table 2) consume 25W (active or placebo) bait pellets (A. Wegmann, personal observation). While brodifacoum is not toxic to land crabs (or other invertebrates) in a bait broadcast exposure scenario (Pain et al. 2000), land crabs that consume bait must be thought of as potential bait-exposure pathways for non-target predators or scavengers (Wegmann 2008). Several subdominant consumers, notably ants, amphipods, cockroaches, and katydids were involved in direct bait take. Although, these organisms should not incur a lethal response from active bait consumption. However, they become potential rodenticide-exposure pathways for non-target predators. Because all of the listed subdominant consumers would be able to access bait housed in bait-stations, an aerial broadcast does not increase the non-target exposure risk associated with the subdominant consumer pathway. Aerial application may decrease this risk by shortening the period in which bait is available to non-target organisms.

In any toxin based rat eradication, carcasses of rats that died from toxin exposure become potential pathways for non-target species exposure to the rodenticide. However, on islands with high land crab densities (Palmyra), the rat carcass exposure pathway is limited to a 24-48 hr period after the rat dies (Fig. 6).

7. CONCLUSION AND RECOMMENDATIONS

A rat eradication campaign at Palmyra atoll will face many challenges: remote location, extensive canopy habitat, high land crab densities, moist conditions, and the potential for rodenticide resistance from a previous eradication attempt. Aerial broadcast of second generation anticoagulant rodenticide bait pellets has the best success record of any eradication method (Howald et al. 2007). Given the above-mentioned difficulties, aerial broadcast of a second generation anticoagulant rodenticide bait will deliver a high probability of eradication success at Palmyra (Howald et al. 2004, Buckelew et al. 2005). The 25W bait product was specifically designed for Palmyra's moist climate. However, the label-specified maximum application rate would not be expected to expose every rat to an amount of bait equivalent to a lethal dosage of brodifacoum and, thus, seems insufficient to kill every rat present on Palmyra Atoll.

The strategy that has the greatest amount of potential for killing all rats without doing irreparable harm to any aspect of the ecosystem is the one that should be pursued. Whatever procedures might be employed to minimize risks of non-target organisms likely to be affected by the rodenticide should be put forward and discussed in future documents. The findings of this study suggest that two successive aerial bait applications within the range of application rates which likely killed all rats on the islands treated in 2005 (Buckelew et al. 2005) will lead to eradication success at Palmyra.

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10. APPENDIX A

Biomarker Field detection results for *Rattus rattus*, Palmyra Atoll 2008. Rats that showed no biomarker sign are identified with "*." Both internal and external biomarker presence was scored according to a system devised during the rat biomarker detection assay; the scores presented in this table are the sum total for each rat including anus, tail, and other external for "External biomarker score," and " stomach, small intestine, and ceacum for "Internal biomarker score."

Study site	***Rat #***	***Days post first application***	***Days post second application***	***External biomarker score***	***Internal biomarker score***
Home	1	4		1	1
Home	2	4		2	0
Home	3	4		2	5
Home	4	4		3	8
Home	5	4		3	9
Home	6	4		2	9
Home	7	4		2	9
Home	8	4		2	9
Home	9	4		4	7
Home	10	4		3	7
Home	11	4		6	9
Home	12	5		1	7
Home	13	5		1	4
Home	14	5		1	3
Home	15	5		2	1
Home	16*	5		0	0
Home	17	10	5	5	6
Home	18	10	5	2	6
Home	19	10	5	3	3
Home	20	10	5	3	3
Home	21	12	7	0	1
Home	22	12	7	3	6
Port	1	4		1	3
Port	2	4		2	2
Port	3	4		2	2
Port	4	4		2	0
Port	5	4		2	6
Port	6	4		2	8
Port	7	4		2	9
Port	8	4		3	2
Port	9	4		3	1
Port	10	4		3	0
Port	11	4		3	5
Port	12	4		3	9
Port	13	4		3	9
Port	14	5		1	0
Port	15	5		2	1
Port	16	5		2	2
Port	17	5		2	0
Port	18	5		2	4

Study site	*Rat #*	*Days post first application*	*Days post second application*	*External biomarker score*	*Internal biomarker score*
Port	19	5		2	8
Port	20	5		2	5
Port	21	5		3	1
Port	22	5		3	2
Port	23	9	4	2	2
Port	24	9	4	3	5
Port	25	10	5	1	0
Port	26	10	5	2	4
Port	27	10	5	2	8
Port	28*	11	6	0	0
Port	29	11	6	2	3
Port	30	11	6	2	0
Port	31	12	7	2	3
Whip	1*	4		0	0
Whip	2	4		1	0
Whip	3	4		1	2
Whip	4	4		1	2
Whip	5	4		1	0
Whip	6	4		1	1
Whip	7	4		1	6
Whip	8	4		1	7
Whip	9	4		1	9
Whip	10	4		2	2
Whip	11	4		2	3
Whip	12	4		2	3
Whip	13	4		3	4
Whip	14	4		2	3
Whip	15	4		3	6
Whip	16	4		2	9
Whip	17	4		3	3
Whip	18	4		4	3
Whip	19	4		3	3
Whip	20	4		3	4
Whip	21	4		4	3
Whip	22	4		3	5
Whip	23	4		4	5
Whip	24	4		3	7
Whip	25	4		4	8
Whip	26	4		4	7
Whip	27	4		4	9
Whip	28	4		3	9
Whip	29	4		3	9
Whip	30	4		4	9
Whip	31	4		3	9
Whip	32*	5		0	0
Whip	33*	5		0	0
Whip	34*	5		0	0

Study site	*Rat #*	*Days post first application*	*Days post second application*	*External biomarker score*	*Internal biomarker score*
Whip	35	5		1	0
Whip	36	5		1	0
Whip	37	5		1	1
Whip	38	5		1	0
Whip	39	5		1	3
Whip	40	5		1	1
Whip	41	5		1	2
Whip	42	5		2	0
Whip	43	5		2	1
Whip	44	5		2	0
Whip	45	5		3	2
Whip	46	5		2	2
Whip	47	5		2	0
Whip	48	5		2	6
Whip	49	5		2	4
Whip	50	5		2	4
Whip	51	5		2	3
Whip	52	5		3	1
Whip	53	5		4	4
Whip	54	5		3	5
Whip	55	5		3	9
Whip	56*	9	4	0	0
Whip	57*	9	4	0	0
Whip	58*	9	4	0	0
Whip	59*	9	4	0	0
Whip	60*	9	4	0	0
Whip	61	9	4	1	0
Whip	62	9	4	1	0
Whip	63	9	4	3	3
Whip	64	9	4	3	4
Whip	65	9	4	3	8
Whip	66*	10	5	0	0
Whip	67*	10	5	0	0
Whip	68*	10	5	0	0
Whip	69*	10	5	0	0
Whip	70*	10	5	0	0
Whip	71*	10	5	0	0
Whip	72*	10	5	0	0
Whip	73*	10	5	0	0
Whip	74*	10	5	0	0
Whip	75*	10	5	0	0
Whip	76	10	5	1	0
Whip	77*	11	6	0	0
Whip	78*	11	6	0	0
Whip	79*	11	6	0	0
Whip	80*	11	6	0	0
Whip	81*	11	6	0	0

Study site	***Rat #***	***Days post first application***	***Days post second application***	***External biomarker score***	***Internal biomarker score***
Whip	82*	11	6	0	0
Whip	83*	11	6	0	0
Whip	84	11	6	1	0
Whip	85	11	6	1	0
Whip	86	11	6	1	0
Whip	87	11	6	2	1
Whip	88*	12	7	0	0
Whip	89*	12	7	0	0
Whip	90*	12	7	0	0
Whip	91	12	7	2	0

APPENDIX F

THE ECOTOXICOLOGY AND PALATABILITY OF TWO RODENTICIDE PRODUCTS: FIELD-BASED ASSESSMENT AT PALMYRA ATOLL

PALMYRA ATOLL RAINFOREST RESTORATION PROJECT

THE ECOTOXICOLOGY AND PALATABILITY OF TWO RODENTICIDE PRODUCTS: FIELD-BASED ASSESSMENT AT PALMYRA ATOLL

PREPARED BY

ISLAND CONSERVATION: AURORA ALIFANO AND ALEX WEGMANN*

FOR

THE PALMYRA ATOLL RAINFOREST RESTORATION PROJECT

***Correspondence: Alex Wegmann, Island Conservation, 100 Shaffer Rd. Santa Cruz, CA, 95060 USA / +1831.359.4787 / alex.wegmann@islandconservation.org / www.islandconservation.org**

1. EXECUTIVE SUMMARY

From 29 April to 28 May, 2010, two Island Conservation personnel visited Palmyra Atoll to assess the fate, palatability, and environmental impacts associated with the broadcast application of two rodenticide bait products. The main goals of this expedition were to:

1) Evaluate the environmental fate of the matrix and active ingredients of bait products currently approved for use to eradicate rats on Palmyra Atoll.

2) Determine the toxicity of rodenticide residue in body tissues and excrement after bait consumption by land crabs

3) Assess the palatability, for rats and land crabs, of the two bait products currently registered in the USA for broadcast application.

4) Conduct site-specific research needed to inform the development of an operational plan for a successful rat eradication at Palmyra Atoll.

The palatability and rodenticide residue in soil and land crab excrement for two anticoagulant bait products was assessed in this study. The goal of this study was to better understand the potential efficacy and potential impact associated with the use of each bait product in a rat eradication at Palmyra Atoll (Palmyra). The two bait products tested were "25W" and "D50." 25W is a 2nd generation anticoagulant product manufactured by Bell Labs® (Madison, WI) that contains 25ppm brodifacoum. D50 is a rodenticide bait product manufactured by HACCO® (Randolph, WI) that contains the first generation anticoagulant diphacinone. Both products were identified as potential candidates for use in the proposed eradication of Black rats (*Rattus rattus*) from Palmyra.

Toxicant residue from the two bait products was not readily incorporated into or retained in the topsoil layer (< 2 cm) of either of Palmyra's two primary soil types – sandy and humus. All soil samples yielded very low concentrations of either toxicant despite abundant rainfall, insect consumption, and pellet degradation during the study period. Low toxicant detection in the soil samples suggests that the bait products tested here do not transfer high concentrations of rodenticide to Palmyra's topsoil.

The concentration of brodifacoum found in crab tissue between day 2 and day 56 after initial exposure (1.8 – 0.01 ppm) (USDA-APHIS 2006) is less than the concentration of brodifacoum in the bait pellets that the crabs fed on (25 ppm), suggesting that some quantity of the toxicant is evacuated through defecation, metabolized by the crab, or both. In this study, captive crabs (*Cardisoma carnifex*) fed ad lib on bait pellets for 7 days, with no cumulative increase of rodenticide concentrations in crab excrement between day 2 and day 6. When crabs were switched from a diet consisting entirely of bait pellets to a diet of food items from their natural environment (day 7), rodenticide concentrations in crab excrement dropped to near-trace levels within three days (day 10).

Secondary consumers (hermit crabs and cockroaches) were observed consuming *C. carnifex* excrement. Consumption of crab excrement by other invertebrates likely increases the rodenticide residue period for crabs, and possibly for other invertebrates, such as cockroaches; however, residue concentrations were not measured beyond the primary consumer.

Both 25W and D50 were found to be palatable to rats and crabs when presented alongside three commonly available food items: coconut endosperm (meat), the meristematic tissue of young coconut palms, and the fleshy mesocarp of *Pandanus* fruit. Both 25W and D50 were consumed by rats and crabs in the presence of other natural food items, and neither bait product was significantly more palatable than the other. The average time for consumption of a 1 g pellet of 25W and D50 was 50 minutes, and the pellets were fully consumed in over 50% of the palatability trials. Coconut was the food item consumed most quickly and frequently.

A total of 156 genetic samples were collected from individual *R. rattus* captured on 12 of Palmyra's 25 distinct landmasses. The genetic samples will be banked to assist in determining the source of any rats captured after the eradication.

Multiple locations exist around the atoll where coconut palms extend over the water. If an aerial broadcast method is selected for the eradication, the overhanging palm crowns will need to be baited by hand. The average number of *C. nucifera* palms with 100% canopy coverage extending beyond the high tide line of the shore, was estimated both inside and outside the lagoon.

The preliminary results of egg predation monitoring and non-target species capture methods are also presented.

Table of Contents

1 INTRODUCTION

1.1 Project Setting

Palmyra Atoll National Wildlife Refuge (Palmyra), at 6° N and 162° W in the Line Islands – Central Pacific, represents a globally important conservation opportunity. The U.S. Fish and Wildlife Service (FWS) and The Nature Conservancy (TNC) co-manage Palmyra's emergent land area, while the FWS retains sole jurisdiction over marine resources extending 12 nautical miles out from the atoll. Palmyra is the only fully (federally) protected moist tropical forest ecosystem in the Central Pacific, yet native biota are currently threatened by an introduced, invasive rodent – the black rat (*Rattus rattus*). Palmyra provides important breeding habitat for 10 seabird species; however, rat related egg and chick predation has likely led to the extirpation of six additional species (Table 1). Without the consumptive pressure of an established human population, Palmyra's land crab ("crab") community is one of, if not the richest and most robust in the Central Pacific region. Palmyra is home to seven crab species (excluding the intertidal families Grapsidae and Ocypodidae), 4 of which are super abundant (Table 2).

Table 1: Resident seabirds of Palmyra Atoll.

Family	Common Name	Scientific Name	Breeding Pairs	IUCN
Procellariidae	Audubon's Shearwater	*Puffinus lherminieri*	Believed extirpated	LC
	Wedge-tailed Shearwater	*Puffinus pacifica*	Extirpated	LC
	Phoenix Petrel	*Pterodroma alba*	Believed extirpated	EN*
Hydrobatidae	White-throated Storm Petrel	*Nesofregetta fuliginosa*	Believed extirpated	VU*
Sternidae	Black Noddy	*Anous minutes*	2,500	LC
	Blue Noddy	*Procelsterna cerulea*	Believed extirpated	LC
	Brown Noddy	*Anous stolidus*	1000	LC
	Sooty Tern	*Sterna fuscata*	10,000	LC
	Gray-backed Tern	*Sterna lunata*	Believed extirpated	LC
	White Tern	*Gygis alba*	150	LC
Fregatidae	Great Frigatebird	*Fregata minor*	500	LC
	Lesser Frigatebird	*Fregata aerial*	Non-breeder	LC
Phaethontidae	White-tailed Tropicbird	*Phaethon rubricauda*	15	LC
	Red-tailed Tropicbird	*Phaethon rubricauda*	20	LC
Sulidae	Red-footed Booby	*Sula sula*	5,000	LC
	Brown Booby	*Sula leucogaster*	150	LC
	Masked Booby	*Sula dactylatra*	20	LC

* = Declining population trend

Table 2: Crab abundance survey results, Palmyra Atoll (Howald et al. 2004). Units represent #/hectare estimates.

Crab species	Mean	Standard dev.	Mass (g)[2]
Birgus latro	7	38[1]	1000
Coenobita brevimanus	46	8	50
Coenobita perlatus	182	80	50
Cardisoma carnifex	33	8	300
Cardisoma rotundum	28	5	300

[1] Large variance probably due to low probability of encounter and patchy distribution.
[2] Approximate adult mass

1.2 **Project Background**

Two bait products have been identified as potential candidates for use in the proposed eradication of *R. rattus* from Palmyra Atoll: 25W and D50. 25W is a 2nd generation anticoagulant product manufactured by Bell Labs® that contains 25ppm brodifacoum. 25W was field-tested at Palmyra in 2005, when Island Conservation (IC) and the FWS conducted trial broadcast-based eradications on five islets totaling 4.08 ha (Buckelew et al. 2005). A concurrent bait consumption trial indicated that an application rate within 60-90 kg/ha will be necessary to ensure that all rats have access to bait for four days post application despite crab competition for bait pellets. Recent Section 3 registration of the 25W product label set the maximum aerial broadcast rates at 18 kg/ha for the first application, and 9kg/ha for the second application – occurring five to seven days after the initial bait application. A 2008 assessment of bait application rates found that 25W's maximum application rate of 18 and 9 kg/ha will not effectively ensure that all rats have access to bait given the measured bait consumption capacity of the resident crab populations (Wegmann et al. 2008).

Due to the persistence of brodifacoum in the environment, and its toxicity to birds (Eason et al. 1999, Fisher et al. 2003, 2004, Alifano and Wegmann 2010), an alternative rodenticide "D50" is under consideration for use in the rat eradication effort. D50 is a rodenticide bait product manufactured by HACCO® that contains the first generation anticoagulant diphacinone. Diphacinone is less toxic to rats than brodifacoum, and typically requires multiple feedings over several days to illicit a toxic effect. To date, D50 has been field-tested at Palmyra Atoll only in brief palatability and bait degradation trials (Howald et al. 2004), though its palatability was not thoroughly tested against natural food items. Little is known about the fate or efficacy of D50 within Palmyra's eradication environment; the reduced toxicity of D50 to at-risk non-target species warrants further investigation of this bait product.

1.3 **Study Sites**

Palmyra consists of 250 ha of emergent land (fragmented into 25 islands), 16 of which were used during these studies. Rats were live-captured on the following islands: Strawn, Cooper, Aviation, Quail, Whippoorwill and Bunker, Eastern, Portsmouth, Barren, the South Island Complex, Paradise, Home, Sand, Fern, Lost, and the North-South Causeway (Figure 1). Soil samples were obtained from Lost Island and Cooper Island. All *Cardisoma carnifex* were collected haphazardly from Cooper Island and Strawn Island. *Coenobita perlatus* were collected from Whippoorwill Island.

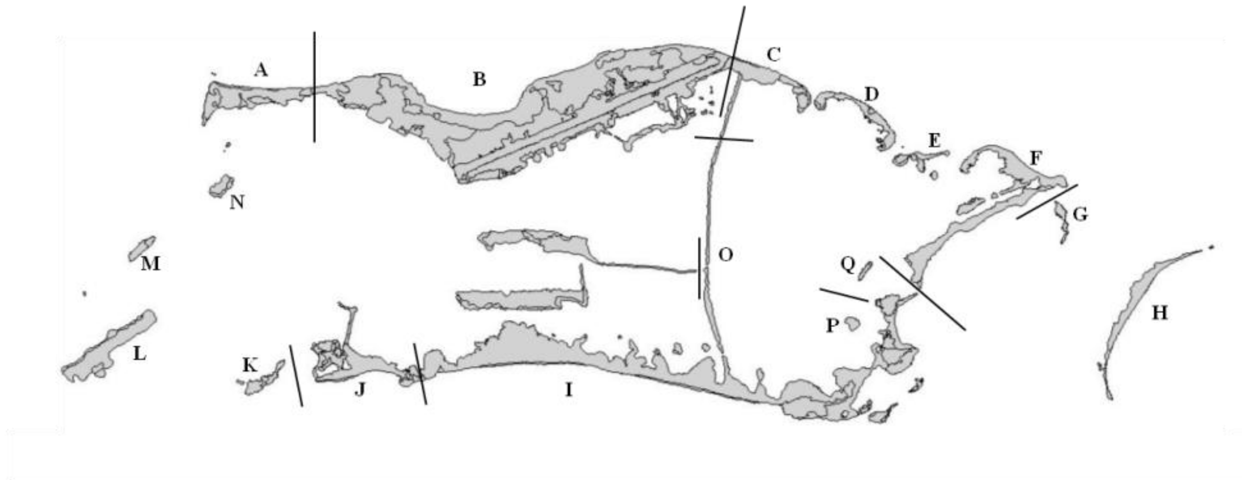


Figure 1. Islands from which samples were collected: (A) Strawn, (B) Cooper, (C) Aviation, (D) Quail, (E) Whippoorwill and Bunker, (F) Eastern, (G) Portsmouth, (H) Barren, (I) South Island Complex, (J) Paradise, (K) Home, (L) Sand, (M) Leslie, (N) Dudley, (O) North-South Causeway, (P) Fern, (Q) Lost.

1.4 **Study Questions**

1.4.1 Toxicant residue in soil

Study Question: For the rodenticide bait products 25W (containing brodifacoum) and D50 (containing diphacinone), will prolonged contact between a bait pellet and soil result in detectible concentrations of the given rodenticide in the soil environment, and if so, will the concentration decrease over time?

Although it is unlikely for a bait pellet to remain unconsumed on Palmyra for more than 4-7 days (Buckelew et al. 2005, Wegmann et al. 2008), it is currently unknown whether or not toxicants leach from bait pellets into the soil, and if so, how long the toxicant persists in the soil medium. In order to investigate the integration of rodenticides into soil, pellets of two bait products were placed on the two predominant soil types of Palmyra Atoll: sandy soil and humus soil. Soil was collected directly below each pellet at standardized depths and at specific time intervals. The concentration of toxicant in the sample was determined by High Performance Liquid Chromatography (HPLC) and mass spectrometry analysis performed by the California Animal Health and Food Safety Lab at the University of California, Davis.

1.4.2 Toxicant residue in crab excrement

Study Question: For the rodenticide bait products 25W (containing brodifacoum) and D50 (containing diphacinone), will consumption of bait pellets result in detectible concentrations of the given rodenticide in the excrement of crabs, and if so, will the concentration of toxicant in the excrement decrease over time?

C. carnifex represent a large portion of the crab biomass at Palmyra and consume a wide assortment of items ranging from vegetation and seeds to abandoned seabird eggs and dead seabird chicks. These opportunistic omnivores are known to consume bait pellets, as documented in the 2008 biomarker study (Wegmann et al. 2008). Although anticoagulants are not thought to cause harm to invertebrates, some quantity of the consumed toxicant might become available to other organisms if it is incorporated in crab excrement. It is unknown if toxicants are incorporated into crab excrement following bait consumption, and if so, over what timeframe crabs continue to shed the toxicant via their excrement. After 56 days, crabs retain only trace amounts of brodifacoum in their tissues (USDA-APHIS 2006), and it is likely that diphacinone will have even a shorter residence period in crabs (Fisher 2009). This study examined toxicant concentrations in crab excrement at post bait consumption time intervals that range from 2 to 27 days.

1.4.3 Toxicant reside in hermit crab tissue

Study Question: What is the average concentration of brodifacoum residue in hermit crab tissue 5 years post-exposure?

In 2005, a broadcast trial eradication was conducted at Palmyra Atoll using one bait product "PI-25" - containing 25 ppm brodifacoum,- manufactured by Bell Laboratories Inc.) (Buckelew et al. 2005). Tissue from hermit crabs on Home and Whippoorwill Islands were sampled at 2, 6, 10, and 56 days post-baiting and analyzed for brodifacoum residue by the National Wildlife Research Center Analytical Lab (USDA-APHIS 2006). In 2010, crabs were sampled and analyzed again, providing an opportunity to examine crab tissue for brodifacoum residue five years post-exposure.

1.4.4 Crab excrement coprophagia

Study Question: Do crabs and other invertebrates consume crab excrement?

Organisms that consume rodenticide bait may eliminate the toxic compounds through defecation, thus re-creating the potential availability of the toxicant to other organisms. Several factors determine the availability and concentration levels of eliminated rodenticide, including the rate of elimination by the organism and the transformation of the toxicant by internal metabolic processes. Rats and crabs consume nearly all of the available rodenticide pellets after a broadcast; however, little is known about the secondary pathways of the toxicant after primary consumption. The extent to which crab excrement is consumed by other organisms is unknown. If crab excrement does not serve as a trophic resource for Palmyra's scavengers, the toxicant consumed by crabs will be metabolized, or be eliminated in excrement and breakdown in the soil. Conversely, if small invertebrates such as cockroaches consume crab excrement they may become a tertiary toxicant pathway to other non-target species. Crab excrement consumption by invertebrates was examined to better understand this potential toxicant pathway.

1.4.5 Bait palatability

Study Question: When exposed to one bait product (25W or D50) in the presence of natural food items, which product is more palatable to rats within a short (2 hour) exposure window (palatability is measured by first physical contact, taste, amount consumed, and time to entire consumption of bait pellet)?

Little is known about the development of food preferences in wild rodents, but they usually select familiar foods (Jackson 1972). It is of the utmost importance that rodenticide bait product utilized for an eradication be attractive enough that every rat will consume a lethal dose. From the 2005 and 2008 trials, 25W (in both active and inactive forms) was consumed by rats on several islands, including Home, Portsmouth, Whippoorwill, and Bunker. However, there has not been a concerted effort to assess the palatability of the two bait products under consideration for the Palmyra rat eradication: 25W and D50. This study challenged both bait products against natural food items. Palatability was primarily measured as the amount (g) of the bait pellet (1 g) eaten, in contrast to the amount (g) of the other food items consumed by the rat, and the following variables were also assessed: item first contacted, item first tasted, item first consumed.

1.4.6 Live trapping and genetic sampling

Study Question 1: Are rodenticide-resistant alleles present in the current (pre-eradication) population?

Resistance to anticoagulant rodenticides was first recorded in the Brown Rat, *Rattus novegicus*, in Scotland in 1958 and has since been found in other countries and species. Anticoagulant resistance is thought to be due to a single major gene, of which there are at least two or possibly more alleles whose effects are subject to the action of modifiers and whose phenotypic expression is usually dominant. Resistance by three commensal rodents (*R. novegicus, R. rattus*, and *Mus musculus*) has been widely documented for first-generation anticoagulants, like diphacinone, and cases of resistance for two of the three commonly used second-generation anticoagulants (diphenacoum and bromadiolone) are now known; however, resistance to brodifacoum by black rats (*R. rattus*) has not been documented, yet cases of high tolerance have been reported (Lund 1984). The presence of rodenticide resistance within Palmyra's rat population would greatly influence the design of the eradication program. Therefore, DNA samples (tail snips) collected from rats at Palmyra will be screened for the alleles that are associated with rodenticide resistance.

Study Question 2: In the event that rats are discovered on Palmyra Atoll post-eradication, are those individuals missed rats or do they represent a post-eradication incursion?

R. rattus is the only species of rat currently present at Palmyra. Recent rat density estimates suggest that there could be as many as 139 rats/ha, resulting in a population size of 32,000 rats across the atoll (Wegmann et al. 2008). In case of eradication failure, analysis of *R. rattus* DNA (tail snips) from the pre-eradication population was collected, and will allow the project Partnership to determine if rats that are found post-eradication are missed target animals or from an incursion.

1.4.7 Bait application impacts on the marine environment

Study Question: In the event of bait drift during an aerial broadcast at Palmyra Atoll, how will marine organisms react to bait pellets in the marine environment?

The use of rodenticide bait is not anticipated to negatively impact marine organisms. Both toxicants in consideration for use on Palmyra (brodifacoum and diphacinone) have low solubility in water. Given the non-polarity of brodifacoum molecules and the ionic strength of seawater, the solubility of brodifacoum is likely in the low parts per billion range (Pierce et al. 2008). Water sampling conducted after aerial application of diphacinone pellets to Mokapu Island, in February 2008, found no diphacinone residues in any seawater samples, and even in the extreme case of 20 tons of brodifacoum bait spilled into the ocean off New Zealand, brodifacoum levels were not detectable within 36 hours after the spill (Pierce et al. 2008). New Zealand scientists estimated that during a normal helicopter aerial bait application, incidental bait discharge into the nearshore marine waters resulted in 0.0000006 mg/l, or about seven orders of magnitude below the level known to be lethal to bluegill sunfish (New Zealand Department of Conservation 2000). Although the low water solubility of the toxicant and the use of a deflector on the bucket during the aerial application decreases the likelihood of exposure to marine organisms to bait, the reaction of near-shore consumers to bait pellets should be examined.

1.4.8 Egg predation

Study Question: Can rat predation of ground-nesting seabird eggs be captured on video?

Several cases are known where predation on seabirds can be reliably attributed to black rats. These include sooty terns (*Sterna fuscata*) in the Seychelles Islands (Feare 1979), Bonin petrels (*Pterodroma hypoleuca*) in Hawaii (Grant et al. 1981), Galapagos dark-rumped petrels (*Pterodroma phaeopygia*) in the Galapagos Islands (Harris, 1970), and white-tailed tropicbirds (*Phaethon lepturus*) in Bermuda (Gross, 1912). Rat husking stations on Palmyra Atoll containing seabird eggshells are frequently observed near seabird breeding colonies; however, no direct observation of rat predation on seabird eggs or chicks has been made. Here, we attempt to video- and photo-document rats preying on bird eggs.

1.4.9 Coconut palms (*C. nucifera*) that overhang mean high-tide line

Study Question: How many coconut palms overhang the high-tide line?

To minimize the amount of bait that lands in the nearshore marine environment during an aerial broadcast at Palmyra, the pilot would apply bait, using a directional deflector, several meters inside the mean high-tide line. Palm trees seeking light often overhang the shoreline; such palms represent potential rat habitat yet they would not be baited during the aerial broadcast. Overhanging palms would be treated by hand-canopy baiting (Wegmann et al. 2008). To estimate the number of overhanging palms and the effort required to effectively bait them, we counted the number of palms along measured stretches of lagoon-facing and ocean-facing shoreline.

1.4.10 Curlew capture

Study Question: Can curlews be successfully captured by noose carpet?

During the rat eradication, Bristle-thighed Curlews (*Numenius tahitiensis*) and Pacific Golden Plovers (*Pluvialis fulva*) will be put at risk of primary and secondary exposure to rodenticide. Active mitigation of this risk through a capture-hold or capture-translocation action may be required. However, capture, holding, and transport of wild birds can result in mortalities; care should be taken. This study tested the feasibility of one method of capture.

2 METHODS

2.1 Toxicant Residue in Soil

2.1.1 Study locations and plot placement

Two predominant soil types exist at Palmyra Atoll. Within forests of *Pisonia grandis*, soils are highly phosphatic and composed almost entirely of organic matter (Christophersen 1927); we refer to this soil type as "humus." In contrast, soils associated with *C. nucifera* (coconut palm) forests are sandy and non-phosphatic with medium or low organic matter (Christophersen 1927); we refer to this soil type as "sandy." Soil nutrients are significantly elevated in dicot (*Pisonia* mixed with other tropical broadleaf tree species) forests (NO_3^-= 100.74 ± 26.10 µg/g; NH_4^+ = 65.09 ± 5.23µg/g) as compared to palm forests (NO_3^-= 8.04 ± 2.31 µg/g; NH_4^+ = 39.59 ± 6.21µg/g; n = 57). Isotopic values of $\delta^{15}N$ in soil are significantly different across forest type; there are no significant differences in $\delta^{13}C$ in soils across forest type (Young et al. 2010).

To estimate the maximum likely integration of rodenticide into Palmyra's soil after a broadcast bait application, bait pellets were placed directly on the soil for seven days. Samples of sandy soil were collected from Cooper Island, and samples of organic humus soil were collected from Lost Island. Application of rodenticide products have not occurred at either site since the culmination of the previous rat eradication attempt in 2002. During this study, pellets of two bait products (25W and D50), were left to naturally degrade in select locations for seven days. The soil directly beneath pellets was sampled after 2 days, 7 days, 28 days, and 50 days.

2.1.2 Soil plot design

25W and D50 pellets of similar mass were selected to standardize, as best as we could, the amount of toxicant placed in each soil plot: 2.4 g ± 0.1 g for 25W, 1.04 g ± 0.1 g for D50. Exclusion tubes (7.6 cm x 5.1 cm PVC) with wire mesh over the top prevented the pellets from being disturbed by rats and crabs, while maintaining bait pellet exposure to weathering factors such as sunlight, rain, humidity, small invertebrates, and micro-organisms. Each exclusion tube was secured to a 30 cm plastic stake driven into the ground – this prevented crabs from removing the tubes. One bait pellet was placed on the soil in the center of each exclusion tube. After seven days, or two days for the "2 day sample," the tubes and intact portions of the pellets were removed. The exact location of each pellet within the tube was marked with two steel pins that defined each end of the pellet (Figures 2 and 3). Three replicate exclusion tubes containing one bait product were installed within the same microhabitat (1 sq meter plot); and plots containing 25W were approximately 5 meters away from those containing D50. Natural degradation and weathering of the bait occurred over time, including disturbance and consumption by small organisms like ants and microbes.

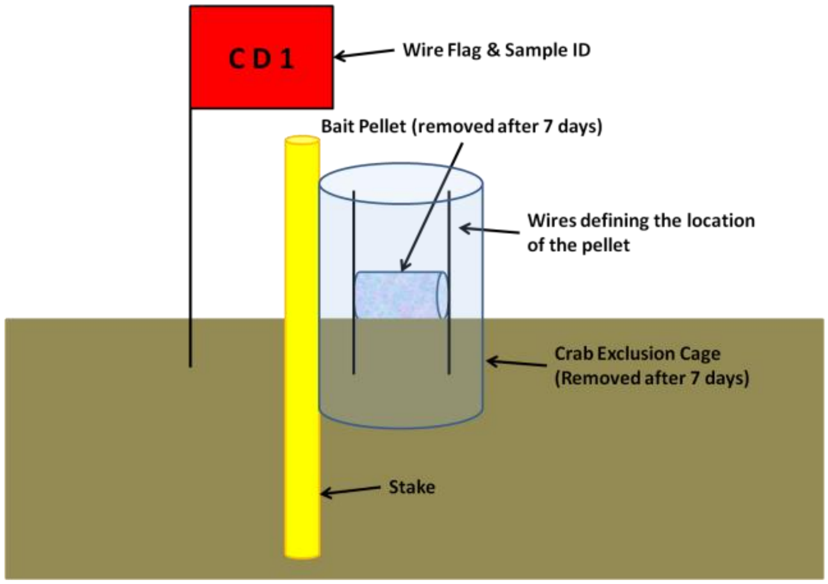


Figure 2. Cartoon of the toxicant residue in soil study plot.

Figure 3: Lost Island 28 day soil plot with stake, PVC crab exclusion tube with wire mesh, and one 25W bait pellet inside.

Three replicates for each bait product were sampled from both soil types, at four separate exposure periods, resulting in a total of 48 surface soil samples. Sub-surface samples were also collected at a depth of 6 cm during the 28 and 50 day collections to assess the depth of penetration of the toxicant. Soil that was not exposed to bait pellets was collected from each study site during each sampling period.

2.1.3 Soil core sampling

Soil samples were collected using a stainless-steel core (2.5 cm inside diameter x 70 cm length). Soil was carefully extracted from the core onto fresh wax paper for sample collection (Figure 4).

Surface soil samples were collected from the top 2 cm of the core sample, while soil between 5.5 and 6.5 cm depth was collected as sub-surface samples. Soil samples were transferred into sterile plastic vials with screw-top lids by scooping soil with a new plastic knife. The stainless-steel soil core was sanitized with a 3-step process before and after the collection of each core sample. Particulate matter was flushed from the core with salt water, the walls of the core were wiped down with acetone to remove toxicant residue, and then the core was rinsed thoroughly with fresh water.

The soil core depth varied between study sites due to differences in the depth of soil above bedrock. The average core depth at Lost Island was 8 cm ± 2 cm; the core met refusal from bedrock between 9 and 11cm. The soil on Cooper Island was deep enough to allow core depths of 20 cm without refusal. To ensure consistency among locations, core depth at Cooper Island was limited to 10cm during sampling. To ensure that samples could be obtained from all locations and replicates, the sub-surface samples were taken from a core depth of 6 cm (for 28, 36, and 50 plots only). Surface samples were collected from all soil samples in the top 2cm of the core.

Sample vials were sealed with parafilm, labeled, and stored in a -80°C freezer to prevent further microbial degradation of the soil. High Performance Liquid Chromatography (HPLC) and mass spectrometry analysis was performed by the California Animal Health and Food Safety Lab at the University of California, Davis to quantify toxicant concentrations in each sample.

Figure 4: Soil core from Cooper Island with lighter colored sand at depth, and darker sand including organic content and plant matter at the surface.

2.2 **Toxicant Residue in Crab Excrement**

2.2.1 Crab selection and cage construction

C. carnifex were selected as the subject of the toxicant residue in crab excrement study due to their relative abundance, and their role as primary consumers of bait. Thirty-two adult *C.*

carnifex (mean weight = 370g ± 77g (1SD)) were haphazardly captured from Cooper Island for inclusion in this trial. Crab cages (N=8) (0.9 m x 0.9 m x 0.45 m) were constructed from 1.3cm wire mesh (19 gauge), divided into four crab "apartments" per cage (46 cm x 46 cm x 46 cm) and filled with 20-30 cm of sand. Each apartment was fitted with a "pool" – a 10 cm diameter x 8 cm high pail – that provided the crabs with a water source for brachial saturation. *C. carnifex* were individually housed to prevent competition for bait or natural food items, and to prevent confrontations that would likely lead to injury during the course of the experiment (Figure 5). Four cages were dedicated to 16 *C. carnifex* that were fed 25W ad lib for seven days, and four cages were dedicated to 16 *C. carnifex* that were fed D50 ad lib for seven days. All four crabs housed within one cage were fed the same bait product. Crabs were weighed, sexed, and marked with a unique identifier at the initiation of the experiment.

Figure 5: *C. carnifex* cage. Each cage contained 4 "apartments" with fresh sand, a pool, and individual access to standardized amounts of food items for the duration of the 28 day experiment. Each cage was dedicated to crabs consuming either 25W or D50.

The majority of bait applied during an aerial broadcast will only be available for 4 days on average, and it is extremely unlikely for bait to remain on the ground for longer than 7 days at Palmyra due to high rates of consumption by rats and crabs (Buckelew et al. 2005, Wegmann et al. 2008). To determine the maximum concentration of toxicant in *C. carnifex* excrement during a worst-case scenario, crabs were offered as much bait as they could consume for 7 continuous days (Figure 6).

Figure 6: *C. carnifex* in a crab “apartment”, carrying a 25W bait pellet in each claw. All food items were delivered in the sandy area of each crab apartment, but crabs frequently dragged food items into the pools for consumption.

After 7 days, all bait pellets were counted and removed from the crab cages. All sand and organic matter was also removed. The pools were scrubbed and rinsed with fresh water, wiped with acetone and rinsed again, and the cages were thoroughly rinsed with seawater to remove any bait pellet particles. Subsequently, the cages were refilled with fresh sand and the pools were refilled with fresh water. Crabs were fed a diet of natural food items for the remainder of the experiment. Crabs were offered a mixture of food items that they were observed consuming in their natural environment, including *Pandanus* fruit, coconut solid endosperm and meristem, fresh-cut grass, and *Scaevola*, *Pisonia,* and *Tournafortia* leaves.

2.2.2 Sampling

Excrement collection occurred on days 2, 6, 10, and 27 post initiation of the experiment. To prevent excrement samples from being contaminated by bait product particles stuck to the crab’s legs and carapace, each crab was thoroughly rinsed with fresh water before being placed in a 2 gallon bucket. Each crab was assigned to a bucket, which was scrubbed, rinsed with fresh water and wiped cleaned with acetone between each use to prevent cross-contamination of samples. Excrement collection was conducted using the thin edge of a sterile weigh boat to scrape the excrement into sterile screw-cap vials. If a crab provided less than 2 grams of excrement in 24 hours, the excrement was pooled with the excrement of another crab from the same cage to meet the minimum weight requirements for HPLC analysis. Sample vials were sealed with parafilm, labeled, and stored in a -80°C freezer to stop microbial degradation of the toxicant. After the final excrement collection, crabs were released near their site of capture on Cooper Island.

2.3 **Toxicant Residue in Crab Tissue**

2.3.1 Hermit crab collection and sampling

In 2005, a broadcast trial eradication was conducted at Palmyra using one bait product, PI-25 - the prototype for 25W (Buckelew 2005). In association with this trial eradication, hermit crabs (*Coenobita perlatus*) from Home and Whippoorwill Islets were sampled at 2, 6, 10, and 56 days post-baiting and analyzed for brodifacoum residue by the National Wildlife Research Center Analytical Lab (USDA-APHIS 2006). This visit to Palmyra provided an opportunity to sample crabs from Whippoorwill Island (baited at 95 kg/ha in 2005) and analyze crab tissue for brodifacoum residue 5 years post-exposure. On May 6th, 2010, ten adult *C. perlatus* were collected from Whippoorwill Island, euthanized by freezing, and analyzed for brodifacoum residue at the USDA National Wildlife Research Center in Fort Collins, CO. Whole frozen hermit crabs were homogenized with a SPEX Certiprep Model 6850 Freezer Mill. Each sample was analyzed in duplicate. Brodifacoum residues were surrogate corrected with difenacoum.

2.4 **Crab Excrement Coprophagia**

2.4.1 Crab selection and bait consumption

Crabs are physiologically capable of eating great quantities of bait, resulting in potentially substantial amounts of toxicant-laden excrement made available to other consumers. To reduce variability in excrement production due to individual physiology or size during different life history stages, only large adult crabs were selected for this study. Orange land crabs (*C. carnifex)* weighing 300-500 grams were offered more bait pellets than they could possibly consume in a 24 hour period. The average mass of 25W pellets (1.55g) was slightly more than the average mass of D50 pellets (1.02g) therefore the number of 25W pellets offered was adjusted to standardize the weight of bait product offered to both groups. *C. carnifex* in the 25W group (N=20) were given 15 25W pellets for a 24 hour period (Figure 7). *C. carnifex* in the D50 group were exposed to 30 D50 pellets for a 24 hour period. After 24 hours, the number of pellets remaining were counted. Crab excrement that contained visible traces of bait (either blue or green stain) was collected and stored in a -80ºC freezer.

Figure 7: A *Cardisoma carnifex* in a five-gallon bucket, consuming D50 pellets ad lib during a 24 hour bait consumption study.

Crab excrement from crabs that had not consumed either bait product was collected by placing crabs in a clean bucket for 24 hours. The resulting scat was collected and stored in a -80ºC freezer.

2.4.2 Cardisoma excrement consumption by cockroaches

Three types of crab excrement were offered to other organisms to detect a difference in preference for excrement containing bait vs. natural excrement: excrement post-consumption of D50, excrement post-consumption of 25W, and excrement from crabs that had not consumed either bait product. Fourteen cockroaches were collected from Cooper Island, held in individual plexiglass pens, and offered a standardized amount (0.2g) of crab excrement without other alternatives for 8 hours. The three types of excrement were placed in different corners of a pen. The fourth corner of the pen was left empty. Excrement was placed in the corners of the pen just before the cockroach was placed in the center. Presence or absence of the excrement in the pen at the end of the experiment was used to determine whether or not cockroaches consume crab excrement, and if so, do they prefer excrement from crabs that have recently consumed bait.

2.4.3 Cardisoma excrement consumption by hermit crabs

Forty-eight *C. perlatus* were collected from Cooper and Whippoorwill Island, held in individual plexiglass pens, and offered a weighed amount of crab excrement without other alternatives for 8 hours. Excrement was placed in 3 corners of the pen, as described above. Excrement was placed in the corners of the pen just before the hermit crab was placed in the center. Presence or absence of each type of excrement in the pen at the end of the experiment was used to determine consumption of excrement by hermit crabs. Hermit crabs were marked with a sharpie to ensure that individuals were not resampled, and released on Cooper Island.

2.5 **Bait Palatability**

2.5.1 Rat capture

Rats were captured in live traps from 9 islets: Aviation, Barren, Cooper, Eastern, Fern, North-South Causeway, Paradise, Sand, and Whippoorwill (Figure 1) and brought to Cooper Island for the bait palatability trials. These rats were trapped using peanut butter smeared on a plastic disc hung on the trigger hook of a Hagaruma® live-capture trap. Rats were held in individual Tomahawk™ traps and given access to fresh water, during a 24 hr acclimatization period. Each rat was weighed, sexed, and assigned a unique number.

2.5.2 Rat palatability trials

To accommodate the natural foraging pattern of the captive rats, trials were run at night with start times no earlier than 19:00. Just prior to a palatability trial, captured rats were transferred into 30 cm x 15 cm x 15 cm plastic pens. Each pen had a clear plexiglass lid with holes for ventilation and opaque walls so rats could not make visual contact with rats in neighboring pens or be subject to outside distractions during the trials. Four food items (solid coconut endosperm – "coconut meat", coconut meristem, mesocarp from the *Pandanus fischerianus* propogule, and either 25W or D50) cut into pieces weighing 1 g ± 0.5 g were prepared prior to each trial. One food item was placed in each corner of the pen - placement was randomly selected for each rat using a random number generator (Haahr 1998). After the rat was transferred from the holding cage to the study pen, all four food items were staged on the four corners of the plexiglass lid, and were simultaneously inserted into the cage by pushing them through 0.5 cm radius holes positioned over each corner.

Each rat experienced concurrent exposure to the four food items for two hours. Trials consisted of one rat per pen, monitored by a video camera to eliminate the disturbance that a human observer might cause. The number of rats (and pens) per trial ranged from one to six, and was dependent on the number of rats captured for that trial session. When the trial was complete, rats were removed from the pens and euthanized according to AMVA guidelines (AMVA 2007). After euthanizing the rats, a 1-2 cm section of the distal end of each rat's tail was collected and placed in a sample vial containing 95% ethanol; the tail segments were kept for genetic analysis (described in 4.6.2). Rat carcasses were incinerated to ensure that the toxicant residue from consumption of bait during the palatability trials was not available to other organisms.

The remains of all four food items were weighed on an Escali™ 50 gram electronic balance. This value was subtracted from the pre-trial weight of each item to determine the amount (g) consumed during the trial. Video footage was downloaded and analyzed for each rat trial, with the following variables recorded: item first contacted, item first tasted, item first consumed, and time to full consumption of the bait pellet and percent mass of the bait pellet remaining after two hours.

2.5.3 Crab palatability trials

Thirty-two *C. carnifex* were collected for bait palatability trials. Crabs were collected at various locations on Cooper Island. Individual crab weight and sex was recorded prior to each trial. Crab weight ranged from 150 g to 550 g with a mean of 332 g (SD 82). *C. carnifex* were presented with 4 food options for 4 hours, after which percent remaining was determined for each item. Each crab was housed in a separate 5 gallon bucket. Four food items (coconut,

coconut meristem, *Pandanus*, and a bait product: 25W or D50) were cut into pieces weighing 1g ± 0.5g (measured on an Escali™ 50 gram electronic balance). These items were placed simultaneously into the bucket and in front of the crab. A lid with holes for ventilation was placed on the bucket to prevent the crab from escaping. After the 4 hour study, crabs were removed, marked with a permanent marker to prevent recapture, and released on Cooper Island. All remaining food items were weighed immediately after the trial, and the mass was recorded for each item. All remaining bait products were incinerated.

2.6 **Live Trapping and Genetic Sampling**

2.6.1 Live trapping

Hagaruma® live traps (with wire mesh bases) were systematically deployed at study sites throughout the atoll. Standardized trap lines were established within all study sites. Two methods of trapping were employed; some traps were placed on upside-down 20 liter plastic buckets on the ground to reduce crab interference, while other traps were nailed to tree trunks. On Sand Island, the high density of large coconut crabs required the use of more robust Tomahawk® traps secured to horizontal tree branches with bungee cords. Solid coconut endosperm coated with creamy peanut butter was used as bait for all rats that did not participate in the palatability trials. All traps were checked daily.

2.6.2 Genetic sampling

A 2-3 cm section of each rat tail was collected using sterilized dissection shears and stored in a plastic screw-top vial containing 95% ethanol. All rat tail samples were transferred to a buffer solution containing the active ingredients dimethyl sulfoxide and ethylenediaminetetraacetic acid to preserve DNA integrity and shipped to Ecogene™, a subsidiary of Landcare Research New Zealand Ltd., for storage and analysis. In the event of a post-eradication rat detection (and collection), Ecogene will genotype the pre-eradication Palmyra rat population by obtaining multilocus microsatellite genotypes from each sample using a set of 9 loci (Abdelkrim et al. 2007). Evidence for allelic drop-out, scoring error due to stutter, and presence and frequency of any null alleles will be assessed with MICRO-CHECKER (Oosterhout et al. 2004) using a Bonferroni adjusted 95% confidence interval and 10,000 repetitions. Genetic diversity indices will be calculated using GenAlEx v 6.2 (Peakall and Smouse 2006) and tests for Hardy-Weinberg and linkage disequilibrium will be conducted using GENEPOP v 4.0 (Raymond and Rousset 1995). Pairwise F_{ST} parameters for each population pair will be estimated according to Weir and Cockerham (Weir and Cockerham 1984). The data will then be analysed using the Bayesian clustering method implemented in STRUCTURE ver 2.3 (Pritchard et al. 2000) to provide another estimate of pairwise F_{ST} parameters and to determine the number of distinct genetic units (K) in the dataset. The same analysis will be applied to samples collected from any rats captured at Palmyra after the eradication operation.

Rodenticide resistance in the pre-eradication population will be assessed by Ecogene. Ecogene will screen for the amino acid substitution Tyr139 in the VKORC1 gene using the ARMS PCR technique (Pelz et al. 2005). Recent work has shown a larger range of mutations in the VKORC1 gene, including a Trp59Arg substitution found in Argentine rats that may also be associated with resistance (Rost et al. 2009). Following ARMS-PCR, DNA sequencing is then required to verify the presence of the Y139C mutations in Exon 3 and to look for other possible mutations.

2.7 Bait Application Impacts on the Marine Environment

2.7.1 Shallow water trial

On May 21st, 2010, a placebo (non-toxic) version of 25W, in the same pellet configuration as the active form, was scattered into the near-shore water off of Cooper Island to simulate bait drift into the marine environment during an aerial broadcast; the water depth was approximately 1 meter. Observers stood on a deck overhanging the study site. A ten minute observation period of the area resulted in the identification and recording of 16 fish species in the study area. Placebo 25W pellets were dropped into the water and reactions by fish were documented. Video monitoring of the site recorded some fish-bait interactions (no interest, investigated, bumped, mouthed and then spit out, consumed). Individual pellets were observed as they fell through the water column, and for three minutes once the pellet landed on the bottom. If no reaction was observed after three minutes, another pellet was dropped in a different location. This trial was repeated 12 times in the shallow water location.

2.7.2 Mid water trial

The shallow water trial was repeated in water approximately 3 meters in depth off the seaplane ramp on Cooper Island. Bait was dropped from the seaplane ramp and surface observations were made from the ramp. Due to the limited surface visibility, a snorkeler entered the water and used a video camera to record fish reactions to the placebo bait as it fell through the water column. This trial was replicated 5 times at this location.

2.7.3 Deep water trial

To assess the reaction of fish that may not frequent shallow water areas to bait pellets, placebo bait drop trials were conducted off of the ripple wharf on Cooper Island. The depth was approximately 10 m, and contained larger fish species such as sharks, snapper, and giant trevally. Bait was dropped by observers standing on the ripple wharf, and fish-bait interactions were recorded on video by a snorkeler. This trial was replicated 6 times at this location.

2.7.4 Bait on the flats

To determine the reaction of intertidal organisms that may encounter a bait pellet on the sand flats inside the lagoon, 3 video stations were installed during low tide. 5 placebo bait pellets were placed on the sand in the presence of fiddler crabs (*Uca sp.*), Bristle-thighed Curlews, and Pacific Golden Plovers. Each set of five pellets was monitored by video for 2 hours. Subsequently, the video stations were removed and all leftover placebo pellets were removed.

2.8 Egg Predation

2.8.1 Egg predation monitoring

Rats are known to prey on the eggs of ground- and tree-nesting seabirds (Jones et al. 2006, Jones et al. 2008), and are assumed to contribute to seabird egg and chick mortality at Palmyra Atoll. Attempts to capture egg predation by rats on film were conducted using chicken eggs. Eggs were removed from the refrigerator an hour prior to the trial, allowing the egg to reach the ambient temperature. At night, an egg was placed on the ground outside the Sooty Tern colony. The egg was dimly lit with a headlamp and monitored for two hours by a video camera (Figure 8).

Figure 8: Daytime trial of egg video monitoring near the range marker in the Sooty Tern Colony.

In the event that the illumination of the egg was a deterrent for foraging rats, several trials were also conducted with an infrared camera and without lighting.

2.9 Toxicant concentrations in the bait products used in this study: brodifacoum in 25W and diphacinone in D50

The concentration of a toxicant individual bait pellets can vary. 25W and D50 were sampled to determine: 1) the variation of toxicant concentrations found bait pellets, and 2) the mean concentration of toxicant for a small sample of pellets for each bait product. A bucket of bait for each product was haphazardly sampled by extracting 10 similar-mass bait pellets (± 0.3g). Each pellet was analyzed for toxicant concentration at the California Animal Health and Food Safety laboratory at the University of California, Davis.

2.10 Coconut palms (*C. nucifera*) that overhang mean high-tide line

2.10.1 *C. nucifera* canopy description

In the event of an aerial broadcast, certain areas of the atoll would be baited by hand to prevent bait drift into the marine environment. To reduce the chance that bait drift will occur, aerial baiting operations will not target vegetation that overhangs the high-tide line. There are multiple locations around the atoll where coconut palms extend over the water; the crowns of such palms (Figure 9) need to be baited by hand.

Figure 9: *C. nucifera* on the ocean-facing side of Cooper Island (North Beach area) that extend over the high tide line.

2.10.2 Overhanging palm crown estimation

To estimate the number of coconut palms that extend over the high tide line, we walked a measured section of shoreline, and counted each coconut palm overhanging the high tide line. The section of shoreline walked was tracked with a hand-held GPS, which provided a measurement of the length of shoreline sampled and the subsequent calculation of the number of overhanging palms in a given length of shoreline. Nine counts were conducted on the following islands: Cooper, Strawn, Holei, Papala, and Engineer.

2.11 **Bristle-thighed Curlew Capture**

2.11.1 Capture method

This study field-tested a method for capturing curlews. Curlews were slowly herded towards a noose carpet placed on North beach, North Road, or the runway. The noose carpet consisted of a 1 m x 5 m strip of astro-turf with hundreds of mono-filament nooses stitched in (Figure10). Curlews that walked across the carpet would become entangled in one or more of the nooses. Preparations were made to band all captured Curlews prior to release.

Figure 10: The noose carpet stretched across North Road on Cooper Island in an area where curlews are frequently observed. Hundreds of monofilament nooses (20 lb test) are incorporated into the carpet.

3 ANALYSIS:

Statistical analysis was conducted in Minitab® 16 statistical software. We used an alpha level of .05 for all statistical tests. The quantitative analysis of toxicant residue in the soil samples did not always yield a reportable concentration. When the concentration of toxicant was below the stated reporting limit it was reported as "trace", indicating that the analyte was detected but the concentration was between the reporting limit and zero. The reporting limit is the lowest routinely quantified concentration of an analyte in a sample. In soil samples, the reporting limit for brodifacoum was 0.2 ppm, and the reporting limit for diphacinone was 2.0 ppm. In crab excrement samples, the reporting limit for brodifacoum was 0.2 ppm, and the reporting limit for diphacinone was 5 ppm. In "trace" instances, we assigned a value of ½ the reporting (detection) limit to the samples, as it would be inappropriate to analyze these results as zero concentration values. The difference in reporting limits is due to the difference in sensitivity of the instruments used to detect diphacinone and brodifacoum.

A one way ANOVA was conducted to compare the concentrations of brodifacoum and diphacinone in soil over four temporal exposure periods

A one-way ANOVA test with Tukey's pairwise comparisons was conducted to look for differences in the concentration of brodifacoum residue in crab excrement between the four exposure periods. A one-way ANOVA was used to look for differences in the concentrations of diphacinone in crab excrement for the 4 exposure periods. A two-sample t-test was used to determine if the number bait pellets from one product were preferentially consumed over the other, and to determine if, on average, crabs consumed different amounts of 25W and D50.

One-way ANOVA tests were conducted to look for differences in the amounts of three types of crab excrement consumed by cockroaches and hermit crabs.

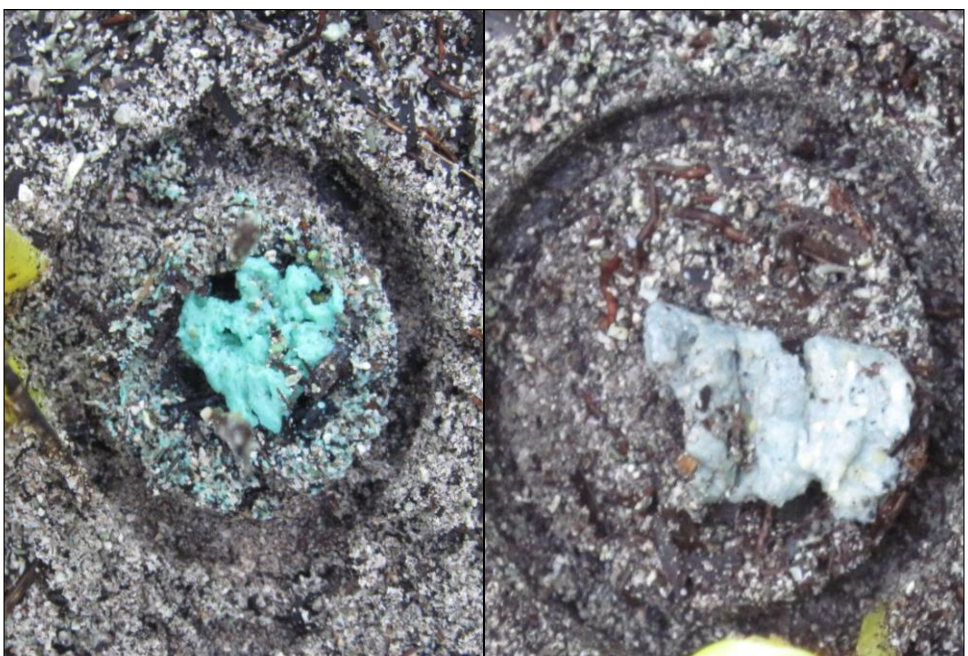
A two-sample t-test was conducted to determine if the amount (grams) of 25W consumed during rat palatability trials differed from the amount of D50 consumed.

A one-way ANOVA test with Tukey's pairwise comparisons was conducted to look for differences in the time to consumption for 25W compared to the three other food items it was tested against. A one-way ANOVA test with Tukey's pairwise comparisons was also conducted to determine differences in the time to consumption for D50 in comparison to the same three food items.

4 RESULTS

4.1 Toxicant Residue in Soil

Bait pellets were removed from soil plots seven days after placement, with the exception of the two-day plots in which pellets were removed two days after placement. Visual estimates were made of the percent remaining of each pellet. In some instances, pellets remained intact and were simply removed by a gloved hand. All intact pellets or portions of pellets were removed at the allotted time: two days or seven days post placement. Pellet condition did not vary among study site replicates, but did vary between study sites (Table 3).



Disintegrated D50 Pellet Cooper Island	Disintegrated 25W Pellet Cooper Island

Figure 11: Disintegration of bait pellets from Cooper Island plots, potentially due to ants, precipitation and weathering. D50 pellets (left) disintegrated more quickly and more frequently than 25W pellets (right).

The soil plots with the longest exposure period were installed on April 8th, 2010 and proceeded to run for 50 consecutive days. The total amount of precipitation during that period was 1,477 mm; rainfall was an almost daily occurrence (Figure 12). The average daily maximum temperature was 29.1°C and fell to an average daily minimum of 25.1°C.

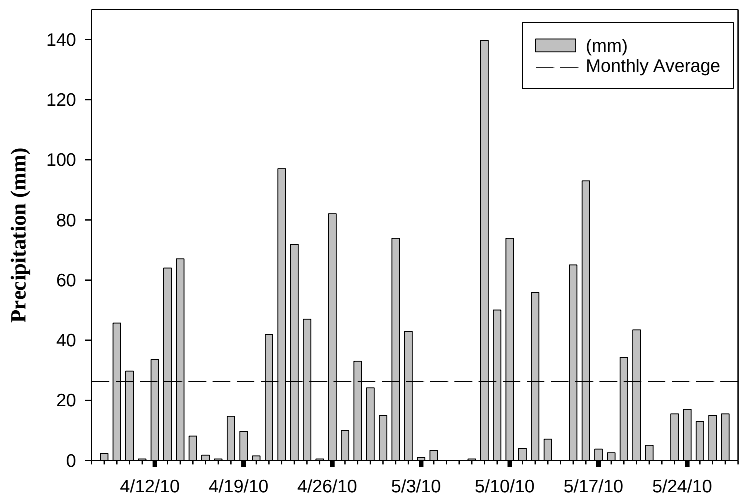


Figure 12: Plot of daily rainfall at Palmyra Atoll measured each morning at 7:30am. The dashed line represents the monthly average precipitation (28.96 mm).

Table 3: Description of bait pellets remaining 2, 7, 28, 36, and 50 days after placement. Bait pellets that were not intact but had crumbs or other visible evidence remaining were classified as disintegrated. (-) indicates non-applicable at that location.

Sample Day	**Cooper Island (Sandy Soil)**		**Lost Island (Organic Soil)**	
	25 W	**D50**	**25W**	**D50**
Day 2	Intact	Disintegrated	Intact	Disintegrated
Day 7 (7day plots)	Gone	Gone	Intact	Gone
Day 7 (28 day plots)	Gone	Gone	Intact	Disintegrated
Day 7 (36 day plots)	Gone	Gone	-	-
Day 7 (50 day plots)	-	-	Gone	Gone

Low concentrations of rodenticide active ingredients were found in sandy and organic soil regardless of exposure period. We found no difference in brodifacoum concentration in sandy soil between exposure periods (DF=3 F=1.59 P= 0.26). Diphacinone was not detected in sandy soil samples, regardless of exposure period. We found no difference between exposure periods for brodifacoum concentration (DF= 3 F= 0.33 P=0.80), or diphacinone concentration (DF= 3 F= 2.67 P= 0.11) in organic soil.

Out of 48 samples (not including controls), only two contained a concentration of toxicant that was high enough to quantify. The rest of the samples yielded a zero value (toxicant not detected) or a ‘trace’ value (toxicant detected but < MLOD) (Figure 13).

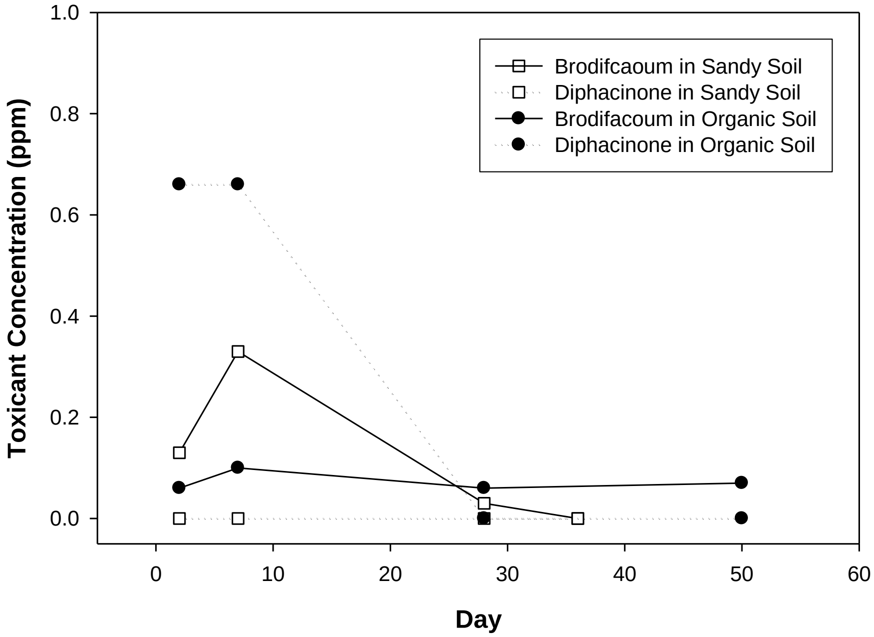


Figure 13: Mean concentration of brodifacoum (N=3 per day) and diphacinone (N=3 per day) found in surface samples of sandy soil and organic humus soil over four exposure periods. Samples were taken directly beneath bait pellets (or remains of pellets) on day 2 and day 7. Samples taken on days 28, 36, and 50 were taken directly beneath where a pellet had rested for 7 days.

4.2 Toxicant Residue in Crab Excrement

The mean concentration of toxicant within crab excrement varied by exposure period for both analytes. Toxicants were most concentrated within crab excrement during the first two sampling periods. Both brodifacoum and diphacinone were actively consumed during these periods, until the bait products were removed from crab diets on day 7. A reduction in the toxicant concentration was observed between day 6 and day 10 (Table 4, Figure 14).

Table 4: Mean concentration of toxicant (ppm) within excrement samples from crabs that consumed 25W or D50 bait pellets ad lib for 7 days.

Analyte	Day 2 concentration ± (1SD)	Day 6	Day 10	Day 23
Brodifacoum (ppm)	2.8 (1.2)	2.6 (1.3)	1.0 (0.7)	0.25 (0.3)
Diphacinone (ppm)	8.4 (2.9)	8.9 (8.4)	2.5 (0)	2.5 (0)

4.2.1 <u>25W in crab excrement</u>

There was a significant effect of toxicant concentration at the $p < 0.05$ level for the 4 exposure periods (DF=3 F = 8.10, P = 0.002). Post hoc comparisons using the Tukey HSD test indicated that the mean score of day 2 (M= 2.87 SD=1.28) and day 6 (M=2.64 SD=1.39) were significantly different from day 23 (M= 0.30 SD=0.30). However, day 10 (M= 1.06 SD=0.74) did not differ significantly from day 2, 6, or 23.

4.2.2 <u>D50 in crab excrement</u>

One diphacinone value for day 6 was unusually higher than the rest, and was likely due to human error in removing the toxicant from the crab or the holding bucket. The outlying value was excluded from the analysis. There was a significant effect of the toxicant concentration at the p <0.05 level for the 4 exposure periods (DF=3 F = 3.67 P = 0.033), suggesting that diphacinone concentrations in crab excrement changed over time.

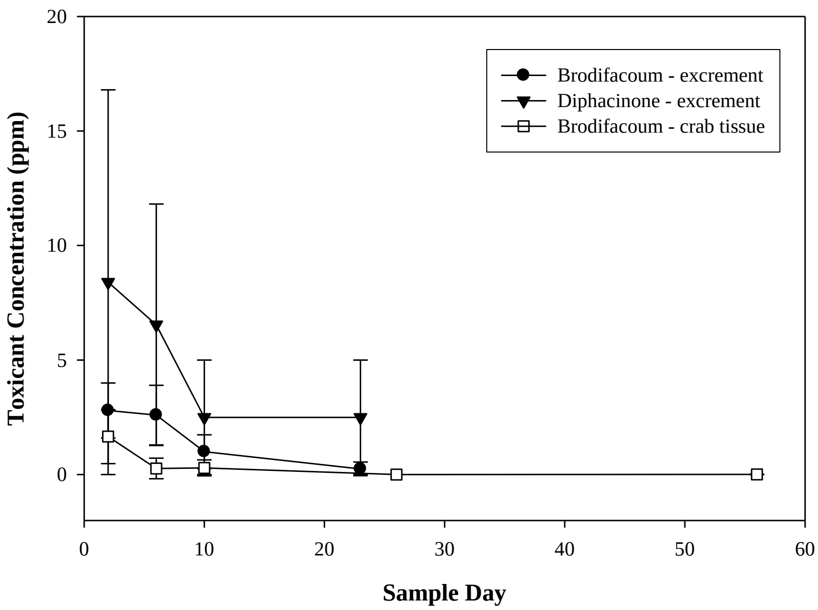


Figure 14: Comparison of the concentration (ppm) of brodifacoum in crab excrement and tissue over time to the concentration (ppm) of diphacinone in crab excrement. The concentration of brodifacoum in crab tissue was determined by the National Wildlife Research Center Analytical Lab (USDA-APHIS 2006) after a trial broadcast eradication in 2005.
Crabs consumed rodenticide until day 7, and subsequently fed on natural food items. Positive "trace" results were included as ½ the reporting limit (0.1 for brodifacoum and 2.5 for diphacinone).

4.3 Toxicant Residue in Crab Tissue

No brodifacoum residue was detected in hermit crab tissue samples from Whippoorwill Island five years after the trial broadcast eradication conducted in 2005. Quality control data reported recoveries that ranged from 93.8% to 99.8%.

4.4 **Crab Excrement Coprophagia**

4.4.1 *C. carnifex* excrement consumption by cockroaches and hermit crabs

After an 8 hour exposure period to *C. carnifex* excrement containing 25W, D50, or no toxicant, cockroaches consumed at least 20% of each excrement type. There was no significant effect of excrement type on percent consumed by cockroaches at the $p < 0.05$ level (DF=2 F = 0.72, P = 0.492), which suggests that cockroaches do not exhibit a preference for crab excrement that comes from crabs who have recently consumed bait, or a preference for excrement that comes from crabs who have consumed D50 or 25W.

Coenobita perlatus consumed more *C. carnifex* excrement than did cockroaches. On average, *C. perlatus* consumed 94% of 25W excrement, 98% of D50 excrement, and 77% of natural excrement, while cockroaches consumed, on average, 43% of 25W excrement, 21% of D50 excrement, and 36% of natural excrement (Figure 15).

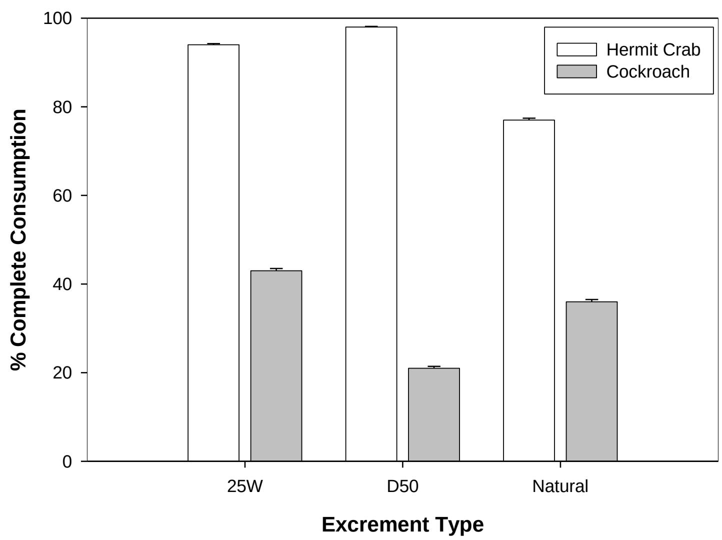


Figure 15: Hermit crab and cockroach consumption of three types of *C. carnifex* excrement.

Hermit crab consumption of the three crab excrement types differed significantly (DF=2 F = 5.41, P = 0.005). Post hoc comparisons using the Tukey HSD test indicated that the mean percent consumption of 25W excrement (M= 0.93 SD=0.24) and D50 excrement (M=0.95 SD=0.20) were significantly different from natural excrement (M= 0.77 SD=0.42). However, the percent consumption of 25W excrement did not differ significantly from percent consumption of D50 excrement after hermit crab consumption.

4.5 **Consumption of Bait Pellets by *C. Carnifex***

4.5.1 Daily consumption of bait pellets by *C. carnifex*

C. carnifex were divided into two treatment groups and offered either 25W or D50 pellets. The mean weight (±1 SD) of crabs in the 25W group 340.2g ± 80.1 was similar to that of crabs in the D50 group 338.8 ± 78.5.

The amount of bait consumed varied among individual crabs. *C. carnifex* offered 25W pellets consumed 1.55 g to 21.7 g over a 24 hour period. *C. carnifex* offered D50 consumed 1.02 g to 15.3 g over a 24 hour period. Despite individual variance, the mean number of pellets consumed and the mean total weight of pellets consumed remained similar for both treatment groups (Table 8). We found no significant difference between the number of 25W pellets or the number of D50 pellets consumed within a 24 hour period $t(37)=-0.97$ $p= 0.339$. On average, *C. carnifex* consumed 2.5-3% of their body weight during the bait product feeding trials. We found no significant between-group difference in the amount (g) of bait consumed when compared to the weight (g) of the study crabs for $t(37)= -0.21$, $p = 0.837$.

Table 5: *C. carnifex* consumption of 25W and D50 pellets per 24 hour exposure period.

Bait Product	**Mean # of** Pellets Consumed ± (1SD)	**Mean Wt** Consumed (g)	**Mean %** Body Wt Consumed
25W	6.8 (3.5)	10.5 (5.4)	3.0% (0.01)
D50	7.9 (3.8)	8.1 (3.8)	2.5% (0.01)

4.6 **Bait Palatability**

4.6.1 Rat palatability

Palatability trials were run on 68 rats. Rat weight ranged between 54 g to 212 g with a mean of 145 g (SD 37.1). Coconut was the item fully consumed first, regardless of treatment group. Coconut was completely consumed by 83% of rats in the 25W group and by 88% of rats in the D50 group. 25W pellets were consumed in entirety by 53% of rats in that study group, while D50 pellets were eaten by 51% of rats in that study group. Meristem was fully consumed by 57% of rats in the 25W group, and 68% of rats in the D50 group. *Pandanus* was consumed by 37% of rats in the 25W group, and by 54% of rats in the D50 group. The amount (g) each food item consumed in each trial varied by study group and food item (Table 6).

Table 6. *Rattus rattus* consumption of 4 food items in each trial, established by rank in order of preference and mean % consumed.

Food Item	**Consumption Rank**	**Mean % Consumed**	**Std. Dev (%)**
	25W Trials		
Coconut Endosperm	1	89.0	0.29
25W	2	60.5	0.45
Coconut Meristem	3	59.3	0.47
Pandanus	4	55.1	0.44
	D50 Trials		
Coconut Endosperm	1	86.0	0.34
Coconut Meristem	2	70.1	0.44

Pandanus	3	69.1	0.43
D50	4	54.5	0.46

Neither bait product was significantly more palatable than the other. Both 25W and D50 were consumed by rats in the presence of other natural food items. Results indicate no significant difference in percent consumed for 25W or for D50 t(65)= -0.47, p = 0.641.

Time to full consumption varied among food items and between treatment groups. Of the items that were completely consumed during the trial, coconut was consumed the quickest (Table 7).

Table 7. Mean time to consumption of items that were consumed in entirety (excludes items untouched or only tasted by rats).

Food Item	# of rats that consumed item	Mean Time to Consumption (sec)	Maximum Time to Consumption (sec)	Minimum Time to Consumption (sec)
		25W Trials		
Coconut Endosperm	26	1614	6127	226
Coconut Meristem	18	2304	5449	83
25W	15	2908	4964	232
Pandanus	12	2712	5744	151
		D50 Trials		
Coconut Endosperm	29	1458	4269	221
Coconut Meristem	21	2339	6310	458
D50	17	3019	6970	309
Pandanus	17	3382	5458	710

From initial bite until full consumption, the mean time for rats in the 25W group to consume 1g of coconut was 27 minutes, while rats in the D50 group averaged 24 minutes. There was no significant difference in the mean time for rat consumption of 1 g of 25W or D50; each averaged 49-50 minutes respectively. Similarly, rats consumed meristem in 37-38 minutes on average, regardless of treatment group. Rats in the 25W group consumed *Pandanus* in 45 minutes, while rats in the D50 group fully consumed it in 56 minutes.

Although there was no difference in mean time to consumption of either bait product, results varied among treatments. Within the D50 treatment group, the consumption time of the four food items differed significantly (DF = 3 F = 5.51, P = 0.002) (Figure 16). Post hoc comparisons using the Tukey HSD test indicated that the mean time to consumption for coconut (M= 1458 SD= 1219) differed significantly from D50 (M= 3019 SD= 2852) and Pandanus (M= 3382 SD= 1593). Consumption time of coconut meristem was not significantly different from other food items.

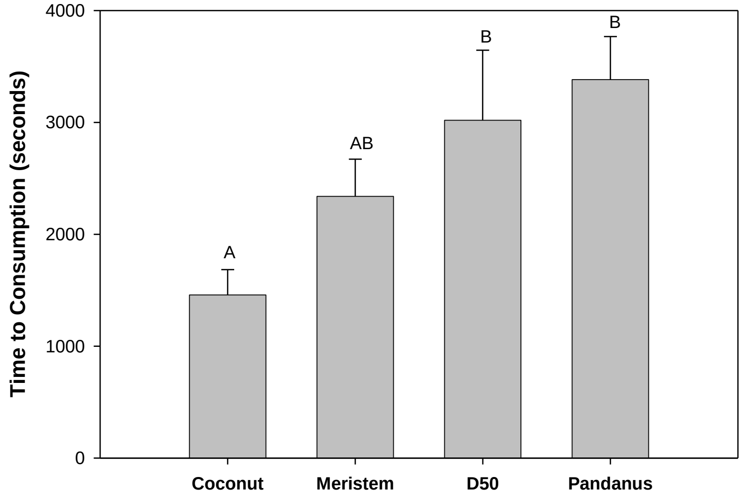


Figure 16: Comparison of mean time to consumption in seconds for four food items (1g each) offered to rats participating in D50 trials. Mean values that do not share a letter are significantly different.

No significant difference in time to consumption was found among food items within the 25W treatment group (DF = 3, F= 2.47, P = 0.070) (Figure 17).

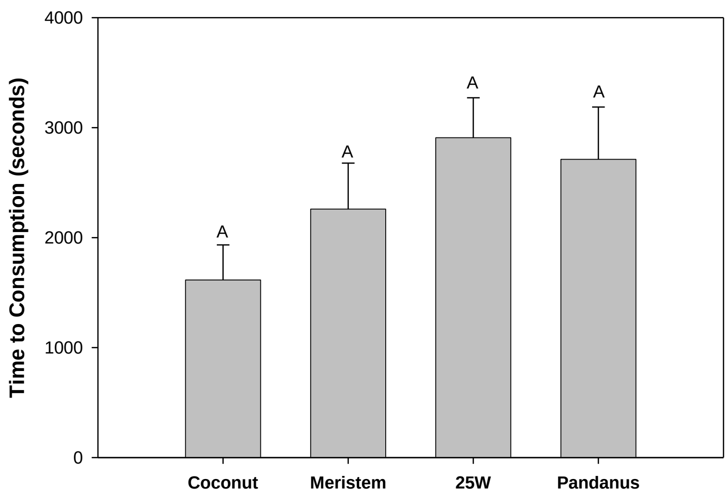


Figure 17: Comparison of mean time to consumption in seconds for four food items (1g each) offered to rats participating in 25W trials. The mean values all share a letter, indicating that they are not significantly different.

4.6.2 Crab palatability

Adult *C. carnifex* and *C. rotundum* (N=34) were collected for bait palatability trials. *Pandanus* and solid coconut endosperm were the most palatable items for both species (Table 8). The two bait products, 25W and D50 were also frequently consumed, and on average were more than 50% consumed after the 4 hour exposure period (Table 8).

Table 8: *Cardisoma* consumption of 4 food items in each trial, established by rank in order of preference and mean % consumed.

Food Item	Consumption Rank	Mean % Consumed	Std. Dev
	25W Trials		
Pandanus	1	77.8	0.41
Coconut Endosperm	2	73.5	0.42
25 W	3	58.8	0.50
Coconut Meristem	4	31.9	0.45
	D50 Trials		
Pandanus	1	76.4	0.38
Coconut Endosperm	2	72.8	0.42
D50	3	53.4	0.50
Coconut Meristem	4	49.5	0.49

Neither bait product was found to be significantly more palatable than the other in comparison to natural food items. Results indicate no significant difference in percent consumed for 25W or for D50 $t(31) = -0.31$, $p = 0.761$.

4.7 Live Trapping and Genetic Sampling

The recommended genetic sampling of Palmyra Atoll (Ross 2009) calls for the collection of 477 samples from different individuals trapped throughout the atoll. The sampling scheme allows for the assessment of the allele frequencies for each of Palmyra's landmasses and provides a sampling pool that can be used to determine the allele frequency of the whole atoll. The trapping effort conducted concurrently with the studies described in this report resulted in the completion of 3 landmasses and partial completion of 9 others (Table 9). A total of 156 genetic samples were obtained.

Table 9: Number of rat genetic samples obtained, grouped by landmass.

Landmass #	Location	# Required	# of Rats Trapped	% Complete
1	Cooper	50	54	100%
2	Quail	22	5	23%
3	Whippoorwill	26	12	46%
4	Eastern	50	4	8%
5	Portsmouth	11	6	63%
6	Barren	50	9	16%
7	Southern Complex	50	9	18%
8	Home	24	1	4%
9	Sand	50	26	52%
13	North-South Causeway	49	11	22%
14	Lost	6	7	100%
15	Fern	7	9	100%

R. rattus genetic samples were stored for genetic diagnostic analysis at Ecogene™, Landcare Research Ltd. in New Zealand.

4.8 **Bait Pellet Consumption by Fish**

4.8.1 Fate of bait pellets

The reaction of fish to individual bait pellets falling through the shallow water column varied. During the first 3 trials, fish showed no interest in the bait pellets. Subsequent trials observed Black-spot sergeant (*Abudefduf sordidus*), Stripe-belly puffer (*Aronthron hispidus*), and Camouflage grouper (*Epinephelus polyphekadion*) mouthing and consuming pellets (Table 10). Bait pellets dropped into the mid-water column were quickly consumed by Bohar (*Lutjanus bohar*). Black tail snapper (*Lutjanus fulvus*) also consumed bait pellets as they continued to sink. In 10m of water, both snapper and surgeonfish were observed grabbing bait pellets as the pellets sank, though complete consumption could not be confirmed due to limited visibility.

Table 10: Interactions of species observed in Palmyra Lagoon during bait application trials. Location of observations (S) shallow water, (M) mid-water, and (D) deep-water are indicated in parenthesis.

Scientific Name	Common Name	Consumed Bait	Mouthed Bait
Abudefduf septemfasciatus	Seven Stripe Damselfish	-	-
Abudefduf sordidus	Black-spot Sergeant	Yes (S)	Yes (S)
Acanthurus nigracans	White-cheek Surgeonfish	-	-
Acanthurus triostegus	Convict Tang	-	-
Arothron hispidus	Stripe Belly Puffer	Yes (S)	Yes (S)
Caranx ignobilis	Giant Trevally (Ulua)	-	-
Carcharhinus melanopterus	Black-tip Reef Shark	-	-
Chaetodon auriga	Thread-fin Butterflyfish	-	-
Chaetodon lunula	Raccoon Butterflyfish	-	-
Ellochelon vaigiensis	Squaretail Mullet	-	-
Epinephelus polyphekadion	Camouflage Grouper	Yes (S)	Yes (S)
Lutjanus bohar	Bohar	Yes (M)	Yes (M)
Lutjanus fulvus	Black-tail Snapper	Yes (M)	Yes (M)
Lutjanus monostigma	One-spot Snapper	-	-
Manta birostris	Manta Ray	-	-
Moolgarda engeli	Kanda Mullet	-	-
Mulloidichthys flavolineatus	Yellow-Lined Goatfish	-	-
Pseudobalistes flavimarginatus	Peach Faced Triggerfish	-	-
Stegastes nigracans	Dusky Farmerfish	-	Yes (D)
Thalassoma lunare	Moon Wrasse	-	-

4.8.2 Intertidal fate of bait pellets

There was no observed interaction between any organism (fiddler crab or shorebird) and the bait pellets placed on the tidal flats.

4.9 **Egg Predation**

Eight unsuccessful attempts were made to video rat predation of chicken eggs. Analysis of the video footage showed that hermit crabs were unable to carry or break into the egg. Rats were not seen in the footage.

After several video trials without rat detection, two chicken eggs were placed on the ground, one near camp on Cooper Island, and the other at the Sooty Tern colony near Strawn Island. These eggs were checked daily. The egg on Cooper remained untouched for four days. On the fourth day, a small hole was poked into the shell, and the egg was subsequently devoured by hermit crabs. The egg on Strawn Island remained in place and intact for five days, after which it disappeared.

4.10 **Toxicant Concentrations in the Bait Products**

The average mass of the sampled 25W pellets (n = 10) was 2.73g ± 0.3g, and the concentration of brodifacoum in each pellet ranged from 30.2 ppm to 14.8 ppm, with a mean value of 21.4 ppm (SD 63). The average mass of sampled D50 pellets (n = 10) was 1.04 g ± 0.15 g, and concentration of diphacinone in each pellet ranged from 16.7 ppm to 11.4 ppm, with a mean value of 14 ppm (SD 1.7). Alpo spike recovery rates measured during the analysis of the bait pellets were 84% and 94% for brodifacoum, and 83% and 85% for diphacinone.

4.11 ***C. nucifera* Canopy Counts**

C. nucifera are abundant at Palmyra Atoll, estimated at 119,425 individuals (0-30 m in height) (Wegmann 2009). The number of coconut palms that lean over the high tide line varies by location, with more occurring on lagoon-facing shores than on ocean-facing shores (Table 11).

Table 11: Average and maximum number of *C. nucifera* palms with 100% canopy coverage extending beyond the high tide line of the shore, inside and outside the lagoon.

Atoll Location	Average # of Overhanging Palms/km (± 1 SD)	Maximum # of Overhanging Palms/km
Lagoon	166 ± 47	215
Ocean	109 ± 55	187

4.12 **Bristle-thighed Curlew Capture**

4.12.1 Runway

Several attempts were made to capture Bristle-thighed Curlews on the runway. A 15 ft x 3 ft noose carpet was laid flat on the runway within 50 m of 5 curlews. A team of 3 people formed a line and slowly walked toward the curlews, herding them in the direction of the noose carpet. Curlews were able to be herded 20-30ft, after which they spooked and took flight, landing on the other side of the carpet. The team circled back and attempted to herd the curlews back toward the carpet several times, all unsuccessfully.

4.12.2 <u>Forest</u>

The noose carpet was laid flat across North Road in the presence of curlews. The team retreated to the beach and approached the noose carpet from both sides, making several attempts to encounter a curlew between the team and the noose carpet, however no curlews were encountered.

4.12.3 <u>North Beach</u>

The noose carpet was laid flat on the beach at low tide near the water line and extended 15ft up the beach, no successful curlew captures were made.

5 DISCUSSION

The results of the three primary studies (toxicant residue in soil, toxicant residue in crab excrement, and bait palatability) are presented below.

5.1 Rodenticide Environmental Fate

For the rodenticide bait products 25W (containing brodifacoum) and D50 (containing diphacinone), will prolonged contact between a bait pellet and soil result in detectible concentrations of the given rodenticide in the soil environment, and if so, will the concentration decrease over time?

Analysis of the top 2 cm of soil upon which bait pellets sat for seven days yielded extremely low concentrations of brodifacoum or diphacinone (less than 1 ppm) at all sampling periods. This suggests that toxicant residue from the two bait products is not readily incorporated into or retained in either of Palmyra's two primary soil types – sandy and humus. The consistently low detection of either toxicant supports other studies (Ogilvie et al. 1997) that suggest that anticoagulant rodenticide bait pellets used in broadcast eradications do not transfer high concentrations of toxicants to soil, even in warm, moist conditions where the breakdown of bait pellets is rapid.

It must be noted that the measured concentration of brodifacoum and especially diphacinone in sampled 25W and D50 pellets, respectively, was lower than what is reported on the product labels. For 25W, the lapel states that pellets contain 25 ppm brodifacoum; we measured just over 21 ppm. For D50, the lapel specifies 50 ppm of diphacinone, and we found the mean concentration to be 14 ppm. While the difference between the label-specified and measured concentration of brodifacoum in 25W pellets is probably too small to influence the results of this study, the low concentration of diphacinone measured in the sampled D50 pellets (36 ppm below what is stipulated on the product label) could have caused an underestimation of amount of diphacinone that transfers to the soil from D50 pellets.

The degradation of the bait pellets may have been expedited by greater than usual rainfall (1,477 mm) during the course of the study. The 25W bait is manufactured with sorbitol, a sugar alcohol that prevents pellet fragmentation in moist environments; 25W pellets retained shape and cohesiveness longer than did D50 pellets. Despite moisture resistant properties, 25W pellets at the Cooper island site were completely consumed by small invertebrates (ants) and/or disintegrated between day 2 and day 7. On Lost Island, 25W pellets remained mostly intact for 7 days. The difference between degradation rates for the two study sites could be due to differences in invertebrate (ant) populations; though, this was not measured. All samples yielded very low concentrations of either toxicant in topsoil despite (or because of) abundant rainfall, insect consumption, and pellet degradation during the study period.

5.2 **Toxicity of Rodenticide Residue in Crabs**

For the rodenticide bait products 25W and D50, will consumption of bait pellets result in detectible concentrations of the given rodenticide in the excrement of crabs, and if so, will the concentration of toxicant in the excrement decrease over time?

While land crabs do not appear to be adversely affected by anticoagulant rodenticide compounds (Pain et al. 2000, Buckelew et al. 2005), crab competition with rodents for broadcast bait pellets constitutes a significant operational problem. Brodifacoum residue is found in crab tissue for up to 56 days after a bait broadcast, and the concentration of brodifacoum decreases from 1.8 ppm to 0.4 ppm in 10 days (USDA-APHIS 2006); however, until this study we did not know if crabs redistributed rodenticide through defecation, and if so at what concentration.

The difference between the concentration of brodifacoum in the bait pellets that the crabs fed on in the 2006 study cited above (25 ppm), and the concentration of brodifacoum in crab tissue (1.8 – 0.01 ppm) suggests that some quantity of the toxicant is either evacuated through defecation or metabolized by the crab. Crabs feed almost continuously and gastric evacuation (defecation) occurs within 12 hours of feeding (Nordhaus et al. 2006). *Cardisomta guanhumi* maintains a mean gut clearance rate of 6.6 hrs, with larger crabs (>170 g) having a longer gut passage time (9.4 hrs) and smaller crabs (<130 g) passing excrement over shorter time periods (3.5 hrs) (Wolcott and Wolcott 1987). The rapid gut turnover rate indicates that the gastric residence time of items consumed by *Cardisoma* spp. is not likely to exceed 10 hours.

Brodifacoum and diphacinone concentrations within crab excrement did not increase from day 2 to day 6, suggesting that as crabs continued to feed on bait pellets during the first week, there was no cumulative increase of toxicant concentrations in crab excrement. Consumption of bait pellets and nothing else for seven days resulted in an evacuation of brodifacoum and diphacinone at concentrations that were much lower than found in the bait pellets. Once the bait pellets were removed from the crabs' diet, the toxicant concentration in crab excrement dropped to near-trace levels within three days. Two weeks after crabs stopped consuming bait pellets, the concentration of brodifacoum and diphacinone in crab excrement was below the mean level of detection.

This study did not attempt to identify or understand the process by which crabs metabolize or breakdown rodenticides, and no direct discussion of this could be found in the available literature. It is possible that neither brodifacoum nor diphacinone are metabolized by crabs, and that amount of toxicant that is not absorbed into the crabs' tissue is evacuated through defecation. If this is the case, the results from this study suggest that crabs reduce the risk of non-target organisms coming to harm through secondary and tertiary exposure to the applied rodenticide by reducing the concentration at which the rodenticide will be available. Because crab excrement contains detectable concentrations of brodifacoum or diphacinone for less than three days post consumption of rodenticide bait, it is unlikely that crab excrement is a significant vector of active rodenticide ingredients to secondary consumers.

Secondary consumers (hermit crabs and cockroaches) were observed eating *C. carnifex* excrement. Cockroaches ate crab excrement infrequently (less than 50% of the time), and did not prefer crab excrement produced through the consumption of 25W or D50 excrement produced by crabs on a 'natural' diet. Consumption of crab excrement by other crabs is an environmental benefit, as there will be less bait-contaminated excrement available to other consumers that could potentially be harmed by exposure to the rodenticide. Because crabs readily consume bait pellets, and because the concentrations of brodifacoum or diphacinone in crab excrement are greatly diluted, crabs can to some extent bioremediate (or "biomitigate") the risk of exposure to rodenticides for "at risk" non-target species.

5.3 Rodenticide Palatability for Rats and Crabs

When exposed to one bait product (25W or D50) in the presence of natural food items, which product is most palatable to rats within a short (2 hour) exposure window (palatability is measured by first physical contact, taste, amount consumed, and time to entire consumption of bait pellet)?

Palmyra presents a complex eradication environment where high levels of productivity are maintained by the aseasonal warm, moist climate and prodigious rainfall. At Palmyra, rats consume a wide array of food items, most of which are available year-round. Ideally, the rodenticide bait used to eradicate rats from Palmyra would be highly palatable, and would be preferred over available, natural food items.

This study found that both 25W and D50 bait are highly palatable in comparison to three commonly available food items: coconut endosperm (meat), the meristematic tissue of young coconut palms, and the fleshy mesocarp of *Pandanus* fruit. Coconut endosperm was the only food item that scored higher (1st to be consumed, shortest time to consumption) than did the bait products in the palatability trials. This suggests that coconut palm reduction may be beneficial to the eradication by reducing the amount of naturally available food that could distract rats from consuming bait pellets.

6 APPENDIX: RAW DATA

6.1 Toxicant Residue in Soil Results

Soil sample	Location	Analyte	Sample day	Result (ppm); trace values = ½ of the reporting limit*
C-5-9-10-2-25W-1	Cooper	25W	2	0.1
C-5-9-10-2-25W-2	Cooper	25W	2	0.2
C-5-9-10-2-25W-3	Cooper	25W	2	0.1
C-5-14-10-7-25W-1	Cooper	25W	7	0.8
C-5-14-10-7-25W-2	Cooper	25W	7	0.1
C-5-14-10-7-25W-3	Cooper	25W	7	0.1
C-5-28-10-28-25W-1	Cooper	25W	28	0.1
C-5-28-10-28-25W-2	Cooper	25W	28	0
C-5-28-10-28-25W-3	Cooper	25W	28	0
C-5-28-10-36-25W-1	Cooper	25W	36	0
C-5-28-10-36-25W-2	Cooper	25W	36	0
C-5-28-10-36-25W-3	Cooper	25W	36	0
L-5-9-10-2-25W-1	Lost	25W	2	0.1
L-5-9-10-2-25W-2	Lost	25W	2	0.1
L-5-9-10-2-25W-3	Lost	25W	2	0
L-5-14-10-7-25W-1	Lost	25W	7	0.1
L-5-14-10-7-25W-2	Lost	25W	7	0.1
L-5-14-10-7-25W-3	Lost	25W	7	0.1
L-5-28-10-28-25W-1	Lost	25W	28	0
L-5-28-10-28-25W-2	Lost	25W	28	0.1
L-5-28-10-28-25W-3	Lost	25W	28	0.1
L-5-28-10-50-25W-1	Lost	25W	50	0
L-5-28-10-50-25W-2	Lost	25W	50	0.1
L-5-28-10-50-25W-3	Lost	25W	50	0.1
C-5-9-10-2-D50-1	Cooper	D50	2	0
C-5-9-10-2-D50-2	Cooper	D50	2	0

Soil sample	Location	Analyte	Sample day	Result (ppm); trace values = ½ of the reporting limit*
C-5-9-10-2-D50-3	Cooper	D50	2	0
C-5-14-10-7-D50-1	Cooper	D50	7	0
C-5-14-10-7-D50-2	Cooper	D50	7	0
C-5-14-10-7-D50-3	Cooper	D50	7	0
C-5-28-10-28-D50-1	Cooper	D50	28	0
C-5-28-10-28-D50-2	Cooper	D50	28	0
C-5-28-10-28-D50-3	Cooper	D50	28	0
C-5-28-10-36-D50-1	Cooper	D50	36	0
C-5-28-10-36-D50-2	Cooper	D50	36	0
C-5-28-10-36-D50-3	Cooper	D50	36	0
L-5-9-10-2-D50-1	Lost	D50	2	0
L-5-9-10-2-D50-2	Lost	D50	2	1
L-5-9-10-2-D50-3	Lost	D50	2	1
L-5-14-10-7-D50-1	Lost	D50	7	0
L-5-14-10-7-D50-2	Lost	D50	7	1
L-5-14-10-7-D50-3	Lost	D50	7	1
L-5-28-10-28-D50-1	Lost	D50	28	0
L-5-28-10-28-D50-2	Lost	D50	28	0
L-5-28-10-28-D50-3	Lost	D50	28	0
L-5-28-10-50-D50-1	Lost	D50	50	0
L-5-28-10-50-D50-2	Lost	D50	50	0
L-5-28-10-50-D50-3	Lost	D50	50	0
L-5-9-10-2-Control	Lost	Control	2	0
C-5-9-10-2-Control	Cooper	Control	2	0
L-5-14-10-7-Control	Lost	Control	7	0
C-5-14-10-7-Control	Cooper	Control	7	0
L-5-28-10-28+36/50-Control	Lost	Control	28 + 36	0
C-5-28-10-28+36/50-Control	Cooper	Control	28 + 50	0

* Reporting limit for brodifacoum = 0.02 ppm. Reporting limit for diphacinone = 2 ppm.

6.2 Toxicant Residue in Crab Excrement

Excrement sample	Analyte	Exposure Time (days)	Result (ppm); trace values = ½ of the reporting limit*
C-1p-2-25W	25W	2	2.2
C-3p-2-25W	25W	2	3.8
C-5p-2-25W	25W	2	4.1
C-7p-2-25W	25W	2	1.4
C-1p-6-25W	25W	6	4.3
C-3p-6-25W	25W	6	1.1
C-5p-6-25W	25W	6	3
C-7AB-6-25W	25W	6	3.5
C-7CD-6-25W	25W	6	1.3
C-1B-10-25W	25W	10	0.1
C-3D-10-25W	25W	10	0.5
C-3p-10-25W	25W	10	1.8
C-5p-10-25W	25W	10	1.7
C-7p-10-25W	25W	10	1.2
C-1B-23-25W	25W	23	0.1
C-3A-23-25W	25W	23	0.1
C-3p-23-25W	25W	23	0.3
C-5A-23-25W	25W	23	0.3
C-5B-23-25W	25W	23	0.9
C-7p-23-25W	25W	23	0.1
C-2p-2-D50	D50	2	5.3
C-4p-2-D50	D50	2	6.8
C-6p-2-D50	D50	2	9.5
C-8p-2-D50	D50	2	12
C-2p-6-D50	D50	6	2.5
C-4p-6-D50	D50	6	2.5
C-4C-6-D50	D50	6	2.5

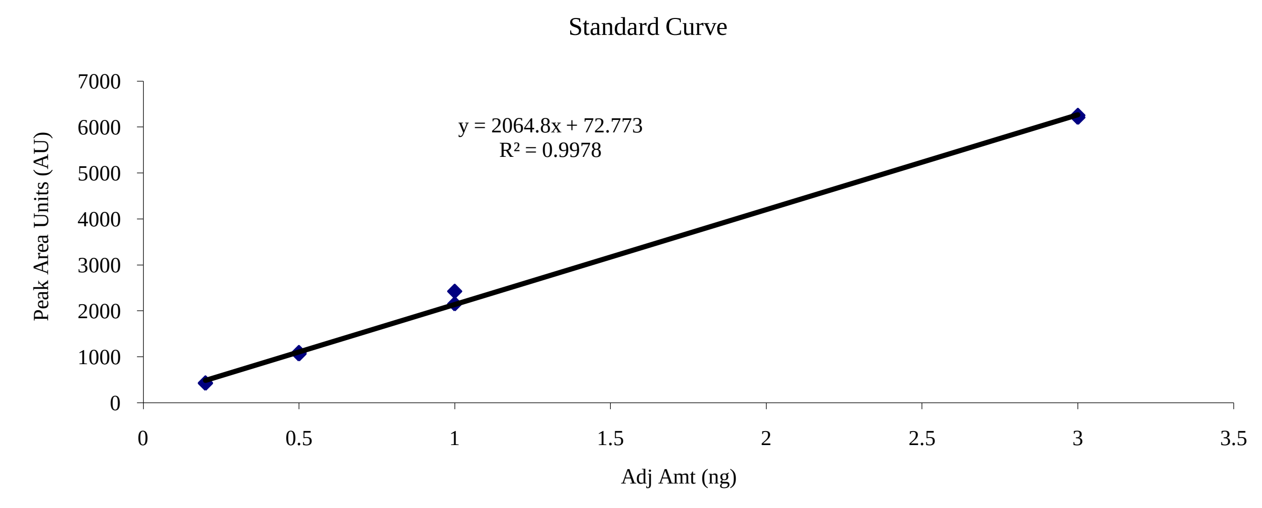
Excrement sample	Analyte	Exposure Time (days)	Result (ppm); trace values = ½ of the reporting limit*
C-6p-6-D50	D50	6	9.7
C-6B-6-D50	D50	6	2.5
C-8p-6-D50	D50	6	15
C-8C-6-D50	D50	6	11
C-2p-10-D50	D50	10	2.5
C-4p-10-D50	D50	10	2.5
C-6p-10-D50	D50	10	2.5
C-8A-10-D50	D50	10	2.5
C-8p-10-D50	D50	10	2.5
C-2p-23-D50	D50	23	2.5
C-4p-23-D50	D50	23	2.5
C-6p-23-D50	D50	23	2.5
C-8D-23-D50	D50	23	2.5
C-8p-23-D50	D50	23	2.5

* Reporting limit for brodifacoum = 0.02 ppm. Reporting limit for diphacinone = 2 ppm.

6.3 **Toxicant Concentration in Bait Pellets: 25W and D50**

6.3.1 25W - brodifacoum

Standard Curve							
Standard ID	**Std (ng)**	**Peak Response (AU)**	**Response Factor (AU/ng)**	**Avg Sens (AU/ng)**	**S.D.**	**%RSD**	**r^2**
051110A\AN000005	3	6207.266	2069.089	2168.200	94.53	4.36	0.9978
051110A\AN000006	1	2427.250	2427.250				
051110A\AN000007	0.2	435.269	2176.345				
051110A\AN000008	0.5	1089.340	2178.680				
051110A\AN000013	0.5	1088.880	2177.760				
051110A\AN000025	0.5	1064.535	2129.070				
051110A\AN000041	0.5	1096.325	2192.650				
051110A\AN000058	1	2152.673	2152.673				
051110A\AN000059	0.2	425.797	2128.985				
051110A\AN000060	0.5	1066.683	2133.366				
051110A\AN000061	3	6252.981	2084.327				



QC Data							
Sample ID	**Peak response (AU)**	**Calculated Amount (ng)***	**Sample Amount inj (mg)**	**Spike Level (ppm)**	**ppm found**	**Adjusted ppm found**	**Recovery (%)**
reagent blank	ND	Nd		NA	ND		
Alpo Check	ND	ND	1.0	NA	ND		
Alpo Spike1	420.121	0.168	1.0	0.2	0.168	0.168	84
Alpo Spike2	461.869	0.188	1.0	0.2	0.188	0.188	94

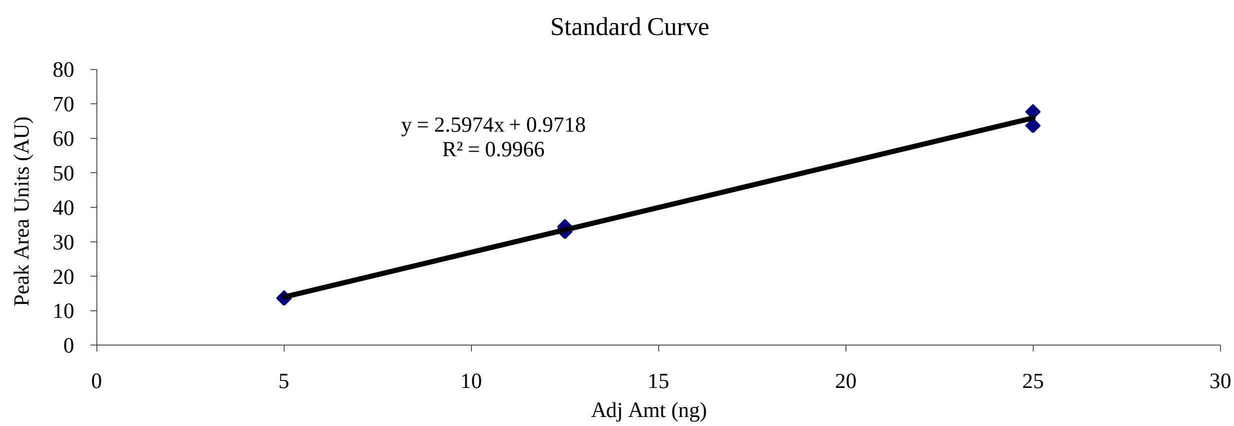
Sample Data						
Sample ID	Peak Response (AU)	Calculated Amount * (ng)	Sample Amount inj (mg)	ppm found	Average	Comments
D1004428-01.0011 My60 bait	1292.163	0.591	0.02	29.53	30.3	
D1004428-01.0011 My60 bait	3275.397	1.551	0.05	31.02		
D1004428-01.0012 My60 bait	674.482	0.291	0.02	14.57	15.3	
D1004428-01.0012 My60 bait	1730.983	0.803	0.05	16.06		
D1004428-01.0013 My60 bait	703.926	0.306	0.02	15.28	15.9	
D1004428-01.0013 My60 bait	1774.931	0.824	0.05	16.49		
D1004428-01.0014 My60 bait	1241.878	0.566	0.02	28.31	28.8	
D1004428-01.0014 My60 bait	3088.068	1.460	0.05	29.21		
D1004428-01.0015 My60 bait	967.108	0.433	0.02	21.66	22.3	
D1004428-01.0015 My60 bait	2441.785	1.147	0.05	22.95		
D1004428-01.0016 My60 bait	1243.642	0.567	0.02	28.35	29.1	
D1004428-01.0016 My60 bait	3163.777	1.497	0.05	29.94		
D1004428-01.0017 My60 bait	997.655	0.448	0.02	22.40		
D1004428-01.0017 My60 bait	2437.501	1.145	0.05	22.90	23.2	
D1004428-01.0017 dup	1025.459	0.461	0.02	23.07		
D1004428-01.0017 dup	2607.258	1.227	0.05	24.55		
D1004428-01.0018 My60 bait	669.595	0.289	0.02	14.45	15.2	
D1004428-01.0018 My60 bait	1715.479	0.796	0.05	15.91		
D1004428-01.0019 My60 bait	652.256	0.281	0.02	14.03	14.7	
D1004428-01.0019 My60 bait	1662.74	0.770	0.05	15.40		
D1004428-01.0020 My60 bait	1920.431	0.895	0.05	17.90	17.8	

**** Note:** Calculations based on **Standard Curve***

6.3.2 D50 - diphacinone

Standard Curve

Standard ID	Std (ng)	Peak Response (AU)	Response Factor (AU/ng)	Avg Sens (AU/ng)	S.D.	%RSD	r^2
051110A\AN000006	25	63.726	2.549	2.686	0.06	2.33	0.9966
051110A\AN000007	5	13.617	2.723				
051110A\AN000008	12.5	33.601	2.688				
051110A\AN000013	12.5	32.984	2.639				
051110A\AN000025	12.5	33.687	2.695				
051110A\AN000041	12.5	33.418	2.673				
051110A\AN000058	25	67.746	2.710				
051110A\AN000059	5	13.731	2.746				
051110A\AN000060	12.5	34.418	2.753				



QC Data

Sample ID	Peak response (AU)	Calculated Amount (ng)*	Sample Amount inj (mg)	Spike Level (ppm)	ppm found	Adjusted ppm found	Recovery (%)
reagent blank	ND	ND		NA	ND		
Alpo Check	ND	ND	1.0	NA	ND		
Alpo Spike1	11.746	4.148	1.0	5.0	4.148	4.148	83
Alpo Spike2	11.990	4.242	1.0	5.0	4.242	4.242	85

Sample Data					
Sample ID	**Peak Response (AU)**	**Calculated Amount * (ng)**	**Sample Amount inj (mg)**	**ppm found**	**Comments**
D1004428-01.0001 My60 bait	15.775	5.699	0.50	11.4	
D1004428-01.0002 My60 bait	21.217	7.794	0.50	15.6	
D1004428-01.0003 My60 bait	18.858	6.886	0.50	13.8	
D1004428-01.0004 My60 bait	18.982	6.934	0.50	13.9	
D1004428-01.0005 My60 bait	17.135	6.223	0.50	12.4	
D1004428-01.0006 My60 bait	16.955	6.154	0.50	12.3	
D1004428-01.0007 My60 bait	18.343	6.688	0.50	13.4	
D1004428-01.0008 My60 bait	20.387	7.475	0.50	14.9	
D1004428-01.0009 My60 bait	22.669	8.353	0.50	16.7	
D1004428-01.0010 My60 bait	20.724	7.605	0.50	15.2	

**** Note:*** *Calculations based on* ***Standard Curve***

6.4 **Bait Product Labels**

6.4.1 <u>25W</u>

PRECAUTIONARY STATEMENTS

HAZARDS TO HUMANS AND DOMESTIC ANIMALS

Keep away from humans, domestic animals and pets. If swallowed, this material may reduce the clotting ability of the blood and cause bleeding. Wear protective gloves when applying or loading bait. With detergent and hot water, wash all implements used for applying bait. Do not use these implements for mixing, holding, or transferring food or feed.

ENVIRONMENTAL HAZARDS

This pesticide is toxic to birds, mammals and aquatic organisms. Predatory and scavenging mammals and birds might be poisoned if they feed upon animals that have eaten bait.

PERSONAL PROTECTIVE EQUIPMENT (PPE)

Applicators and other handlers must wear:
- long sleeved shirt and long pants
- gloves
- shoes plus socks

For aerial application, in addition to the above PPE, loaders must wear protective eyewear or a face shield and a dust/mist filtering respirator (MSHA/NIOSH TC-21C).

USE RESTRICTIONS

It is a violation of Federal law to use this product in a manner inconsistent with its labeling. A copy of this label must be in the possession of the user at the time that the product is applied.

READ THIS LABEL: Read this entire label and follow all use directions and precautions.

IMPORTANT: Do not expose children, pets or other non-target animals to rodenticides. To help prevent accidents:

1) Keep children out of areas where this product is used or deny them access to bait by use of tamper resistant bait stations.
2) Store this product in locations out of reach of children, pets, and other nontarget animals.
3) Apply bait only according to the directions authorized.
4) Dispose of product container and unused, spoiled, or unconsumed bait as specified in the "STORAGE AND DISPOSAL" section.

(SEE RIGHT PANEL FOR ADDITIONAL USE RESTRICTIONS)

RESTRICTED USE PESTICIDE

DUE TO HAZARDS TO NON-TARGET SPECIES

For retail sale only to: USDA Animal and Plant Health Inspection Service Wildlife Services, U.S. Fish and Wildlife Service, and the U.S. National Park Service to be used only by Certified Applicators or persons under their direct supervision and only for those uses covered by the Certified Applicators certification.

BRODIFACOUM-25W CONSERVATION

PELLETED RODENTICIDE BAIT FOR CONSERVATION PURPOSES

For control or eradication of invasive rodents in wet climates on islands or vessels for conservation purposes

ACTIVE INGREDIENT
Brodifacoum (CAS No. 56073-10-0) 0.0025%
INERT INGREDIENTS 99.9975%
TOTAL 100.0000%

KEEP OUT OF REACH OF CHILDREN

CAUTION

First Aid

If swallowed	-Call a physician or poison control center immediately for treatment advice. -Have person sip a glass of water if able to swallow. -Do not induce vomiting unless told to do so by a poison control center or doctor. -Do not give anything by mouth to an unconscious person.
If on skin or clothing	-Take off contaminated clothing. -Rinse skin immediately with plenty of water for 15-20 minutes. -Call a poison control center or doctor for treatment advice.
If inhaled	-Move person to fresh air. -If person is not breathing, call 911 or an ambulance, then give artificial respiration, preferably mouth-to-mouth if possible. -Call a poison control center or doctor for further treatment advice.
If in eyes	-Hold eye open and rinse slowly and gently with water for 15-20 minutes. Remove contact lenses, if present, after the first 5 minutes, then continue rinsing eye. -Call a poison control center or doctor for treatment advice.

Have the product container or label with you when calling a poison control center or doctor, or when going for treatment.

For a medical emergency involving this product, call (877) 854-2494
NOTE TO PHYSICIAN: If swallowed, this material may reduce the clotting ability of blood and cause bleeding. If ingested, administer Vitamin K_1, intramuscularly or orally, as indicated in bishydroxycoumarin overdose. Repeat as necessary based on monitoring of prothrombin times.

USE RESTRICTIONS, (CONT)

This product may be used to control or eradicate Norway rats (*Rattus norvegicus*), roof rats (*Rattus rattus*), Polynesian rats (*Rattus exulans*), house mice (*Mus musculus*) or other types of invasive rodents on islands for conservation purposes, or on grounded vessels or vessels in peril of grounding.

This product may be applied using bait stations, burrow baiting, canopy baiting or by aerial and ground broadcast application techniques.

This product is to be used for the protection of State or Federally-listed Threatened or Endangered Species or other species determined to require special protection.

Do not apply this product to food or feed.

Treated areas must be posted with warning signs appropriate to the current rodent control project.

This product is for use in wet climates.

DIRECTIONS FOR USE

BAIT STATIONS: Tamper-resistant bait stations must be used when applying this product to grounded vessels or vessels in peril of grounding, or when used in areas of human habitation. Bait must be applied in locations out of reach of children, non-target wildlife, or domestic animals, or in tamper-resistant bait stations.
<u>TO BAIT RATS</u>: Apply 4 to 16 ounces (113 to 454 grams) of bait per placement. Space placements at intervals of 16 to 160 ft (about 5 to 50 meters). Placements should be made in a grid over the area for which rodent control is desired.
<u>TO BAIT MICE</u>: Apply 0.25 to 0.5 ounces (7 to 14 grams) of bait per placement. Space placements at intervals of 6 to 12 ft (about 2 to 4 meters). Larger placements, up to 2 ounces (57 grams) may be needed at points of very high mouse activity. Placements should be made in a grid over the area for which rodent control is desired.
<u>FOR BOTH RAT AND MOUSE BAITING</u>: Maintain an uninterrupted supply of fresh bait for at least 15 days or until signs of rodent activity cease. Where a continuous source of infestation is present, permanent bait stations may be established and bait replenished as needed.

Page 1 of 2
EPA Reg. No. 56228-36
Revised 11/23/2009

DIRECTIONS FOR USE (CONT.)

BURROW-BAITING: Place bait in burrows only if this can be done in a way that minimizes potential for ejection of bait and exposure of bait non-target species.
<u>TO BAIT RATS</u>: Place 3 to 4 ounces (85 to 113 g) of bait inside each burrow entrance. Baits used in burrows may be applied in piles or in cloth or resealable plastic bags. The bags should be knotted or otherwise sealed to avoid spillage and holes should be made in plastic bags to allow the bait odor to escape.
<u>TO BAIT MICE</u>: Place approximately 0.25 ounces (7 grams) of bait in a cloth or resealable bag in each active burrow.
<u>FOR BOTH RAT AND MOUSE BAITING</u>: Place one such bag or placement in each active burrow opening and push bag into burrow far enough so that its presence can barely be seen. Do not plug burrows. Flag treated burrows and inspect them frequently, daily if possible. Maintain an uninterrupted supply of bait for at least 15 days or until rodent activity ceases. Remove bait from burrows if there is evidence that bags are ejected.

CANOPY BAITING (bait placement in the canopy of trees and shrubs): In areas where sufficient food and cover are available to harbor populations of rodents in canopies of trees and shrubs, canopy baiting should be included in the baiting strategy. Approximately 4 to 7 ounces (113 to 200 grams) of bait should be placed in a cloth or resealable plastic bag. The bags should be knotted or otherwise sealed to avoid spillage and holes should be made in plastic bags to allow the bait odor to escape. Using long poles (or other devices) or by hand, bait filled bags should be placed in the canopy of trees or shrubs. Baits should be placed in the canopy at intervals of 160 ft (about 50 meters) or less, depending upon the level of rodent infestation in these habitats. In some vegetation types, bait stations may need to be used to ensure bait will stay in the canopy.

DIRECTIONS FOR USE (CONT.)

BROADCAST APPLICATION: Broadcast applications are prohibited on vessels or in areas of human habitation. Broadcast bait using aircraft, ground-based mechanical equipment, or by gloved hand at a rate no greater than 16 lbs of bait per acre (18 kg bait/hectare) per application. Make a second broadcast application, typically 5 to 7 days after the first application, depending on local weather conditions, at a rate no higher than 8 lbs. of bait per acre (9 kg bait/hectare). In situations where weather or logistics only allow one bait application, a single application may be made at a rate no higher than 16 lbs. bait per acre (18 kg/ha).

Aerial (helicopter) applications may not be made in winds higher than 35 mph (30 knots). Pilot in command has final authority for determining safe flying conditions. However, aerial applications will be terminated when the following conditions are present:

> Windspeed in excess of 25 knots with an evaluation of the terrain and impact of the wind conditions and not to exceed a steady wind velocity of 30 knots.

Set the application rate according to the extent of the infestation and apparent population density. For eradication operations, treat entire land masses.

Assess baited areas for signs of residual rodent activity (typically 7 to 10 days post-treatment). If rodent activity persists, set up and maintain tamper-resistant bait stations or apply bait directly to rodent burrows in areas where rodents remain active. If terrain does not permit use of bait stations or burrow baiting, continue with broadcast baiting, limiting such treatments to areas where active signs of rodents are seen. Maintain treatments for as long as rodent activity is evident in the area and rodents appear to be accepting bait.

For all methods of baiting, monitor the baited area periodically and, using gloves, collect and dispose of any dead animals and spilled bait properly.

STORAGE AND DISPOSAL

Do not contaminate water, food, or feed by storage or disposal.

STORAGE: Store only in original closed container in a cool, dry place inaccessible to unauthorized people, children and pets. Store separately from fertilizer and away from products with strong odors, which may contaminate the bait and reduce acceptability. Spillage should be carefully swept up and collected for disposal.

PESTICIDE DISPOSAL: Wastes resulting from the use of this product may be disposed of at an approved waste disposal facility.

CONTAINER DISPOSAL: Nonrefillable container. Do not reuse or refill this container. Offer for recycling, if available. Otherwise, dispose of empty container in sanitary landfill or by incineration, or, if allowed by State and local authorities, by burning. If burned, stay out of smoke.

NOTICE: Buyer assumes all risks of use, storage, or handling of the material not in strict accordance with directions given herewith. The efficacy of the product may be reduced under high moisture conditions.

UNITED STATES DEPARTMENT OF AGRICULTURE
ANIMAL AND PLANT HEALTH INSPECTION SERVICE
Riverdale, MD 20737-1237
EPA Est. No. 56228-ID-1
EPA Reg. No. 56228-36

Net Weight ________________

Batch Code No.: ______________

6.4.2 D50

ENVIRONMENTAL HAZARDS

This product is toxic to mammals and birds. Predatory and scavenging mammals and birds might be poisoned if they feed upon animals that have eaten bait.

STORAGE AND DISPOSAL

Do not contaminate water, food or feed by storage or disposal.

STORAGE: Store only in original closed container in a cool, dry place inaccessible to children and pets. Store separately from fertilizer and away from products with strong odors which may contaminate the bait and reduce acceptability. Spillage should be carefully swept up and collected for disposal.

PESTICIDE DISPOSAL: Wastes resulting from the use of this product may be disposed of on site or at an approved waste disposal facility.

PLASTIC CONTAINER DISPOSAL: Nonrefillable container. Do not reuse or refill this container. Triple rinse container (or equivalent) promptly after use. Offer for recycling, if available. Otherwise, puncture and dispose of in a sanitary landfill, or, if allowed by state and local authorities, by burning. If burned, stay out of smoke.

DIRECTIONS FOR USE

It is a violation of Federal law to use this product in a manner inconsistent with its labeling.

READ THIS LABEL: Read this entire label and follow all use directions and use precautions.

IMPORTANT: Do not expose children or pets to this product. Take all appropriate steps to limit exposure to and impacts on nontarget species, especially those for which special conservation efforts are planned or ongoing. To help to prevent accidents:

1. Store product not in use in a location out of reach of children and pets.
2. Apply bait only as specified on this label and in strict accordance with the "**USE RESTRICTIONS:**" and "**APPLICATION DIRECTIONS:**". For applications involving bait stations, the bait stations must be tamper-resistant. The bait stations must deny access to bait compartments by children, pets, and other non-target species larger in body size than the type(s) of rats or mice being targeted by the bait program. Lock and secure bait stations, as necessary, to exclude such nontarget species. In locations where captive or feral livestock occur, either remove and exclude such animals from the application site prior to treatment or make sure that the bait stations used are capable of denying them access to bait compartments, and
3. Dispose of product container, and unused, spoiled and unconsumed bait as specified on this label.

USE RESTRICTIONS: This product may be used only to control or eradicate Norway rats (Rattus norvegicus), roof rats (Rattus rattus), Polynesian rats (Rattus exulans), house mice (Mus musculus) or other types of invasive rodents for conservation purposes on islands, grounded vessels or vessels in peril of grounding. This product may be applied only using bait stations, burrow baiting, canopy baiting or aerial and ground broadcast application techniques.

This product is to be used for the protection of State or Federally-listed Threatened or Endangered Species or other species determined to require special protection.

Do not apply this product to food or feed.

Treated areas must be posted with warning signs appropriate to the current rodent control project.

(**DIRECTIONS FOR USE** continued on right panel of this label)

RESTRICTED USE PESTICIDE
DUE TO HAZARDS TO NON-TARGET SPECIES

For retail sale only to: USDA Animal and Plant Health Inspection Service Wildlife Services, U.S. Fish and Wildlife Service, and the U.S. National Park Service to be used only by Certified Applicators or persons under their direct supervision and only for those uses covered by the Certified Applicators certification.

Diphacinone-50: Pelleted Rodenticide Bait for Conservation Purposes

Fish Flavored, Weather-resistant Rodenticide for Control or Eradication of Invasive Rodents on Islands or Vessels for Conservation Purposes

ACTIVE INGREDIENT: Diphacinone: (2-Diphenylacetyl-1,3-Indandione)	0.005%
INERT INGREDIENTS:	99.995%
TOTAL	100.000%

KEEP OUT OF REACH OF CHILDREN

CAUTION

PRECAUTIONARY STATEMENTS

HAZARD TO HUMANS AND DOMESTIC ANIMALS

Caution: Keep away from humans, domestic animals and pets. If swallowed, this material may reduce the clotting ability of the blood and cause bleeding. Wear protective gloves when applying or loading bait. With a detergent and hot water, wash all implements used for applying bait. Do not use these implements for mixing, holding or transferring food or feed.

FIRST AID Have label with you when obtaining treatment advice.	
If swallowed	• Call a poison control center, doctor, or 1-800-222-1222 immediately for treatment advice. • Have person sip a glass of water if able to swallow. • Do not induce vomiting unless told to do so by the poison control center or doctor.
If on skin or clothing	• Take off contaminated clothing. • Rinse skin immediately with plenty of water for 15-20 minutes. • Call a poison control center, doctor, or 1-800-222-1222 immediately for treatment advice.
• **Note to Physician:** If ingested, administer Vitamin K_1, intramuscularly or orally as indicated in bishydroxycoumarin overdose. Repeat as necessary based on monitoring of prothrombin times.	

For a medical emergency involving this product, call 1-800-222-1222.

UNITED STATES DEPARTMENT OF AGRICULTURE
ANIMAL AND PLANT HEALTH INSPECTION SERVICE
4700 River Road, Unit 149
Riverdale, MD 20737-1237
EPA Reg. No 56228-35
EPA Est. No. (61282-WI-1) or (056228-GU-1)

Net Contents: ______________

Batch Code No.: ______________

DIRECTIONS FOR USE
(continued from left panel)

APPLICATION DIRECTIONS:

Bait Stations: Tamper-resistant bait stations must be used when applying this product on grounded vessels or vessels in peril of grounding or when used in areas of human habitation. See item 2) under "**IMPORTANT:**" regarding the performance characteristics needed for tamper-resistant bait stations. To bait rats: Apply 4 to 16 ounces (113 to 454 grams) of bait per placement. Space placements at intervals of 5 to 50 meters. Placements should be made in a grid over the area for which rodent control is desired. To bait mice: Apply 0.25 to 0.5 ounces (7 to 14 grams) of bait per placement. Space placements at intervals of 2 to 4 meters. Placements should be made in a grid over the area for which rodent control is desired. Larger placements (up to 2 ounces) may be needed at points of very high mouse activity. For both rat and mouse baiting: Maintain an uninterrupted supply of fresh bait for at least 15 days or until signs of rodent activity cease. Where a continuous source of infestation is present, permanent bait stations may be established and bait replenished as needed.

Burrow-baiting: Place bait in burrows only if this can be done in a way that minimizes potential for ejection of bait and exposure of bait to seed-eating birds and other non-target species. To bait rats: place 3 to 4 ounces (85 to 113 g) of bait inside each burrow entrance. Baits used in burrows may be applied in piles or in cloth or resealable plastic bags. The bags should be knotted or otherwise sealed to avoid spillage and holes should be made in plastic bags to allow the bait odor to escape. To bait mice: place approximately 0.25 ounces (7 grams) of bait in each active burrow. For both rat and mouse baiting: place one such bag or placement in each active burrow opening and push bag into burrow far enough so that its presence can barely be seen. Do not plug burrows. Flag treated burrows and inspect them frequently, daily if possible. Maintain an uninterrupted supply of bait for at least 15 days or until rodent activity ceases. Remove bait from burrows if there is evidence that bags are ejected.

Canopy Baiting (bait placement in the canopy of trees and shrubs): In areas where sufficient food and cover are available to harbor populations of rodents in canopies of trees and shrubs, canopy baiting should be included in the baiting strategy. Approximately 4 to 7 ounces (113 g to 200 g) of bait should be placed in a cloth or resealable plastic bag. The bags should be knotted or otherwise sealed to avoid spillage and holes should be made in plastic bags to allow the bait odor to escape. Using long poles (or other devices) or by hand, bait filled bags should be placed in the canopy of trees or shrubs. Baits should be placed in the canopy at intervals of 50 meters or less, depending upon the level of rodent infestation in these habitats. In some vegetation types, bait stations may need to be used to ensure bait will stay in the canopy.

Aerial and Ground Broadcast: Broadcast applications are prohibited on vessels or in areas of human habitation. Broadcast bait pellets by helicopter or manually at a rate of 10 to 12.5 lbs. of bait per acre (11.1 to 13.8 kg/ha) per treatment. Make a second broadcast application typically 5 to 7 days after the first application, depending upon local weather conditions, at a rate no higher than 12.5 lbs. (13.8 g/ha) of bait per acre. In situations where weather or logistics only allow one bait application, a single application may be made at a rate no higher than 20.0 lbs. bait per acre (22.5 kg/ha).

Aerial (helicopter) applications may not be made in winds higher than 35 mph (30 knots). Pilot in command has final authority for determining safe flying conditions. However, aerial applications will be terminated when the following conditions are met:

- Windspeed in excess of 25 knots with an evaluation of the terrain and impact of the wind conditions and not to exceed a steady wind velocity of 30 knots.

If rat activity persists after broadcast application, set up and maintain tamper-resistant bait stations or apply bait directly to rodent burrows in areas where rodents remain active. If terrain does not permit use of bait station or burrow baiting, continue with broadcast baiting, limiting such treatments to areas where active signs of rats are seen. Maintain treatments for as long as rodent activity is evident in the area and rodents appear to be accepting bait.

For all methods of baiting, monitor the baited area periodically and, using gloves, collect and dispose of any dead animals and spilled bait properly. Dead animals and spilled bait may be buried on site if the depth of burial makes excavation by nontarget animals extremely unlikely.

USDA APHIS revised 11/23/2009

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APPENDIX G

PALMYRA ATOLL RAINFOREST RESTORATION PROJECT: RAT GENETIC SAMPLING, DETECTION METHOD TESTING, AND CANOPY BAIT TESTING

PALMYRA ATOLL RAINFOREST RESTORATION PROJECT: RAT GENETIC SAMPLING, DETECTION METHOD TESTING, AND CANOPY BAIT TESTING

September- October 2010

Island Conservation: Aurora Alifano, Alex Wegmann*, Madeleine Pott, Erik Oberg

***Correspondence: Alex Wegmann, Island Conservation, 100 Shaffer Rd. Santa Cruz, CA, 95060 USA / +1831.359.4787 / alex.wegmann@islandconservation.org / www.islandconservation.org**

1. Executive Summary

Primary Objectives:

- Collect genetic samples from the *Rattus rattus* population at Palmyra Atoll.
- Measure the baseline detection success of three devices: chew blocks, tracking tunnels, and live traps.
- Construct and deploy bait stations in a variety of environments to measure variability in bait removal rates, crab interference, structural integrity of the stations, and overall attractiveness to rats.
- Determine the degradation rates and effects of weathering and decay for different types of canopy bait designs and measure the persistence of canopy baits in the crowns of coconut palms.
- Photograph rats consuming pellets and canopy baits in the crowns of coconut palms; determine which type of bola material is preferred by rats.
- Field-test three canopy bait launching devices and establish the situations in which each performs best.
- Monitor placebo bait pellets in the marine environment to determine degradation rates of the matrix under varying conditions
- Quantify the degradation rate of rat carcasses in areas with high shorebird densities, and photograph any avian species interested in consuming the carcasses.

A team of three personnel (Aurora Alifano, Erik Oberg, and Madeleine Pott) conducted several studies at Palmyra Atoll from September 22, 2010 until Oct. 17th, 2010. Rodent live trapping confirmed that rats were present on all landmasses visited, with the exception of Dudley Island where no rats were detected. Captured rats (304 total) ranged from juvenile to adult (24 g to 227 g), indicating that breeding had recently taken place. Chew blocks were slightly more successful at detecting rats in comparison to live traps, but needed frequent replacement, as the hard candy interior lasted less than 24 hours due to rats, crabs, ants, and rain. Tracking tunnels were unsuccessful at detecting rat presence until coconut bait was placed inside as an added incentive. Bait station performance, pellet removal rate, and station resistance to crab-related interference varied widely depending on the location of the station.

Surgitube, a tubular gauze dressing, was the most effective material for canopy bait (“bola”) construction. It was easy for rats to chew through, retained pellets during high-velocity launches, and prevented inside bait from molding. Three launching devices were tested, the HyperDog slingshot, the Big Shot pole-mounted sling shot, and the Squall 250 air cannon. Each device performed best within specific conditions, and it was evident that a combination of methods may be required for fast and accurate canopy baiting. Once in place, bolas were typically consumed within 24 hours.

Placebo bait pellets placed in the marine environment degraded completely within 48 hours, disappearing faster on the intertidal ocean-facing side of the atoll (within 24 hours). Rat carcasses placed in locations frequented by shorebirds and typified by low crab densities (North Beach and along the runway) degraded due to consumption and environmental decay within 72 hours; carcass feeding by shorebirds was not observed in the images captured by motion sensing cameras.

Contents

2. Introduction

2.1 Project Setting

Palmyra Atoll National Wildlife Refuge (Palmyra), at 6° N and 162° W in the Line Islands – Central Pacific, is a globally important refuge for populations of numerous indigenous animals and plants. The U.S. Fish and Wildlife Service (FWS) and The Nature Conservancy (TNC) co-manage Palmyra's emergent land area, while the FWS retains sole jurisdiction over marine resources extending 12 nautical miles out from the atoll. Palmyra is the only fully (federally) protected moist tropical forest ecosystem in the Central Pacific, yet native biota are currently threatened by an introduced, invasive rodent – the black rat (*Rattus rattus*). Palmyra provides important breeding habitat for 10 seabird species; however, rat related egg and chick predation has possibly led to the extirpation of six additional species.

Palmyra consists of 250 ha of emergent land (fragmented into 25 islands), 14 of which were investigated during these studies. Rats were live-captured on the following islands: Ainsley, Barren, Bunker, Dudley, Eastern, Home, Leslie, North Fighter Strip, South Fighter Strip, North-South Causeway, Portsmouth, Quail, Sand, South Complex, Whippoorwill.

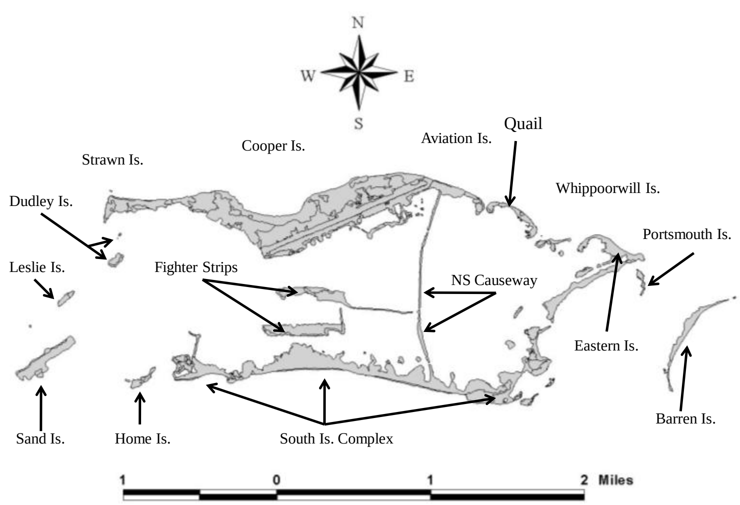

Figure 1: The independent landmasses of Palmyra Atoll that were targeted for genetic samples.

2.2 Project Background

R. rattus is the only species of rat currently present at Palmyra. Recent rat density estimates suggest that there could be as many as 139 rats/ha, resulting in a maximum population size of 32,000 rats across the atoll (Wegmann and Middleton 2008). In case of eradication failure, analysis of *R. rattus* DNA from the pre-eradication population was collected, and will allow the project Partnership to determine if individuals that re-populate Palmyra are missed animals from the target population(s) or from a post-eradication incursion.

The use of rodenticide bait is not anticipated to negatively impact marine organisms. Given the non-polarity of brodifacoum molecules and the ionic strength of seawater, the solubility of brodifacoum is likely in the low parts per billion range (Pierce et al. 2008). An extreme case of 20 tons of brodifacoum bait spilled into the ocean off New Zealand found that brodifacoum levels were not detectable within 36 hours after the spill (Pierce et al. 2008). New Zealand scientists estimated that during a normal helicopter aerial bait application, incidental bait discharge into the nearshore marine waters resulted in 0.0000006 mg/l, or about seven orders of magnitude below the level known to be lethal to bluegill sunfish (New Zealand Department of Conservation 2000). Although the low water solubility of the toxicant and measures taken during the aerial application to decreases the likelihood of bait drift into marine environment, the degradation rate of bait pellets in the lagoon and ocean-facing reef should be assessed.

To minimize the amount of bait that lands in the marine environment during an aerial broadcast at Palmyra, bait will be applied using a directional deflector, several meters inside the mean high-tide line. Palm trees seeking light often overhang the shoreline; such palms represent potential rat habitat yet they will not be baited during the aerial broadcast. Overhanging palms would be treated by hand-canopy baiting (Wegmann et al. 2008). To determine the efficacy of various bait application methods, several launching devices were used to shoot various types of canopy baits ("bolas") into overhanging palms.

3. Methods

3.1 Rat Trapping and Detection

3.1.1 Live Trapping *Rattus rattus*

Trap lines were established along transects of varying lengths, trap placement was standardized using predetermined GPS points to space traps 25 meters apart. The length of each transect depended upon the length of each landmass and the number of samples required from each site. Hagaruma® live traps (with wire mesh bases) were systematically deployed at study sites throughout the atoll. Two methods of trapping were employed; some traps were placed on upside-down 20 liter plastic buckets on the ground to reduce crab interference, while other traps were nailed to tree trunks. On Sand Island and Eastern Island, an abundance of large coconut crabs required the more robust Tomahawk® traps secured to horizontal tree branches with bungee cords. Solid coconut endosperm coated with creamy peanut butter was used as bait for all rats. All traps were checked daily.

3.1.2 Genetic Sampling

A 2-3 cm section of each rat tail was collected using sterilized dissection shears and stored in a plastic screw-top vial containing a DNA preserving solution called DMSO Buffer. All rat tail samples were transported in the buffer solution containing the active ingredients dimethyl sulfoxide and ethylenediaminetetraacetic acid to preserve DNA integrity and shipped to Ecogene^{TM}, a subsidiary of Landcare Research New Zealand Ltd., for storage and analysis. In the event of a post-eradication rat detection (and collection), Ecogene will genotype the pre-eradication Palmyra rat population by obtaining multilocus microsatellite genotypes from each sample using a set of 9 loci (Abdelkrim et al. 2007). Evidence for allelic drop-out, scoring error due to stutter, and presence and frequency of any null alleles will be assessed with MICRO-CHECKER (Oosterhout et al. 2004) using a Bonferroni adjusted 95% confidence interval and 10,000 repetitions. Genetic diversity indices will be calculated using GenAlEx v 6.2 (Peakall and Smouse 2006) and tests for Hardy-Weinberg and linkage disequilibrium will be conducted using GENEPOP v 4.0 (Raymond and Rousset 1995). Pairwise F_{ST} parameters for each population pair will be estimated according to Weir and Cockerham (Weir and Cockerham 1984). The data will then be analysed using the Bayesian clustering method implemented in STRUCTURE ver 2.3 (Pritchard et al. 2000) to provide another estimate of pairwise F_{ST} parameters and to determine the number of distinct genetic units (K) in the dataset. The same analysis will be applied to samples collected from any rats captured at Palmyra after the eradication operation.

3.1.3 Chew Blocks

Trapping is one way to detect the presence of rodents, but some rats may be trap-shy or may not encounter a trap. Other indicators of rat presence like chew blocks and tracking tunnels may be more appealing or less threatening than traps. Chew blocks consist of small (2 cm x 2 cm) square sections of corrugated plastic, filled at one end with a hard candy (peanut butter and melted sugar mixture). Chew blocks were nailed to a tree within 3 meters the associated trap. When chewed by a rat, rodent incisor marks were easy to spot (Figure 2). This method was then compared to the success of tracking tunnels to determine which method provides more consistent and accurate detection measures.

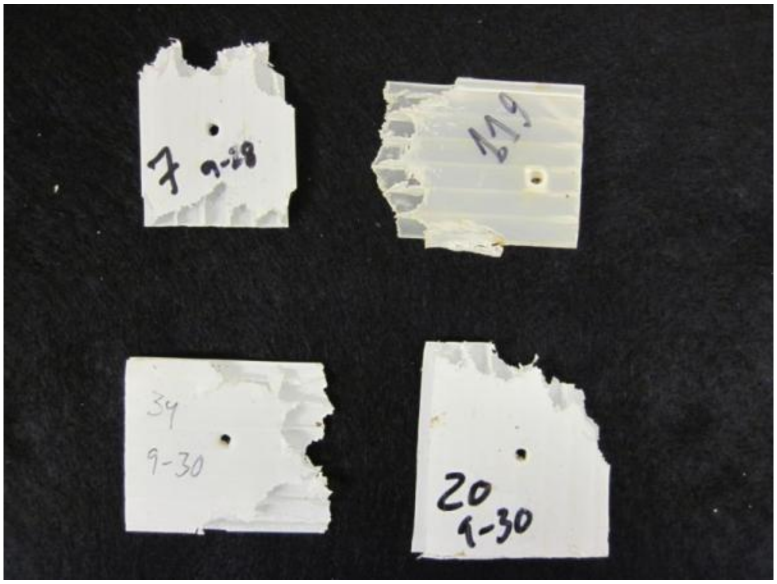

Figure 2: Chew blocks gnawed by rat incisors, indicating rat presence. The smooth edges of the block are untouched; the chewed sides were originally filled with hard candy.

3.1.4 Tracking Tunnels

Tracking tunnels were constructed from 3" PVC pipes cut into 25cm sections and secured to the lid of a bucket with cable ties. Each tube was lined with paper with a felt pad in the center that was then moistened with black ink mixed with peanut oil. The scent of peanut oil was intended to attract rats, which would then enter the tube, leaving paw prints behind on the paper as they exit. A small squirt of oil-based ink and a few ounces of oil stirred in a 20 ml sample vial provided the correct consistency of ink and oil for Palmyra's humid climate. Tracking tunnels were deployed on various islands with Bushnell Trophy Cam motion sensing cameras to measure the efficacy of tunnels to detect rat presence.

Figure 3: Rat investigating a tracking tunnel on the North Fighter Strip.

To increase the attractiveness of each tracking tunnel, diced shavings of fresh coconut were later sprinkled onto the felt ink pad during some trials.

3.2 Bait Stations

3.2.1 Bait Station Construction

To create bait stations that made bait accessible for rats but not crabs, a “T” design was employed using PVC and a T fitting. Most crabs were unable to climb the slick sides of the PVC, but rats easily leaped from the ground to the T fitting. Several pieces of thin wall 4” PVC pipe were cut to pre-determined lengths to vertically support the T fitting. Bait stations were constructed to a variety of heights from 6 ½” to 10 ½”, to compare the effect of station height on pellet removal.

Four bait stations were fitted with curved 4” PVC elbows to allow rats access and prevent rain from entering the station. The vertical portion of each station was filled with a bag of sand and a small plastic baffle disc was placed inside as a platform for the bait. The baffle was placed approximately ¾” below the T fitting. When loaded with bait, the loaded baffle was slightly lower than the two PVC elbow entrances. The internal sand bag provided a weighted, solid base. Each bait station was anchored with cable ties to a 1 meter length of rebar pounded into the ground to keep the station upright.

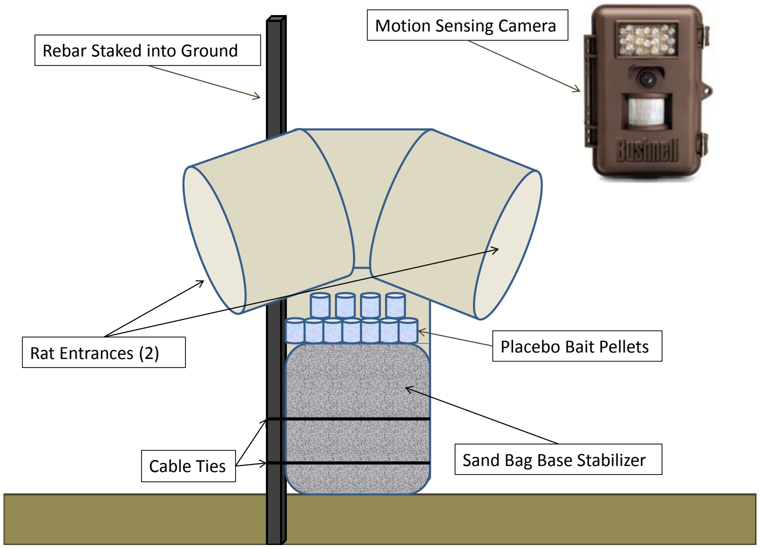

Figure 4: Bait station illustration.

3.2.2. Bait Station Sites

Bait stations were installed in variety of environments to test the attractiveness to rats and the ability of the station to deter crabs. Bait station designs were tested at North Beach (Cooper Island), Compost Pit (Cooper Island), Strawn Trail (Cooper Island), Sand Island, and the North Fighter Strip. Bait stations remained in place until all pellets were gone, with the exception of Sand Island. Within 24 hours of deployment on Sand Island, bait stations and motion sensing cameras suffered so much damage from coconut crabs that they were removed and not redeployed.

3.3 Bait in the Marine Environment

3.3.1 Intertidal and Subtidal Trials within the Lagoon

To track the degradation of pellets inside the lagoon, 3 pellets were placed inside a round PVC exclusion cages with a mesh lid. Water and marine fauna smaller than ½ cm flowed freely in and out, but larger benthic or pelagic consumers were excluded. Exclusion cages were placed 4 meters apart at the same tidal height. Plastic stakes 20cm in length were pounded into the sand and cable ties were used to secure exclusion cages to the stakes (one cage per stake). Three placebo bait pellets were placed in each exclusion cage (Figure 5). Three exclusion cages were installed in the shallow lagoon in a location that always remains subtidal, and three plots were installed in locations that go dry at least once per day. Plots were monitored daily, and the presence, absence, and status of pellets inside the cages were assessed using a pellet degradation scale (Table 1). Plots were monitored daily as long as bait pellets or fragments remained detectable.

Table 1: Bait pellet degradation scale

Bait Pellet Degradation Scale	Bait Pellet Condition
1	Bait hard, intact, whole
2	Bait hard, intact, partially gone
3	Bait soft, intact, whole
4	Bait soft, intact, partially gone
5	Bait mushy, disintegrated
6	Bait dry, disintegrated
7	Bait pellet gone

Figure 5: Placebo bait pellets inside the PVC exclusion cage with mesh top (yellow stake visible).

3.3.2 Intertidal and Subtidal, Outer-Lagoon Trials

This experiment was set up identically to the inner-lagoon trials discussed above, but was installed on the ocean-facing side of the atoll where bait pellets were exposed not only to tidal forces, but also increased wave action. Six plots were installed (3 intertidal, 3 subtidal) and monitored daily.

3.4 Bolas

3.4.1 Bola Construction

Several bola prototypes were created to investigate both the palatability to rats and length of time that the bait pellets within the bolas persisted in the crowns of coconut palms. The criteria for the design of the bola was that the material be biodegradable, easily chewed through by rats, weather resistant, and easily launched. Prototypes bola designs consisted of tea filter bags, cheesecloth, and two variations of Surgitube dressings, one thin version were pellets were lined up vertically in a “tootsie roll” shape, and a second tube of large diameter in which pellets were stuffed to create a ball shape (Figure 6).

Figure 6: Three examples of bait bolas: from top to bottom: Tea bag, Cheesecloth, Surgitube ball.

To ensure uniformity of bola weight across the four prototypes, 25g ± 0.5g of placebo bait pellets were measured on an Escali™ 50 gram electronic balance (approximately 10-14 pellets) and sealed inside each bola liner described above. Two bags were joined by 1.5 ft of 100% cotton twine, resulting in each bola weighing a total of 50g.

Each bait bola was relatively easy to make. Tea filter bags were the fastest since the required number of bait pellets could be dispensed directly into the bag and tied off directly with twine. Surgitube dressings were also easy to construct. After being cut to 8-10 cm lengths, one end was tied in a knot and bait was dispensed inside before tying off the other end with the twine. Cheese cloth bolas required more effort to manufacture. Squares (8 cm x 8 cm) of cheesecloth were cut, bait placed inside, and edges of the cloth were then wrapped upward and tied off with the twine. This required some coordination to keep the edges pinched off while attempting to tie a knot of twine around them.

3.4.2 Bola Launching

Bolas were launched into the crowns of coconut palms using three methods, the Hyper Dog Ball Launcher, the Big Shot, and the Squall 250. The Hyper Dog Ball Launcher made by Hyper Products® was a high performance dog toy slingshot designed to shoot a tennis ball over 200 ft. It consisted of a durable, high-quality steel frame constructed with a rust-resistant baked-on coating and webbed pouch bound to surgical-grade elastic tubing.

The Big Shot, distributed by Sherrill Tree®, is a sling-shot mounted on an 8 ft fiberglass round pole. It is designed to be used by one person to launch climbing and throw lines over 100 ft into tree canopies.

The Squall 250 was an air cannon rented from Air Cannons Inc. The cannon was fitted with a pressure regulator that controls bursts of compressed air, designed to launch tee-shirts and other paraphernalia into crowds at distances of 10- 250 ft. The 20" barrel was made of 100% aluminum and the cannon weighs approximately ten pounds with a full (20 oz) air cartridge. The cartridge was rated to 1800 psi, and was filled from a SCUBA cylinder using a High Pressure Fill Station adapter purchased from WaveToGo Paintball. When filling by cascade from a 3000 psi SCUBA cylinder to a 20 oz cartridge rated to 1800 psi, special care was taken to fill slowly and monitor the gauge to prevent over-pressurization.

All methods were tested on trees of varying heights. Palm canopy height was estimated with a laser range-finder (Laser Tech Inc. Impulse, Model 200). The tallest palm in which bait bolas were successfully planted was 21.3 meters (~70 ft). Bolas were also launched into smaller palms ranging from 14.8 to 10.2 meters in height.

3.4.3 Bait Bola Degradation

To determine the natural degradation rate of each bait bola prototype, bolas were placed in palm crowns and monitored for two weeks. To prevent consumption of bait bolas by rats or other opportunistic consumers, three exclusion cages (0.9 m x 0.9 m x 0.45 m) were constructed from 1.3 cm wire mesh (19 gauge). Bolas were secured to the roof of one wire cage contained within another mesh cage (Figure 7). The four bola types were hung inside each cage and placed on the roof of the research lab facility to allow maximum weathering and minimum interference from rats and crabs. All cages were deployed on October 3st, 2010, and remained until October 14th 2010. Each day, each cage was opened and each bola was checked for number of pellets, pellet condition (using the pellet degradation scale), and bola integrity.

Figure 7: Bait bola degradation cages, designed to exclude large consumers (rats and crabs).

3.4.4 Bait Bola Fate in Palm Canopy

Bolas were placed into the canopy of low hanging palms and monitored daily with motion sensing cameras for bola integrity, bait degradation, and consumer activity (Figure 8).

Figure 8: Bolas (cheesecloth in foreground, and Surgitube in background) placed on fronds of a palm canopy

3.4.5 Rat Carcass Degradation

To monitor the degradation of the carcass, eight rats were euthanized and the carcasses were tethered to a stake or cinderblock. Rat carcasses were placed on the runway and on North Beach because both locations are frequented by shorebirds, and both are typified by a low density of crabs. A measurement for the rate at which rat carcasses are consumed high-density crab habitat exists; here we are interested in measuring the carcass degradation rate in low-density crab habitats. Motion sensing cameras were installed to monitor each carcass, and visual inspections of the remains and any consumers were recorded daily.

4. Analysis

Data on rodent capture was used to generate an index of trapping success by calculating the following.

Total trap nights (TTN) = # nights that traps were open x # of traps Adjusted trap nights (ATN) = TTN-(# number of traps sprung without a rat capture/2) Trapping success = Rats captured/ATN = capture per trap night (CTN). The same formula was applied to the detection of rat presence by chew blocks. One chew night was assigned to chew blocks that contained rat incisor marks, as well as chew blocks that were unchewed with bait remaining after 24 hours. One half chew night was assigned to instances when bait was gone from the block, or when the block itself was missing. As the samples were drawn independently from each other, a two-sample t-test was conducted in Minitab 16 to test the difference between the two population means (Chew success vs. Trap success)

5. Results

5.1. Genetic Sampling

Over the course of a 20-day trapping period, a total of 304 rats were captured and sampled (Table 2). The sex ratio of captured rats was evenly distributed, with 150 females and 154 males: however this ratio varied among islands. On small islands (<10,000 m^2), more female rats were caught than male rats, with a mean ratio of 0.77 (N=3).

Table 2: Total number of rats captured per island, with island size (m^2), sex ratio of female to male, and the mean weight of female and male rats.

Island	Total captured	Island size (m^2)	Sex ratio F/M	Female mean weight (g)	Male mean weight (g)
Ainsley	10	1290	0.80	148	149
Barren	17	54130	0.35	134	162
Bunker	3	1840	0.67	147	139
Eastern	46	126646	0.39	142	148
Home	23	16711	0.35	148	171

Island	Total captured	Island size (m^2)	Sex ratio F/M	Female mean weight (g)	Male mean weight (g)
Leslie	14	10040	0.43	120	152
North Fighter Strip	41	71440	0.51	124	144
NS Causeway	34	35190	0.38	133	116
Portsmouth	7	7740	0.86	133	29
Quail	19	16332	0.68	137	145
Sand	27	81660	0.59	119	161
South Complex	43	591240	0.49	136	156
South Fighter Strip	9	93330	0.33	109	192
Whippoorwill	11	17470	0.82	142	143

Trap status was checked daily, and resulted in 1,178 trap nights during the sampling period. No activity, meaning that bait was untouched and the trap door was open, was the most frequent occurrence (Table 3). Rat capture was the second most frequent occurrence, indicating that the traps worked effectively to trap rats when rats entered.

Table 3: Tally of each potential trap status over 1178 trap nights.

Trap Status	Count
Bait Gone	150
Crab	54
Trap Destroyed	7
Rat Escape	7
No Activity	407
Rat Capture	304
Rat Recapture	67
Trip No Capture	181
Grand Total	**1178**

Rat response to release from capture indicated that the majority of rats remained on the ground while fleeing (Table 4). A small subset of rats elected to run up nearby trees. Of the 13 rats that escaped into a tree, nearly 85% were female rats, indicating a potential sex difference in this behavior.

Table 4: Rat response (to flee on ground or up a tree) to release after capture and genetic sampling.

Release response	# of observations	Female	Male
Ground	278	48.92%	51.08%
Tree	13	84.62%	15.38%

During the trapping effort, 645 chew blocks were deployed, spaced with every other trap (Table 5). Only 8 blocks (1%) were found missing from their original position of deployment and not recovered.

Table 5: Number of chew block nights and chew block success vs. number of live trap nights and live trap success among islands.

Island	Chew nights	Chew Success	Trap nights	Trap success
Ainsley	8	38%	23	61%
Barren	37.5	29%	74	27%
Bunker	18	31%	24.5	16%
Dudley	8.5	0%	23.5	13%
Eastern	53.5	66%	104.5	62%
Home	39.5	85%	57.5	49%
Leslie	22.5	84%	27.5	65%
North Fighter Strip	34	46%	77.5	55%
NS Causeway	68.5	56%	155.5	33%
Portsmouth	14.5	34%	23	35%
Quail	39	38%	79	29%
Sand	37	62%	65	49%
South Complex	82	62%	163.5	30%
South Fighter Strip	9.5	42%	25	40%
Whippoorwill	38.5	44%	86	13%
TOTAL	**510.5**	**48%**	**1009**	**38%**

Chew blocks detected rat presence with 10% more success than did the live traps. A two-sample t-test did not find a significant difference between success of chew blocks and success of traps to detect rat presence ($T = 1.28$, $P = 0.214$, $DF=26$).

Tracking tunnels were deployed at 5 locations within the atoll. Tunnels that only used peanut oil to attract rats resulted in less rat detections. Small diced pieces of coconut were placed inside the tunnel on the ink pad to increase the incentive for rats to enter the tunnels, and yielded variable detection rates among locations (Table 6). Tunnels that offered coconut bait on the ink pad increased the number of successful rat tracks by 48%.

Table 6: Number of tunnel nights and percent of tunnel success for 5 locations.

Island	Tunnel Nights		Tunnel Success	
	no bait	bait	no bait	bait
Barren	38.5	-	3%	-
Cooper North Road	-	8	-	38%
Home	3	3	0%	33%
NS Causeway	-	15	-	60%
South Complex	23	-	0%	-

Island	Tunnel Nights		Tunnel Success	
	no bait	bait	no bait	bait
Grand Total	**64.5**	**26**	**2%**	**50%**

Tracking tunnels were deployed on Cooper Island in combination with motion sensing cameras that recorded rats and crabs nearby and on the tunnels. Photographs revealed rats entering and exiting the tunnels, but also provided evidence of rats investigating the tunnels without entering or leaving behind evidence of their presence. Both rats and crabs were detected passing through the site without physically investigating tracking tunnels.

5.2 Bait Stations

Removal of bait pellets from bait stations was not uniform between locations. Bait stations were first deployed at North Beach on Cooper Island. All bait was removed overnight, with camera footage depicting intense rat activity immediately after sunset until 2300. Trials were replicated 3 times at this location with varying number of pellets inside each bait station (n = 20, 35, 75). The stations were consistently emptied by rats each night. Bait disappeared swiftly on the North Fighter Strip, with only 3 pellets remaining (out of 80) after the first day of bait station deployment. Rat activity was recorded by the motion sensing cameras; rats entered and exited each station multiple times throughout the evening. Land crabs (*Cardisoma sp.*) were present in the images recorded by the cameras, but they did not seem interested in the stations. Bait station height (6-10 in) had no effect on the removal of pellets by rats.

Bait removal rates from three locations on Cooper Island were highly variable (Table 7). Large quantities of bait were removed overnight from North Beach, while a small quantity of bait lasted more than four days at the compost pit and on the trail to Strawn Island. Although rat density estimates for these exact locations are unknown, rats were present in images taken by cameras at all locations. Despite the images of rats near the stations, rats were not frequently observed entering and exiting from stations. Rats on the Strawn Trail took four days to remove a significant quantity of bait from the stations. Rats at the compost pit began to remove bait after 48 hours of exposure to the stations.

Table 7: Average percent of bait pellets removed from bait stations over a four day period. Each bait station (n=4) originally contained 20 pellets.

Location	Day 1	Day 2	Day 3	Day 4	Rats Present
Cooper: Compost Pit	10.0%	44.4%	52.5%	75.0%	Yes
North Fighter Strip	96.3%	-	-	-	Yes
Cooper: North Beach	100.0%	-	-	-	Yes
Sand Island	50.0%	-	-	-	Yes
Cooper: Strawn Trail	0.0%	0.0%	1.3%	53.8%	Yes

Bait stations were deployed on Sand Island for 24 hours. Within 24 hours, all bait stations and some motion cameras were knocked over or otherwise compromised by coconut crabs. The destruction of equipment prevented further investigation of bait removal rates on this island, and no photographs of animal interactions with bait stations were captured.

5.3 Marine Environment

Placebo bait pellets degraded within two days in the marine environment (Table 8). Bait pellets in areas that went dry at low tide broke down more quickly than those that remained constantly submerged. Pellets in the intertidal plots were exposed to longer periods of wave activity and sediment movement, in addition to potential consumption by subtidal and intertidal organisms. Pellets on the outer, ocean-facing edge of the atoll broke down more quickly than pellets within the lagoon. After one day in salt-water, pellets typically became soft and in some cases enlarged, obtaining a marshmallow-like consistency. After two days, pellets were mucilaginous in consistency, and were impossible to pick up as a unit. Any remains of a pellet after three days of exposure either adhered to the sandy substrate or was swept away with the tide.

Table 8: Measured degradation of placebo 25W bait pellets placed in the marine environment. Three plots were established at each location, and each plot consisted of a cage containing three pellets. "Pellets remaining" is the ratio of cages that contained pellets on the given day. Pellet condition was assessed for all remaining pellets on each sample day and follows this degradation scale: 1 = Bait pellet is hard, intact, whole; 2 = Bait pellet is hard, intact, partially gone; 3 = Bait pellet is soft, intact, whole; 4 = Bait pellet is soft, intact, partially gone; 5 = Bait pellet is mushy, disintegrated; 6 = Bait pellet is dry, disintegrated; 7 = Bait pellet is gone. The pellet condition value presented below is the mean value for all plots at the given location on the given day.

Location	Day 1		Day 2		Day 3		Day 4	
	Pellets remaining	Pellet condition	Pellets remaining	Pellet condition	Pellets remaining	Pellet condition	Pellets remaining	Pellet condition
Lagoon Intertidal	3/12	3	2/12	3	1/12	5	0/12	7
Lagoon Subtidal	5/12	6	3/12	5	2/12	5	0/12	7
Ocean Intertidal	0/6	7	-	-	-	-	-	-
Ocean Subtidal	3/3	4	3/3	4	2/3	5	0/3	7

5.4 Bola Launching and Fate

Bolas were launched into palm crowns with varying success. Successful bola placement depended on the bola material, the launching device, and the operator. Making contact between the bola and the palm tree was successful 67% of the time, however, getting the bola to wrap and stick inside the palm crown was an added challenge (Table 9).

Table 9: Overall success of all bolas types launched using all devices.

Hit Palm	Wrapped	Remained Intact After Wrapping
67.5%	34.9%	61.0%

The success of each shot depended on the height of the tree and the device used to launch the bola. The air cannon consistently launched bait into tall palms (max 21.8 m in height) with greater accuracy than any other method (Table 10). The pole-mounted slingshot performed best when launching bait into palms between 10 and 20m high. The HyperDog slingshot varied in accuracy and performance depending on the skill and physical strength of the user, but was the most efficient of the three devices.

Table 10: Percent of successful canopy baiting attempts of three launching devices; the values presented here represent a pooling of all bola types.

Launching Device	# of Trials	Hit Tree	Bola in canopy	Bola Intact	10-15m Height	16-21m Height	Avg. Time to Shoot (sec)
Air Cannon	28	71.4%	35.7%	75.0%	64.7%	81.8%	49
HyperDog	25	60.0%	40.0%	56.0%	58.8%	62.5%	22
Pole-Mounted	30	70.0%	30.0%	58.6%	81.3%	57.1%	32

The air cannon was the most time consuming device to use, requiring the manipulation of the safety switch, pressure valve, careful loading of a towel used as wadding, careful packaging of the bola, and the subsequent location and collection of the towel after each shot. Overall, each launching device took less than 1 minute to complete one shot.

The material used for bola construction had a large impact on the success of bola application. Tea bags were the easiest bola to construct, but were far too thin to hold pellets when launched at high velocity. Tea bags remained intact less than half of the time, and frequently ripped or separated from the twine upon initial release, spilling bait during the launch (Table 11).

Table 11: Percent success of bola integrity and percent success of type to remain in the palm canopy.

Bola Type	Bola Intact	Wrapped in Tree
Surgitube Ball	69.0%	40.5%
Cheese Cloth	68.8%	31.3%
Tea Filter Bag	41.7%	28.0%

Cheesecloth bolas were time consuming to construct. The process required cutting squares, wrapping up pellets inside, and knotting the twine around the cloth. Knots frequently slipped off the cheesecloth, causing the pellets to separate from the twine mid-flight. The stress of the launch occasionally caused the cheesecloth to separate and the weave to loosen, creating large holes that pellets fell out of.

Surgitube bolas were easy to construct- the tubular gauze was cut to a predetermined length, a knot was tied in one end, and pellets were loaded from the other side. The tight weave of the Surgitube held pellets in place during launching and wrapping in the canopy. Failures were frequently attributed to a failed knot, as the Surgitube itself rarely sustained holes or damage to the sides. This bola type was the most structurally sound, and ranked highest in its ability to land in the palm canopy (Table 11).

Bait bola degradation was monitored for 12 days. All bolas remained intact during the first week, and bait pellets were hard and intact - a "1" on the degradation scale. On day 9, light rain fell (0.6 inches) and pellets inside the bolas were wet, soft, and intact. By day 10, fruit flies were observed in the cages, circling around the bolas. The tea bag material began to show discoloration on day 10 and the discoloration progressed until day 12, when the bolas were removed and inspected. Bait pellets inside the teabags had retained moisture and were moldy (Figure 9).

Figure 9: Moldy bait pellets after 12 days inside a tea bag bola.

Pellets in other bolas types softened during the rain, but due to the ventilated nature of gauze fabrics, hardened again in the sun. These pellets were significantly harder than they had been originally, taking on a "petrified" appearance, impossible to indent with a fingernail. By the end of the experiment, 5 of the original 12 bolas were consumed or compromised by rats that had gotten into the cages. Rats entered the cage and pulled the bolas up by the string, consuming pellets through the bars of the inside cage. The first bola was attacked on day 6, the rest were attacked on the last day of the experiment (day 12).

Bolas placed in palm crowns were monitored with motion sensing cameras to determine if rats would chew bolas in the canopy. Of 29 bolas deployed, 82% disappeared within the first 24 hours. All of the bolas disappeared within 48 hours of deployment. When a camera detected rat presence, the bola always disappeared the first night, suggesting that bolas that remained untouched the first night may not have been encountered by a rat. No preference by rats for a certain bola type was detected. Shredded remains of bola material found at the site was evidence that rats can and will chew into all bola types to get to the bait pellets.

5.5 Rat Carcass Degradation

At North Beach, rat carcasses degraded rapidly when exposed to the elements. Within 24 hours, the carcasses were torn open by crabs, and swarmed by ants. After 72 hours the carcasses were hollowed, leaving only fur and bones around an empty body cavity. Motion sensing cameras detected coconut crabs, hermit crabs, and burrowing marine crabs consuming the carcasses, in addition to ants and other insect consumers. Several bird species were present within 4 ft of the carcass including Bristle-thighed Curlews, Pacific Golden Plovers, Wandering Tattlers, and Red Footed Boobies. Birds were photographed in the vicinity of the carcass, but were not observed feeding on or around the carcasses.

6. Discussion

These studies were conducted at Palmyra during an unusual 3 month drought. The total rainfall during the study period was only 3.9 inches, with an average high temperature of 87° F. The drought may have negatively impacted the rat population on islands where water sources are naturally scarce. For example, the rat population on Barren Island appeared depressed compared to previous trapping efforts in that location. Barren Island is primarily coral rubble, and lacks the soil or lush forest characteristic of other islets at Palmyra. A long trap line averaged only 1 rat capture per day during the first week of trapping while using coconut and peanut butter as bait. During the last week, small plastic cups were secured to the cage interior and filled with water in an attempt to attract more rats. The first night water was offered in traps, 7 rats were caught on Barren Island. Without the typical rainfall that maintains Palmyra's moist environment, rats may alter their foraging patterns and as a result might be harder to detect.

All rats that survived capture were released post-assessment and observed until they disappeared from view. Most rats (91%) fled on the ground. Rarely, a rat would run directly up a tree next to the trap that they were caught in. The majority of rats that climbed a tree immediately after being released were female (85%). It is possible that these females were actively tending nests in the canopy at the time of capture, resulting in behavior that differed from that of the captured male rats.

Chew blocks detected rat presence with 10% more success than standard live traps; however, whether chew blocks are more likely to detect rats than traps during periods of low rat density remains to be determined. Rat detection methods for post-eradication monitoring will likely use both traps and chew blocks, with the consideration that both are time-consuming methods and require daily checks/replacement. To ensure that tracking tunnels work effectively as a detection device, a more attractive bait than peanut oil must be used. Diced coconut was effective but was temporary. More effort could be spent to develop a long lasting attractant that can be placed in the tunnels, allowing for an extended time period between checks.

Bait pellet removal from bait stations was high in some locations. At North Beach, time stamped photographs show rats approaching the station within 30 seconds of the departure of the installment team. Rats at this location were photographed entering bait stations, carrying pellets in their mouth as they exited, and running up a nearby tree multiple times in an evening, suggesting that they were heavily utilizing the canopy habitat (Figure 10).

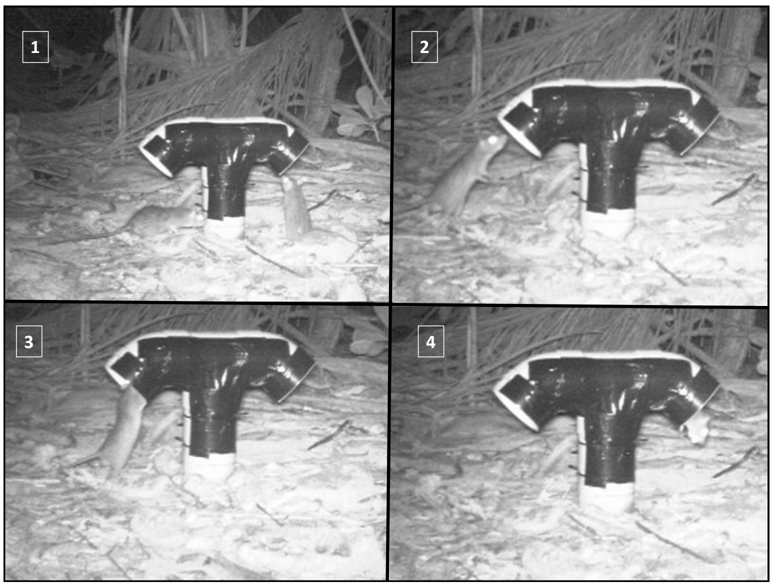

Figure 10: Rat activity in a bait station at North Beach:1. Rats approached the station. 2. Rat investigated the station. 3. Rat jumped from the ground into the entrance. 4. Rat exited the station carrying a bait pellet in its mouth.

Bait stations could be improved by 1) developing a secure anchoring system that cannot be knocked over by coconut crabs, and 2) increasing the height of the bait station to deter *Cardisoma* and hermit crabs. Hermit crabs that could not climb the station sides were observed climbing *Pandanus* and other low hanging trees, then dropping onto the top of the bait station. If installed, care must be taken to clear all surrounding foliage from around the bait stations.

Placebo bait pellets degraded quickly in the marine environment, with most pellets breaking down within 24 hours of exposure. After more than one day of softening, the pellet matrix became so mucilaginous that the remains were impossible to pick up intact. If pellets are not immediately consumed by marine organisms, they are not likely to remain intact for more than two days in the lagoon or ocean-facing near-shore marine environments.

Of the materials tested, Surgitube gauze was the best material for with which to construct bolas. It was the strongest and most durable bola bag, it was easily chewed through by rats, and it did not appear to deter rats from accessing the pellets contained within. The 100% cotton fabric weave allowed maximum aeration and deterred mold from accumulating on the pellets. Launching of the bait bolas was more complex, each method was both valuable yet limited in very different ways (Table 12).

Table 12: Pros and cons of three bait bola launching devices tested on Palmyra Atoll.

Squall 250 Air Cannon	
Pros	**Cons**
Requires no muscle strength or effort	Heavy to carry
Easily baits the tallest palm trees	Must find/fetch towel after each shot
Easy to learn, easy to aim	Limited # of shots (15 with 20 oz tank)
PSI may be adjusted for trees of different heights	Lots of parts that can break in the field
Adaptable design, easily modified	Expensive ($1,500), time consuming to fill
Adaptation: Carry larger air canister on a backpack for a longer-lasting air supply.	
Hyper Dog Ball Launcher	
Pros	**Cons**
Small in size	Tiresome, hard on forearms and muscles
Least expensive option ($35)	Difficult for novices to aim
Lightweight, easily portable through forest	Highly dependent on skill / strength of user
Fastest method per shot	Amount of force needed is hard to estimate
Adaptation: Tighten wrist mount to increase accuracy, pad forearm to absorb shot pressure.	
Big Shot Pole-Mounted Slingshot	
Pros	**Cons**
Lightweight, breaks down for storage	Cumbersome to carry through thick forest
Anyone can aim and use without training	Only shoots vertically, if canopy is thin
Requires little force or strength	Moderately expense ($130)
Self supported, easier to operate	8 ft pole is too tall for some people to use
Adaptation: Cut or otherwise adjust pole length to be optimal for users of different heights.	

The preferred method for launching bolas into the canopy depends on the following variables: 1) the size and strength of the operator, 2) the height of the palm, 3) thickness of the canopy, 4) the distance and density of trees between locations, 5) the amount of time allotted for baiting. The adaptations described in Table 12 may increase the effectiveness of all methods, and should be developed further. Bolas that were successfully launched into palm canopies were typically consumed by rats within 24 hours, indicating that this method could be a successful measure to ensure, that bait is delivered to all rat territories.

Research has shown that shorebirds may consume rodenticide bait pellets directly (Pierce et al. 2008) or may sustain secondary or tertiary exposure to rodenticides after ingesting smaller organisms that previously consumed bait. The Bristle-thighed Curlew, a species classified as Vulnerable on the IUCN Red List 2008 (ICUN Red List of Threatened Species 2010) is at risk of exposure to rodenticide through direct and indirect pathways. Curlews were ever-present throughout the atoll during these studies, and were frequently captured in photographs by the motion sensing cameras that were monitoring bait stations, tracking tunnels, and rat carcasses. Though frequently sighted, curlews, plovers, wandering tattlers, and boobies seemed more interested in the camera itself than in the bait pellets or carcasses. Birds were occasionally photographed looking in the direction of a carcass or bait station, yet no close inspection or contact was made.

Figure 11: Bristle-thighed Curlew inspecting a motion sensing camera on Strawn Island, bait station visible in the background.

The persistence of bait pellets in the crown of coconut palms was difficult to ascertain. Pellets that were placed in the crooks of palm fronds invariably slipped into a groove between the frond and the trunk, disappearing from view. Pellets were difficult to find, making accurate counts of pellet removal or observations of persistence nearly impossible. The natural shape of a coconut palm crown acts like a funnel, causing pellets to roll downhill into the tightest possible spaces. Special consideration should be given to locating pellets and sampling methods before repeating pellet fate trials in palm crowns.

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APPENDIX H

SUMMARY OF RISKS & POTENTIAL MITIGATION OPTIONS FOR BRISTLE-THIGHED CURLEWS (*NUMENIUS TAHITIENSIS*) AT PALMYRA ATOLL DURING A RAT ERADICATION CAMPAIGN

Summary of Risks & Potential Mitigation Options for Bristle-thighed Curlews (*Numenius tahitiensis*) at Palmyra Atoll during a Rat Eradication Campaign

Prepared for:

Palmyra Atoll Rainforest Restoration Project

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Photo: © Glen Tepke

Prepared by:

COASTAL CONSERVATION

Chris Gill, MSc.

Registered Professional Biologist

P: (250) 835-8256

e: chris@coastalconservation.ca

Table of Contents

Background

Palmyra Atoll National Wildlife Refuge (Palmyra), located in the Line Islands of the central Pacific Ocean and approximately 1,693 kilometers south of the main Hawaiian Islands, is the northernmost atoll of the Line Islands chain and second largest of 10 atolls under U.S jurisdiction (The Nature Conservancy 2010). The atoll is comprised of 54 islets encompassing 228 hectares that rise to a maximum elevation of 2 metres. The atoll has a 1.6 kilometer long runway that is maintained by The Nature Conservancy staff.

Non-native black rats (*Rattus rattus*) were introduced to Palmyra, likely during the US military occupation of the atoll in the 1940s. The establishment of rats on Palmyra is considered to have had a major negative impact on the ecosystem, especially on seabirds, invertebrates, and vegetation (Howald et al. 2004).

The US Fish and Wildlife Service, in partnership with The Nature Conservancy and Island Conservation began the Palmyra Atoll Rainforest Restoration Project (PARRP) to undertake a rat eradication campaign at Palmyra to restore the atoll's terrestrial ecosystem. This campaign, however, places non-resident migratory shorebirds, including Bristle-thighed Curlews (*Numenius tahitiensis*), at risk of both primary and/or secondary exposure to rodenticide bait that will be deployed during the rat eradication. Due to its limited population size, the Bristle-thighed Curlew (BTCU) is classified as Vulnerable on the IUCN Red list (2008) because its population is small and believed to be declining, largely due to predation on the wintering grounds, when perhaps more than 50% of adults are flightless during autumn molt. The BTCU is also listed as a high conservation concern in the US Pacific Islands Regional Shorebird Conservation Plan (Engilis 2004) as well as the US Shorebird Conservation Plan (Brown et. al. 2001). This species is generally found on Palmyra during the non-breeding season although some individual juvenile birds are present throughout the year.

This document summarizes the risks to BTCUs posed by the eradication campaign and explores several potential mitigative measures that, if implemented, may minimize this species' risk of exposure to the primary, secondary, and/or tertiary poisoning.

Description

The BTCU is a medium-sized curlew with a wingspan of approximately 40-44 cm and blue-gray legs. The moderately long and decurved bill is flesh colored at the base turning to brown near the tip and a dark lateral crown is present on the head along with eye stripes. The upperparts are spotted buff while the underparts are lighter with a few dark streaks on the flanks and more extending up the neck to the throat (Figure 1). The voice is a short '*chi-u-it'*, whistling '*whe-whe-whe-whe'*, and a ringing '*whee-wheeoo*' (Birdlife International 2010).

Their name comes from the bristle-like extensions at the base of their legs, although these are generally inconspicuous. Females are heavier than males and have longer wings and a shorter bill. Juveniles are similar to adults except for the presence of larger cinnamon-buff spots on the upperparts, and virtually unstreaked underparts (del Hoyo et. al. 1996).

Figure 1. Bristle-thighed Curlew. Photos © Glen Tepke.

Geographic Distribution

During the breeding season, BTCUs are found in the remote mountainous regions of western Alaska in the Andreafsky Wilderness Area north of the Yukon River mouth and on the central Seward Peninsula (McCaffery and Peltola 1986, Kessel 1989, Gill et al. 1990, Marks et al. 2002).

During the non-breeding season this species is found on remote Pacific Ocean islands and atolls (Marks et al. 1990) including the Hawaiian Islands (USA), US Minor Outlying Islands, Northern Mariana Islands (to USA), Federated States of Micronesia, Marshall Islands, Nauru, Kiribati, Tuvalu, Tokelau (to New Zealand), Fiji, Tonga, Niue (to New Zealand), Samoa, American Samoa, Cook Islands, and French Polynesia, also reaching the Solomon Islands, Norfolk Island (to Australia), Kermadec Islands (New Zealand), Pitcairn Islands (to UK) (notably Oeno) and Easter Island (Vilina et al. 1992, Brooke 1995b[1]). Sub-adults may remain in the Pacific until they are nearly three years old (Collar et al. 1992). Site fidelity on both the breeding and wintering grounds is high with many birds returning to the same location on an island for multiple years (Marks and Redmond 1996).

The geographic distribution of BTCUs has contracted in recent years (Marks et. al. 2002).

Population Size Estimate

Based on comprehensive surveys of the known breeding range on the Seward Peninsula, the population size is estimated at approximately 3,200 breeding pairs (via a statistically valid sampling regime last assessed in 2000-2001, L. Tibbitts pers. comm.), while Engilis and Naughton (2004) state that the total number of Bristle-thighed Curlews is closer to 10,000. Numbers may be declining, although data on population trends are not available (Marks et. al. 2002).

This species breeds at two different locations in Alaska separated by approximately 300 km (C. Handel unpublished data[2]). The two genetically distinct populations differ in size (the northern population is

[1] Source: http://www.birdlife.org/datazone/species/index.html?action=SpcHTMDetails.asp&sid=3010&m=0

[2] Source; Marks, Jeffrey S., T. Lee Tibbitts, Robert E. Gill and Brian J. Mccaffery. 2002. Bristle-thighed Curlew (*Numenius tahitiensis*), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology. Downloaded from

smaller), breeding phenology (southern birds breed slightly earlier than northern birds), morphology (northern birds are slightly larger), and location of core winter range (the northern population winters further south, Marks et. al. 2002).

Two survey methodologies have been employed on the Atoll to count shorebirds including BTCUs: Runway counts and all-Atoll counts.

Runway Counts

Runway counts were initiated in 2001 although the methodology used to conduct the survey was changed in 2008[3]. Runway counts are conducted on the island's runway at high tide approximately once each week[4]. One surveyor walks the runway in the direction of the wind and counts each individual bird. The resulting dataset is an indirect measure of the atoll's population size; when runway count data is correlated with all-atoll count data, runway count values appear to represent 25% of the BTCU counted during the all-atoll counts (USFWS 2010, unpublished data).

Table 1 shows a comparison of 2009 and 2010 BTCU runway survey results for (June and July only). Average bird counts recorded for June 2009 and 2010 were similar (2009=38.4 birds, n=5 surveys; 2010= 37 birds, n=5 surveys). July 2009 numbers were slightly higher (41.5 birds compared to 34 individuals in 2010) although survey data is limited (2009 n=2 surveys, 2010, n=3 surveys). The lowest bird count occurred from late June to mid-July for both years.

Unfortunately the age of birds was not recorded for either survey method, possibly because adult and sub-adult curlews can be somewhat difficult to distinguish. However, birds remaining through the austral winter are most likely sub-adults which do not migrate back north until they are approximately 34 months old (Marks 1993, Marks and Redmond 1996).

Table 1. BTCU runway surveys. Comparison of numbers counted in June and early July in 2009 versus 2010.

2009 Survey Data			2010 Survey Data	
Survey Date	**Count**		**Survey Date**	**Count**
6/1/09	117		6/4/10	32
6/6/09	29		6/10/10	56
6/13/09	19		6/12/10	30
6/21/09	14		6/18/10	25
6/27/09	13		6/25/10	42
7/4/09	71		7/3/10	16
7/12/09	12		7/8/10	21
			7/10/10	65

All-Atoll Counts

All-Atoll counts are conducted approximately once per month and involve a survey at low tide of all of the shorebird congregation sites including, but not limited to, beaches, lagoon flats, runway, and roads.

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http://bna.birds.cornell.edu/bna/species/705/articles/introduction?must_change_password:int=0&initial_login:int=1 on 13/09/2010.

[3] From 2001 to Aug 2008, runway counts were conducted in the morning regardless of tidal conditions. Beginning in September 2008, runway counts were only conducted at high-tide - during low tide, most of the shorebirds are foraging on the exposed lagoon flats (A. Wegmann pers. comm.). Given the change in survey methodologies it is difficult to compare data collected prior to 2008 to the more recent data.

[4] During low tide cycles the shorebirds forage on the lagoon flats but during high tide they congregate on the runway (A. Wegmann pers. comm.).

The survey usually requires 5 to 6 people and takes at least 4 hours to complete. Figure 1 shows the areas surveyed during the all-Atoll count in 2010.

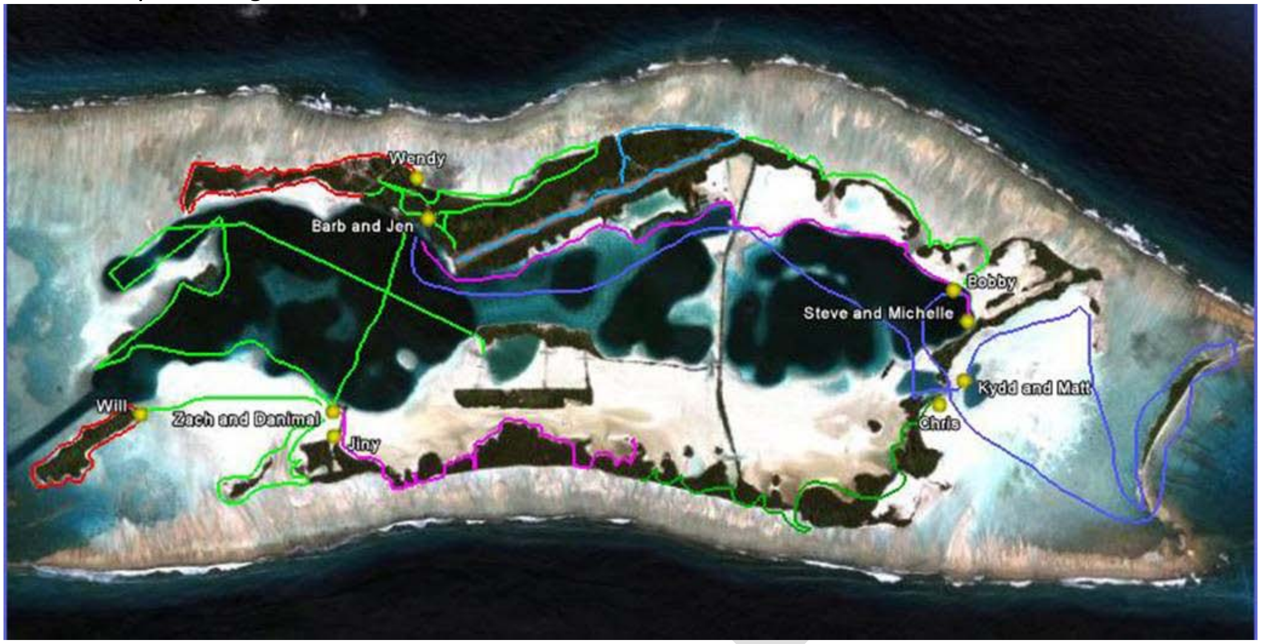


Figure 1. Areas surveyed during the all-Atoll count on Palmyra (USFWS unpublished data).

In July 2010, observers counted 149 BTCUs on the Atoll (USFWS unpublished data), which was higher than anticipated based on the results of the runway count. It is possible that the lack of Sooty Tern (*Onychoprion fuscatus*) breeding on the Atoll in 2010 could explain the higher than expected numbers. Sooty Tern eggs are a preferred food source for BTCUs (Bailey 1956, Ely and Clapp 1973) because the protein-rich eggs allow a rapid increase in body mass and condition in preparation for their migration back to the breeding grounds in Alaska. In 2010 the el Niño-Southern Oscillation (ENSO) returned to the tropical Pacific bringing warm, nutrient-poor water from the western Pacific in the equatorial current, likely resulting in a reduction in prey availability for seabirds including the Sooty Tern and consequently the lack of breeding activity for this species on Palmyra Atoll in this year (Schreiber & Schreiber 1984, Forchhammer et. al. 1998, Post & Forchhammer 2002, Ramos et. al. 2002, Frederiksen et. al. 2004, Jaquement et. al. 2007). Therefore, the lack of Sooty Tern eggs in 2010 may have prevented some curlews from returning to their breeding grounds in Alaska (B. Flint email communication with M. Rubega, A. Wegmann pers. comm.) thus leading to an abnormally high all-Atoll count for that year.

Threats

Although its tundra breeding grounds have remained largely undisturbed, some researchers believe that BTCUs are negatively impacted by introduced mammalian predators including rats on their wintering grounds and atolls, including Palmyra Atoll (Marks et al. 1990). This is likely due to the fact that this species has evolved a rapid prebasic molt during which about 50% of the adults become flightless for approximately 92 days between August and December (Marks 1992, 1993). Consequently, disturbance or mortalities on the wintering grounds could have a significant impact on the total population size.

Conservation Status

Classified as Vulnerable on the IUCN Red List 2008 (ICUN Red List of Threatened Species 2010). BTCUs are considered species of high conservation concern because of their small population size and because of anthropogenic pressures on the wintering grounds (habitat loss and degradation, introduced mammalian predators, etc). The risk of a steep and sudden population decline is serious threat because these birds are long-lived and site-faithful (L. Tibbitts pers. comm.).

Non-breeding Habitats

Winter habitats include ocean terraces or reef flats, ocean beaches, inter-islet channels, lagoon sand beaches, lagoon coral reefs, mudflats, saltpans, coconut groves, and vegetated clearings (Pratt et al. 1987). Gill and Redmond (1992) found that wintering birds were associated principally with saltpans (36%) and inter-islet channels (27%). During molt, flightless birds take shelter during the day in dense stands of bunchgrass (*Eragrostis variabilis*) (Marks et al. 1990) and gather in communal nocturnal roosts in shallow water ponds of up to approximately 120 individuals (Tibbitts 1990).

Summary of Risks to BTCUs during the Rat Eradication Campaign

In the non-breeding season BTCUs forage primarily in terrestrial habitats consuming spiders, land crabs, insects, seabird eggs, lizards, and carrion (Marks 1993). Stomach contents of 14 curlews collected in Polynesia contained vegetation, crustaceans, insects, gastropods, and scorpions (Johnsgard 1981).

Palmyra supports six land crab species including the large coconut crab (*Birgus latro*), two terrestrial reptile species - an introduced house gecko (*Hemidactylus frenatus*) and a native mourning gecko (*Lepidodactylus lugubris*), as well as a diverse collection of both native and non-native insects (Handler et. al. 2007, Howald et. al. 2004). Given the diverse diet of this species there are several potential secondary/tertiary exposure pathways including:

1. Feeding on land crabs or hermit crabs that have consumed bait or scavenged rat carcasses[5];
2. Feeding on insects that have consumed bait or scavenged rat carcasses;
3. Feeding on lizards that have consumed insects that have ingested the bait; and/or
4. Feeding directly on rat carcasses.

Additionally, research has shown that some BTCUs will ingest baits containing the rodenticide directly so the risks to this species are not confined to secondary poisoning (Pierce et. al. 2008).

Impact on BTCU Population

The 149 BTCUs counted on July 10, 2010 during the all-Atoll survey account for approximately 2% of the total population estimate. It is possible that a significant portion of the population present on the Atoll during the eradication would be exposed to the rodenticide bait if no mitigative measures are implemented.

[5] During a 2005 visit to the atoll by Island Conservation personnel, Bristle-thighed Curlews were observed along shorelines and above open water but also occasionally sighted beneath the forest canopy in the interior of the islets. Researchers found the evidence that these birds were foraging on hermit crabs which suggests that this species comprises at least a portion of the curlew's diet, thereby confirming their potential risk of secondary exposure to the rodenticide (Buckelew et. al. 2005).

Merton et. al. (2002) reported mortality rates for several bird species following a rat eradication campaign on four islands in the Indian Ocean. Two of the species have similar diets to Bristle-thighed Curlews: Ruddy Turnstone (*Arenaria interpres*) and Asiatic Whimbrel (*Numenius phaeopus variegates*). Green-dyed bait and 20ppm brodifacoum concentration was used for the eradication and following the campaign estimated population mortality rates were 61% for Turnstones and 20% for Asiatic Whimbrel).

McClelland (2002) reported that 80% of fernbirds (*Bowdleria punctata wilsoni*), a warbler that forages on invertebrates, disappeared from a 25 hectare test plot that was used to assess risk of brodifacoum on non-target species prior to implementation of a rat eradication operation on Codfish Island, New Zealand. No birds in a neighboring control plot were lost, which suggested that the proposed aerial bait drop on Codfish Island posed a significant risk to the fernbirds at a population level. Although fernbirds are not closely related to BTCUs this data may be used to predict the potential impact of the Palmyra rat eradication operation on bird species at risk of high exposure to rodenticide.

Other eradication projects reported non-target mortality of BTCUs (e.g.: Pierce et al 2008). However surveys for dead or dying shorebirds were not comprehensive for most eradication projects (e.g. S. Cranwell pers. comm. regarding the Ringold (Fiji) rat eradication project and R. Pierce pers. comm. regarding the Phoenix Islands eradication project). It is also likely that most carcasses are rapidly consumed by scavengers making estimations of mortalities resulting from rodenticide bait difficult to predict.

R. Pierce (pers. comm.) theorized that mortality rates of birds present on Palmyra Atoll at the time of the eradication campaign would be variable depending on factors such as rainfall (increasing bait palatability) and social facilitation (e.g. birds learning of the rodenticide bait palatability from watching a neighbour ingest it rather than learning by itself, Peirce et. al. 2008).

Based on the non-target mortality rates reported by Merton et. al. (2002) and data from McClelland (2002) it may be reasonable to anticipate mortality rates in the range of 60-80% for BTCUs summering on the Atoll during the rat eradication campaign. Two questions remain: 1) what proportion of sub-adult population versus adult population present on the Atoll during the eradication will be impacted; and 2) how will these losses impact the total population size and stability?

Population viability analysis (completed by Island Conservation)

The following BTCU population viability analysis (PVA, Morris and Doak 2002, Doak et. al. 2009) was completed by the partnership behind PARRP (2010) to explore the implications of incidental poisoning mortality of BTCUs due to activities associated with the proposed rat eradication on Palmyra. The PVA uses a female-only stage structured matrix model (Table 2) parameterized using available data (Table 2). The model structure assumes birds pass through a series of immature life stages, with recruitment occurring at ages 3 - 5 (i.e., participation in migration starts at 35 – 59 months), and most birds recruiting at age 3 (Marks et al. 2002). In addition, a very small proportion of adults skip breeding in some years. The matrix assumes a pre-breeding census.

At least some species-specific data were available for most parameters (Table 3), although data on reproduction was notably lacking. The modeler was forced to use surrogate data, in some cases from smaller-bodied shorebirds, for survival from egg to hatch, hatch to fledge, and fledge to first birthday. In addition, no information was available on temporal variance in survival rates, and thus, stochastic dynamics were explored by assuming a 10% coefficient of variation (CV) in adult survival and adult breeding probability (S_{br}, S_{nb}, G_{br}, G_{nb}). A nest success CV of 73% was estimated from existing data. These CVs are consistent with expectations for more variable rates of reproduction than survival in long-lived birds (Erikstad et al. 1998). Annual demographic rates for stochastically varying parameters were randomly chosen from a beta distribution (Morris and Doak 2002).

Table 2: Stage structured matrix describing BTCU life history (see Table 2 for parameter definitions and values).

0	0	0	0	0	SR*CL*NS*EH*HF*FS	0
S_{nb} *(1-G_1)	0	0	0	0	0	0
0	S_{nb} *(1-G_2)	0	0	0	0	0
0	0	S_{nb} *(1-G_3)	0	0	0	0
0	0	0	S_{nb}*(1-G_4)	0	0	0
S_{nb} * G_1	S_{nb} * G_2	S_{nb} * G_3	S_{nb} * G_4	S_{nb} *G_5	S_{br} *G_{br}	S_{nb} * G_{nb}
0	0	0	0	0	S_{br}*(1- G_{br})	S_{nb} *(1- G_{nb})

The modeler explored the likely effects on global BTCU populations of mortality of 10, 50, and 150 BTCU individuals on Palmyra Atoll. Given the timing of eradication, the majority of mortalities should be sub-adult birds remaining on the atoll during the breeding season, but we conservatively assume that 50% of the mortalities are adults. For all scenarios, a second conservative assumption of an additional 50 BTCU lost due to a simultaneous but unrelated one-time event was added, again assumed to be 50% adults. The modeler assessed the effect of these spikes in mortality on the population futures of BTCU by simulating 20,000 replicate runs for each scenario, with the added mortality imposed in the first year, and tracking population trajectories over 50 years, and reported the extinction risk and projected median and lower 90th percentile of population size.

The model does not account for demographic stochasticity, which is unlikely to be important at current population levels. Likewise, the model does not take into account uncertainty in parameter estimates, correlations in demographic rates, catastrophes, density dependence, possible Allee effects at low population levels, or implications for the local population on Palmyra.

Results and Discussion

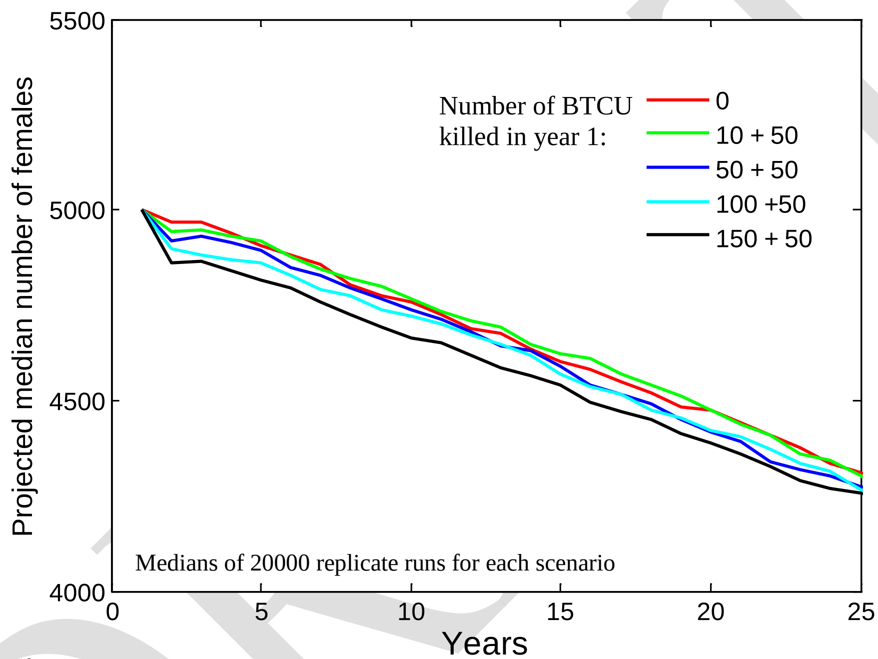
The population growth rate (λ) for the deterministic matrix was 0.997, suggesting a population that is slowly declining in the absence of environmental fluctuations. Adding temporal variance in some demographic rates (Table 3) yields a stochastic λ estimate of 0.994, again suggesting a slowly declining population. The population is currently thought to be approximately stable, although some recent reports consider it declining (Morrison et al. 2006 and references therein). Thus, the modeled population generally accords with expectations, but may reflect some conservative assumptions.

With a starting population of 10,000 (Morrison et al. 2006), 884 adults and 239 sub-adults are expected to die in the first year due to natural mortality, assuming a stable stage distribution. The mortality scenarios considered here (10 – 150 +50 individuals) represents a 3-8% increase in adult mortality and a 13-31% increase in sub-adult mortality for one year.

The mortality events considered here appear to have a minor and diminishing effect on projected population futures (Figure. 2). The one-time mortality events do not alter deterministic λ and result in only minor decreases in stochastic λ. In addition, the mortality events do not appear to put the population in danger of increased risk of stochastic extinction over 50 years. With the current parameter estimates, there is no risk of extinction over the next 50 years under any scenario (although with $\lambda < 1$, the modeled population is in a deterministic decline towards eventual extinction).

An analysis of the sensitivity of deterministic λ to BTCU demographic rates indicates that the population growth rate is most responsive to changes in adult survival. Elasticity values, which denote proportional changes in λ for proportional changes in demographic rates, were 0.58 for adult survival, and 0.32 for sub-adult survival; all other demographic rates had elasticities of ≤0.10. These sensitivity results underscore the importance of minimizing adult mortalities.

These model predictions should be viewed as general qualitative descriptors of the BTCUs likely future dynamics under various one-time mortality scenarios. This PVA was constrained by available data – most demographic rates were estimated from sparse data, or were assumed or borrowed from surrogate species. Care should be taken to minimize BTCU mortalities, because at ~10,000 individuals, the global population size of BTCU is small.



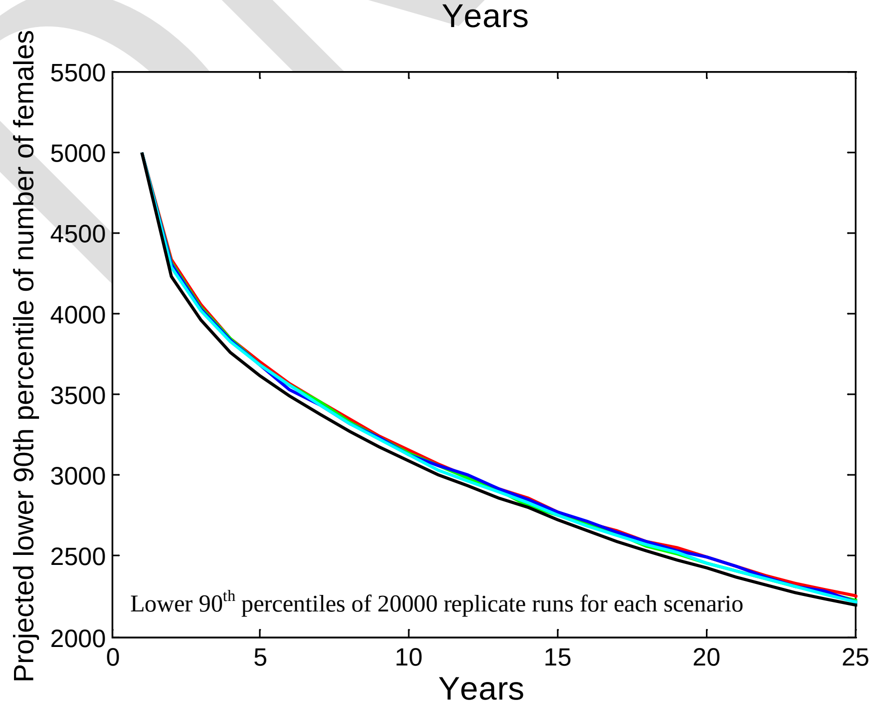


Figure 2. Effect of Effects of one-time mortality events on BTCUs.

Table 3: Parameter values used in matrix population model for BTCU

Symbol	Parameter	Estimate	Species	Process variance (CV)	Source
Nstart	Starting population size	10,000	BTCU		Morrison et al. 2006
SR	Egg sex ratio	0.50			Assumed. Also assumed no sex differences in age-specific survival throughout life (Marks et. al. 2002 reports no difference for adults)
CL	Mean clutch size	3.85	BTCU		Marks et. al. 2002
NS	Probability of nest success (≥1 chick fledging)	0.37	BTCU	73%	Marks et. al. 2002 (estimated from data therein, process variance estimated using Kendall's method, (Kendall 1998)
EH	Probability of surviving, egg to hatch	0.95	LBCU		Redmond and Jenni 1986 (re-estimated to exclude livestock damaged eggs)
HF	Probability of surviving, hatch to fledge	0.53	LBCU, PIPL		Mean: Long-billed curlew (0.39, Redmond and Jenni 1986) and Piping plover (0.66, Calvert et. al. 2006)
FS	Probability of surviving, fledgling to 1st birthday	0.46	SNPL		Stenzel et. al. 2007
Snb	Annual survival probability, nonbreeder	0.92	BTCU	10%	Marks and Redmond 1996, process variance assumed
SB	Annual survival probability, breeder	0.87	BTCU	10%	Marks et. al. 2002, process variance assumed
G1	Probability of recruitment, 1st year	0	BTCU		Marks and Redmond 1996, Marks et. al. 2002
G2	Probability of recruitment, 2nd year	0	BTCU		Marks and Redmond 1996, Marks et. al. 2002
G3	Probability of recruitment, 3rd year	0.91	BTCU		Marks and Redmond 1996, Marks et. al. 2002
G4	Probability of recruitment, 4th year	0.91	BTCU		Marks and Redmond 1996, Marks et. al. 2002
G5	Probability of recruitment, 5th year	1.00	BTCU		Marks and Redmond 1996, Marks et. al. 2002
GBr	Probability breeder remains a breeder, >5th year	0.98	BTCU	10%	Marks and Redmond 1996, Marks et. al. 2002, process variance assumed

Lower 90th percentiles of 20000 replicate runs for each scenario

GNb	Probability nonbreeder returns to breeding pool, >5th year	0.98	BTCU	10%	Marks and Redmond 1996, Marks et. al. 2002, process variance assumed

Benefits of Rat Eradication to BTCU Population

Some researchers believe that BTCUs are being negatively impacted by introduced mammalian predators including rats on their wintering grounds and atolls, including Palmyra (Marks et al. 1990). Removal of rats from Palmyra would therefore have a positive impact on the population. In addition to this direct benefit, other researchers have suggested that the high density of introduced nest-predating rats greatly reduces ground nest success and fledging rates of Sooty Terns on Palmyra (USFWS 2010). Therefore removing rats from the Atoll may also indirectly benefit BTCUs by increasing the breeding population of Sooty Terns, and thus egg production on Palmyra - Sooty Tern eggs are a preferred food source for BTCUs (Bailey 1956, Ely and Clapp 1973) because the protein-rich eggs allow for a rapid increase in body mass and condition in preparation for their migration back to the breeding grounds in Alaska.

Mitigation Options

Several mitigative options have been proposed that could minimize exposure of BTCUs to bait containing the rodenticide during the eradication campaign on Palmyra Atoll (Flint 2010, G. Howald pers. comm.). These include:

1. Timing implementation of the eradication for when the population is lowest;
2. Modifying the methodology used to distribute the bait;
3. Trapping individuals and keeping them in captivity until risk of exposure is eliminated or greatly reduced or translocating trapped individuals to Christmas Island;
4. Hazing;
5. Supplemental feeding of a high lipid diet prior to implementation of the eradication campaign to increase fat stores, which may encourage more birds to migrate back to the breeding grounds in Alaska thereby exposing less birds to risks of primary and secondary poisonings.

However the main issue confronting these mitigative measures is that they cannot compromise the eradication campaign, otherwise the success of the project may be put at risk.

Recommended

1. Timing of eradication implementation

During a 2004 assessment of Palmyra Atoll for eradication feasibility (Howald et. al. 2004), the assessment team concluded that the most effective mitigation for these species is to conduct the eradication between early June and mid-July when most adult BTCUs have left the atoll for their breeding grounds in Alaska (Howald et. al. 2004). This will minimize the risk of short term rodenticide exposure to the majority of curlews overwintering on the Atoll. Any birds remaining on the atoll at this time of year are likely sub-adults (aged 1 to 3 years) that remain on the tropical Pacific islands until they mature (B. Gill email correspondence with B. Flint[6], Flint 2010).

Pierce et. al. (2008) noted that it was easier for Bristle-thighed Curlews to ingest rodenticide bait after it had been softened by rainfall. Therefore, if aerial broadcast will be employed it will be important to assess weather conditions prior to the bait drop in order to minimize exposure of the rodenticide bait to rainfall.

[6] Wildlife Biologist, US Fish and Wildlife Service, Pacific Reefs National Wildlife Refuge Complex, 300 Ala Moana Blvd. Room 5-231, Honolulu, HI 96850.

2. *Using an eradication method that may reduce exposure to the bait*

A large portion of Palmyra Atoll (approximately 48%) is comprised of nonnative coconut palm (*Cocos nucifera*) forming a dense vegetative canopy over the island that is utilized by the rats (Howald et al. 2004). Radio telemetry experiments on the Atoll compared the movements of rats live-trapped in coconut palms with rats trapped on the ground and demonstrated the use of a three dimensional environment with individuals regularly moving between the tree canopy and the ground (Howald et. al. 2004). Although logistically complex and costly, using a combination of bait stations and a modified aerial broadcast (or another method to accurately distribute bait into the palm trees) may be the best method to expose rats on the forest floor, as well as those inhabiting the vegetation canopy to the bait containing the rodenticide. These combined methodologies were used successfully during a ship rat (*Rattus rattus*), Norway rat (*R. norvegicus*) eradication campaign on islands in the Seychelles group, Indian Ocean (Merton et. al. 2002). If bait stations are not used there is an increased risk of primary and secondary poisoning of BTCUs because aerial broadcast will make the rodenticide bait more readily available to the birds and also to potential prey species such as land crabs and hermit crabs.

In addition to incorporating a combination of bait stations and selective aerial broadcast techniques, there are other ways to reduce rodenticide bait exposure and toxicity although some of these options could potentially compromise the eradication campaign[7]:

a) Brodifacoum versus Diphacinone Rodenticide

The second generation anticoagulant brodifacoum is one of the most commonly used rodenticide for rat eradications around the world (Howald et. al. 2007) because of its high acute toxicity - a single feeding will induce death (Eason and Spurr 1995, G. Howald pers. comm.). However, brodifacoum is also highly toxic to other species including birds, which increases the risk of primary and secondary poisonings to species including BTCUs.

Diphacinone, a first generation anticoagulant is less persistent and virtually non-toxic to birds when compared to brodifacoum (e.g. Newton et. al. 1990). However this rodenticide is most effective against rats when they can freely consume multiple doses for 10 days or more without running out of bait (Fisher & Broome 2004, Swift 1998). There are obvious challenges associated with using this rodenticide. For example:

- Rats must select the rodenticide bait over any naturally occurring food sources available to them on the Atoll. This is compounded by the palatability issues associated with diphacinone (G. Howald pers. comm.).
- Using diphacinone would require a significant amount of rodenticide bait being distributed on the Atoll- 100 tons compared to 50 tons if brodifacoum was used (G. Howald and A. Wegmann pers. comm.).

Although highly toxic to birds, brodifacoum is likely the preferred choice based on its acute toxicity and the obvious disadvantages of using diphacinone with respect to successful rat eradication on Palmyra Atoll.

[7] Note: it is not feasible to collect rat carcasses due to the density of vegetation on the islands and the rapidity in which land crabs consume carrion. Therefore this was not included in the list of proposed options to reduce rodenticide bait exposure.

b) *Bait Coloration:*
The rodenticide bait used for the Palmyra Atoll eradication should be dyed blue-green, which is a color known to be least visible/preferred to non-target species including shorebirds (National Park Service 2000).

c) *Bait Station Design*
Howald et. al. (2004) proposed a modified bait station design that would exclude the majority of land crabs and hermit crabs, which are preferred BTCU prey species. Using a design similar to this may help to reduce secondary exposure to the rodenticide. However, it is not possible to keep all hermit crabs and land crabs, or other BTCU prey, such as geckos and insects out the bait stations.

Recommended

3. Capturing Bristle-thighed Curlews prior to the eradication campaign

Live trapping BTCUs prior to the eradication campaign and either holding the birds in captivity on the Atoll, or translocating them to another island would eliminate the risk of exposing these individuals to primary and/or secondary rodenticide exposure. Although feasible, it is unlikely that a significant portion of the wintering population, the majority of which are likely sub-adult birds (1-3 years old), could be captured (please refer to Appendix 1 for opinions from several prominent wading bird specialists on the challenges of capturing BTCUs). Furthermore there are also risks associated with capturing birds, including physical injury and physiological stress that could result in the death of some individuals.

If this mitigative option is selected, prior to undertaking a trapping campaign all communal sites would need to be identified because BTCUs tend to congregate in small groups when roosting or foraging. Several different trapping methods would need to be employed to maximize success because this species tends to be extremely wary. Marks and Redmond (1994) captured Bristle-thighed Curlews on Laysan Island in the South Pacific at night using a hoop net after temporarily blinding individuals with a flashlight. There are a number of other trapping options including walk in traps, although the potential of other species incapacitating the trap such as land crabs and rats would have to be taken into consideration. Consultation with shorebird/wading bird experts regarding trapping methodologies would be essential to maximize capture success.

If a trapping campaign is successful, the captured BTCUs could be:

a) held in captivity on the Atoll until during the eradication campaign until the bait has degraded and the toxicity in prey items such as land crabs has decreased to levels that will not put BTCUs at risk; or
b) transported and released on Christmas Island.

Both options have distinct advantages and disadvantages that are described in Table 4.

Table 4. Pros and cons of temporary captivity on Palmyra Atoll versus translocation of trapped BTCUs to Christmas Island.

Capture/hold options	Difficulty	Risk to captive birds	Cost	Advantages	Disadvantages
 ***Option 1: Keep birds in captivity on Palmyra Atoll***	***High*** • Maintaining wild birds in captivity can be challenging. • Need experienced personnel dedicated to maintaining the captive birds. • Birds would be in captivity for approximately 6 weeks[8].	***High*** • Stress. • Injuries in captivity. • Disease. • Death. • Diet challenges (keeping birds healthy).	***Low/Moderate*** • Build aviaries to house birds. • Feed birds. • Staff wages to maintain birds.	• Eliminates exposure to rodenticide bait for a portion of the BTCU population. • Relatively inexpensive.	• Could lose birds as a result of stress, injury, and/or starvation. • BTCUs are quite aggressive so birds may need to be housed individually. • Need experienced personnel dedicated to maintaining captive birds.
Option 2: Translocate birds to Christmas Island and release	***High*** • Temporarily holding and maintaining wild birds in captivity until enough birds are captured for translocation is challenging. • Need experienced personnel dedicated to maintaining the captive birds. • Transport logistics (boat/helicopter).	***High*** • Stress. • Injuries while being staged for translocation or during translocation. • Disorientation/death from moving birds to a foreign location. • Diet challenges (keeping birds healthy while being staged for translocation or during translocation).	***High*** • Cost of boat or plane to translocate birds • Build aviaries to temporarily house birds on Palmyra until enough are captured to justify costs of transporting them to Christmas Island. • Feed birds. • Staff wages to maintain birds during staging and translocation.	• Eliminates exposure to rodenticide bait for a portion of the BTCU population without having to hold birds for approximately 6 weeks.	• Could lose birds as a result of stress, injury, starvation, or disorientation. • Logistically difficult – need to house captured birds until transport is available. Birds may need to spend weeks in captivity until enough individuals can be captured to warrant the cost of transporting them. BTCUs are quite aggressive so birds may need to be housed individually. • Need experienced personnel to take care of birds until they can be released on Christmas Island.

[8] The period when the bait is on the ground and toxicity in prey items such as land crabs is sufficiently high enough to harm BTCUs (Buckelew et. al. 2005).

Housing BTCUs on Palmyra Atoll may be less expensive and less logistically complex compared to translocating birds to Christmas Island. If translocation to Christmas Island is preferred there are several questions that must be answered prior to implementing this mitigative option:

- Is Christmas Island far enough from Palmyra Atoll to ensure that the birds do not immediately return to Palmyra Atoll upon release? BTCUs exhibit high site fidelity on their breeding and wintering grounds with many individuals observed occupying the same site on an island for multiple years (Marks and Redmond 1996).
- Is the prey base for BTCUs on Christmas Island similar to that found on Palmyra Atoll?
- Will the birds be disoriented by the translocation with respect to route finding during migration to their breeding grounds in Alaska?

<u>Holding birds in captivity - challenges</u>
Although feasible, holding wild birds in captivity, especially active species such as waders can be very challenging (please refer to Appendix 2 for opinions from several prominent wading bird specialists on the challenges of keeping BTCUs in captivity). However, several species of shorebirds and waders have been successfully held in captivity for short periods of time (D. Lank email correspondence with B. Flint, R. Lanctot email correspondence with K. Swinnerton, M. Rubega email correspondence with K. Swinnerton. See Appendix 2 for additional information). Birds have also been successfully captured and temporarily housed for other rat eradication campaigns including a project recently completed on Frégate Island (Merton et al. 2002). Prior to the operation 39 magpie-robins (100% of the island's population) and 330 Seychelles fodys (50% of the island's population) were taken into captivity before the eradication campaign was initiated. The birds were held in rat-proof enclosures until the rodenticide baits were no longer available (6 weeks). No magpie-robins died during the period of confinement although 7.5% of the fodys perished (Merton et. al. 2002).

It is possible that some BTCUs may die during the captivity period due to stress, injury or illness. Careful planning is required to ensure that the birds remain healthy during the period of confinement including consultation with shorebird/wading bird experts regarding housing options (e.g. house birds separately or hold small groups in large, lightly netted aviaries) and avian nutritionists for diet and nutrition requirements.

4. *Hazing*

Bird hazing and deterrent techniques are widely employed to disperse and exclude birds from croplands, aquiculture facilities, and airports. Hazing techniques rely on the use of auditory and visual devices to scare birds away from an area, e.g., bird distress calls, pyrotechnics, propane exploders, flashing lights, effigies of humans or predators, and flagging (Greer and O'Connor, 1994). However, birds can rapidly habituate to these tactics if the use of such devices falls into a predictable pattern (Brush, 1971; Bornford and O'Brien, 1990). Thus, hazing requires diligence to ensure the effectiveness of the negative stimuli.

Pierce et. a. (2008) suggested that it may be practical to attempt to scare BTCUs away from the target islands prior to implementing an eradication campaign if aerial broadcast of rodenticide bait is used. However, it is unlikely that this technique would be an effective solution to reducing exposure of BTCUs to the rodenticide bait given the mobility of this species, high site fidelity (Marks and Redmond 1996), and general logistics required to carry out an effective hazing operation.

5. ***Supplemental feeding of a high lipid diet to encourage migration to breeding grounds***
   Migratory birds undergo an endogenously controlled seasonal onset of fat storage in preparation for departure to the breeding or wintering grounds (Gwinner 1990). Researchers have suggested that differences in fat deposit gains and migratory departure dates are correlated with food abundance (e.g. Bibby and Green 1981, Graber and Graber 1983). Supplemental feeding a high lipid diet (chicken eggs) to the BTCUs on Palmyra Atoll prior to implementation of the eradication operation may thus encourage more adults[9] to depart for the Alaskan breeding grounds, or at least enable a subset of this population to reach the required body condition more rapidly, resulting in earlier departure dates from the Atoll. However, more recent studies suggest that birds possess heritable or acquired differences in fuelling efficiency and/or moulting resulting into variations of migration schedules (Moller 1994, Conklin et. al. 2010) while other experts have suggested that birds such as BTCU can assess conditions on their breeding grounds from great distances thus influencing whether or not birds migrate or delay their departure (B. Gill email communication with B. Flint). Therefore, supplemental feeding of BTCUs may not greatly influence departure dates or the actual number of birds migrating back to the breeding grounds.

   Although supplemental feeding may not greatly affect departure dates or the number of birds migrating to the breeding grounds it is a relatively simple and low cost mitigative measure to implement. Therefore a pilot study should be initiated as soon as possible to determine if BTCUs will accept supplemental feeding (e.g. hardboiled chicken eggs). Consultation with avian nutrition experts regarding supplemental feeding would be required prior to implementing the pilot study.

Summary

Non-target impacts to species including shorebirds during invasive species eradication operations have been previously reported (e.g. Merton et. al. 2002, Pierce et. al. 2008). Based on these studies it is reasonable to anticipate that 60% or more of the BTCUs present on Palmyra Atoll during the eradication campaign may be at risk of primary and secondary poisoning. The population viability analysis completed by Island Conservation predicts that any BTCU mortalities resulting from the eradication operation would have a minor impact on the future population health. However the model predictions should be interpreted with caution based on the vulnerability of this species due to its small population size and current state of decline.

The degree of impact to BTCUs will be influenced by the number of birds present on the Atoll during the eradiation operation, including the number of adults versus sub-adults[10], as well as the method of bait disbursement. Although the significance of sub-adult mortalities versus adult mortalities on the population's health is unknown, because this species is long-lived, the mortality of sub-adult birds may cause less of an impact than adult mortalities.

Several mitigative options have been recommended in this document that may minimize, but not eliminate impacts to BTCUs during the eradication operation. There are risks to BTCUs associated with some of the measures, including physiological stress from disturbance and potential for accidental mortalities (e.g. resulting from live trapping). These risks must be weighed against the risk of exposure to the rodenticide bait.

[9] It is unlikely that sub-adults will migrate to the breeding grounds even with supplemental feeding.
[10] It is likely that a higher number of sub-adults will be present on the Atoll during the eradication operation.

It is also important to evaluate how the mitigative options may affect the outcome of the actual eradication operation. If the success of the campaign may be compromised by implementing the mitigative options, the anticipated risk to BTCUs may be too great (e.g. the eradication operation fails *and* BTCUs are killed).

However, if the outcome of the operation is not affected by implementing the mitigative options, the successful eradiation of rats from Palmyra Atoll can result in direct and indirect benefits to BTCUs, including reduced disturbance (Marks et. al. 1990) and a potential increase in the breeding population of Sooty Terns (Sooty Tern eggs are a preferred food source of BTCUs, Bailey 1956, Ely and Clapp 1973). Therefore, the potential loss of a portion of the wintering BTCU population on Palmyra during the eradication campaign may be offset by the long-term benefits to the overall population health of this species, to other species on the Atoll, and to the island ecosystems as a whole (Dowding et al. 1999, Empson & Miskelly 1999, Lovegrove & Ritchie 2005).

Recommended Additional Research

1. Conduct all-Atoll and runway surveys in 2011 between June and early July. Compare survey results to 2010 (e.g. was 2010 all-Atoll survey an anomaly?). Identify numbers of adults versus sub-adults present on the Atoll at this time;
2. If BTCUs will be trapped, identify day/night roost sites and other aggregation sites;
3. Undertake a pilot study to determine if BTCUs will accept supplemental feeding (e.g. hardboiled chicken eggs);
4. Investigate options that can be implemented to accurately disperse rodenticide bait into the vegetative canopy.

About the Author

Chris Gill is a registered professional biologist with a Master of Science degree in environmental toxicology from Simon Fraser University (1998). He is currently involved in two proposed invasive mammal eradication projects in British Columbia in collaboration with Island Conservation. Previously Chris has provided expert opinion on the impact of the Anacapa Island rat eradication project (Island Conservation) on the resident raptor population and has worked throughout North American including projects in Florida (effects of mercury contamination in wading birds), California (impact of wind generation plants on Golden Eagles), Arizona (bald eagle research project), Montana (raptor migration study), and Idaho (wild turkey research, radio tracking falcons). Chris has coauthored papers on the effects of food supply, environmental contaminants, tides, and weather on raptor and wading bird populations.

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Appendix 1 – Expert opinions on live trapping BTCUs

Eight scientists with significant field experience working with BTCUs or similar species were consulted by Flint (2010), A. Wegmann, or K. Swinnerton regarding the feasibility of capturing this species. Below are pertinent excerpts from their email communications or conversations.

Jeff Marks
Director of Bird Conservation for Montana Audubon

…I think it would be difficult to catch a lot of birds, and perhaps even more difficult to hold them…

Lee Tibbitts
USGS, 4210 University Dr., Anchorage, AK

..I agree that it would be very difficult to capture a large number of birds in the time frame that you would like (i.e., around the application time)...

Wally Johnson
Plover expert

…In my opinion, it would be nearly impossible to catch/transport/hold BTCUs. Seems like it would be a huge challenge to capture more than a few…

Bob Gill
Shorebird research program, U.S. Geological Survey, Alaska Science Center.

…very unlikely that a meaningful number could be captured….

David Lank
Dept. of Biological Sciences, Simon Fraser University, Burnaby BC Canada

…You are dealing with a single location, have more infrastructure to work out of and a more focused goal. I am only in part being naive here. I know that both species are wary, no doubt about that, particularly the curlews, but we could give it a try…

Richard Lanctot
Shorebird Coordinator, Alaska Region, US Fish and Wildlife Service, Migratory Bird Management, Anchorage, AK

…Capturing all or a significant portion of the bird population would be difficult. To capture these birds would require as Dov [Lank] said a very focused effort and a large effort.
Bristle-thigheds don't go around in huge flocks so the reward for effort might be a bit meager!...

Simon Tonge
Executive Director, Paignton Zoo Environmental Park., Totnes Road, Paignton, Devon

…Catching the birds could also be extremely difficult, I would guess…

Margaret Rubega
Associate Professor of Ecology and Evolutionary Biology, University of Connecticut

…In principle, I don't see why it wouldn't be possible to catch and hold the number of birds you are talking about...

Appendix 2 – Expert opinions on keeping BTCUs in captivity

Eight scientists with significant field experience working with BTCUs or similar species were consulted by Flint (2010), A. Wegmann, or K. Swinnerton regarding the feasibility of housing this species. Below are pertinent excerpts from their email communications or conversations.

Jeff Marks

" I held birds over night several times without incident until the night when I put two in the screen tent. One was dead by morning, for reasons unknown. They did not seem to eat (dead and incapacitated ghost crabs) or drink overnight, but sample sizes were small."

Lee Tibbitts

…I doubt you could hold them in captivity and keep them healthy; stress levels would be so high in the captive birds and we've found that stress is a big factor in how curlews ultimately tolerate banding and satellite-tagging…

Wally Johnson

In my opinion, it would be nearly impossible to catch/transport/hold BTCUs. Seems like it would be a huge challenge to capture more than a few, and there would be injuries and problems trying to hold them for longer than the usual time required for routine banding. I guess I'd view it as a necessary trade-off - the loss of some birds for the long-term good of the atoll...

Bob Gill

…Any curlew husbandry should be thoroughly evaluated a year ahead of time (different needs by age, sex, molt status, etc.). Recent experience with Dunlin and Rock Sandpipers was very enlightening and not something I'd want to jump into with curlews…

D. Lank email correspondence with B. Flint (message truncated)

If you captured the birds, I believe that you could keep them. I have maintained golden plovers in captivity for over a year. The curlews might be more of a challenge, but I believe that they could handle crowding for a month. They may be in the wild quite territorial, but like other shorebirds, would adapt to situations. The golden plover, for example, can either be territorial during the winter or flock. I don't see fundamentally why the curlews would not do so as well.

R. Lanctot email correspondence with K. Swinnerton

As a general rule with waders the bigger they are the more of a challenge they become because they are aggressive to each other, when confined, and as they are so mobile they are extremely prone to trauma injuries when flying into fence posts etc. Our experience with black-tailed godwits at Living Coasts was not a happy one for that reason.

If it has to be done in the winter I am sure that you could probably hold small groups of birds in large, lightly-netted aviaries, and if they are like other curlews they should be pretty catholic feeders that will learn quite quickly to take food from a dish (but do we know much about their feeding ecology?). So from that perspective the task is 'doable' but you will almost certainly get losses from trauma unless you feather clip them but then you would be stuck with them for a year.

Simon Tonge email correspondence with K. Swinnerton, Island Conservation (message truncated)

… If it has to be done in the winter I am sure that you could probably hold small groups of birds in large, lightly-netted aviaries, and if they are like other curlews they should be pretty catholic feeders that will learn quite quickly to take food from a dish (but do we know much about their feeding ecology?). So from that perspective the task is 'doable' but you will almost certainly get losses from trauma unless you feather clip them but then you would be stuck with them for a year.

Margaret Rubega email correspondence with K. Swinnerton (message truncated)

…In principle, I don't see why it wouldn't be possible to catch and hold the number of birds you are talking about. I would be more than happy to work with you on this, assuming that you really have exhausted all the other possibilities, because catching and holding the birds seems to me like a very labor and resource-intensive way to achieve the ultimate goal…
….Jacklighting them on a high tide?....

So: to be clear: I don't think holding the birds would be that much of a challenge, though it will likely be expensive --- it will either be labor intensive, so you'll need a lot of people, or it can be less labor intensive, but then you have to build good facilities.

Dov [Lank] holds that many birds all the time, though not in temporary facilities. I've held....10 species of shorebird now, for periods ranging up to 3 years, although none since UConn closed the animal care facility containing my spaces. I've advised a couple of zoos on a number of other species, and I believe you can hold pretty much anything in captivity for six weeks with the right resources and careful planning ahead of time.

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APPENDIX I

HERMIT CRAB PREDATION BY BRISTLE-THIGHED CURLEWS

Slamming Crabs: Bristle-thighed Curlew predation of hermit crabs (*Coenobita* sp.) at Palmyra Atoll

A technical report prepared for the US Fish and Wildlife Service, Palmyra Atoll National Wildlife Refuge

Alexander Wegmann*, February 1, 2011.

*Contact: Island Conservation, 100 Shaffer Rd, Santa Cruz, California, 95060, +1-831-359-4787; alex.wegmann@islandconservation.org

INTRODUCTION

Several million shorebirds annually migrate from summer Arctic breeding grounds to winter foraging areas (Morrison et al. 2000) along nine primary north-to-south flyways (Piersma and Lindstrom 2004). Many species spend non-breeding months on Polynesian islands in the tropical pacific. This habitat shift, from Arctic tundra to tropical islands, often requires diversified foraging behavior by migratory birds. The Bristle-thighed Curlew (*Numenius tahitiensis*), one of the largest wading birds (Scolopacidae) in the world, winters on islands from the Northwestern Hawaiian Archipelago well into the south Pacific. Bristle-thighed Curlews (BTCU) leave Pacific wintering islands in late July, and depart for Arctic breeding grounds in early May (Marks 2002). The BTCU is the only migratory shorebird that winters exclusively on oceanic islands, the only shorebird that becomes flightless while molting feathers, and the only shorebird known to use "tools" (Marks and Hall 1992) while foraging. BTCUs engage in "slamming," to break shells and carapaces to access high yield food resources like seabird eggs and crustaceans (Marshall 1951, Child 1960, Carpenter et al. 1968, Marks and Hall 1992). When slamming, a bird holds the prey in its beak, raises it overhead, and hurls it against a flat rock or hard patch of earth. This action repeats until the prey, or the prey's protective cover, is broken and easily consumed.

On many tropical islands, land crabs, as the largest, native terrestrial consumers influence plant recruitment through decomposition of leaf-litter (O'Dowd et al. 2003) seed dispersal (Lindquist and Carroll 2004), and seed and seedling predation (Sherman 2002, Lindquist and Carroll 2004) . Few records of BTCU foraging behavior document hermit crab predation (Marshall 1951, Gill and Redmond 1992), while most published accounts involving terrestrial decapods and BTCUs discuss shore crabs (*Hemigrapsus* sp.) (Leeman et al. 2001), ghost crabs (*Uca* sp.) and fiddler crabs (*Ocypode* sp.) (Marks et al. 2002). This study provides the first quantitative account of hermit crab predation by BTCUs, and discusses how this foraging activity may put BTCUs at risk of secondary poisoning during toxicant based invasive mammal eradication programs.

METHODS

This study lasted 106 days, from 30 June to 14 October, 2006, at Palmyra National Wildlife Refuge (Palmyra) in the Line Island Archipelago (5º 52' N, 162 º 06' W). Palmyra is a tight formation of 25 small, low islands totaling 218 hectare of emergent land; shallow coral reef stretches 16 km east to west by 3 km north to south. Rainfall on Palmyra often exceeds 4000 mm annually (Depkin 2002), and Palmyra's tropical climate promotes impressive vegetative growth. The atoll is home to five native land crab species, and one introduced rodent (*Rattus rattus*). Eleven seabird species nest and roost at Palmyra, while ten shorebird species migrate to the atoll seasonally (Wegmann 2006). Of Palmyra's five land crab species, the two hermit crabs, *Coenobita perlatus* and *C. brevimanus*, are most abundant. An atoll-wide land crab population survey conducted in July, 2004, measured the following mean hermit crab densities (crabs/ha.) for the three dominant forest types: *Pisonia grandis* forest, *Tournefortia argentea* forest, and *Terminalia catappa* forest; 123 ± 47 (SD), 193 ± 113 (SD), and 324 ± 87 (SD) (Howald et al. 2004).

I monitored eight BTCU slamming stations in three different forest habitats on two islands at Palmyra; One station in *T. argentea* forest, two stations in *T. catappa* forest, and five stations in *Pisonia grandis* forest. I identified slamming stations by the conspicuous arrangement of tens to hundreds of fractured turban snail (Turbanidae) shells and other gastropod shells surrounding a flat stone. At each station I first counted the number of slammed shells by collecting and tallying only whole shells or apex shell fragments, thus avoiding multiple tallies from fragments of the same shell, and then swept all shell fragments clear from a 1 m. diameter swath around the slamming rock (Figure 1). The swaths were cleaned again after each sample. Each shell tallied equaled one hermit crab predation event. Turban snail shells (2-5 cm long), were counted as adult hermit crab predation events, and smaller gastropod shells (0.5-2 cm long) equaled juvenile hermit crab predation events. After initial sampling, I opportunistically re-sampled each slamming station; shells in the previously-swept perimeter around the slamming stone counted as new predation events.

From 30 August to 7 September, I positioned a Bushnell Trail Scout® digital motion-sensing camera trap at one BTCU slamming station in *P. grandis* habitat to identify other potential organisms responsible for broken turban snail shells near slamming stations. BTCUs are easily disturbed by humans, often flushing 30-50 meters away from an observer (A. Wegmann per. obs.); camera traps allow for direct observation of slamming stations. The camera trap recorded still images and fifteen-second video clips.

RESULTS

Periodic sampling of BTCU slamming stations at Palmyra Atoll shows that hermit crab predation rates vary by station, and predation on adults is more intense than predation on juveniles (one-tailed T test, $T = 1.99$, $P = 0.03$) (Table 1). The five slamming stations sampled in *P. grandis* forest represent all of the slamming stations on 1.2 ha Home Island. The median slamming rate for Home Island is 0.23 hermit crab predation events per day; scaled to the island's area, this becomes 0.19 crab predation events per day, per hectare. Palmyra Atoll's hermit crab population is estimated at 248,956 individuals (Howald et al. 2004). Based on the Home Island median slamming rate per hectare, Palmyra's BTCU population of 250-300 individuals (USFWS unpublished data 2010) slams and consumes 1,306 hermit crabs during their 315 day wintering season at Palmyra.

The camera trap captured 26 images (still images and video clips) where a BTCU was near or standing on the slamming stone, four images with a Pacific Golden Plover (*Pluvialis fulva*) near the slamming stone, and two images with a large land crab (*Cardisoma carnifex*) near the slamming stone. Of the 26 BTCU images, six images show BTCUs in close association (< 0.5 m) with a hermit crab, three images show BTCUs touching the crab with their bills, and one video clip shows a BTCU slamming an adult hermit crab.

There is no information available on individual BTCU behavior variation at Palmyra. We do not know whether some individuals are hermit crab specialists and others do not engage in this behavior, or whether all of Palmyra's BTCU prey on hermit crabs.

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TABLES AND FIGURES

Table 1. Number of hermit crab predation events at BTCU slamming stations by habitat type and number of days after the initial sample. Predation rate is a measure of individual crabs taken per day. A median predation rate is only shown for the *P. grandis* habitat as this was the only grouping of slamming stations with both adult and juvenile predation events

				Days Since Initial Sample						Predation Rate	
Station	**Habitat**	**Initial sample**		**18**		**34**		**41**			
		Ad.	Jv.	Ad.	Jv.	Ad.	Jv.	Ad.	Jv.	Ad.	Juv.
1	*T. argentea*	149	23	*	*	*	*	0	0	0	0
2	*P. grandis*	70	9	*	*	1	1	4	0	0.30	0.03
3	*P. grandis*	27	5	*	*	2	0	0	0	0.06	0
4	*P. grandis*	168	21	*	*	8	0	14	5	1.12	0.12
5	*P. grandis*	762	288	*	*	5	4	*	*	0.15	0.12
6	*P. grandis*	135	14	*	*	14	2	*	*	0.41	0.06
7	*T.catappa*	1	14	*	*	0	0	*	*	0	0
8	*T.catappa*	18	4	7	0	*	*	*	*	0.39	0

* Data is not available

Figure 1. (A) Turban Snail shell carried by a hermit crab (*Coenobita perlatus*), the arrow indicates the shell's apex. (B) Slamming station prior to initial assessment; note the *C. perlatus* on the slamming rock and surrounding shell fragments. (C) Slamming station swept clean to 1m radius from the stone.

APPENDIX J

PALMYRA FOOD WEB

Appendix J. Palmyra Food Webs

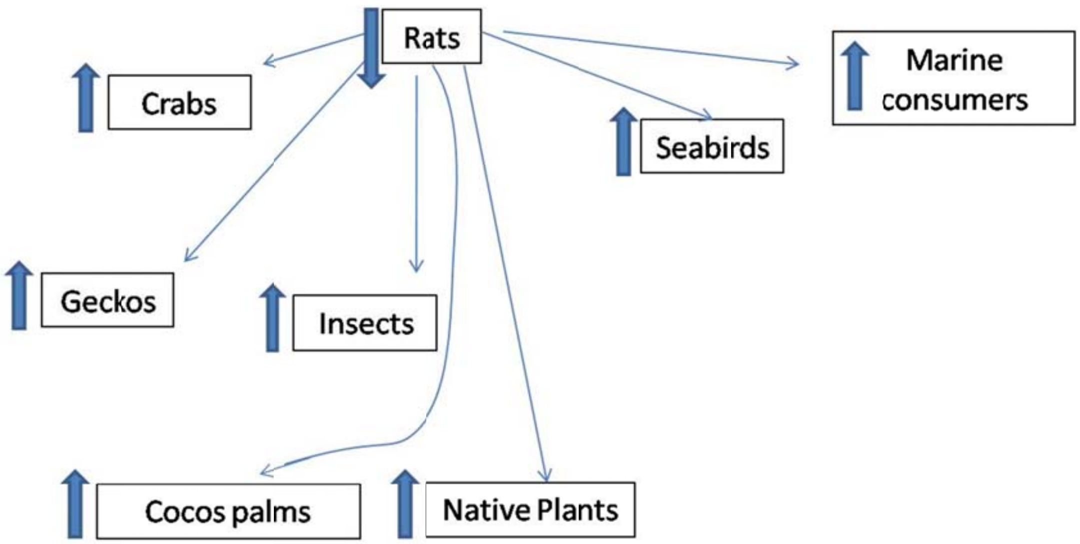

Fig 1: Hypothesized direct effects of rats on Palmyra. Thin arrows show an interaction; bold arrows indicate likely direction of change.

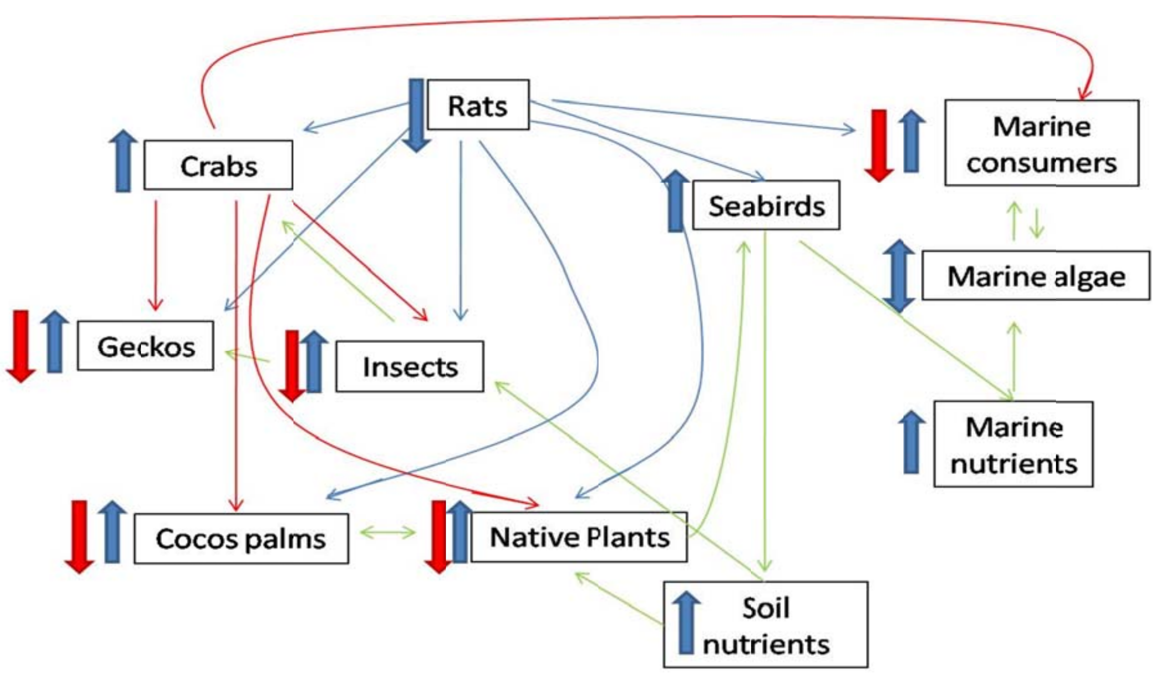

Figure 2: Hypothesized direct & indirect effects of rats on trophic interactions at Palmyra. Thin arrows show an interaction (blue are interactions driven directly by rats, green are interactions driven indirectly by rats, red are interactions driven directly by crabs). Bold blue arrows indicate likely direction of change. In some cases increases in crabs could counter changes caused by decreases in rats (bold red arrows)

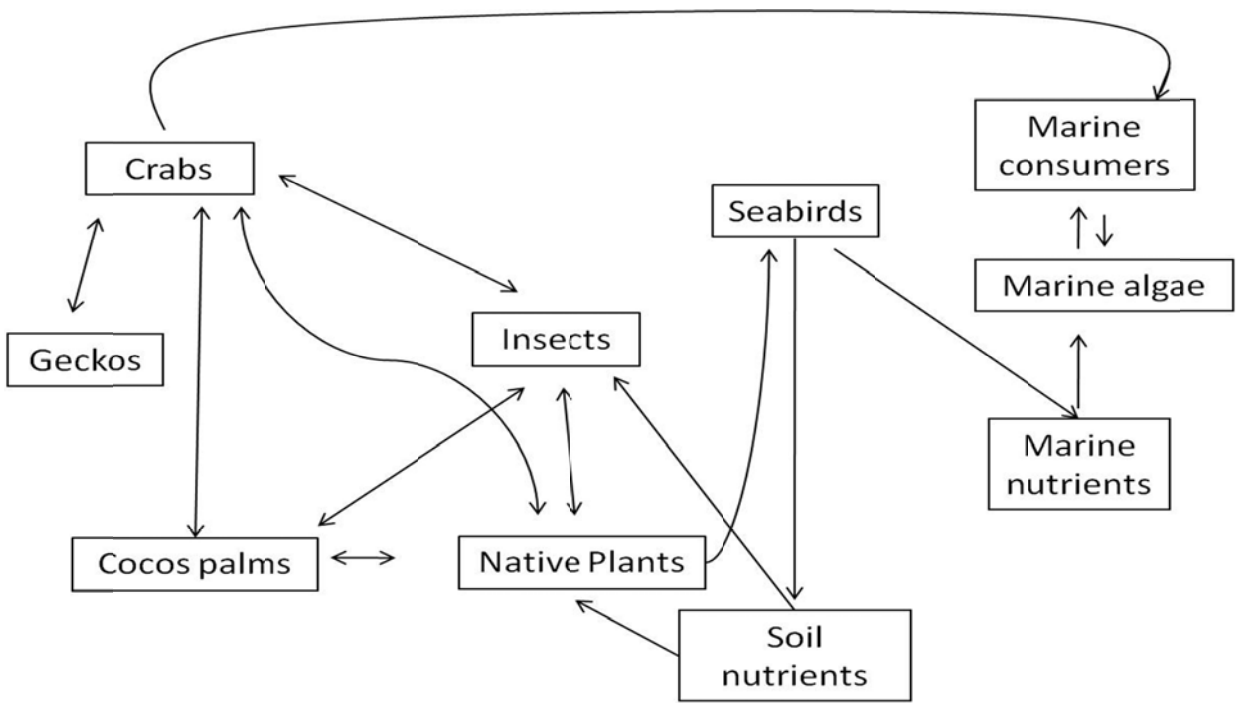

Figure 3: Palmyra food web with rats removed.

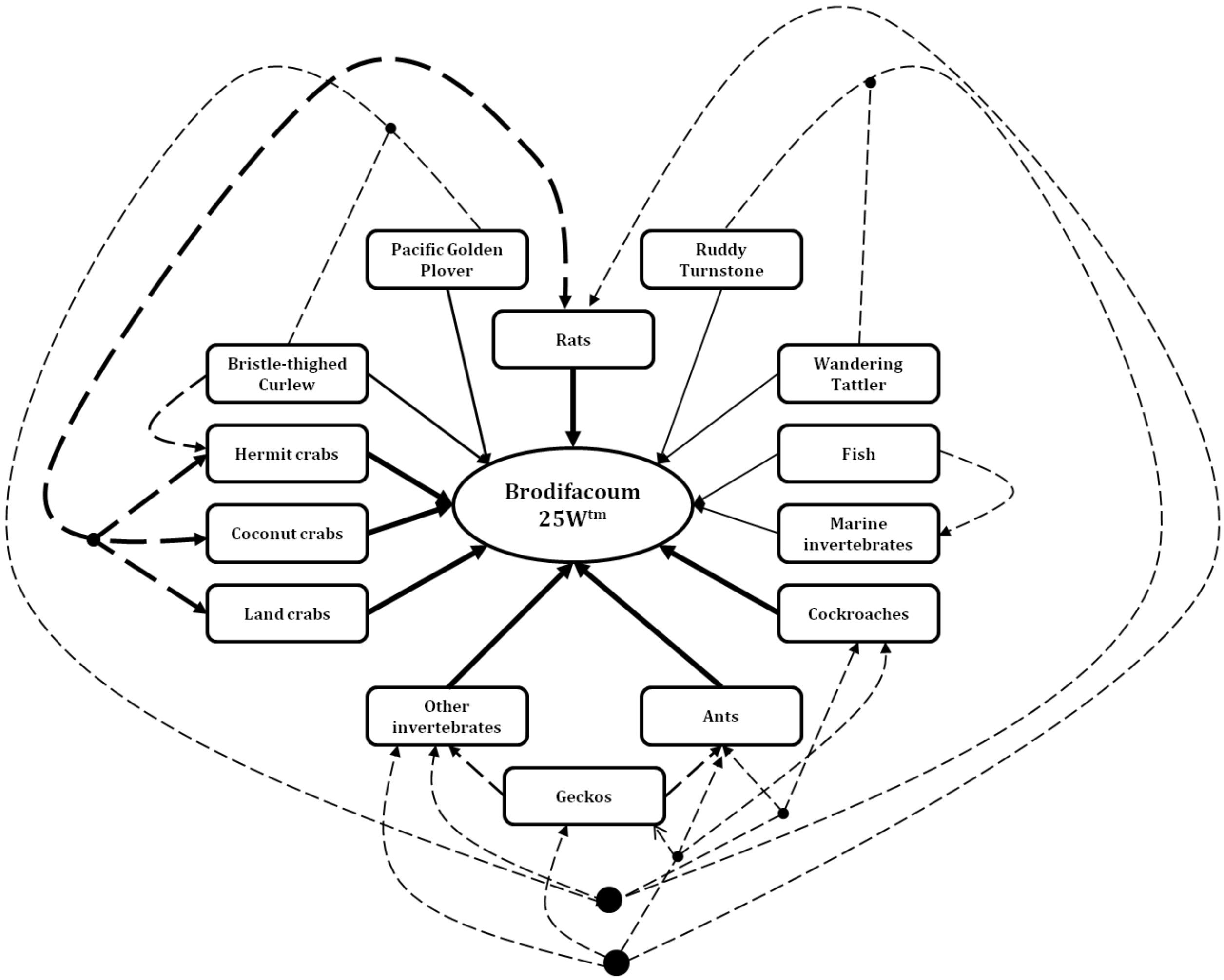

Figure 4. A simplified, terrestrial food-web for Palmyra Atoll that centers on direct and indirect consumption of Brodifacoum 25W^{tm} and subsequent exposure to brodifacoum through secondary pathways. Primary consumption pathways are represented by solid lines, and secondary consumption pathways are represented by dashed lines. Line thickness is scaled to the likelihood of a consumption pathway being realized; a thicker line indicates that the indicated consumption pathway is "more" likely to occur given the foraging biology of the organisms involved in the pathway. Arrows indicate the direction of the pathway, and circles are nodes that connect similar pathways.

Draft Operational Details:

Palmyra Atoll Rat Eradication – Alternative C (Preferred Alternative)

Prepared by:
Island Conservation
100 Shaffer Rd
Santa Cruz, CA 95060

Contact:
Alex Wegmann
alex.wegmann@islandconservation.org

TABLE OF CONTENTS

1 INTRODUCTION

1.1 Purpose

The purpose of this conservation project is to aid in the protection and restoration of the unique native species and habitats of Palmyra Atoll (Palmyra) by removing non-native rats from the atoll that harm native trees, seabirds, land crabs, other populations of native species, and ecosystem processes.

Given the widespread successful colonization of rats on islands and their impact on native species, rats are identified as key species for eradication. The most pronounced impact of introduced rats on island ecosystems is the extinction of endemic species of mammals, birds and invertebrates (Andrews 1909, Daniel and Williams 1984, Atkinson 1985, Howald et al. 2007) (Meads et al. 1984; Hindwood 1940; Tomich 1986). Even if species are not completely extirpated, rats can have negative direct and indirect effects on native species and ecosystem function. For example, comparisons of rat-infested and rodent-free islands, and pre- and post-rat eradication experiments, have shown that rats depress the population size and recruitment of birds (Thibault 1995, Jouventin et al. 2003) (Campbell 1991), reptiles (Whitaker 1973) (Bullock 1986; Cree et al. 1995; Towns 1991), plants (Campbell et al. 1984; Pyle et al. 1999; Wegmann 2009) and terrestrial invertebrates (Ramsey 1978; Bremner et al. 1984).

In addition to preying on seabird chicks, eggs, and sometimes adults, introduced rats feed opportunistically on plants, and alter the floral communities of island ecosystems (Campbell and Atkinson 2002, Wegmann 2009), in some cases degrading the quality of nesting habitat for birds that depend on the vegetation (Young et al. 2010). On Tiritiri Matangi Island, New Zealand, ripe fruits, seeds, and understory vegetation underwent significant increases after rats were eradicated from the island, indicating their previous impacts on the vegetation (Graham and Veitch 2002). At Palmyra, the native tree *Neisosperma oppositifolium* established on islands that were temporarily cleared of rats – this is the first record of *N. oppositifolium* recruitment since rats were introduced to Palmyra 60 years prior.

Rats are known to cause disturbance to sensitive breeding seabirds, resulting in failed breeding attempts and higher susceptibility to predation by other species (Tomkins 1985, Jouventin et al. 2003). Rats also affect the abundance and age structure of intertidal invertebrates (Navarrete and Castilla 1993). Rats alter key ecosystem properties; for example, total soil carbon, nitrogen, phosphorous, mineral nitrogen, marine-derived nitrogen and pH are lower on invaded islands relative to rat-free controls (Fukami et al. 2006). Such changes are a result of indirect negative effects of rats mediated by the reduction in seabird populations – rat predation often drives seabird colonies to near-extirpation (Moller 1983, Atkinson 1985, McChesney and Tershy 1998), resulting in the loss of seabird-derived nutrients on islands (Fukami et al. 2006).

By removing rats from Palmyra, we aim to safeguard the atoll's indigenous flora and fauna, and create a refuge for species within the central Pacific region that are at risk of extinction.

This project will achieve a monumental conservation milestone for the Refuge, and will establish a benchmark for subsequent eradication campaigns on other tropical islands.

1.2 Agencies

In 2001, after a long history of military and private ownership, most of Palmyra and the surrounding coral reef were designated as a National Wildlife Refuge by the Secretary of the Interior. The U.S. Fish and Wildlife Service (FWS) and The Nature Conservancy (TNC) co-manage Palmyra's emergent land area, and in 2009 Palmyra was included within the Pacific Remote Islands Marine National Monument.

In 2008, a three-party partnership (FWS, TNC, and Island Conservation (IC)) was formed to seek funding for, develop, and implement a rat eradication program at Palmyra.

2 GOALS, OBJECTIVES, OUTCOMES

2.1 Goals

The goal of this project is to aid in the protection and restoration of Palmyra's unique native species and habitats by removing non-native rats that harm populations of native trees, nesting seabirds, and land crabs.

2.2 Objectives

The objectives of this project are:

- The complete and permanent removal of black rats from Palmyra with minimal negative impact to native biota.
- Testing and documentation of rodent eradication tools and monitoring methods tailored for tropical environments.

2.3 Outcomes

The anticipated outcomes from this conservation action are:

- Increased recruitment of native tree species
- Increased fledging success for several seabird species, and possible recruitment of several species that were likely extirpated from the atoll in the 20th century.
- Creation of potential refuge for two critically endangered land bird species: *Acrocephalus aequinoctialis* (Christmas Island Warbler) and *Prosobonia cancellata* (Tuamotu Sandpiper).
- Development of conservation tools that will benefit future rodent eradication campaigns on tropical islands.

3 PROJECT SITE

3.1 Biogeography

Palmyra is among the most isolated island systems in the world. It lies in the central Pacific approximately 350 nautical miles north of the equator: longitude 162 04’ 59.05" W, latitude 005 52’ 55.54" N (Figure 1). Palmyra is part of the chain of islands called the Northern Line Islands, along with Kingman Reef to its northwest and the Kiribati Line Islands to its south.

Similar in climate to archetypal continental and high island tropical rainforests, yet drastically dissimilar in biogeography, the tropical forest systems in the Northern Line Islands lack species richness and diversity of flora and fauna (Rock 1916, Mueller-Dombois and Fosberg 1998). Palmyra has a remnant, regional flora that is typified by low species richness and low rates of endemism (Wester 1985, Mueller-Dombois and Fosberg 1998), yet this atoll provides important habitat for resident and migratory fauna, including seabirds, shorebirds, reptiles, and land crabs.

Through the last two-hundred years, Palmyra experienced major habitat manipulation and numerous plant and animal invasions, including the introduction of black rats (*Rattus rattus*). Palmyra’s biotic community is no longer subject to direct anthropogenic disturbance, and this latter factor renders Palmyra’s biotic community unique among Central Pacific tropical moist forest systems.

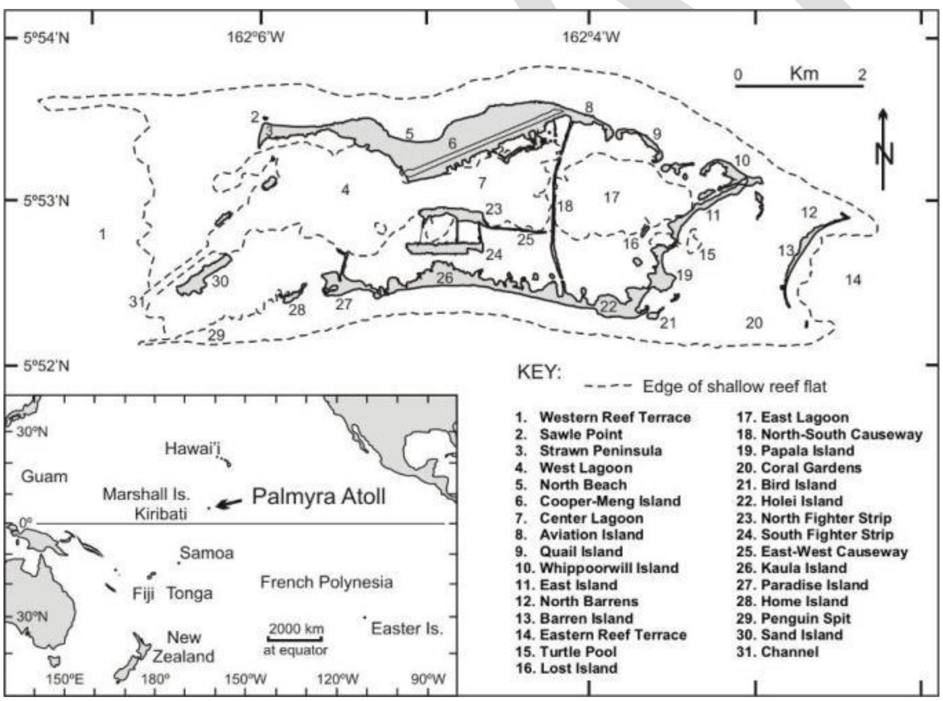

Figure 1. Geographic map of Palmyra Atoll (Collen et al. 2009).

Palmyra’s native flora and fauna have been marginalized due to WWII-era landform restructuring and introductions of non-native species, notably coconut palms, ants, scale insects, and black rats. Nevertheless, Palmyra is an important center of biodiversity and species abundance in the Central Pacific region. Now protected within the US Fish and Wildlife Service's National Wildlife Refuge system, Palmyra sharply contrasts with other moist Central Pacific island groups where the degradation of terrestrial and marine ecosystems keeps pace with increased anthropogenic resource exploitation. However, the continued presence of omnivorous black rats on the atoll will not allow recruitment or population establishment of those species which are limited by the direct or indirect impact of the alien rat population.

3.2 Palmyra's eradication environment

Tropical oceanic islands represent some of Earth's most biologically unique ecosystems, yet the very remoteness that fuels high levels of endemicity and species radiations on islands also renders such systems vulnerable to invasive species. Invasive mammal eradications are a proven, effective method of restoring damaged ecosystems and preserving biodiversity on Islands (Towns and Broome 2003, Howald et al. 2007). The presence of indigenous land crabs on most tropical islands poses a novel challenge to eradication projects, and especially eradications targeting rodents (Wegmann 2008). Land crab consumption of rodenticide bait complicates rodent eradication programs by requiring inflated bait application rates, which increases the risk of non-target species exposure to rodenticide. Because current rodent eradication practices are based on successful temperate or subantarctic campaigns, the conservation community does not have time-tested methods for mitigating land crab interference; Palmyra's eradication environment presents a novel suite of challenges.

Palmyra's emergent land area consists of 25 distinct islands ranging in size from < 0.1 ha to over 100 ha. The islands are separated by shallow channels or lagoon flats, some of which are emergent at low tide. Three deep lagoons run east-west between the two major island groups, and a thin (10-20m) wide causeway runs north-south between the Center Lagoon and Eastern Lagoon (Figure 1).

Palmyra is a breeding refuge for 10 seabird species; however, rat related egg and chick predation may have led to the extirpation of six additional species (Table 1). Without the consumptive pressure of an established human population, Palmyra's land crab community is among the richest and most robust in the Central Pacific region. Palmyra is home to six species of terrestrial crabs (excluding the intertidal families Grapsidae and Ocypodidae), 4 of which are super abundant (Table 2). Palmyra's crab community includes the coconut crab (*Birgus latro*), the world's largest terrestrial invertebrate.

Table 1. Breeding seabirds of Palmyra Atoll; * = Declining population trend

Family	Common Name	Scientific Name	Breeding Pairs	IUCN
Procellariidae	Audubon's Shearwater	*Puffinus lherminieri*	Believed extirpated	LC
	Wedge-tailed Shearwater	*Puffinus pacifica*	Extirpated	LC
	Phoenix Petrel	*Pterodroma alba*	Believed extirpated	EN*
Hydrobatidae	Polynesian Storm Petrel	*Nesofregetta fuliginosa*	Believed extirpated	VU*
Sternidae	Black Noddy	*Anous minutus*	2,500	LC
	Blue Noddy	*Procelsterna cerulean*	Believed extirpated	LC
	Brown Noddy	*Anous stolidus*	1000	LC

Family	Common Name	Scientific Name	Breeding Pairs	IUCN
	Sooty Tern	*Sterna fuscata*	10,000	LC
	Gray-backed Tern	*Sterna lunata*	Believed extirpated	LC
	White Tern	*Gygis alba*	150	LC
Fregatidae	Great Frigatebird	*Fregata minor*	500	LC
	Lesser Frigatebird	*Fregata aerial*	Non-breeder	LC
Phaethontidae	White-tailed Tropicbird	*Phaethon lepturus*	15	LC
	Red-tailed Tropicbird	*Phaethon rubricauda*	20	LC
Sulidae	Red-footed Booby	*Sula sula*	5,000	LC
	Brown Booby	*Sula leucogaster*	150	LC
	Masked Booby	*Sula dactylatra*	20	LC

Table 2. Land crab and rat abundance survey results, Palmyra Atoll (Flint 1992, Howald et al. 2004). Units represent #/hectare estimates and range in measured body mass. [a] (Burggren and McMahon 1988), [b](Wegmann and Middleton 2008).

Species		Mean (#/ha) ± SD	Adult mass (g)
Land Crabs	*Birgus latro*	7 ± 38	5000[a]
	Cardisoma carnifex	33 ± 8	300[a]
	Cardisoma rotundum	28 ± 5	200[a]
	Coenobita brevimanus	46 ± 8	100[a]
	Coenobita perlatus	182 ± 80	100[a]
Rodent	*Rattus rattus*	90 ± 60	164[b]

Palmyra's plant community includes five distinct associations: *Lepturus repens* grassland, *Hibiscus tiliaceus* forest, *Terminalia catappa* forest, *Pandanus fischerianus* forest, and *Phymatosorus grossus* meadow. Presently, *C. nucifera* forest and *S. taccada – T. argentea* forest respectively cover 40% and 30% of Palmyra's land area. Patchy stands of *Pisonia grandis, Pandanus fischerianus, H. tiliaceus, T. catappa,* and meadows of *L. repens* and *Phymatosorus grossus* constitute the remaining 30%; nine additional tree species occur in low numbers at Palmyra. Mature *C. nucifera* trees comprise 45% of Palmyra's forest canopy. Much of Palmyra's vegetated area is difficult to traverse by foot, and paths cut through the dense vegetation require frequent maintenance

Palmyra's WWII legacy includes remnant concrete structures (bunkers, gun emplacements, pill boxes) and unexploded ordinance (UXO). The enclosed concrete structures, along with structures associated with the PARC research station, provide refuge for rats and will be treated as rat habitat during the eradication.

Lying within the Intertropical Convergence Zone, Palmyra is frequented by low pressure systems that result in over 400 cm of rain each year. A summary of several climate factors measured at Palmyra (2002 – 2009) for June and July, the months targeted for this operation, is presented in Table 3.

Table 3. A summary of climate factors measured at Palmyra between the years 2002 and 2009.

Month	Daily		Monthly				
	Max precip (mm)	Mean precip (mm)	Mean # of days with < 10 mm of precip	Mean max temp in the shade (°C)	Mean wind direction (°)	Min wind speed (kts)	Mean of max wind (kts)
June	190	13	20	31	80	4	10
July	108	15	17	31	83	3	10

3.3 Facilities

In 2004, TNC partnered with 10 academic institutions and government agencies in the establishment of the Palmyra Atoll Research Consortium (PARC). In 2005, a research station was constructed on Cooper Island (TNC 2005). The station includes 16 small residential cottages, a galley, shower house, bathrooms, a research laboratory, a wharf for offloading supplies from large ships and barges, tractors (with forks) and flat-bed trucks, a backhoe, three 15' lagoon boats, a 25' offshore boat, and a large workshop area. The station is capable of housing and supporting 25 staff and researchers at one time. Fresh water is supplied through a refurbished 100,000-gallon rainwater catchment tank. Electric power is generated and transmitted by two 50 kW diesel generators, and a satellite dish was installed in 2006 to supply the station with internet connectivity and web-based telephones. Pre-existing infrastructure in use on Cooper Island includes a seaplane ramp, a crushed-coral runway, and several WWII era concrete foundations and bunkers used for storage of supplies.

4 SITE PREPARATION

4.1 Facilities and infrastructure

While the PARC facility will provide many advantages to the eradication operation (use of equipment, vehicles, storage, meeting, and office space), the structures are potential rat habitat and the presence of human food and food-based refuse create regular feeding opportunities for rats; these factors warrant mitigation.

Food within the camp provides potential sustenance for rats. To avoid providing opportunity for rats to eat anything other than bait during the implementation, all food stores in camp and kitchen areas will be secured. Personnel will work with the Palmyra Field Station Manager to ensure the security of all food storage areas. The compost pit, used for years, has been buried and all food and food-related waste is incinerated daily.

Fresh potable water is supplied through a refurbished 100,000-gallon fresh water catchment tank (Figure 2). Personnel will cover the roof of the water catchment with large tarps to ensure that bait applied during the aerial broadcast does not contaminate the potable water supply, and the screening around the top three feet of the tanks walls will be reinforced to make sure that potential bait consumers (rats, cockroaches, etc) will not contaminate the potable water system. Other non-potable water supply catchment tanks are within the hand broadcast area and will not need to be covered; however, screens will be placed over the intake ports for all non-potable water tanks to prevent rats and invertebrates that have been exposed to the rodenticide from entering the tanks. After the baiting operation has been completed, samples from the potable water system will be tested for brodifacoum residue. If brodifacoum residue is detected, an alternate potable water system will be established and used until the primary system has been cleaned and subsequent tests fail to detect brodifacoum residue.

The dry lab facility will be converted into the base of operations during the implementation. Electronics will be stored inside the air-conditioned lab facility. Other supplies will be stored outside the lab on concrete and protected from the elements by a roof. The large shop area will be used to house the helicopters, and buckets, and for short-term storage of bait pods.

5 ERADICATION TECHNIQUE

The rat eradication action at Palmyra will include several bait application techniques that have been tailored to suit Palmyra's eradication environment. US Environmental Protection Agency (EPA) regulations restrict the intentional spread of bait into the marine environment. Given Palmyra's tortuous coastline and the small size of some of the islands (Figure 1), several broadcast baiting strategies will be employed to minimize the accidental spread of bait into the water bodies, which is termed "bait drift," and maintain a uniform bait application at the designated sowage rates across the entire treatment area.

In order to ensure eradication success a second bait application will occur 10 to 14 days after the first to minimize the likelihood of missing competitively inferior adult rats or juvenile rats that survive the initial broadcast because they did not have an opportunity to feed on bait. For each bait application, there will likely be two to three consecutive days of bait broadcast. The extra four days allotted for the time between broadcasts will be contingency time in case of a delay with the first application.

Bait will be applied according to the limitations set by the EPA's pesticide regulations. The bait application rate for the Palmyra rat eradication is based on the results of several bait availability studies conducted at Palmyra (Buckelew et al. 2005b, Wegmann et al. 2008). "Bait availability" is the time period within which rats have direct access to bait pellets broadcast on the ground. The 2005 trial eradication found that with bait application rates as high as 90 kg/ha, bait is available to rats for a maximum of seven days, and is only uniformly available for four days. Bait consumption by land crabs (c. 300 crabs/ha) is the primary factor determining bait availability. In order to ensure that rats have access to bait for four days, this operation requires bait application rates that exceed the maximum bait application rate specified by the bait product's FIFRA registration. The project partnership is currently working with the US Department of Agriculture – National Wildlife Research Center to develop a supplementary registration specifically designed for and exclusive to use in Palmyra's eradication environment.

5.1 Bait and bait sowage rates

During the operation, the baiting plan calls for 39,147kg of 25W to treat Palmyra's 250ha of emergent land twice at a sowage rate of 80kg/ha for the first application, and 75 kg/ha for the second application. An additional 10% of this amount will be brought as contingency bait (Table 4). The contingency bait will replace spoiled, spilled, or otherwise unusable bait, and will be used to fill in significant (≥ 10m) gaps between swaths of bait applied by air, but will not be applied to the treatment area in an amount that, when summed with amounts of bait previously applied to the same area during the same application, is in excess of the maximum bait application rate specified by the supplemental bait label (the supplemental label is in development and on scheduled to be released on 15 April, 2011). The target sowage rate for the second application will be lowered to 75kg/ha to account for an expected reduction in the number of bait consumers (rats) following the first bait application.

Table 4. Bait usage table for the Palmyra Atoll rat eradication operation. The treatment area (Palmyra's total emergent land area) is 250 ha. The target bait sowage rates are presented in the Notes column.

Bait application type	Bait brought to Palmyra (kg)	Contingency	Bait for application (kg)	Calculation notes
Aerial Application	40,920	10%	37,200	AERIAL APPLICATION: 1st application @80kg/ha, 2nd application @75kg/ha (240 ha - accounts for areas baited by hand) + 10% contingency
Hand Application	1,947	10%	1770	HAND APPLICATION: 1st application @80kg/ha, 2nd application @75kg/ha (10 ha) + bait for bait stations: 150 stations x 120g/application x 10 applications + bait for abandoned structures: 100 structures @ 200g/structure x 2 applications + 10% contingency
Canopy Bait	195	10%	177	CANOPY: 2 applications @ 25g/crown (3546 crowns) + 10% contingency
TOTAL BAIT - TREATMENT OF EMERGENT LAND	**42,867**	**10%**	**38,970**	
TOTAL BAIT - TREATMENT OF OVERHANING PALM CANOPY	**195**	**10%**	**177**	
TOTALS	**43,062**	**10%**	**39,147**	

5.1.1 Bait transport and storage

Any damage (fragmentation, molding) to the bait that happens during the transportation process could inhibit the bait application. Therefore, specific precaution will be taken with regard to handling, packing, transport, and storage to ensure that bait is in the optimal condition when it reaches Palmyra.

Following manufacture, bait will be packed and shipped from Bell Labs in Madison Wisconsin to the support vessel in Seattle, Washington. One bulk bag (Flexible Intermediate Bulk Container custom manufactured by BulkLift®) containing 318 kg of bait will be placed inside a large plastic bag, and then inside a Buckhorn® Fixed Wall container ("pod"): [external dimensions (with lid in place) 47.9" x 43.8" x 31") (internal dimensions 45.6" x 42.0" x 23.9"). While inside the pod, each bulk bags will be filled with 318 kg of bait. When full, a desiccant pack will be placed between the bulk bag and the large plastic bag, the plastic bag will be sealed, and the pod's lid will be secured in place. The pods will be stored inside 20 ft and 40 ft shipping containers. The 20' containers will be loaded directly onto the deck of the support vessel, while the pods in the 40' containers will be transferred from the containers to below-deck hold space on the vessel. Pods will be moved into and out of the containers with a forklift or pallet jack.

In addition to bait packaged in the bulk bags and pods, bait will be shipped in 11.3 kg (20 l) buckets. Bait from the 20 l buckets will be used to hand-bait areas of the atoll that cannot be baited via helicopter, and to fill and refill bait stations. The buckets will be strapped to pallets for secure transport and placed inside the 20'shipping container that is partially filled with pods.

Prior to shipment, temperature and humidity data loggers will be placed in seven pods: 2 pods from the beginning of the bait manufacturing process, 3 pods from the middle, and 2 pods from the end. The containers will remain unopened until the vessel makes a port call in Honolulu in route to Palmyra. At this point, each container will be opened and the bait inside one pod in each container will be inspected and the data from the data logger will be downloaded and assessed. Bait in at least one pod in each of the ship's below-deck holds will also be inspected at this time and the data loggers (one in a pod in each hold) will be retrieved and the data will be assessed. All data loggers will be placed back in the pods from which they came, and will be checked again when the ship arrives at Palmyra. If the bait appears moist or moldy, immediate action will be taken to dehumidify the containers and the holds.

Upon arrival at Palmyra, the vessel will tie up at the Wharf (Figure 2) and offload the three pods containing non-toxic bait (for bucket calibration) and 60 pods of active bait for the first bait application. The pods will be retrieved from the 20' containers by using a motorized pallet-jack, and then the pods will be lifted from the ship's deck with a 10 ton 50 ft telescopic crane. A second crane (12 ton 40 ft reach) will be used as a spare in the event of failure of the first crane. The empty containers will remain on the ship for the duration of the implementation. This process of offloading bait pods from the ship to the Wharf will be repeated prior to the second bait application.

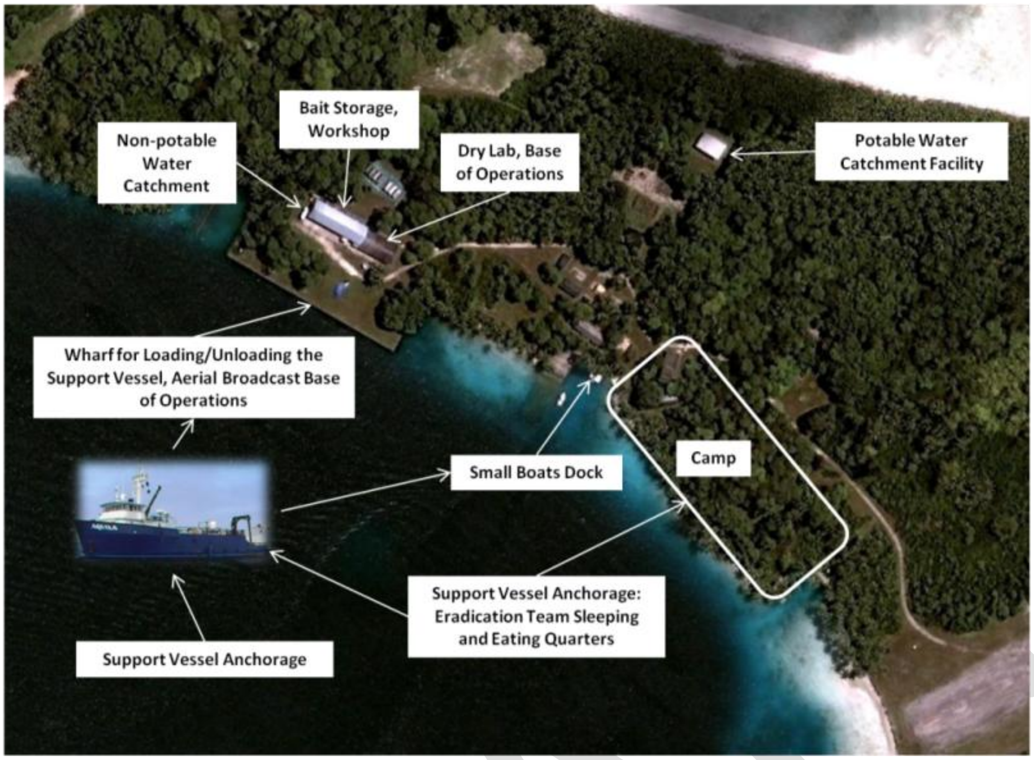

Figure 2. Location of primary operational components for the Palmyra rat eradication project.

5.2 Aerial broadcast

Bait broadcast by helicopter will consist of multiple low-altitude overflights of Palmyra's emergent land area. The baiting system will follow a script (Section 5.5) that is specifically designed to minimize bait spread into the marine environment while maintaining uniformity and compliance with the targeted sowage rates.

5.2.1 Helicopter operations plan

Refer to Appendix for a presentation of the helicopter operations plan.

5.2.2 Preventing bait spread into the marine environment

Every reasonable effort would be made to minimize the risk of bait broadcast into the marine ecosystem. A directional deflector will be attached to the hopper for all treatment of areas where the use of a full swath bucket would result in the application of bait into the marine environment. The deflector will broadcast bait to the onshore side of the helicopter, to minimize the risk of bait entering the ocean on the opposite, or seaward, side. Additionally, the hopper will be used with the broadcast motor off and spinner removed to sow narrow swaths of bait onto land areas that are less than 20 m and greater than 10 m wide.

Palm trees growing along the shoreline commonly hang over the high tide line. To prevent bait from entering the marine environment, overhanging palms will be baited by hand (Wegmann et al. 2008) rather than with the helicopter and bait hopper.

5.2.3 Coverage of baiting gaps

In cases where it is evident or suspected that a portion of the targeted land area greater than 5 m x 10m did not receive full coverage from aerial or hand baiting, there will be supplemental, systematic broadcast by hand or helicopter to fill in the gap.

5.2.4 Resuming baiting after unplanned stops

Bait will be applied to the atoll according to a section-by-section plan, so that an unexpected halt to baiting operations will result in a minimized unbaited edge for the previously baited section(s). When baiting resumes after the application was halted due to poor weather conditions, mechanical failure or other unforeseen logistical problems, the following guidelines direct how far back into previously baited areas baiting should commence to target rats that may have reinvaded treated areas.

Time delay	Strategy to resume baiting
1 day	At boundary of previous drop
2-3 days	2-4 swath widths behind the boundary (20-80 m)
> 3 days	4-6 swath widths behind the boundary (80 – 160m)

5.2.5 Baiting of Cooper Island

For Cooper Island, bait will be applied to the coastal block with the directional swath bucket, and each pass will be baited at 100% of the target sowage rate. A second, non-overlapping pass will be made with a directional swath bucket along the inland edge of the coastal block – this block will be baited at 50% of the target sowage rate and will be overlapped by 50% of a swath laid down by the full swath bucket (Figure 3). With the full swath bucket, each bait swath will overlap the previous swath by approximately 50 percent to prevent the formation of gaps between baiting lines. The runway on Cooper Island will not be baited as it is not a refuge for rats and it is the primary roosting site for Palmyra's shorebird populations (Figure 4). Other exclusions from the aerial baiting will include the camp area, inland bodies of water, and very small islets that are prominent shorebird roosting sites: Rust, Pillbox, and Dadu islets.

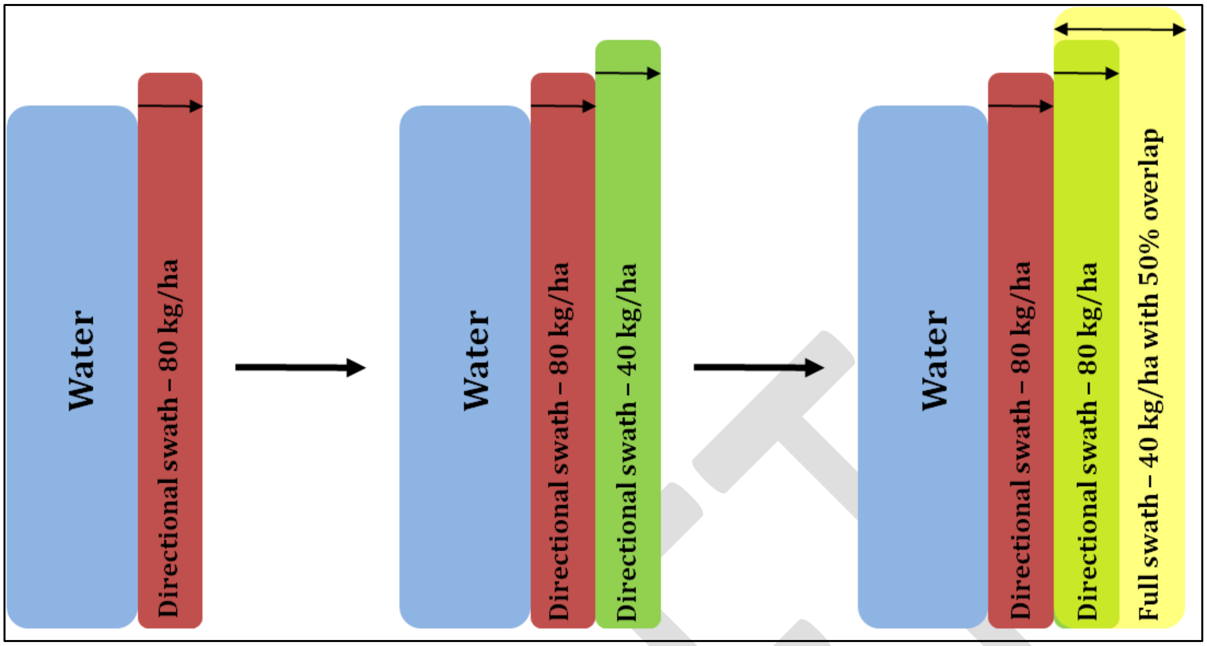

Figure 3. A depiction of the bait application strategy that will be used to transition from treatment of the coastal block to treatment of the interior block. The shapes to the left of the water indicate baiting blocks that are over the treatment area. The arrows at the top of the blocks indicate the relative direction of the bait flow from the baiting bucket. The flight lines will be along the left edge of the swaths that are sown with the directional swath bucket, and they will be down the center of the swaths that are sown with the full swath bucket.

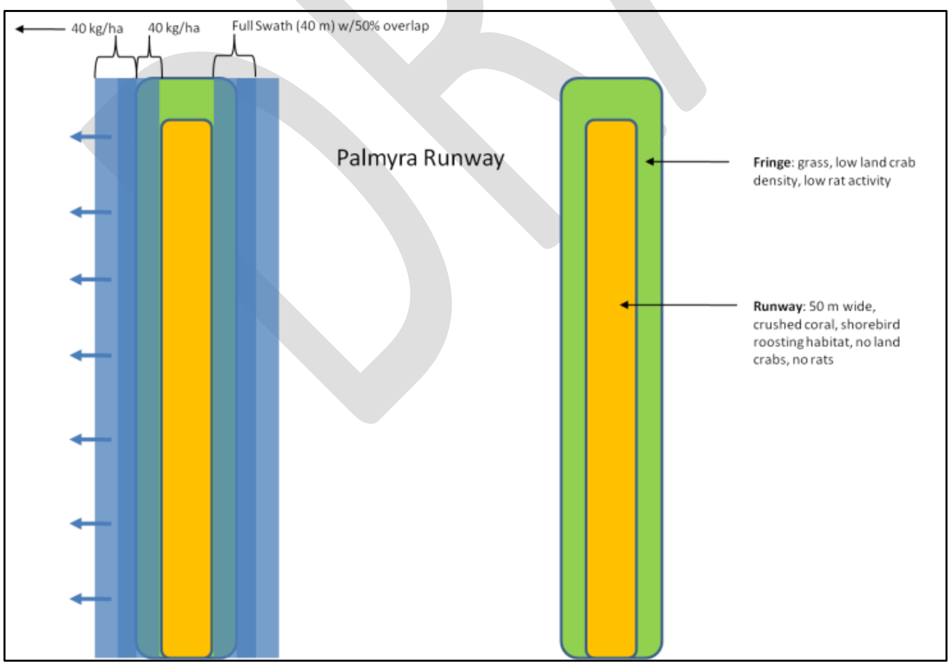

Figure 4. Strategy for excluding the runway on Cooper Island from the aerial bait application

5.2.6 Baiting of land areas other than Cooper Island

Other land areas will be treated with both the directional swath bucket, and the narrow swath bucket. All aerial bait application will be guided by a TracMap® GPS guidance system that shows baiting coverage and cautions the pilot against baiting outside predetermined areas. Adjustments in bait flow rates, helicopter speed, and flight lines will be made as is necessary to meet the optimal application rate, and while staying within the bait application limits legally required by the bait product's FIFRA registration.

5.3 Hand broadcast

Concurrent to the aerial bait application, four to eight personnel trained in hand broadcast baiting (Wegmann et al. 2008) will treat land areas that are too narrow for aerial treatment and the camp area – 2.7 ha (Figure 5). The hand broadcast team will apply bait at the prescribed application rates at each pre-determined baiting point. The hand broadcast team will take care to ensure that the bait spread is uniform and that there are no gaps between the hand broadcast area and the aerial broadcast area. Areas slated for hand broadcast will be treated directly after the adjacent area is treated by aerial broadcast. Bait will also be broadcast directly inside abandoned buildings at a rate that does not exceed the specifications of the bait product use label. After a building has been baited it will be marked (waypointed) with a GPS unit. Sixty abandoned structures have been located and mapped (waypointed); additional structures that are found during eradication activities will be mapped and treated accordingly.

Figure 5. The camp area exclusion from the aerial broadcast treatment. The camp area (2.7 ha) will be treated by hand broadcast of bait to the ground and palm canopy, and placement of bait stations in and directly around buildings.

5.4 Bait stations

As a precautionary measure, bait stations containing 25W bait pellets will be placed around the research station, the wharf, and at select shorebird roosting sites (120 g/station x 50) (Figure 6). Bait stations will be at a density that is in compliance with the 25W product use label. Bait stations will be loaded with 120 g of 25W bait pellets (the same bait that would be used for the broadcast portion of the bait application) at the onset of the bait application. All stations will be checked every five days, and bait will be refreshed as needed, and at least every two weeks for two months. All bait stations will be put in place at least four weeks prior to the operation.

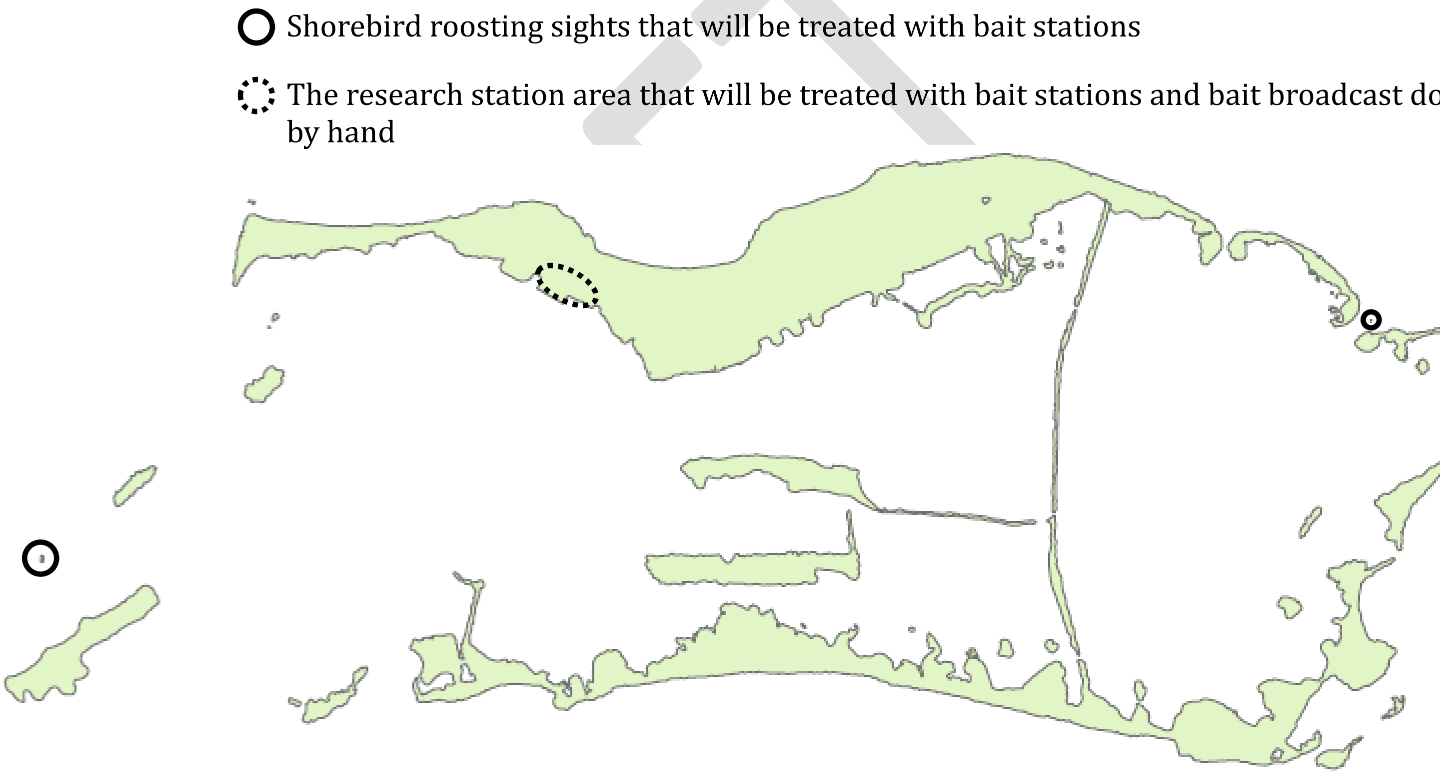

Figure 6. Areas that will be treated with bait stations during the Palmyra Atoll rat eradication

5.4.1 Bait station placement guidelines for commensal buildings

Tamper-resistant bait stations will be placed in and around inhabited buildings in the camp area 6 weeks prior to the initiation of the bait broadcast. All bait stations locations have been mapped (waypointed). The following protocols were used to situate the stations and reduce a neophobic response by rats when the stations are activated.

1. Bait station quantities and spacing
    a. Quantity of stations around the outside of each building
        i. 1 station for every 400 ft^2 of building

b. Quantity of stations inside each building
    i. 1 station for every 200 ft^2 of building
c. Station spacing
    i. Space stations 5 – 50 m apart

2. Bait station placement
    a. Placement of stations around the outside of buildings
        i. Place each station on an overturned 5 gal bucket or other (slippery plastic) stand crabs cannot climb.
            1. Secure each station to the stand with a cable tie, string, or wire.
        ii. Stations should be placed along the edges of buildings and (if possible) in the shade and/or under some type of protective cover
            1. Placing the stations in a protected location will increase the probability that rats will access the stations due to rat preference for covered/protected habitat
            2. The bait stations themselves do not need to be covered or sheltered from rain/sun
        iii. Mark each station placement with flagging tape, permanent marker, or by some other means
    b. Placement of stations inside buildings
        i. Place each station on the floor and against a wall – rats are more likely to run along walls than across an open space
        ii. Stations should be placed near points where rats are expected to enter or exit the building – e.g., near the back doors at the galley.
        iii. If the building contains potential sources of food for rats (dishwasher, food prep area, food stores, shorebird feed, pet feed, etc.), stations should be placed near the food source.
        iv. Stations should be placed out of the way of everyday foot traffic.

5.5 Criteria for selecting bait application methods

The following script explains the criteria by which different bait application methods will be selected. The script uses the type of treatment area as the primary factor (underlined), and then describes the bait application process through an ordered presentation of the following factors: bait application method (e.g., hand broadcast), sowage rate (e.g., 80 kg/ha) and sowage features (e.g., 5 m swath, 0% overlap), treatment of gaps in the initial application, and exclusions from bait application. The aerial baiting components of this script pertain to the first bait application; for the second bait application, sowage rate values will change from 80 kg/ha to 75 kg/ha, and from 40 kg/ha, to 37.5 kg/ha.

1. <u>Land 1 – 10 m wide</u>
    - a. Hand broadcast
        - i. 80 kg/ha, 5 m swath, 0% swath overlap
            - 1. Follows aerial treatment of adjacent blocks - occurs within 2 hours of aerial treatment
        - ii. Exclusions
            - 1. Active seabird nests on the ground
                - a. 2 m exclusion of bait broadcast around each nest
            - 2. Water bodies
                - a. 1 m exclusion of bait broadcast along the edge of the water body
                - b. Exclusion of bait broadcast below the high water line
            - 3. Inhabited structures
                - a. 1 m exclusion of bait broadcast around each inhabited building, no bait broadcast inside inhabited buildings

2. <u>Land > 10 m wide</u>
    - a. Aerial broadcast
        - i. Land 10 – 20 m wide
            - 1. Narrow swath bucket
                - a. 80 kg/ha, 5 m swath, 0% swath overlap
        - ii. Land > 20 m wide except for Cooper Island
            - 1. Coast & Interior
                - a. Directional swath bucket
                    - i. 80 kg/ha, 20 m swath, 0% swath overlap
            - 2. Gaps
                - a. Narrow swath bucket
                    - i. 80 kg/ha, 5 m swath, 0% swath overlap
        - iii. Cooper Island
            - 1. Coast
                - a. Directional swath bucket
                    - i. Outside pass
                        - 1. 80 kg/ha, 20 m swath, 0% swath overlap
                    - ii. Inside pass

            1. 40 kg/ha, 20 m swath, 0% swath overlap, 50 % overlap with Interior passes - assuming 20 m "throw-forward" at the beginning and end of each Interior line
    2. Interior
        a. Full swath bucket
            i. 40 kg/ha, 40 m swath, 50% swath overlap
    3. Gaps > 5 m wide and 10 m long
        a. 0 kg/h recorded
            i. Narrow swath bucket
                1. 80 kg/ha, 5 m swath, 0% swath overlap
        b. 40 kg/ha recorded
            i. Narrow swath bucket
                1. 40 kg/ha, 5 m swath, 0% swath overlap
iv. Exclusions
    1. Cooper Island Runway
        a. Full swath bucket
            i. 40 kg/ha, 40 m swath along outside edge of runway, 50% overlap starting 20 m out from edge of runway
                1. The grass fringe surrounding the runway (20 m) will receive 40 kg/ha
    2. Camp
        a. Full swath bucket
            i. 40 kg/ha, 40 m swath centered on the camp exclusion boundary, 50% overlap starting 20 m inside the camp exclusion boundary
                1. 50% overlap with the hand baited area will result in 80 kg/ha treatment across the camp exclusion boundary
    3. Inland water bodies
        a. Land 10-20 m wide
            i. Narrow swath bucket
                1. 80 kg/ha, 5 m swath around the edge of the water body
                    a. 1 m exclusion of bait broadcast around the edge of the water body
    4. Land > 20 m wide except Cooper Island
        a. Directional swath bucket
            i. 80 kg/h, 20 m swath along the edge of the water body
                1. Gaps > 5 m wide and 10 m long
                    a. Narrow swath bucket
                        i. 80 kg/ha, 5 m swath, 0% overlap

5. Coast
    a. Exclusion of bait broadcast below the high water line

3. <u>Abandoned structure</u>
    a. Hand Broadcast
        i. Up to 200 g of bait broadcast into structures less than 2,500 ft^2, up to 450 g of bait broadcast into structures greater than 2,500 ft^2.

4. <u>Palm crown overhanging water</u>
    a. Canopy bait
        i. Crown overhanging ocean-facing shoreline that is inaccessible by foot
            1. Air
                a. 50 g bait bola dropped into every stand alone crown, or every 3rd interconnected crown
        ii. Crown overhanging lagoon-facing shoreline
            1. Ground
                a. 50 g bait bola shot into every stand alone crown, or every 3rd interconnected crown

5. <u>Inhabited structure</u>
    a. Bait Stations
        i. Inside
            1. 1 station for every 19 sq m of building space, 120 g of bait per station
        ii. Outside
            1. 1 station for every 37 sq m of building space, 120 g of bait per station
    b. Traps (glue, snap)
        i. Inside
            1. 1 trap (glue and snap) for every 37 sq m of building space

6. <u>Shorebird roosting islets not treated by broadcast baiting (Rust, Pillbox, Dadu)</u>
    a. Bait Stations
        i. 1 - 2 stations per islet, 120 g bait/station

6 SHOREBIRD PROTECTION

6.1 Population Monitoring to identify optimum rodenticide broadcast schedule that will minimize shorebird exposure to bait.

Surveys will be conducted pre-broadcast to detect migration pulses and stabilization of summer numbers once all migrants have departed. Remaining birds will be captured when shorebird numbers remain low for 3 days. Weekly high tide counts serve as an index to shorebird numbers at Palmyra and have been done continuously since 2009. They will continue to be made once per week during the highest weekly tide until June 1 when they will be carried out daily. Atoll wide low tide counts are done once per month depending on available staff. Low tide counts count of all the shorebirds on Palmyra will be done twice in May and once between June 1 and June 7 at the best tide available.

6.2 Capture of over-summering shorebirds for protective captive care

Capture sites have been identified on the 6,000 foot crushed coral runway, North Beach, tidal flats and known roost sites. The utility of any particular capture location will depend on the tide, time of day, weather and bird behavior. Methods of capture to be employed include: decoys and call playback in combination with net-guns, mist-nets, noose carpets, drop nets and a catapult net.

6.3 Handling Protocols

Once shorebirds are captured they will be covered with a towel to reduce stress and banded. Morphological measurements, blood, and feather samples will also be taken. Birds will be placed in a plywood transport box (18”x16”x16”) and transported to the aviary. Before release into the aviary birds will have primary feathers trimmed to restrict flight and reduce the chance of injury. Bristle-thighed Curlews are unusual among shorebirds in that they go through a flightless period when they molt and are scheduled to molt 1 to 2 months after they are released from protective care.

6.4 Aviary Facilities

The aviary frame is made of 1” metal conduit that is divided into 10 10’x8’ pens (Total = 50’x16’) and covered with 70% shade cloth. The bottom outside edge will be covered with a 2’ aluminum sheeting to act as a visual barrier and to prevent rats and crabs from entering. The structure will be attached to the ground with concrete anchors to prevent wind damage. The flooring will consist of a rubberized flooring (Elephant Bark™) that sits on top of a 6” layer of sand. The aviary will be outfitted with an irrigation system that will provide water flow over the floor periodically during the day. This will prevent overheating, aid in cleaning and help maintain feathers. Natural and artificial visual barriers within the aviary and along will give birds the opportunity to hide and help reduce the urge to pace. Each pen will have a capture door to aid in capture and reduce risk of injury.

6.5 Bird Care Personnel

The veterinary doctor and wildlife biologists will monitor behavior, food consumption, water intake, temperature, ventilation, fecal output, signs of capture myopathy, and stress of the birds 3 times a day. Behavioral observations will be made from a blind and activity and noise will be restricted in the vicinity of the aviary. Birds with significant loss in body weight will be given gavage treatment. If a bird shows increasing signs of stress, the veterinarian will treat it as appropriate. Talking and visitation by nonessential personnel will be prohibited. The number of birds captured and put in each 10’x8’ pen will depend on the levels of intra-specific aggression they show.

Birds in the aviary will be offered fresh and salt water, trout chow, locally collected seeds and invertebrates (pre-broadcast), hard-boiled egg yolk and vitamin/mineral supplements. Unconsumed food and water will be removed from the aviary each day.

6.6 Post-eradication Protocol

Healthy birds will be released with their aviary mates at their respective capture sites in the early morning once the toxicant in no longer a threat. The released birds will not be disturbed but will be monitored with a spotting scope or binoculars. Sightings of the color-banded birds will be recorded during the weekly high tide shorebird count.

Food bowls will be placed at release sites to provide supplemental feeding opportunities for birds with clipped primaries until they molt and are again flighted. Feedings will occur during the same times as they were in the aviaries.

7 OPERATIONS TEAM

The operations team for the Palmyra rat eradication will entail 39 personnel who will fill 51 positions, with some staff filling more than one position. Reporting will follow the command structure from the bottom up (Figure 7).

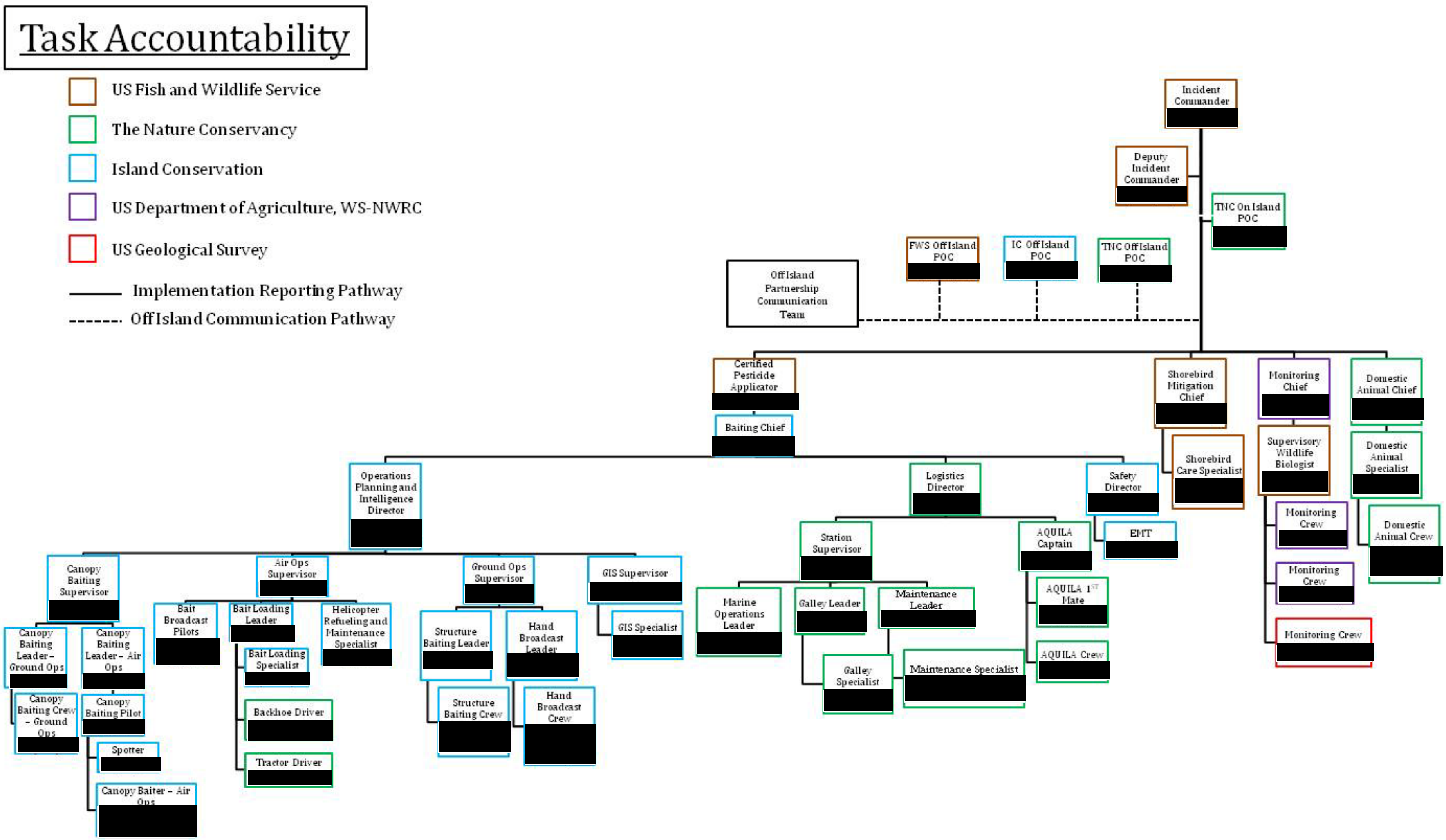

Figure 7. Command structure for the Palmyra rat eradication operations team.

7.1 Position descriptions and responsibilities

Brief descriptions of each position are given below. A more detailed explanation of positions including the inherent roles and responsibilities will be provided to personnel prior to the operation.

Incident Advisory Group (IAG)

The IAG will include the Incident Commander, the Deputy Incident Commander, and the Chiefs; Supervisors, Directors, and other personnel will be brought into IAG meetings when needed. The IAG will be lead by the IC, and the IC will facilitate IAG meetings.

Incident Commander (IC)

The IC is ultimately responsible for the entire operation, all Chiefs report to the IC.

Deputy Incident Commander (DIC)

The DIC will assume responsibility for the operation if the IC is no longer able to do so.

TNC On Island Point of Contact

The TNC On Island Point of Contact will represent TNC's interests during the operation, will partake in IAG meetings.

Off Island Partnership Communication Team

The Off Island Partnership Communication Team will receive reports from the IC, and will be responsible for communications with media.

Off Island Point of Contact

The Off Island Points of Contact will be available for consultation on operational, regulatory, or partnership issues that need an audience that is larger than the IAG. The Off Island Support person may be included on IAG discussions and debriefs.

DOI Certified Pesticide Applicator (CPA)

The CPA ensures that the pesticide application follows federal (EPA, FIFRA) and DOI regulations. The CPA is on site for the entire bait application. The CPA reports to the IC.

Baiting Chief (BC)

The BC is responsible for all aspects of the bait application section, including logistics and safety. The BC reports to the CPA and the IC.

Shorebird Mitigation Chief (SMC)

The SMC is responsible for all aspects of the shorebird capture and care section. The SMC reports to the IC.

Shorebird Care Specialist (SCS)

The SCS, a wildlife veterinarian, supervises and is directly involved in the capturing of and caring for Bristle-thighed Curlews and Pacific Golden Plovers. The SCS reports to the SMC.

Monitoring Chief (MC)

The MC is responsible for all aspects of the monitoring section. The MC reports to the IC.

Supervisory Wildlife Biologist (SWB)

The SWB, a USFWS biologist, ensures that the monitoring actions are in compliance with Refuge policy and have minimal impact to native flora and fauna. The SWB reports to the MC.

Monitoring Crew (M-Crew)

The M-Crew works with the MC and SWB to carry out the monitoring tasks. M-Crew personnel report to the MC.

Domestic Animal Chief (DAC)

The DAC is responsible for all aspects of domestic animal section. The DAC reports to the IC.

Domestic Animal Specialist (DAS)

The DAS, a wildlife veterinarian, supervises the care of the domestic animals (1 dog, 2 cats) and ensures that they are removed from risk of exposure to rodenticide. The DAS reports to the DAC.

Domestic Animal Assistant (DAA)

The DAA's work with the DAS to ensure that the domestic animals are cared for according to the guidelines determined by the DAC and DAS. The DAA's report to the DAS.

Operations Planning and Intelligence Director (OPID)

The OPID is responsible for the bait application unit, including ground and air operations, and GIS intelligence. The OPID reports to the BC.

GIS Supervisor (GSU)

The GSU is responsible for recording, summarizing, and reporting the GPS-based data generated during aerial and ground baiting operations, and is specifically responsible for the data generated by the air operations. The GSU reports to the OPID.

GIS Specialist (GSP)

The GSP works with the GSU to manage the GPS-based data generated during baiting operations, and is specifically responsible for the management of data generated by ground operations. The GSP is will exchange memory sticks with the Broadcast Baiting Pilots during air-based baiting operations. The GSP reports to the GSU.

Ground Operations Supervisor (GOS)

The GOS is responsible for all ground-based bating operations during the two bait applications, including hand broadcast baiting and structure bating. The GOS reports to the OPID.

Hand Broadcast Leader (HBL)

The HBL is responsible for all hand broadcast operations, including the hand broadcast treatment of the camp area. The HBL is responsible for training and equipping personnel involved in hand broadcast operations. The HBL reports to the GOS.

Hand Broadcast Crew (HBC)

The HBC works with the HBL to complete all hand broadcast assignments. HBC members report to the HBL.

Structure Baiting Leader (SBL)

The SBL is responsible for all structure baiting operations, including the baiting of inhabited structures in camp and abandoned structures throughout the atoll. The SBL is responsible for training and equipping personnel involved in structure baiting operations. The SBL reports to the GOS.

Structure Baiting Crew (SBC)

The SBC works with the SBL to complete structure baiting assignments. SBC members report to the SBL.

Air Operations Supervisor (AOS)

The AOS is the site controller for helicopter operations and will be the point of contact for the helicopter pilots during baiting operations. During aerial baiting operations, the AIS will relay bait bucket load statistics to the GS. The AOS will report to the OPID.

Broadcast Baiting Pilot (BBP)

The BBP is responsible for all aspects of the helicopter during aerial baiting operations. The BBP is responsible for the aerial application of bait in accordance with the bait application plan. The BBP will consult with the OPID and BC on the bait application plan. While piloting the helicopter, the BBP reports to the AOS.

Helicopter Refueling and Maintenance Specialist (HRMS)

The HRMS is responsible for the maintenance of the helicopters and refueling the helicopters during air operations. The HRMS will supervise the reassembly and disassembly of the helicopters when they are removed from and put back in the shipping containers. The HRMS works with the pilots to identify and address helicopter maintenance needs. During air operations, the HRMS reports to the AOS.

Bait Loading Leader (BLL)

The BLL is responsible for the loading of the bait bucket during air baiting operations, including the staging of bait pods, the securing of pod lids and empty bulk bags, and loading the bait bucket with the prescribed amount of bait. The BLL reports to the AOS.

Bait Loading Specialist (BLS)

The BLS works with the BLL to stage bait pods, secure pod lids and empty bulk bags, and load the bait bucket. The BLS reports to the BLL.

Backhoe Driver

The Backhoe Driver lifts the bulk bags from the pods and positions them over the bait bucket. The Backhoe Driver reports to the BLL.

Tractor Driver

The Tractor Driver moves full bait pods from the Pod Storage Bay to Staging Area 1 and from Staging Area 1 to Staging Area 2 (Appendix). The Tractor Driver reports to the BLL.

Canopy Baiting Supervisor (CBS)

The CBS is responsible for all aspects of the canopy baiting operation, including air and ground operations. The CBS directs the canopy baiting operation from the command center. The CBS reports to the OPID.

Canopy Baiting Leader – Ground Operations (CBL-G)

The CBL-G is responsible for the implementation of the ground-based canopy baiting operation. The CBL-G orients personnel to canopy baiting techniques and directs the ground-based canopy bating effort from the field. The CBL-G reports to the CBS.

Canopy Baiting Crew – Ground Operations (CBC-G)

The CBC-G works with the CBL-G to implement the ground-based canopy baiting operation. CBC-G personnel report to the CBL-G.

Canopy Baiting Leader – Air Operations (CBL-A)

The CBL-A is responsible for the implementation of the air-based canopy baiting operation. The CBL-A orients personnel to canopy baiting techniques and directs the air-based canopy baiting effort from the field. The CBL-A reports to the CBS.

Canopy Baiting Pilot (CBP)

The CBP is responsible for piloting the helicopter during air-based canopy baiting operations. The CBP will work with the CBL-A to develop a flight plan. The CBP reports to the CBL-A.

Spotter

The Spotter rides in the helicopter during air-based canopy baiting operations and observes the bait application. The Spotter reports to the CBP.

Canopy Baiter - Air Operations (CB-A)

The CB-A is responsible for the placement of canopy baits ("bolas") in designated palm crowns. The CB-A reports to the CBP.

Logistics Director (LD)

The LD is responsible for the logistical aspects of the operation, including station facilities and assets, and the alliance between the station and the support vessel. The LM reports to the BC.

Station Supervisor (SS)

The SS is responsible for the functioning of the station, including all station facilities and assets. The SS reports to the LD.

Marine Operations Leader (MOL)

The MOL oversees all small boat operations, including boat-based transportation of field staff and equipment, boat maintenance, and providing personnel with boat operation training. The MOL reports to the SS.

Galley Leader (GL)

The GL is responsible for the operation of the station's housing facilities, including the galley, the shower house, toilet house, and the laundry. The GL reports to the SS

Galley Specialist (GS)

The (GS) assists the GL with the operation of the station's housing facilities. The GS reports to the GL.

Maintenance Leader (ML)

The Maintenance Leader is responsible for the operation and care of the station's assets, including the power and water systems, vehicles and heavy equipment, and structures. The ML reports to the SS.

Maintenance Specialist (MS)

The MS works with the ML to care for the station's assets. The MS reports to the ML.

M/V AQUILA Captain

The Captain of the AQUILA is responsible for the vessel and the vessel's crew, for directing the offloading and loading of project supplies and equipment, for transporting personnel to and from the project site, and for housing personnel during the operation.

M/V AQUILA 1st Mate

The 1st Mate of the AQUILA works with the Captain to manage the vessel and the associated responsibilities. The 1st Mate will assume responsibility of the vessel if the Captain is no longer able to do so. The 1st Mate reports to the Captain.

M/V AQUILA Crew

The Crew of the AQUILA work with the 1st Mate and Captain to maintain the vessel and support the operation. The Crew report to the Captain.

Safety Director (SD)

The SD's responsibilities include: ensuring that personnel are briefed on safety issues and plans, that personnel have access to appropriate PPE, that safety issues are addressed and resolved, and that the medics are prepped to respond to a medical emergency. The SM reports to the BC.

EMT

The EMT will assist personnel with minor to moderate medical needs, and will be the primary care giver and liaison with off-site medical advisors during medical emergencies. The EMT reports to the SD.

8 OPERATIONS COMMUNICATION PLAN

Communication between project personnel will be via VHF radio and will be structured to reduce the amount of traffic to any one individual. Without a clear communications plan that is strictly followed, communication channels can be easily overwhelmed or personnel may find it difficult to sift out extraneous information during operations based communications. The communication plan mirrors the incident command structure, allowing for diffusion of information through the appropriate personnel channels. Information should move freely up and down the chain of command, utilizing the "talk up one and down one" concept; meaning personnel need to talk up the command chain one slot to their supervisor and down one to everyone they supervise. However, this should not prevent Operational Groups from communicating and sharing information.

A total of 23 portable VHF radios will be required to support this operation (Table 5). Portable radios will be programmed to operate on ten unique channels (Figure 8). Channels will be assigned for communication with and between six operational groups: Command, Ground Ops, Air Ops, Logistics, Monitoring, and Emergency. Personnel will be briefed on radio use and procedures prior to operating in the field. A pocket card will be distributed to all personnel outlining the schedule of radio frequencies and the radio call signs for all project positions (Figure 9). General Radio Procedures:

- Be specific: Before transmitting, know what you are going to say.

- <u>Indicate objectives:</u> Personnel should know exactly where to go, to whom they should report, the task and its objective.

- <u>Use clear tone/effective rate:</u> Speak clearly at a normal rate, not too fast or too slow.

- <u>Well timed/spaced transmissions:</u> Prioritize your messages. Do not waste valuable airtime with unimportant messages and insignificant details. Maintain an awareness of the overall situation and how you fit in. Wait until a message transaction has been completed before transmitting.

- <u>Pause between concurrent messages:</u> A pause makes it clear when one message has been completed and another started. It will also give other personnel a chance to transmit important messages.

8.1.1.1 Making a Transmission

Transmission procedures should ensure that messages are received and comprehended. Radio tranmissions are initiated when the intended receiver indicates readiness to receive a message. The

message is transmitted and the receiver restates the message to confirm that it was understood. If correct, the original sender confirms, completing the communications sequence. For example, an exchange between the Ground Ops Supervisor and the Struture Baiting Supervisor would follow these five steps:

1. "Structure Baiting Supervisor, this is Ground Ops Supervisor on Marine 1A."
2. "Ground Ops Supervisor, Structure Baiting Supervisor." (Sructure Baiting Sup. transmitting)
3. "Move your team to structure 43 and begin application." (Ground Ops Sup. transmitting)
4. "Team to structure 43, begin application." (Structure Baiting Sup. transmitting)
5. "Affirmative." (Ground Ops Sup. transmitting)

8.1.2 <u>Emergency Traffic</u>

The phrase "emergency traffic" is used to gain priority access to the emergency channel or an operational channel (if needed). The phrase is transmitted by the personnel in need, causing the Safety Director to defer to the caller until normal traffic can resume.

An example exchange:

1. "All personnel, standby for emergency traffic." (This statement gains priority access)
2. "Safety Director, this is Monitoring Chief on Marine 16."
3. "Monitoring Chief, Safety Director."
4. "Need immediate medical attention at location X, possible heat exhaustion."
5. "Medical attention needed for heat exhaustion at location X."

6. "Affirmative."

Table 5. Portable VHF radios and radio headsets (blue shading) required during the PARRP Operations.

Position	Radios needed
Incident Commander	1
Deputy Incident Commander	1
Shorebird Mitigation Chief	1
Shorebird Care Specialist	1
Monitoring Chief	1
Supervisory Wildlife Biologist	1
Baiting Chief	1
Safety Director	1
Logistics Director	1
Station Supervisor	1
Marine Operations Supervisor	1
Galley Supervisor	1
Galley Specialist	1
Operations Planning and Intelligence Director	1
Air Ops Supervisor	1
Bait Loading Leader	1
Bait Loading Specialist	1
Backhoe Driver	0
Tractor Driver	1
Helicopter Refueling and Maintenance Specialst	1
Ground Ops Supervisor	1
Structure Baiting Leader	1
Structure Baiting Crew	1
GIS Supervisor	1
Radios provided by IC	**13**
Radios provided by TNC	**5**
Radios provided by USFWS	**5**
TOTAL RADIOS NEEDED	**23**
TOTAL HEADSETS NEEDED	**6**

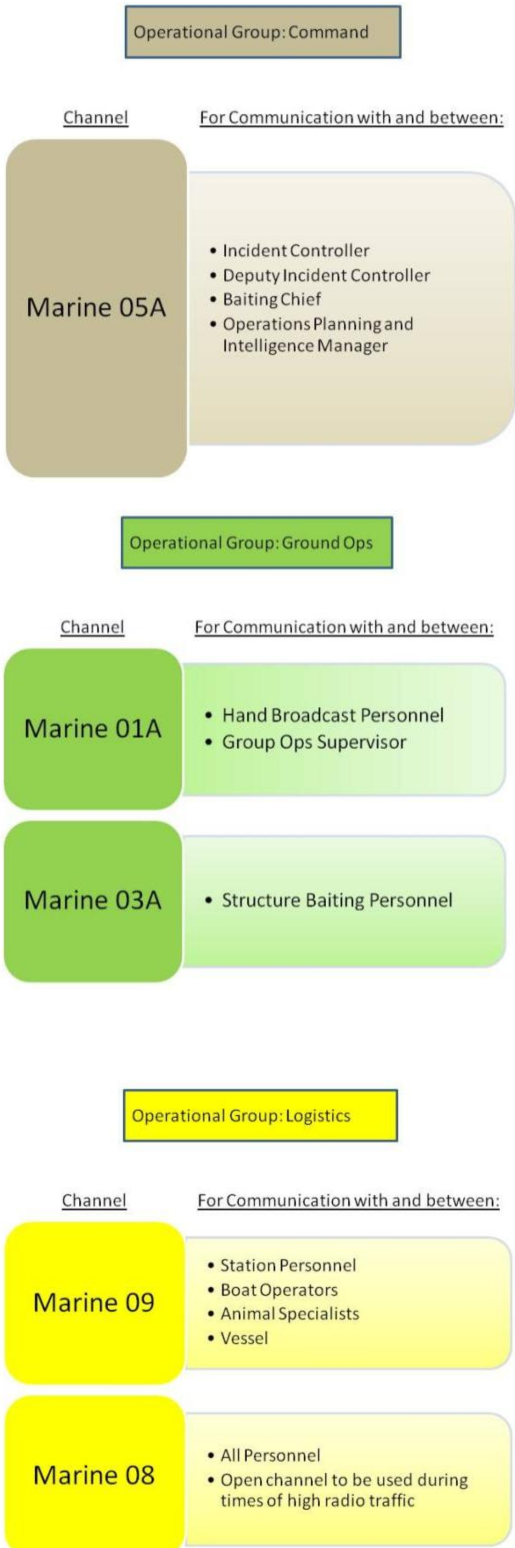

Figure 8. PARRP Radio Channels by Operational Group.

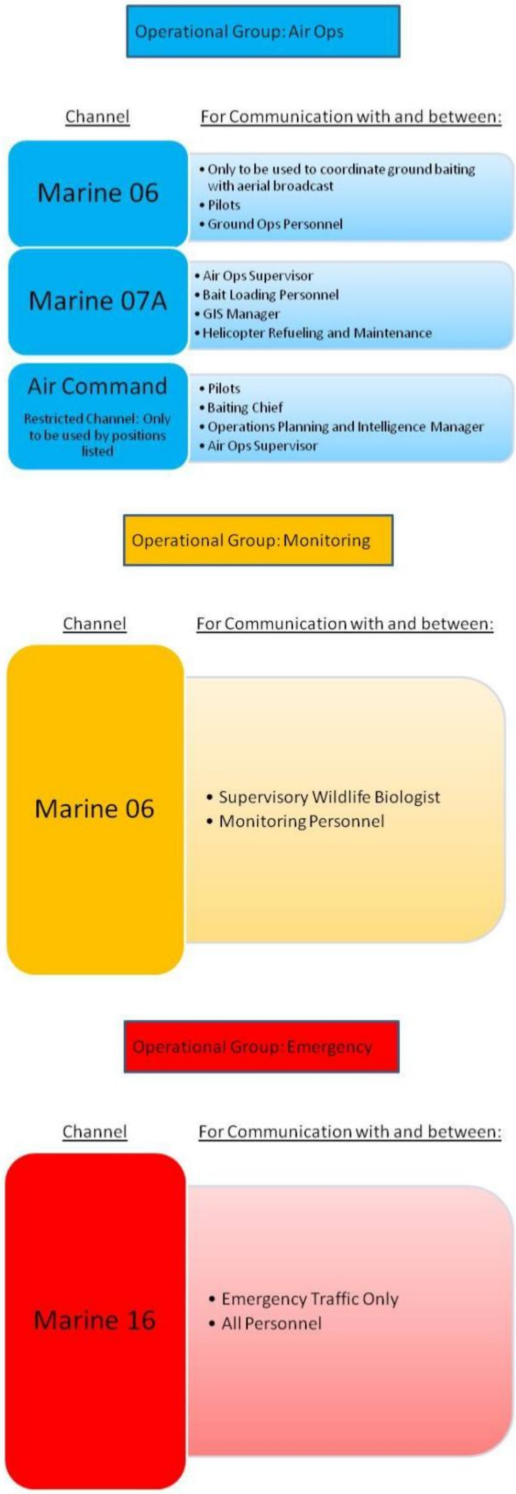

Figure 8. PARRP Radio Channels by Operational Group.

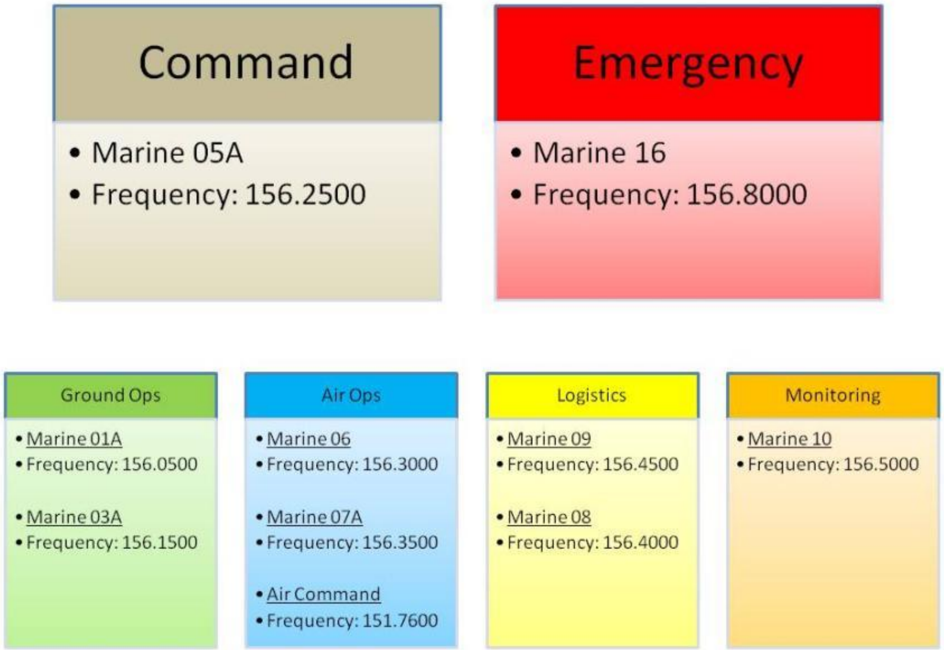

Figure 8. PARRP Radio Channels by Operational Group.

Group	ID	Who	Frequency
Command	Marine 05A	Incident Command	156.2500
Ground Ops	Marine 01A	Hand Broadcast Personnel	156.0500
	Marine 03A	Structure Baiting Personnel	156.1500
Air Ops	Marine 06	Pilots, Ground Ops	156.3000
	Marine 07A	Air Ops Personnel	156.3500
	Air Command	Pilots, Incident Command	151.7600
Logistics	Marine 09	Station/Vessel/Animal Care	156.4500
	Marine 08	Open Channel	156.4000
Monitoring	Marine 10	Monitoring Personnel	156.5000
Emergency	Marine 16	All Personnel	156.8000

Figure 9. PARRP Radio Pocket Card all personnel will carry in the field.

9 BRIEFING, TRAINING, AND DEBRIEFING

9.1.1 Briefing and Training

After all project personnel arrive at Palmyra and before the commencement of the first bait application, briefings and training sessions covering all operational, safety, and teamwork aspects will occur.

9.1.2 Hot Debriefing

On site debriefings will happen every evening of the operation. General debriefings will be held with the entire operations crew (Figure 7) and led by the IC. Specific debriefings will be held with the IAG.

9.1.3 Post Operation Audit

Following the operation, a full audit will be conducted by an outside party and the results of that audit will be recorded and disseminated to all partners and stakeholders.

10 TIMING

10.1 Biological window

This operation will be implemented when the non-target species that are at the greatest risk of harmful exposure to rodenticide (shorebirds) are least abundant at Palmyra – during the summer breeding season: June through July (Gill et al. 1990, Marks et al. 2002).

11 MONITORING

Monitoring of the eradication action will occur according to the eradication Monitoring Plan (Pitt et al. 2011)

12 HEALTH AND SAFETY

12.1 Safety Plan

Refer to the Helicopter Operations Plan – Appendix. A Palmyra Rat Eradication Safety Plan is in development

12.2 Domestic Animal Care

There are three elderly domestic animals that have resided on Palmyra Atoll for many years. The 2 cats and 1 dog live at research station on Cooper Island. The animals will be cared for during the operation to prevent any exposure to the rodenticide or animals that have consumed the rodenticide that they might eat.

Months preceding the eradication the animals will be crate trained to reduce stress during their period of restraint. During the operation, the animals will be housed in a vessel with operational personnel, stationed offshore. They will be attended by a veterinarian and two animal care specialists. After the vessel departs the animals will be kept indoors on the station for an additional two to four weeks. During this time, the veterinarian will continuously evaluate whether or not prophylactic Vitamin K would be necessary.

13 IMPLEMENTATION TIMELINE

Refer to Table 6 for project of the sequencing of the major activities that will be undertaken during this operation.

Table 6. Activity chart for the implementation phase of the Palmyra rat eradication project.

Implementation Timeline		Implementation Day																												
	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Activity																														
Strike team arrives at Palmyra	X																													
Prep station for operation		X	X	X	X	X	X																							
Vessel arrives at Palmyra						X																								
Offload equipment/supplies						X	X																							
Operations team arrives at Palmyra							X																							
Vessel moves from wharf to mooring							X																							
Establish bucket loading site				X	X	X	X																							
Aerial bait application								X	X	X												X	X	X						
Hand bait application								X	X	X												X	X	X						
Commensal bait application								X	X	X												X	X	X						
Arm bait stations								X																						
Check bait stations								X		X		X		X		X		X		X		X		X		X		X		X
Refresh bait in bait stations																						X								
Canopy bait overhanging palms										X	X	X	X	X										X	X	X	X	X		
Demobilize aerial baiting operation																									X	X	X			
Vessel moves from mooring to wharf																												X	X	
Load vessel																												X	X	
Vessel departs Palmyra[1]																														X
Operations team departs Palmyra[2]																														X

[1]Four extra days have been allotted to the operation as "contingency" time. [2]Personnel will remain behind to continue monitoring tasks

14 DEMOBILIZATION

14.1 Excess bait disposal

Excess bait will be left on island to support the treatment of a residual population of rats if one is found after the eradication operation has finished. All bait will be appropriately labeled and stored in a dry location. Unused bait will be sent back to Honolulu in February 2012, and will be disposed of in a manner that is in accordance with FIFRA regulations.

14.1.1 Supplies, equipment and infrastructure (TBD)

The fate of supplies and equipment will be determined prior to the implementation of this project

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16 APPENDIX: HELICOPTER OPERATIONS PLAN

16.1 Loading Zone (LZ)

The LZ will be located on Ripple wharf and serve as the location for all ground based activities associated with aerial operations. The LZ shall consist of one bait loading zone, one refueling pad, and two helicopter parking pads. The LZ will be outfitted with multiple wind indicators and each pad marked for aerial identification to ensure clear communication and safety between ground personnel and pilots. The perimeter of the LZ will be identified and marked using strung pennant flagging to ensure site security during operations. Additionally, a minimum of three 20-pound 40-B:C fire extinguishers will be available for placement at active pads. The set-up and layout of the LZ will be directed by the Air Operations Supervisor (AOS), with recommendations made by the pilots.

The LZ will also host a work station, located in the Dry Lab, equipped for monitoring of the helicopter GPS data during the operation. The equipment at the LZ work station will include: computers and printers (main and backup sets), island maps (paper and laminated), whiteboard, VHF radios. Additionally, a kit for first aid and crash rescue will be established at the LZ.

16.1.1 Communications (Air Ops)

Communication between pilots and ground crew will be via VHF radio and structured to reduce the amount of traffic to pilots and the AOS. All team members will be briefed on radio use and the schedule of radio frequencies prior to the start of operations. Radios are required for all members of the Air Operations team. See the Operations Communications Plan in the Operational Plan for more detail on communications related it Air Ops.

16.2 Weather forecasts

The NOAA-National Weather Service (NWS) will be utilized as the source for weather predictions. The primary means of acquiring forecast information will be through the following web pages:

- http://www.prh.noaa.gov/hnl/pages/aviation.php
- http://www.prh.noaa.gov/hnl/pages/marine.php

Due to the isolated location of the operational area, a specific weather forecast product is not readily available. However, general trends and potential disruptive weather can be acquired through the combination of marine and aviation forecasts. AOS is responsible for receiving daily weather forecasts and communicating these to the Baiting Chief (BC), Operations Planning and Intelligence Director (OPID), and pilots. In the event further weather forecasting is desired, the Incident Commander (IC) will maintain a communication schedule with a NOAA-NWS representative from the Weather Forecasting Office in Honolulu, HI.

16.3 Helicopter Storage

When not flying, the helicopters will be parked and stored at the designated parking pads of the LZ, unless a more suitable area is identified following recommendations by the Chief Pilot, mechanic, and the Station Supervisor. Anchoring systems will be installed according to and under the direct supervision of the pilots and/or mechanic. Anchoring systems for helicopters may include: concrete anchors for belly hook attachment; tie point attachments from the skids, blades and mast; a pole support system for reducing blade mobility; and a combination of earth auger and duckbill anchoring systems.

The helicopter storage location will also be where the mechanic services the helicopters at night and where role equipment will be staged when not in use. All equipment required to maintain the helicopters while in the field, including, but not limited to, ladders, floodlights, tooling and wash down/decontamination supplies, aircraft auxiliary power unit, etc. will be supplied by the helicopter operator.

In the event of a major storm event helicopters may seek emergency shelter in the TNC warehouse. Prior to initiating the bait application the helicopter mechanic and pilots will examine the warehouse location to determine the protocol for movement and storage of the helicopter in the warehouse.

16.4 Aerial Operations Safety

It is essential that all aviation operations be planned with the utmost consideration given to safety and operational efficiency. Missions can be accomplished safely and efficiently, provided that a high degree of pre-planning, risk analysis, and management is applied. Many users have developed Standard Operating Procedures (SOP) that streamline the planning process, incorporate the lessons learned from others experience, and utilize the best practices that balance the demands for safety and efficiency.

Helicopter safety is the responsibility of every individual on the project; however oversight of helicopter-specific safety is the responsibility of the helicopter vendor and pilots. Given the remote location, helicopter operations on the island are considered high risk. To ensure that a high standard of safety is maintained during the project a separate safety plan will be prepared that details general helicopter safety procedures, flight following, and emergency or crash response procedures. Additionally, the helicopter vendor will provide an Aviation Safety Plan detailing emergency equipment and response. All safety protocols and procedures will follow standard FAA guidelines.

The safety procedures covered in the Palmyra Safety Plan will include external load operations, bait handling & loading, and aerial bait broadcast. The safety plan will also include, but not be limited to, the following:

- Method for the identification of all hazards, including new hazards.
- How these hazardous can be eliminated, or reduced.
- Detail safety equipment and training required for both the positioning and aerial work operations for both flight crews and ground crews.
- Nominate a person responsible and accountable for safety on site.
- Method for dealing with emergencies.
- Method of reporting incidents and accidents.

The following information serves as an overview of aerial operations safety procedures and guidelines to be followed on this project. Refer to *Island Conservation Helicopter Operations SOP, July 2008* for full detail.

16.4.1 Hazard Identification and Mitigation

The BC and OPID will work jointly with the pilots to manage hazards associated with aerial operations. Common hazards associated with a helicopter mission –crew fitness, distraction, mission focus, communication, weather, takeoff or landing weights, landing areas, other aircraft, wire and other obstructions – must be identified and controls provided to mitigate the hazard(s).

Preflight project planning for baiting operations should be intensive because the aircraft and crew are placed in a less forgiving environment. The BC will aid the pilots in aerial hazard identification, creating a hazard map if necessary, and ensure a high-level reconnaissance is made prior to low-level flight

16.4.2 Flight Following (on island)

Flight following requirements will be clearly identified, including check-in procedures, time and locations, individuals responsible for flight following, radio frequencies to be used, and any special circumstances requiring check-ins. The flight following personnel must document position reports to assist in locating an overdue or missing aircraft.

Flight following on island will be coordinated by the OPID, in accordance with the vendor company's Aviation Safety Plan. The AOS or designee will have radio contact with the pilots; check-in intervals will be determined by the BC and pilots prior to operations commencing. Check-ins during flights will be documented by the AOS or designee, in addition to load calculations, cargo and passenger manifests, and flight plans that will be kept on hand at the LZ. Information to be recorded includes: the name of each passenger, the intended destination, load weights, time en-route and estimated time of return.

16.4.3 Overdue Aircraft/Emergency Response

Aircraft mishap, accident and emergency will be managed by the vendor helicopter contractor, unless otherwise arranged. Overdue or missing aircraft will be managed by the vendor helicopter contract. Protocols for aircraft accident reporting and management, and procedures for overdue or missing aircraft should be detailed in the vendor company's Aviation Safety Plan.

16.4.4 Personnel Experience/Training

Inexperience with aerial operations could potentially present safety concerns, as well as reduce operational efficiency. Priority will be given to staffing aerial operation positions with personnel who posses significant aviation experience. If positions are to be filled by in/under-experienced personnel, those team members must complete a helicopter training program combining classroom and field practical, specific to the work being done on the island.

16.4.5 Personnel Protective Equipment (PPE)

16.4.5.1 Helicopter

Personnel working around operating helicopters will wear the following PPE:

- Fire resistant or all-natural fiber clothing (long-sleeved shirt and pants, or flight suit)
- High visibility vest/jacket
- Hardhat with chinstrap, or flight helmet
- Fire resistant or leather gloves
- All leather boots
- Eye protection
- Hearing protection

During refueling operations, the helicopter mechanic will wear appropriate PPE for dispensing aviation fuel, including 'non-static' clothing.

16.4.5.2 Bait Handling and Loading

All personnel that handle bait or monitor the bait application in the field will meet or exceed all requirements for PPE described on the bait's EPA pesticide label. In addition to the required helicopter PPE, the Bait Loading Leader and the Bait Loader Driver will wear disposable masks or respirators when filling the bait buckets.

All personal will wear required PPE (see *PPE* above) when handling/loading bait to prevent exposure to potentially harmful pesticides. An aerial baiting operation requires adherence to standard practices similar to those for external cargo load operations. The bait loading team should remain clear of the loading area until the AOS signals that the bucket is placed into position; no other personnel should be near the site unless approved by the AOS.

The bucket should be placed on the ground by the pilot at the designated loading spot before bait is loaded, and not be pulled into position by the loaders. The bucket should always remain between the bait loading team and the helicopter. When bait loading has been completed, the AOS may signal the pilot to begin movement of the bucket. As the bucket is lifted, ground personnel should keep out of the flight path to avoid injury. The AOS must pay close attention as the helicopter lifts up and tension is applied to the bucket line, if there is a problem with the bucket, the AOS should communicate appropriately with the pilot. The Bait Loading Leader (BLL) will be responsible for securing the empty bulk bags as they are emptied to prevent the potential for foreign object damage (FOD).

16.5 Marshalling / Crash Rescue

The AOS is responsible for directing helicopters during bait reloading operations and relaying helicopter traffic updates to ground staff. The AOS should direct the pilot by radio and remain visible to the pilot at all times. In the event of an aircraft emergency in the LZ, the AOS can respond quickly utilizing the pad's fire extinguisher and initiating crash rescue procedures.

16.6 Aerial Broadcast Implementation

16.6.1 Aerial Ops Command Structure

The command structure of personnel for the aerial broadcast operation is shown Section 8 of the Operational Plan. This diagram is intended to be as closely representative of the actual structure as possible, anticipating that actual roles may change prior to or during aerial baiting operations. The roles and responsibilities of the field team during the aerial baiting operations are listed in Section 8.1 of the Operational Plan. While the specific tasks required during the aerial baiting operations are fixed, additional tasks may be required of the field team during the aerial baiting operations. Of note, the AOS will serve as the Site Controller for the LZ; however if multiple aircraft are operating within the LZ at one time, separate site controllers will be needed to manage each aircraft. Individuals may also be rotated between non-specialist roles (e.g. Bait Loading Specialist) depending on the needs of the team or operations on any given day.

16.6.2 Commencement of Application

Prior to initiating aerial baiting operation, an operations checklist will be reviewed by the BC and OPID to ensure that all equipment has been adequately and safely installed. The checklist prepared by the AOS will be reviewed and approved by the Incident Advisory Team. Following approval, the authorization to commence aerial baiting operations will be given to the baiting pilots. While the BC will be responsible for detailing daily flight activities, the decision to fly on any given day will ultimately be made by the baiting pilots and will depend on suitable weather conditions for safe, effective baiting.

16.6.3 Daily decision to apply bait

Every day following the authorization to commence will be treated as an opportune window for aerial bait application, unless declared otherwise. Before dawn each day the IC, BC, OPID, AOS, and baiting pilots will consult on local weather conditions and forecasts to assess whether they are suitable for baiting (Fig. 9). If conditions are deemed suitable, the team will proceed with preparation and positioning for baiting (see *Daily schedule of events* below).

Poor weather conditions may cause baiting operations to be halted, changed, or delayed. Daily baiting will be delayed (or discontinued if flying has already commenced) if the weather is unsuitable, and/or the pilots feel it is no longer possible to continue flying in a safe manner.

Weather conditions in which baiting may be halted or delayed are:

- wind speeds average 25 knots or gusts to over 30 knots
- visibility conditions in the area being treated are obscured by low clouds, inhibiting the pilot's ability to safely operate
- conditions of heavy rain (loading bait buckets in heavy rainfall may cause "gumming" of bait and potentially cause bait bucket to jam or clog)

16.6.4 Daily schedule of events

16.6.4.1 Pilot preparation:

The BC will discuss the daily flight plan with the pilots and the IAT the night before flying, in order to maximize all optimal weather conditions for aerial baiting. The daily flight plan will be based on several criteria, including: the predicted weather forecast, the area(s) of the island previously treated, the prioritization criteria for applying bait, and the current stage of the operational timeline.

16.6.4.2 Air Ops team preparation:

The BC will conduct a nightly briefing with the field team to review: weather forecasts, baiting plans, task allocation, transportation plans, safety, and any other relevant issues. On each day scheduled for flying, the BC, OPID, and baiting pilots will assess weather conditions at dawn. If conditions are suitable for dropping bait the BC will notify the team and preparations will begin for baiting. Daily preparations will include:

- team briefing of weather forecast
- team briefing of action plan for the day
- review of task requirements of team members
- radio check

Once preparations are complete the bait loading teams and helicopters will be positioned to begin baiting. If weather conditions are not suitable for flying the field team will stand-by, and later in the morning a briefing will occur to inform the team of the updated action plan and assign tasks for the day. All team members will be on stand-by during days of no flying in the event weather conditions become suitable for flying.

16.6.5 Bait-bucket Loading Procedures

Prior to beginning bait operations for the day, the AOS and BLL will oversee that the loading site is properly prepared for operations, including ensuring an adequate amount of bait for the planned daily operation (determined by the BC) is present at Staging Area 1 (approximately 20 pods will be transferred from the pod storage bay in the shop to this location prior to baiting operations), and all required safety equipment is in place. The Tractor Driver will move pods from Staging Area 1 (SA1) to SA2 (at SA2, the lid will be removed from the pod and the bulk bag will be attached to the bucket of the Backhoe). The bait loading team will consist of 5 people: The AOS (site controller), the BLL, a Bait Loading Specialist, the Backhoe Driver, and the Tractor Driver.

Once the all the bait in the bucket has been sown, or the targeted area has been treated, the pilot will notify the AOS via radio and return for reloading at the LZ. When the helicopter arrives to the loading site the AOS will direct the pilot in placing the bucket for reloading. Prior to reloading the bucket at the LZ, the BLL will check the bottom of the bucket for an approximate fistful amount of bait remaining from the previous bucket load – this residual bait is an indicator that the actual area baited is was recorded by the GPS tracking system. The remaining contents of the bucket will be indicated to the AOS. If no bait remains in the bottom of the bucket prior to reloading the OPID will be consulted and the pilot may be required to re-bait a portion of the previously treated area.

When the bucket is on the ground and the remaining contents checked, the Backhoe Driver will approach the bucket with the bulk bag. The BLL will assist the Backhoe Driver in positioning the bulk bag over the bucket, once the bulk bag is in place the BLL will pull the release to fill the bucket with bait. After emptying the bulk bag, the Backhoe Driver and BLL will move away from the bucket ensuring the empty bulk bag is secure and preventing the bulk bag from being blown away or interfering with the flight of the helicopter. The Bait Loading Specialist will roll up empty bulk bags and secure them in a predetermined location. Once the helicopter departs the LZ, the bait loading team will immediately attach another bulk bag to the Backhoe and reposition in preparation for the next bucket loading.

16.6.6 Aerial Data

16.6.6.1 Baiting

At each bucket reload the pilot will communicate via radio to the AOS the amount of area (measured in ha) that was previously treated with bait. The AOS will relay this information, along with the amount of bait dispensed to the GIS Supervisor (GSU), to be recorded into a bait-application monitoring spreadsheet.

16.6.6.2 GPS

On aerial baiting days, GPS information will be downloaded after the first 3 bucket loads applied by each pilot, allowing for any possible errors in flight lines, GPS logging, or bait application rates to be detected. Once the systems are verified, GPS information will be downloaded required by the OPID or BC.

16.6.6.3 Flight Log

A log of all flight activity and onboard passengers will be kept by the GSU, and will include significant aviation activities such as: time helicopter begins flying, time when helicopter arrives back to reload, refueling events, all engine shut downs, arrival/departure times, and passenger manifests. The GSU will maintain the log via direct observations at the LZ and refueling area, or by radio communications with the AOS. A copy of the log will be kept at the point of departure. Should the GSU be unable to observe and document flight activities, another designated person will maintain the flight log.

16.6.7 Refueling

Helicopter refueling will occur in the designated fuel area at the LZ. During helicopter refueling, the bait bucket motor will be refueled with unleaded fuel dispensed from a small jerry can. Fueling will be the responsibility of the Helicopter Refueling and Maintenance Specialist. The fuel drums will be appropriately positioned with the refueling equipment and nozzle bonded to the helicopter before starting the refueling operation. To control spills, self-closing nozzles will be used and not blocked open or dragged along the ground. Additionally, a fuel catchment pan will be placed beneath the helicopter to prevent spillage onto the ground.

APPENDIX L

BRODIFACOUM-25W CONSERVATION LABEL & SUPPLEMENTAL LABELING FOR BRODIFACOUM-25W CONSERVATION TO CONTROL AND ERADICATE BLACK RATS ON PALMYRA ATOLL
EPA REGISTRATION NO. 56228-36

PRECAUTIONARY STATEMENTS

HAZARDS TO HUMANS AND DOMESTIC ANIMALS

Keep away from humans, domestic animals and pets. If swallowed, this material may reduce the clotting ability of the blood and cause bleeding. Wear protective gloves when applying or loading bait. With detergent and hot water, wash all implements used for applying bait. Do not use these implements for mixing, holding, or transferring food or feed.

ENVIRONMENTAL HAZARDS

This pesticide is toxic to birds, mammals and aquatic organisms. Predatory and scavenging mammals and birds might be poisoned if they feed upon animals that have eaten bait.

PERSONAL PROTECTIVE EQUIPMENT (PPE)

Applicators and other handlers must wear:
- -long sleeved shirt and long pants
- -gloves
- -shoes plus socks

For aerial application, in addition to the above PPE, loaders must wear protective eyewear or a face shield and a dust/mist filtering respirator (MSHA/NIOSH TC-21C).

USE RESTRICTIONS

It is a violation of Federal law to use this product in a manner inconsistent with its labeling. A copy of this label must be in the possession of the user at the time that the product is applied.

READ THIS LABEL: Read this entire label and follow all use directions and precautions**.**

IMPORTANT: Do not expose children, pets or other non-target animals to rodenticides. To help prevent accidents:

1) Keep children out of areas where this product is used or deny them access to bait by use of tamper resistant bait stations.
2) Store this product in locations out of reach of children, pets, and other nontarget animals.
3) Apply bait only according to the directions authorized.
4) Dispose of product container and unused, spoiled, or unconsumed bait as specified in the "**STORAGE AND DISPOSAL**" section.

(SEE RIGHT PANEL FOR ADDITIONAL USE RESTRICTIONS)

RESTRICTED USE PESTICIDE

DUE TO HAZARDS TO NON-TARGET SPECIES

For retail sale only to: USDA Animal and Plant Health Inspection Service Wildlife Services, U.S. Fish and Wildlife Service, and the U.S. National Park Service to be used only by Certified Applicators or persons under their direct supervision and only for those uses covered by the Certified Applicators certification.

BRODIFACOUM-25W CONSERVATION

PELLETED RODENTICIDE BAIT FOR CONSERVATION PURPOSES

For control or eradication of invasive rodents in wet climates on islands or vessels for conservation purposes

ACTIVE INGREDIENT
Brodifacoum (CAS No. 56073-10-0) 0.0025%
INERT INGREDIENTS 99.9975%
TOTAL 100.0000%

KEEP OUT OF REACH OF CHILDREN

CAUTION

First Aid

If swallowed	-Call a physician or poison control center immediately for treatment advice. -Have person sip a glass of water if able to swallow. -Do not induce vomiting unless told to do so by a poison control center or doctor. -Do not give anything by mouth to an unconscious person.
If on skin or clothing	-Take off contaminated clothing. -Rinse skin immediately with plenty of water for 15-20 minutes. -Call a poison control center or doctor for treatment advice.
If inhaled	-Move person to fresh air. -If person is not breathing, call 911 or an ambulance, then give artificial respiration, preferably mouth-to-mouth if possible. -Call a poison control center or doctor for further treatment advice.
If in eyes	-Hold eye open and rinse slowly and gently with water for 15-20 minutes. Remove contact lenses, if present, after the first 5 minutes, then continue rinsing eye. -Call a poison control center or doctor for treatment advice.

Have the product container or label with you when calling a poison control center or doctor, or when going for treatment.

For a medical emergency involving this product, call (877) 854-2494
NOTE TO PHYSICIAN: If swallowed, this material may reduce the clotting ability of blood and cause bleeding. If ingested, administer Vitamin K_1, intramuscularly or orally, as indicated in bishydroxycoumarin overdose. Repeat as necessary based on monitoring of prothrombin times.

USE RESTRICTIONS, (CONT)

This product may be used to control or eradicate Norway rats (*Rattus norvegicus*), roof rats (*Rattus rattus*), Polynesian rats (*Rattus exulans*), house mice (*Mus musculus*) or other types of invasive rodents on islands for conservation purposes, or on grounded vessels or vessels in peril of grounding.

This product may be applied using bait stations, burrow baiting, canopy baiting or by aerial and ground broadcast application techniques.

This product is to be used for the protection of State or Federally-listed Threatened or Endangered Species or other species determined to require special protection.

Do not apply this product to food or feed.

Treated areas must be posted with warning signs appropriate to the current rodent control project.

This product is for use in wet climates.

DIRECTIONS FOR USE

BAIT STATIONS: Tamper-resistant bait stations must be used when applying this product to grounded vessels or vessels in peril of grounding, or when used in areas of human habitation. Bait must be applied in locations out of reach of children, non-target wildlife, or domestic animals, or in tamper-resistant bait stations.

<u>TO BAIT RATS</u>: Apply 4 to 16 ounces (113 to 454 grams) of bait per placement. Space placements at intervals of 16 to 160 ft (about 5 to 50 meters). Placements should be made in a grid over the area for which rodent control is desired.

<u>TO BAIT MICE</u>: Apply 0.25 to 0.5 ounces (7 to 14 grams) of bait per placement. Space placements at intervals of 6 to 12 ft (about 2 to 4 meters). Larger placements, up to 2 ounces (57 grams) may be needed at points of very high mouse activity. Placements should be made in a grid over the area for which rodent control is desired.

<u>FOR BOTH RAT AND MOUSE BAITING</u>: Maintain an uninterrupted supply of fresh bait for at least 15 days or until signs of rodent activity cease. Where a continuous source of infestation is present, permanent bait stations may be established and bait replenished as needed.

EPA Reg. No. 56228-36
Revised 11/23/2009

DIRECTIONS FOR USE (CONT.)

BURROW-BAITING: Place bait in burrows only if this can be done in a way that minimizes potential for ejection of bait and exposure of bait non-target species.
TO BAIT RATS: Place 3 to 4 ounces (85 to 113 g) of bait inside each burrow entrance. Baits used in burrows may be applied in piles or in cloth or resealable plastic bags. The bags should be knotted or otherwise sealed to avoid spillage and holes should be made in plastic bags to allow the bait odor to escape.
TO BAIT MICE: Place approximately 0.25 ounces (7 grams) of bait in a cloth or resealable bag in each active burrow.
FOR BOTH RAT AND MOUSE BAITING: Place one such bag or placement in each active burrow opening and push bag into burrow far enough so that its presence can barely be seen. Do not plug burrows. Flag treated burrows and inspect them frequently, daily if possible. Maintain an uninterrupted supply of bait for at least 15 days or until rodent activity ceases. Remove bait from burrows if there is evidence that bags are ejected.

CANOPY BAITING (bait placement in the canopy of trees and shrubs): In areas where sufficient food and cover are available to harbor populations of rodents in canopies of trees and shrubs, canopy baiting should be included in the baiting strategy. Approximately 4 to 7 ounces (113 to 200 grams) of bait should be placed in a cloth or resealable plastic bag. The bags should be knotted or otherwise sealed to avoid spillage and holes should be made in plastic bags to allow the bait odor to escape. Using long poles (or other devices) or by hand, bait filled bags should be placed in the canopy of trees or shrubs. Baits should be placed in the canopy at intervals of 160 ft (about 50 meters) or less, depending upon the level of rodent infestation in these habitats. In some vegetation types, bait stations may need to be used to ensure bait will stay in the canopy.

DIRECTIONS FOR USE (CONT.)

BROADCAST APPLICATION: Broadcast applications are prohibited on vessels or in areas of human habitation. Broadcast bait using aircraft, ground-based mechanical equipment, or by gloved hand at a rate no greater than 16 lbs of bait per acre (18 kg bait/hectare) per application. Make a second broadcast application, typically 5 to 7 days after the first application, depending on local weather conditions, at a rate no higher than 8 lbs. of bait per acre (9 kg bait/hectare). In situations where weather or logistics only allow one bait application, a single application may be made at a rate no higher than 16 lbs. bait per acre (18 kg/ha).

Aerial (helicopter) applications may not be made in winds higher than 35 mph (30 knots). Pilot in command has final authority for determining safe flying conditions. However, aerial applications will be terminated when the following conditions are present:

> Windspeed in excess of 25 knots with an evaluation of the terrain and impact of the wind conditions and not to exceed a steady wind velocity of 30 knots.

Set the application rate according to the extent of the infestation and apparent population density. For eradication operations, treat entire land masses.

Assess baited areas for signs of residual rodent activity (typically 7 to 10 days post-treatment). If rodent activity persists, set up and maintain tamper-resistant bait stations or apply bait directly to rodent burrows in areas where rodents remain active. If terrain does not permit use of bait stations or burrow baiting, continue with broadcast baiting, limiting such treatments to areas where active signs of rodents are seen. Maintain treatments for as long as rodent activity is evident in the area and rodents appear to be accepting bait.

For all methods of baiting, monitor the baited area periodically and, using gloves, collect and dispose of any dead animals and spilled bait properly.

STORAGE AND DISPOSAL

Do not contaminate water, food, or feed by storage or disposal.

STORAGE: Store only in original closed container in a cool, dry place inaccessible to unauthorized people, children and pets. Store separately from fertilizer and away from products with strong odors, which may contaminate the bait and reduce acceptability. Spillage should be carefully swept up and collected for disposal.

PESTICIDE DISPOSAL: Wastes resulting from the use of this product may be disposed of at an approved waste disposal facility.

CONTAINER DISPOSAL: Nonrefillable container. Do not reuse or refill this container. Offer for recycling, if available. Otherwise, dispose of empty container in sanitary landfill or by incineration, or, if allowed by State and local authorities, by burning. If burned, stay out of smoke.

NOTICE: Buyer assumes all risks of use, storage, or handling of the material not in strict accordance with directions given herewith. The efficacy of the product may be reduced under high moisture conditions.

UNITED STATES DEPARTMENT OF AGRICULTURE
ANIMAL AND PLANT HEALTH INSPECTION SERVICE
Riverdale, MD 20737-1237
EPA Est. No. 56228-ID-1
EPA Reg. No. 56228-36

Net Weight ___________________

Batch Code No.: _______________

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

OFFICE OF CHEMICAL SAFETY AND POLLUTION PREVENTION

APR 15 2011

Stephanie Stephens
Biological Scientist
USDA APHIS PPD
Environmental and Risk Analysis Services, Unit 149
4700 River Rd.
Riverdale, MD 20737

Dear Ms. Stephens:

Subject: Supplemental Label for Brodifacoum-25W Conservation to Control and Eradicate Black Rats on Palmyra Atoll
EPA Registration No. 56228-36
Submission Date: February 2, 2011

The proposed labeling referred to above, submitted in connections and registration under the Federal Insecticide, Fungicide, and Rodenticide Act, is acceptable with the following requirement:

- A monitoring plan must be submitted to the Agency that includes the monitoring actions prior to, during, and after the implementation of the eradication within one year of completion of the eradication project.

To allow successful restoration of native species to Palmyra Atoll (Palmyra), all rats must be killed. To achieve this goal, the eradication program involves multiple application methods, including aerial broadcast application as well as bait application to tree canopies. These bait application methods will consequently result in accessibility of bait to nontarget species. However, the benefits of the long term goals of protecting and restoring the native species and habitat of Palmyra by removing non-native rats are believed to be justified and outweigh the associated risks involved.

A stamped copy of the label is enclosed for your records. This supplemental label will expire 3 years from July 31, 2011. Please submit one (1) final printed copy for the above mentioned label including the expiration date before releasing the product for shipment. If you have any questions regarding this label, please contact Jennifer Gaines at (703) 305-5967 or via e-mail, gaines.jennifer@epa.gov.

Sincerely yours,
Jennifer Gaines for
John Hebert
Product Manager (07)
Insecticide-Rodenticide Branch
Registration Division (7505P)

RESTRICTED USE PESTICIDE
DUE TO HAZARDS TO NON-TARGET SPECIES
For retail sale only to: USDA Animal and Plant Health Inspection Service Wildlife Services, U.S. Fish and Wildlife Service, and the U.S. National Park Service to be used only by Certified Applicators or persons under their direct supervision and only for those uses covered by the Certified Applicators certification

ACCEPTED
with COMMENTS
In EPA Letter Dated
APR 15 2011
Under the Federal Insecticide, Fungicide, and Rodenticide Act, as amended, for the pesticide registered under EPA Reg. No.
56228-36

SUPPLEMENTAL LABELING
BRODIFACOUM-25W CONSERVATION

For control and eradication of Roof (black) rats on Palmyra Atoll only.

<u>This supplemental label is only for use on Palmyra Atoll and expires on July 31, 2014 and must not be used or distributed after this date.</u>

KEEP OUT OF REACH OF CHILDREN

CAUTION

(EPA REG. NO. 56228-36, EPA Est. No. 056228-ID-1)

THIS SUPPLEMENTAL LABELING AND THE PACKAGE LABELING FOR BRODIFACOUM-25W CONSERVATION (EPA REG. NO. 56228-36) MUST BE IN THE POSSESSION OF THE USER AT THE TIME OF APPLICATION. READ THIS SUPPLEMENTAL LABEL AND THE PACKAGE LABEL BEFORE APPLYING BRODIFACOUM-25W CONSERVATION. ALL APPLICABLE DIRECTIONS, RESTRICTIONS AND PRECAUTIONS ON THIS SUPPLEMENTAL LABEL AND ON THE PACKAGE LABEL MUST BE FOLLOWED.

DIRECTIONS FOR USE

USE RESTRICTIONS:

This supplemental label applies only to the control and eradication of roof rats (*Rattus rattus)* on Palmyra Atoll. The modifications to the label for EPA Reg. No. 56228-36 that this supplemental label allows regarding rates, application directions, and restrictions and limitations apply only to use of this product on Palmyra Atoll.

The maximum amount of bait to be applied under this label to Palmyra Atoll may not exceed 47,000 kilograms (~103,500 lbs). Determination of the final project application rate will be calculated from the total amount of bait applied (lbs or kg) applied via broadcast and canopy baiting to the emergent land area (in acres or hectares) of Palmyra Atoll that is treated via broadcast and canopy baiting during the eradication effort. Areas where bait stations are used are not to be included in these rate calculations, but the 47,000 kg limit on the total amount of bait used includes bait applied in bait stations.

DIRECTIONS FOR USE

CANOPY BAITING (bait placement in the canopy of trees and shrubs): Hand bait tree and shrub canopies that do not receive bait during broadcast applications. These canopies will likely be in areas where the ground was treated by hand broadcast. Bait these habitats using bait bolas, consisting of two biodegradable bags, each bag containing up to 0.9 ounces (25 grams) of bait, tied together by a short length of string. Sling or place bolas into branches and fronds of every stand-alone palm or every third interconnected palm tree per treatment.

BAIT STATIONS: Tamper-resistant bait stations must be used when applying this product to areas in and around human habitation to keep bait out of reach of children, non-target wildlife, or domestic animals. Apply up to 4.2 ounces (120 grams) of bait per bait station. Space bait stations at intervals no greater than 160 ft (50 meters). Deploy bait stations in a grid pattern over the area for which rodent control is desired. Additional bait stations may be deployed inside or on the perimeters of buildings. Check and replenish bait stations at a minimum of every 5 days for the first 20 days of the operation. Bait stations may be left in place for up to 2 years. Bait stations containing bait must be checked for signs of rodent activity and disturbance by other factors at least every 2 weeks.

Maintain an uninterrupted supply of fresh bait for at least 15 days or until signs of rodent activity cease to be evident. Where a continuous source of infestation is present or a risk of re-invasion is high during times of atoll servicing by barges or when large boats or yachts are present, establish permanent bait stations and replenish bait as needed.

BROADCAST APPLICATION:

The primary method of determining application rate will be calculated using data from onboard bait metering software and GPS flight path data [area treated (acres or ha) and total bait applied (lbs or kg)]. Where feasible, use ground-truthing to verify application rate.

Broadcast bait using aircraft, ground-based mechanical equipment, or by gloved hand. Two aerial broadcast applications may be made during the initial eradication attempt. The first application is to be targeted at 71.3 lbs/acre (80 kg/ha) and will not exceed 80.2 lbs of bait per acre (90 kg bait/hectare). The second application, is to be targeted at 66.8 lbs/acre (75 kg/ha) and will not exceed 80.2 lbs/acre (90 kg/ha). Make the second broadcast application, if judged to be necessary, 10 to 14 days after the first application, depending on local weather conditions. The same rates must be used for hand baiting. These application rates have been established to ensure that the entire land mass is treated with sufficient bait to present a minimum of one lethal dose for each rat present (in each potential rat territory), for long enough that rats can find and consume the bait (typically 3-4 days) and to account for substantial loss of bait to terrestrial crabs and other invertebrates, as well as degradation of bait over that time period.

At points where flight lines overlap, the amount of bait applied might locally exceed the prescribed application rate. This could occur along adjacent borders of parallel swaths, at the end of swaths where they intercept the swath created by shoreline baiting, or in areas missed during the initial baiting operations, as indicated by the GPS flight path data. Minimize areas where the allowable application rate is exceeded as much as possible while ensuring that all areas are baited sufficiently.

DIRECTIONS FOR USE, continued:

If bait application to a specific islet is interrupted due to poor weather conditions before completion, "back baiting" of previously baited swaths is permitted to ensure rats that might have reinvaded treated swaths have access to bait. Use the following rules to determine the extent of back baiting.

Application Delay	Resume baiting strategy
1 day	At drop boundary
2-3 days	2-4 swath widths behind the drop boundary (~20-80 m)
≥ 3 days	4-6 swath widths behind the drop boundary (~80-160 m)

Do not make aerial (helicopter) applications in winds higher than 29 mph (25 knots). Pilot in command has final authority for determining safe flying conditions.

Bait abandoned structures at, or within a day of, the time when bait is broadcast to the same land mass. During each of the two bait application periods, hand-apply up to 7.1 ounces (200g) of bait directly into small abandoned structures. For larger structures over 2,500 square feet of inside area, apply up to 1.0 lb per structure in each of two applications. Where bait will not be exposed to ambient climate and might not degrade if unconsumed, place bait so that it can be recovered readily, and disposed of upon conclusion of the project.

For all methods of baiting, monitor the baited area at least twice per week until 3 weeks have passed since the last application and, using gloves, collect and dispose of any dead animals and spilled or spoiled bait properly.

UNITED STATES DEPARTMENT OF AGRICULTURE
ANIMAL AND PLANT HEALTH INSPECTION SERVICE
4700 River Road, Unit 149
Riverdale, MD 20737-1237

Expires 07/31/2014

APPENDIX M

COMMENTS RECEIVED AND RESPONSES TO COMMENTS

Public Comment on the February 2011 Draft Environmental Impact Statement: Palmyra Atoll National Wildlife Refuge Rat Eradication Project

In accordance with the National Environmental Policy Act (NEPA) of 1969 and implementing regulations, this final environmental impact statement provides responses to comments on the Palmyra Atoll National Wildlife Refuge Rat Eradication Project Draft Environmental Impact Statement. In compliance with the regulations, this final document includes a list of agencies, organizations and individuals commenting on the DEIS; copies of their comments; and responses to the substantive environmental issues raised in the comments.

The DEIS for the eradication of rats from Palmyra Atoll was released for a 45-day public comment period from February 25, 2011 to April 11, 2011 through notice in the Federal Register and letters sent direct to known persons of interest. Written comments were accepted via email and individual letters through the comment period. A total of 21 written or email comments were received.

The following pages show comments received for the DEIS and the Fish and Wildlife Service's responses to those comments. The Service reviewed and considered all comments and determined whether or not they were substantive and warranted further analysis and documentation. Modifications (greater than a few words) to the DEIS are *italicized* in the Final EIS. While the Service greatly appreciates the participation of all those who commented; not all comments required further analysis or changes to the Final EIS. Individual responses are noted when further analysis or modifications are made.

<u>Overall characterization</u>:
We received 21 comments in total:

- 15 (71%) individuals
- 3 (14%) government agencies
- 3 (14%) organizations

<u>Individual comments</u>:

Eric Barker	Kevin Lafferty	Kim Williams
Ralph Black	Cara Losier	Anita Kihei Wintner
John D. Collen	John P. McLaughlin	Chelsea L. Wood
Jonathan Gardner	Carl E. Orazio	Hillary S. Young
Wayne Johnson	Mark Rauzon	

<u>Organizations comments</u>:
American Bird Conservancy (ABC)
Michael Fry, PhD, Director of Conservation Advocacy

Marine Conservation Biology Institute (MCBI)
Lance Morgan, PhD, Vice President

Pacific Seabird Group (PSG)
Craig S. Harrison, Vice Chair for Conservation

<u>Governmental agencies comments</u>:
Protected Resources Division of the NOAA Fisheries Pacific Islands Regional Office
Kim Maison, Sea Turtle Biologist
Alecia VanAtta, Assistant Regional Administrator for Protected Resources

- Official DEIS comment (PIRO PRD2)

National Parks Service, Environmental Quality Division (NPS-EQ)
Melia Lane-Kamahele, Acting Pacific Area Director

USDA Animal and Plant Health Inspection Service – Wildlife Services (USDA)
William H. Clay, Deputy Administrator

U.S. Environmental Protection Agency, Region IX (EPA)
Enrique Manzanilla, Director, Communities and Ecosystems Division

Comment Response Matrix
Final Environmental Impact Statement, April 2011:
Palmyra Atoll National Wildlife Refuge Rat Eradication Project

Comment #	Reviewer	Section	Comment	Response to comment
1	NMFS PIRO PRD	General	NOAA Fisheries was recently petitioned under the ESA to list the bumphead parrotfish (*Bolbometopon muricatum*), as well as 82 species of coral, 21 of which are found within the waters surrounding Palmyra Atoll. Our agency is currently evaluating the petitions to determine whether any of those species warrant listing under the ESA.	Comment noted. No response needed.
2	NMFS PIRO PRD	General	Appendices are labeled with letters but referred to at times in the text as being numbered (example: pg. 42 refers to Appendix 7 which is actually Appendix G).	We have corrected the errors.
3	NMFS PIRO PRD	3.2.7	The list of marine mammals observed in pelagic waters surrounding Palmyra described here does not agree with the list contained on pages 101-102 in Section 4.4.2.2 *Special significance considerations for listed marine mammals under the Marine Mammal Protection Act (MMPA).* It is recommended that all marine mammals known to inhabit the waters surrounding Palmyra be given special significance consideration under the MMPA.	We have amended section 4.4.2.2 to reflect the marine mammal species observed at Palmyra.
4	NMFS PIRO PRD	4.4.2.2	The DEIS incorrectly states that "MMPA regulations prohibit "disturbance" of marine mammals, which is a lower threshold of effect than mortality." The MMPA prohibits "take" of marine mammals, which is defined as "to harass, hunt, capture, or kill, or attempt to harass, hunt, capture, or kill any marine mammal" (16 U.S.C. 1362 Sec. 3(13)). Further, the term "harassment" is defined as "any act of pursuit, torment, or annoyance which – (i) has the potential to injure a marine mammal or marine mammal stock in the wild; or (ii) has the potential to disturb a marine mammal or marine mammal stock in the wild by causing disruption of behavioral patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering" (16 U.S.C. 1362 Sec. 3(18)(A)). The acts described in the subparagraphs (A)(i) and (A)(ii) are also referred to as Level A and Level B harassment, respectively (16 U.S.C. 1362 Sec. 3(18)(C) and Sec. 3(18)(D).	Thank you for the clarification. The document is modified to correctly reflect "take" is prohibited under MMPA.
5	NMFS PIRO PRD	4.4.2.2	If your agency determines there is potential for "take" of any marine mammal species resulting from the proposed action, you may be required to apply for an Incidental Harassment Authorization (IHA) or a Letter of Authorization (LOA) through the NOAA Fisheries Office of Protected Resources. Please refer to the following website for more information on obtaining permits under the MMPA: http://nmfs.noaa.gov/pr/permits/types.htm	Comment noted. No response needed.
6	NMFS PIRO PRD	4.4.2.1	The DEIS acknowledges that the bumphead parrotfish is designated as a candidate species. However, there is no analysis provided in the DEIS on potential impacts to this fish species. We suggest that you provide information on how this species may or may not be at risk of primary or secondary exposure to the toxin.	We have modified the document in section 4.4.4.1.
7	NMFS PIRO PRD	3.2.7	Given the fact that surveys have documented Palmyra to be a significant chelonian foraging area, PIRO PRD is concerned that the potential impacts to sea turtles have not been adequately addressed in the DEIS. The following comments and questions specifically relate to potential impacts of sea turtles (Comment 14-21).	Please see modifications to Section 4.4.4 related to toxicity to reptiles and amphibians. Every effort would be made to prevent accidental entry into the marine environment. In the unlikely event that 1 kg of bait pellets entered the marine environment it would introduce 0.025 grams of toxicant. There are 500 pellets in a kilogram. We are not aware of research specific to marine reptiles, but calculations from a recent preliminary analysis on study of ornate wood turtles by U.S. Department of Agriculture, National Wildlife Research Center, when applied to adult green turtle weights, imply an adult green turtle could consume at least 40.5 lbs (18.4 kg) or 9,200 pellets and an adult hawksbill could consume at least 15.4 lbs (7 kg) with no signs of ill health.
8	NMFS PIRO PRD	2.4.10	Sea turtles can be opportunistic feeders, and have been known to ingest pieces of plastic and other debris of varying sizes and colors; therefore, they could very possibly ingest any bait pellets that end up in the marine environment.	
9	NMFS PIRO PRD	2.4.10	Sea turtles can be opportunistic feeders, and have been known to ingest pieces of plastic and other debris of varying sizes and colors; therefore, they could very possibly ingest any bait pellets that end up in the marine environment.	
10	NMFS PIRO PRD	4.4.4.4	Toxicant risk section: It is reasonable to assume that green or hawksbill turtles would potentially consume bait pellets if they were to come in contact with them in the marine environment. A wide range of life stages are present at Palmyra and juvenile green turtles in particular are more omnivorous and opportunistic feeders. Once they have recruited to nearshore environments like Palmyra, sub-adults and adults tend to primarily feed as herbivores but may still be opportunistic at times. Many necropsies of turtles of all size classes reveal plastic and other types of debris that have been ingested; bait pellets would not appear much different than floating or sunken bits of debris that turtles have been known to ingest.	
11	NMFS PIRO PRD	4.4.4.1	Primary exposure section: there is no mention of potential ingestion by sea turtles if pellets unintentionally end up in the marine environment. While accidental entry into the marine environment will be 'minimized', it can not be eliminated; can you quantify how much of the toxicant is likely to enter the marine environment?	
12	NMFS PIRO PRD	2.4.6	Would measures also be in place to monitor the health of sea turtles potentially exposed to toxicant and is it possible to administer the antidote to reptiles?	Marine turtles would be observed for general health, as encountered. A veterinarian on island would be available to provide wildlife care.
13	NMFS PIRO PRD	3.2.7	Green turtles should not be included in the section on reef fishes; they are discussed in the next section on turtles.	We have made the modification.
14	NMFS PIRO PRD	3.2.7	East Pacific greens are also distinguished by different shell morphology but can only be confirmed with genetic analysis. It is recommended that you remove the term 'rare'.	We have corrected the error.
15	NMFS PIRO PRD	3.2.7	Algae section: McFadden, Sterling, and Naro-Maciel *et al* . may have more info on algal species and abundance on the north and south reef flats as a result of a portion of their research involving algae transects in relation to green turtle food source studies.	We have included the reference in the Affected Environment Section 3.2.7.
16	NMFS PIRO PRD	3.2.7	Green turtle nesting has only rarely been observed at Palmyra so it is difficult to make a connection between rat eradication and the potential to establish or reestablish nesters at this site, especially if there is no evidence that Palmyra was a nesting site used historically with any regularity.	We believe predator-free sites in areas where marine turtles are known to forage have the potential for increasing in importance as nesting habitat. For example, at Laysan Island in the Northwestern Hawaiian Islands, nesting is now occurring where it was once very rare.
17	W. Johnson	General	This plan will cause enormous suffering and agony to living creatures and the blood will be squarely on your hands.	Comment noted. No response needed.

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Final Environmental Impact Statement, April 2011:
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18	E. Barker, K. Williams, U. Heinz	General	Please extend the contact period.	A minimum 45-day comment period is required. Agencies and experts with significant expertise in these matters thoroughly responded within the allotted time.
19	E. Barker, K. Williams, U. Heinz	General	Asked for a public hearing on Oahu/Honolulu.	Palmyra is an unincorporated territory in the Pacific, garnering interest from around the world. Comments were sought from all interested parties.
20	K. Williams	General	I strongly OPPOSE The Nature Conservancy and the USFWS using an aerially dispersion of brodifacoum on Palmyra Atoll. The use of poison does more harm to the environment than good.	Comment noted. No response needed.
21	C. Losier	General	I urge you to reconsider this course of action or take steps to halt the progress of this project. This poison causes extremely painful death to the animals who come in contact with it, which is clearly inhumane. Please consider the lives of the animals who will be affected before condoning this project.	Comment noted. No response needed..
22	U. Heinz	General	Please provide for time to create a better alternative strategy.	We considered a wide range of alternatives. Please see Sections 2.3 through 2.6.
23	C. Wood, J. Gardner, J. McLaughlin, J. Collen, H. Young, C. Orazio	General	I've reviewed the [DEIS] and support the proposed actions, …to protect Palmyra's unique species and habitats. ….look forward to watching the recovery of the atoll's terrestrial ecosystems in the future. ….believe the project is likely to succeed and should result in positive net benefits for the seabird community at Palmyra, providing important nest site protection for many species that are globally declining. ....[support] Based on the science, supporting information, and options presented in the DEIS.	Comment noted. No response needed.
24	J. Gardner	General	This is a necessary and important project which will lead to significant beneficial conservation outcomes.	Comment noted. No response needed.
25	J. Collen	General	From my personal knowledge both of Palmyra Atoll and of the pest eradication projects undertaken in New Zealand (which includes visits to many of NZ's now pest-free offshore and Subantarctic islands), I would like to comment that the proposal is necessary, relevant and well constructed.	Comment noted. No response needed.
26	K. Lafferty	General	Having studied black rats on Palmyra Atoll, I can testify to their incredible numbers and the need to remove them from the Atoll to help project the area's rich and valuable native diversity. The level of study and forethought that has gone into this restoration effort is admirable.	Comment noted. No response needed.
27	C. Orazio	General	The proposed actions support the efforts to protect and restore Palmyra Atoll's ecosystem.	Comment noted. No response needed.
28	R. Black	General	[We support actions] free of chemical eradication for the rats...and will be willing to work along side the providers or caretakers of the palms or any and all that are being decimated by the rats or any foreign invaders of any nature to the atull [sic] islands. And also if empowered to partial chemical eradications we would care to not assist in the chemical portion. But to referee as safeguard for areas too delicate for chemical eradication. As we contend not even a biodegradable is safe for all the atull [sic] islands we believe we have all natural procedures that alone or combined will safely eradicate by well proven and longstanding american means with proven and safe track record with positive final result.	Comment noted. No response needed.
29	M. Rauzon	General	I am familiar with Palmyra from two prior visits and have surveyed the island for seabirds. I have seen firsthand the potential for seabird restoration and have also witnessed the effects of the failed 2001 rat eradication attempt, both on the island and in the community of eradicators. That is why I advocate pressing forward with rat eradication and especially Alternative C that best copes with the very challenging environment that Palmyra presents.	Comment noted. No response needed.
30	M. Rauzon	General	The Palmyra rat eradication has had the greatest breadth of research and preparation than any other US eradication. Since the 2001-02 eradication attempt, research into why it failed and what can be learned, has been on-going.	Comment noted. No response needed.
31	M. Rauzon	General	Overall, the completeness of this EIS, the comprehensive appendices that review the past and future options, determine LD's of toxins, etc. is very remarkable and admirable in scope, showing again how seriously you take your duty to be thorough, responsible and transparent. I say overall, for I did not see what happens if rats are detected after the second drop…	After the rat eradication, contingency bait would be left at Palmyra, available to treat remnant rats if any are detected, and a detection response plan would be in place to guide this action. The detection response plan is discussed in Section 2.4.11.
32	NPS	General	We support the Refuge's goal of eradications rats from Palmyra and anticipate that the project also will yield valuable information on refinement of eradication and follow-up monitoring techniques, particularly for equatorial island environments.	Comment noted. No response needed.
33	NPS	General	The EIS should more clearly state the reasons that diphacinone was not considered appropriate for this particular project. We feel this specificity and additional supporting information are important in light of possible future rodent eradication attempts where diphacinone could be the more appropriate tool.	See section 2.3.6 for revised explanation of our decision not to proceed with alternatives that required the use of Diphacinone-50 product.
34	NPS	2.3.6	This section [2.3.6] would be clearer if the opening paragraph was expanded on or otherwise revised - all five factors contributing to the decision not to further consider the use of diphacinone as an alternative need additional supporting or explanatory information (specified in comments #3-X listed below).	

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35	NPS	2.3.6	The toxicity of the product is confusing in light of later information about the higher toxicity and slower environmental degradation of brodifacoum. The EIS should clarify why and how the lower toxicity of diphacinone (vs. brodifacoum) figured into the decision not to use diphacinone.	The relatively lower toxicity of Diphacinone-50 to rodents when compared with Brodifacoum means that more doses of Diphacinone are required to achieve similar effects to those caused by Brodifacoum 25W. This necessitates maintaining access to the Diphacinone for all rodents for up to 12 days to ensure 100 percent mortality, compared to 4 days exposure necessary for Brodifacoum 25W. Please see Section 2.3.6 for additional information.
36	NPS	2.3.6	Efficacy, including palatability is also mentioned as a consideration, but then later (page 22, lines 15-16 and elsewhere), the EIS judges that the 2 toxicants are of equal and adequate palatability. If efficacy other than palatability is a major issue, this should be more clearly stated in this section, including in this introductory paragraph.	Palatability was inferred from studies that looked at whether rats chose the bait over an alternate food (choice tests). Choice tests in the field and in the laboratory showed different results. These differing results led to uncertainty about palatability. Uncertainty about palability is a factor that influenced our decision.
37	NPS	2.3.6	" ... the extremely dense vegetation at Palmyra inhibiting distribution of product" does not appear to be specific to the use of diphacinone. It instead seems a concern that is related to the method of distribution of any bait.	The document was modified to remove this factor.
38	NPS	2.3.6	" .. , the safety of personnel in applying product, including consideration of unknown but documented unexploded ordnance in the atoll" also is not specific to the use of diphacinone.	The document was modified to remove this factor.
39	NPS	2.3.6	" ... the inordinately dense population of land crabs, their extreme ability to penetrate enclosures, and their voracity of consumption" again does not appear to relate specifically to the use of diphacinone.	The high density of land crabs is germane because of the rapid uptake of available bait by land crabs. The lower toxicity of Diphacinone-50 to rats means it must be available for much longer to result in 100% mortality of rats. The high density of crabs makes it extremely difficult to retain enough bait for rats on the ground for the 12 days we estimate necessary for complete kill of all rats.
40	NPS	General	We also suggest including in this section consideration of the performance of diphacinone if applied atsowage rates comparable to that proposed for brodifacoum in Alternatives B-D. Would this increase change the likely performance of this first generation toxicant and its assessment in the DEIS?	The sowage rates for Diphacinone-50 would be as much as 3 times higher to guarantee bait remaining on the ground for the entire period of exposure necessary to kill all rats. Failure to provide adequate bait exposure period will result in failed eradicationl.
41	NPS	4.4.4.1	We also are concerned about the potential for bristle-thighed curlew mortality. The stated Palmyra resident population of up to 182 birds constitutes roughly 2% of the estimated world population of approximately 10,000 individuals. The DEIS considers population modeling that suggests" ... minor decreases in the population growth rate with diminishing impacts on the projected future population," resulting from a theoretical 80% mortality of resident BTCU at Palmyra (page 113, lines 26-30). Because the species is thought to be in decline, we urge caution and prudence ill light of other factors outside the control of the FWS that may impact this species now and in the future. We ask the FWS to consider additional actions to minimize exposure of curlews to the toxicant; for example, removing crab carcasses and other avenues for secondary poisoning in the days immediately following baiting in areas of high curlew densities, and/or using bait stations rather than aerial broadcast on key curlew islands or in key curlew habitat if feasible.	Alternative C, our Preferred Alternative, institutes employing all feasible methods of shorebird protection will be employed including timing of the action, immediate collection of any carcasses, bait stations only at major curlew roosting sites, and preemptive capture and feeding of non-breeders prior to bait broadcast for the period of highest danger.
42	NPS	General	Lastly, we call your attention to the recent report by Parkes and Fisher (parkes, J and P Fisher. 2011.) "Review of the Lehua Island Rat Eradication Project", Landcare Research Contract Report LC 129 for the Lehua Island. Their catalog of rodent eradication attempts differs from that of this DEIS and may be more complete. Additionally, their simple statistical evaluations of diphacinone vs brodifacoum provide an additional way of viewing the track record of these two toxicants and emphasize the need for more data. Finally, some of the lessons learned from Lehua may be applicable to the Palmyra project.	We have modified Section 2.3.6 to reflect the updated statistics provided in Parkes and Fisher, 2011. All recommendations from this report have been carefully studied and inform this project.
43	ABC	General	We support Alternative C . . . for the eradication to minimize effects on nontarget species.	Comment noted. No response needed.
44	ABC		[Recommendations on experts in shorebird capture and care to consult] . . . Peter Doherty, Virginia Beach, VA, who produces capture nets specifically designed for shorebirds. . . . Monterey Bay aquarium . . . International Bird Rescue Research in Cordelia, CA.	We appreciate the information and will consult these experts, as applicable.
45	ABC	General	Long-legged waders are extremely difficult to capture and hold and can be subject to high rates of mortality during capture and in captivity. It may be useful to try to manage expectations by providing a tentative estimate of mortality in both processes, based on available data.	We recognize there are logistical challenges and uncertainty of successful capture and holding of long-legged waders and agree it is incumbent on us to try to mitigate possible nontarget mortality. We understand, in the worst case scenario, the rat eradication action could cause the death of all bristle-thighed curlews and pacific golden plovers expected to be at Palmyra during the operation and while these birds could still be at risk of exposure to lethal amounts of brodifacoum. Any individual birds that are captured and survive captivity would reduce the overall impact of the eradication on the Palmyra-based population of that species.
46	ABC	General	We have concerns about the cement slab on which it is proposed to maintain the birds on Cooper Island, because curlews tend to develop foot problems in uniform substrates without tidal action.	In an effort to address potential foot problems, the floor of the shorebird holding facility is planned to consist of a 6 inch layer of sand and coral rubble covered by a soft, rubberized matting (elephant bark) that will be flushed with saltwater several times a day to wash away effluent and deter ants from accessing feed.

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47	ABC	General	[The wildlife veterinarian who will be onsite] has plans to monitor fecal corticosteroids, fecal parasites, and blood for CBC and chemistry profiles. ABC thinks this could be a very useful monitoring program to evaluate these fragile birds in captivity and to develop additional expertise for future captive holding of vulnerable birds during island eradications.	Comment noted. No response needed.
48	ABC	General	We expect the risk of conspecific aggression to be low among these birds, because of the timing of the operation and because most will not yet be of breeding age, but if the birds are held in some sort of aviary, provisions should be made for separating some birds and providing a visual barrier for any aggressive individuals.	Captured shorebirds would be held in aviaries specifically designed for shorebirds. As suggested, aggressive individuals will be separated from other birds.
49	ABC	General	One interesting option for the capture and holding of the curlews may be to place them on a nearby islet or rock, if such a place were available and not subject to baiting.	Comment noted.
50	ABC	General	The field studies to determine the amount of rodenticide bait needed to insure adequate coverage of all rat territories appear to have been well planned and executed.	Comment noted.
51	ABC	General	The metabolic fate of brodifacoum and mass balance of residues were not reported in the prior study given in Appendix F of the Draft EIS. The residue analysis for that study was conducted by the California Animal Health and Food Safety Laboratory at UC Davis, and they may have retained the mass spectrometer reconstructed ion chromatograms, which could identify whether any of these potential metabolic products or other products were present in the crab tissues and excreta analyzed in the 2010 study. We strongly suggest contacting them and trying to have the spectroscopist attempt to determine what metabolic products of brodifacoum were present in the feces in addition to the parent compound. . . Without a study of the fate of brodifacoum ingested by crabs, the fate and residue composition of the large amount of brodifacoum spread over Palmyra Atoll will be unclear.	The crab excrement samples collected during the 2010 study were not analyzed for the metabolic fate of brodifacoum, and unfortunately the sample material is no longer available for further analysis.
52	ABC	General	We suggest that when samples are collected and analyzed from the planned Palmyra project, APHIS (and any other lab contracted) report as many residues and metabolic products as possible, and use the information to construct a mass balance. The persistence and toxicity of any identified products should be available from prior studies. We suggest using this data to calculate the expected persistence and toxicity to non-targets (such as curlews) and to hold the curlews in captivity until the toxic residues have dissipated in the Palmyra environment.	We have forwarded these recommendations to the USDA for consideration in the monitoring plan.
53	ABC	General	We found that the low level of detail in [Appendix A] precluded a careful evaluation of the bird monitoring protocols, and suggest that further definition be given to the a) statistical design of the pre- and post-eradication bird monitoring 2) the time frame for evaluation of the persistence of bait in the palm canopy, which should be continued until none is detected or some minimal level is reached.	The bird populations monitoring is a part of regular Refuge inventory and monitoring, and will continue. The description of the bird monitoring effort that surrounds this eradication project has been modified to reflect that bait fate in palm canopies will be monitored until undetectable.
54	ABC	General	We would like to see an evaluation of the shorebird population in subsequent years, though we assume this is part of the long-term strategy for documenting the effect of the action on the atoll.	Evaluation of Palmyra's shorebird community will continue beyond the rat eradication effort as one of the Refuge's standard monitoring activities.
55	ABC	General	The detail given for the food web monitoring was minimal, with only a sketchy description given on where pooled samples will be collected. We believe these should be representative of the entire atoll. 84 samples of non-target terrestrial animals and 80 samples of fish appears to be an adequate number of samples to determine the distribution and fate of rodenticide on the atoll.	To ensure that bait would be delivered to all rats, the bait application will be uniform across the atoll's emergent land area. Because of this, we do not expect location to be a significant driver of variance in residue values. However, samples would be collected from locations that both represent the primary habitat types found at Palmyra, and serve as practical sampling sites.
56	ABC	General	We recommend that a subset of split samples of the rats, fish, gecko, crabs, and bird samples be sent to the U.S. Geological Survey Madison, WI Lab and the USDA National Wildlife Health Center for independent analyses.	Supplementary analysis of split samples at labs other than the USDA NWRC facility in Fort Collins, CO is not currently budgeted for with this project. However, we will explore the possibility of archiving a subset of samples for analysis by a different facility if the results from the NWRC analysis are cause for concern.
57	ABC	General	We believe that directed searches (as opposed to opportunistic searches) for non-target carcasses be conducted in transects for longer than 10 days after the 2nd application in shore bird roosting sites, and that these also concentrate on places where intoxicated curlews might hide to avoid detection. The monitoring plan does not give detail about how often these searches will be conducted.	We have modified the monitoring plan to include directed carcass searching along North Beach and on the Runway (the Atoll's largest shore bird roosting sites) will continue for 30 days after the second bait application.
58	ABC	General	In conclusion, ABC supports the effort to eradicate rats from Palmyra, as it is an important center of biodiversity and species abundance. Specifically, we support the Alternative C (aerial broadcast with capture of shorebirds) option listed in the Draft EIS. We believe this project has been organized and planned carefully, although we would like to have a more complete analysis of the fate of rodenticide moving through the Palmyra ecosystem.	Comment noted. No response needed.
59	MCBI	General	MCBI believes Alternative C (as outlined in the DEIS): Aerial broadcast of brodifacoum, with proactive mitigation of risk for vulnerable shorebird taxa offers the highest probability of removing the nonnative rats while also minimizing harm to the marine and terrestrial ecosystems.	Comment noted. No response needed.
60	MCBI	General	In order to make a more informed decision, a cost comparison of each alternative would have been helpful in determining the efficient use of resources. Regardless of cost, MCBI supports the eradication of nonnative rats on Palmyra Atoll in an effort to restore native wildlife populations.	Table 2.8 has been added and compares costs between treatment types.

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Palmyra Atoll National Wildlife Refuge Rat Eradication Project

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61	USDA	General	The FWS should proceed cautiously and make every effort to document the impacts of this project. Documentation of environmental impacts should be evaluated by an independent party to ensure absolute transparency.	The Palmyra Partnership is securing assistance from USDA to conduct independent monitoring for this project (Appendix A). The monitoring effort has been designed by USDA-NWRC, the monitoring action would be implemented by USDA-NWRC, and the samples would be analyzed and the results would be reported by USDA-NWRC. Refuge personnel will also continue to monitor wildlife responses as a part of our standard refuge monitoring activities.
62	USDA	General	We have also worked cooperatively to draft a post-application monitoring plan to properly document the short-term environmental impacts of this activity. Specifically addressing the high rates of brodifacoum application proposed in Alternative B and C: first application rate is 4.5 times higher than currently allowed rate, second application is nearly 6 times higher than currently allowed rate, total application rate (134 kg/ha) will exceed the current total label allowance (27 kg/ha) by 107 kg/ha.	We worked with USDA and USEPA to develop a supplementary bait label that would be specific to this eradication action at Palmyra Atoll, and would allow for the operational application rates discussed in Chapter 2 of the FEIS. This supplemental abel is included in Appendix L.
63	USDA	General	Massive non-target mortality of shorebirds and other species could occur as a result of primary or secondary exposure. Therefore, this could be interpreted as a direct violation of the Migratory Bird Treaty Act; the FWS should secure a take permit under the Act.	In Chapter 4 of the FEIS we evaluate the non-target species that are at risk of mortality from primary and/or secondary exposure. We are aware of risks and expect some mortality of shorebirds, but do not expect massive morality of non-target species. Aside from shorebirds, no land-foraging birds occur at Palmyra, nor do any native mammals. Also, great effort would be taken to prevent bait from entering the marine environment, further reducing risks there. We will secure a MBTA "Special Purpose Permit" to account for the anticipated worst-case migratory bird mortality.
64	USDA	4.4.4.1	The range of birds listed on page 107 of the DEIS that will likely be lethally taken on do not quite match with the expected lethal take given in the individual accounts discussed starting on page 119.	The population ranges present on page 107 of the DEIS represent the annual range which includes the winter months when shorebirds are most numerous at Palmyra. The expected lethal take values for bird species starting on page 119 were based on the higest values from all atoll counts conducted during the same seasonal period in which the eradicaiton woudl be implemented (June-July). We have clarified this point in Section 4.4.4.1.
65	USDA	4.4.4	We believe that the nontarget lethal take in the DEIS is understated and that the marine reptiles, namely sea turtles, need to be included because they will eat pelleted bait and it is anticipated that broadcast bait will wind up in waters where they could be exposed.	Please see modifications to Section 4.4.4 related to toxicity to reptiles and amphibians. Every effort would be made to prevent accidental entry into the marine environment. In the unlikely event that 1 kg of bait pellets entered the marine environment it would introduce 0.025 grams of toxicant. There are 500 pellets in a kilogram. We are not aware of research specific to marine reptiles, but calculations from a recent preliminary analysis on study of ornate wood turtles by U.S. Department of Agriculture, National Wildlife Research Center, when applied to adult green turtle weights, imply an adult green turtle could consume at least 40.5 lbs (18.4 kg) or 9,200 pellets and an adult hawksbill could consume at least 15.4 lbs (7 kg) with no signs of ill health.
66	USDA	2.3	The DEIS should have included a wider range of Alternatives such as an Integrated Rat Eradication Alternative. In particular, we expected to see the use of other rodenticides as considered alternatives analyzed in detail. Worldwide literature strongly supports first generation rodenticide operations more than is indicated in the DEIS, including tropical environments in Australia and Pacific Islands (Varnham 2010). An example of a recent rat eradication success in a tropical environment using an integrated approach included rodent eradication on Cocos Island, Guam (Lujan et al., 24th Vertebr. Pest Conference, 2010, in press).	Alternatives involving other rodenticides were considered and dismissed in Section 2.3. Different factors were considered, including inordinately dense populations of land crabs at Palmyra. While tropical, the eradication environment at Cocos Island greatly differs from that at Palmyra, notably in the density of land crabs, and the complexity of land crab populations. The preferred alterntative (C) includes an integrated approach to eradicating rats and minimizes risk to non- target species, with multiple methods tailerd to specific environments.
67	USDA	2.4.13	A great uncertainty in the rodent eradication plan is the rats' use of the coconut canopy and the ability to adequately treat the palm canopy. It is our understanding that the Refuge has discussed eradicating coconut palms (potentially another invasive species) from Palmyra Atoll. A viable alternative to one of the alternatives in the DEIS would be to remove the coconut palms prior to the eradication, simplifying the rodent eradication.	Removal of the coconut palms is an on-going management activity to restore the atoll, with the current focus targeting palms over-hanging the water. However, extensive removal of coconut palms was considered early in our planning as a first-phase eradication activity. We concluded that while this action would reduce rat habitat, it would also greatly hinder movement on the ground (because of successional plant growth in the resulting light gaps), and would remove a large component of the only crab-free habitat within Palmyra's terrestrial envrionment (the forest canopy). Bait applied to coconut crowns would not be availble to land crabs, but would be available to rats; refer to Appendix C. We have added Section 2.4.13 to explain this.
68	USDA	2.4.6	The DEIS suggests that rodenticide resistance is unlikely because it has been 6 years since the last treatment. This is an incorrect assumption as it is possible to still have some rodenticide residue in the rats on Palmyra Atoll. The DEIS relies on old information and the reference to Pitt (2010) is erroneous.	We continue to believe it the risk of having resistant rats at Palmyra is negligible. We have modified Section 2.4.6 to further address the comment.

Comment Response Matrix
Final Environmental Impact Statement, April 2011:
Palmyra Atoll National Wildlife Refuge Rat Eradication Project

Comment #	Reviewer	Section	Comment	Response to comment
69	USDA	General	Another concern of ours is baiting in and around human habitation because it is unclear exactly what the protocol will be. This should be explicitly stated in the DEIS. Additionally, if baits are currently being used in these areas, the type of bait, active ingredient, application rate, and duration of baiting being used should be documented.	The use of tamper reistant bait stations in and around human habitation would be conducted in accordance with the bait product label. We have included many preliminary operational details in Appendix K, and will post a working draft version of the operations plan at http://www.fws.gov/palmyraatoll/rainforestrestoration.html
70	USDA	2.3.6	A clarification/correction needs to be made in the DEIS regarding Diphacinone 50:Conservation and Ramik Green. In numerous places in the DEIS reference is made to the differences in the performance of Diphacinone 50:Conservation and Ramik Green [sic] when used in rodent eradication or control projects. These two products are exactly the same formulation. Diphacinone 50:Conservation is simply a repack of Ramik Green [sic]. Consequently, questions raised in the DEIS regarding the uncertainty about relating the performance of the two products is nullified because they are directly comparable.	We have modifed the document to refer to this product generally as Diphacinone-50:Conservation or Diphacinone-50. Ramik® Green (a commercially available product) is only referenced from literature where it was the specific product used.
71	USDA	4.3.1.1	We feel ideas presented in the DEIS regarding the potential residues in surface water mislead the reader. On this page you present the summary of an aquatic risk assessment conducted by Syngenta Crop Protection Inc. (2003). This risk assessment reported residues resulting in surface water from an application of 18 kg/ha brodifacoum. No risk is indicated for fish in this assessment. The proposed application rate in Alternative B and C are 4.6 times higher than 18 kg/ha. Even at this higher application rate, no risk is indicated for fish. However, it is critical to point out in this section that the application rate proposed on Palmyra Atoll will be much higher than that used by Syngenta and, thus, may not result in similar conclusions as suggested.	We have made modifications to Section 4.3.1.1.
72	USDA	General	The DEIS predicts the impact of brodifacoum on nontarget species, especially birds and reptiles. However, the true extent of impacts on nontarget species are largely unknown because many facets of the persistence of brodifacoum are unknown, such as the length of time it remains intact in soils and other environmental compartments and the duration of primary and secondary impacts to aquatic and terrestrial organisms. The longevity of active brodifacoum could become a great concern beyond the 2-month window when birds are relatively rare on the island and potentially long beyond the 1-month monitoring proposed in the included monitoring plan. As a result of the unknowns, monitoring will be extremely important and valuable. We understand the logistical difficulties of keeping a monitoring crew on the atoll beyond 1 month. However, collection of environmental samples during follow-up visits on day 56, 6 months, 1 and 2 years are very important to document the residue decline in the environment.	We agree it is desirable to understand the potential short-term and long-term risks associated with this eradication action and recognize the need to manage the atoll's resources accordingly. We will continue collection and analyses of environmental samples beyond what is scheduled in the montioring plan that was developed by the USDA (Appendix A), as well as presence/absence of rats, status of shorebird populations, and other indices of ecosystem health through regular national wildlife refuge monitoring and within the limitations of funding.
73	USDA	General	The DEIS should include a discussion of professional wildlife damage management principals which guide agency decision making beyond efficacy, such as the intent to minimize adverse effects on non-target animals, and economic (e.g. program cost/benefit) and social factors (public acceptance of various alternatives).	Please see Sections 1.4 through 1.7, Sections 2.1. through 2.5, and Sections 2.9 and 2.10.
74	USDA	General	The DEIS should include lessons learned from Rat Island, with recommendations made by FWS and the Ornithological Council (Salmon and Paul 2010) as they may apply to Palmyra.	We have reviewed the report and lessons learned have been taken into consideration. Many of the recommendations are incorporated into Palmyra's planning, We have included many preliminary operational details in Appendix K, and will post a working draft version of the operations plan at http://www.fws.gov/palmyraatoll/rainforestrestoration.html. Finally we also referencedthe report in the FEIS.
75	USDA	General	For disclosure, the label should be included in the Final EIS to ensure that the proposed action is in conformation with label restrictions.	We have included the label and supplemental label as Appendix L of the FEIS.
76	USDA	General	The DEIS did not cite literature that included pertinent information relevant to the analysis of the effects of brodifacoum and diphacinone that should be considered in an objective analysis of both toxicants including information on the effects of nontargets (Cox and Smith 1990, Dowding et al. 2006, Salmon and Paul 2010), effectiveness on formulations on targets (Swift 1998), registration/environmental concerns (U.S. Environmental Protection Agency 1998), and rat ecology (Varnham 2010).	We have reviewed the literature and modified the FEIS with some of these references. Please see Sections 2.6.4 and 4.4.4.1.
77	USDA	General	As the registrant of the only brodifacoum labels currently approved for using broadcast application to undertake this type of a project, WS is very interested in the short- and long-term effects from this rodenticide.	Comment noted. No response needed.
78	EPA	General	We have rated Alternative A (No Action) as Environmental Concerns Insufficient Information (EC-2): "EC" (Environmental Concerns). The EPA review has identified environmental impacts that should be avoided in order to fully protect the environment. Corrective measures may require changes to the preferred alternative or application of mitigation measures that can reduce the environmental impact. EPA would like to work with the lead agency to reduce these impacts. Category "2" (Insufficient Information). The Draft EIS does not contain sufficient information for EPA to fully assess environmental impacts that should be avoided in order to fully protect the environment, or the EPA reviewer has identified new reasonably available alternatives that are within the spectrum of alternatives analyzed in the Draft EIS, which could reduce the environmental impacts of the action. The identified additional information, data, analyses, or discussion should be included in the Final EIS.	We have made modifications throughout the document to provide clarification and information on items identified during public comment period. All additions are in *italics.*

Comment Response Matrix
Final Environmental Impact Statement, April 2011:
Palmyra Atoll National Wildlife Refuge Rat Eradication Project

Comment #	Reviewer	Section	Comment	Response to comment
79	EPA	General	We have rated Alternative B (aerial broadcast of brodifacoum) and Alternative C (Alternative B with added bird capture to avoid poisoning) as Environmental Objections Insufficient Information (EO-2). "EO" (Environmental Objections). The EPA review has identified significant environmental impacts that should be avoided in order to provide adequate protection for the environment. Corrective measures may require substantial changes to the preferred alternative or consideration of some other project alternative (including the no action alternative or a new alternative). EPA intends to work with the lead agency to reduce these impacts. Category "2" (Insufficient Information) - see comment #2 for definition.	We have made modifications throughout the document to provide clarification and information on items identified during public comment period. All additions are in *italics.*
	Specific Recommendations from USEPA			
80	EPA	General	The alternatives analysis in the FEIS should clearly identify the criteria used in screening potential alternatives to determine which would be brought forward and evaluated in the NEPA document, and these criteria should be consistently applied to all potential alternatives. An objective evaluation of diphacinone alternatives, in a side-by-side comparison, would be helpful to the public and the decision-maker and is recommended. Discuss and define feasibility and how it was assessed for the alternatives. Include cost data, which are likely to be relevant and important to the decision, so that an evaluation of the person-hours and mitigation proposals can be made.	Please refer to modifications made to Section 2.3.6.
81	EPA	2.4	Include a discussion of the management structure for project implementation, and the staff who would be involved, including their expertise in rat eradications. Include a communication plan as an appendix to the FEIS. Discuss budget concerns or limitations. This information is relevant to environment impacts and should be included. FWS may choose to include this information in an adaptive management plan. if so, we recommend it be appended to the FEIS.	We have included many preliminary operational details in Appendix K, and will post a working draft version of the operations plan at http://www.fws.gov/palmyraatoll/rainforestrestoration.html.
82	EPA	General	Clearly present the aerial application rates for both the first and second applications. The EPA recommends that the second application rate be lower than the first unless between-treatment monitoring of other evidence indicates the presence of significant rat activity in a particular area. Once rates are established, they should be adhered to during the operation, and changes only made according to a clear protocol... deviating from the target application rate, should be avoided. Changes to baiting rates in the field should be thoroughly documented. In no case may the limits on application rate established by the label for the product used in the project be exceeded, with some allowances for swath overlap (as covered by the labeling). As recommended in the Rat Island critical evaluation, planning should occur for contingencies and for each… that evaluation recommends developing... "A structured decision-making tool for application of bait other than as planned would require a written assessment of the amount of bait already on the ground, a comparison to the approved label rate and target rates, a written assessment of the additional bait to be applied, a calculation of the total amount of bait that would be applied, and increase in potential risk nontarget species".	
83	EPA	General	The FEIS should disclose how excess bait will be disposed (or shipped off-island) and whether funding for bait disposal will be included in the project, and should include clear directions for proper excess bait disposal in a communication plan. As mentioned above, decisions regarding disposal of bait should be clearly outlined in a structured decision-making tool.	Disposal will be in compliance with directions outlined under label directions identified by EPA.
84	EPA	General	The FEIS should document a more appropriate post-treatment monitoring plan. The EPA recommends monitoring between aerial treatments and shortly after the second round of baiting. Frequent monitoring should occur in bait station areas.	We think that the USDA-NWRC monitoring plan (Appendix A) addresses the deficiencies indicated in this comment.
85	EPA	Appendix B.	We strongly recommend that the biosecurity plan be as comprehensive as possible. We recommend that it include quarantine, surveillance, and contingency components, and provide references and/or discussion that demonstrate thatthe plan has thoroughly considered which, of the proven biosecurity approaches available, will work best for Palmyra. The FEIS should also identify who would implement the biosecurity actions, whether their implementation is dependent on funding, and if so any expectancy of funding deficiences.	We have modifed the modified working-draft biosecurity plan in Appendix B to incorporate many of these recommendations.
86	EPA	General	The FEIS should devote more analysis to logistics and manpower needs of the alternatives, especially since effective canopy baiting is crucial to the success of the project. (See also comment below regarding reducing palms prior to eradication). As recommended above, define and discuss feasibility in relation to the alternatives, and whether sufficient funding is available to meet manpower and all logistical needs.	We have included many preliminary operational details in Appendix K, and will post a working draft version of the operations plan at http://www.fws.gov/palmyraatoll/rainforestrestoration.html.
87	EPA	2.4.4	Correct the statements regarding RUP certification in the FEIS. The FEIS should document if and how responsible parties are following the record keeping requirements for sale and use of RUPs, including the company selling them and the applicator who is using them. Ensuring that all of the restricted use pesticides are accounted for could be a homeland security issue, especially in the quantities being proposed.	We made corrections to Section 2.4.4. We are following State of Hawai`i and FWS policy regarding record keeping for sale and use of RUPs.
88	EPA	2.4.4	There is reference to "EPA —approved label instructions" that do not currently exist. As noted above, the existing label for EPA Reg. No. 56228-36 would have to be amended or Palmyra-specific application directions would have to be authorized via another provision of FIFRA.	Comment noted. No response required.
89	EPA	2.5.1	The name, registrant, and registration number of the product intended to be used on Palmyra are misidentified on page 29 and elsewhere. The product's name is "brodifacoum-25W Conservation", without a trademark symbol. The registrant is the Animal and Plant Health Inspection Service (APHIS), USDA. The registration number is 56228-36.	We have corrected the errors.

Comment Response Matrix
Final Environmental Impact Statement, April 2011:
Palmyra Atoll National Wildlife Refuge Rat Eradication Project

Comment #	Reviewer	Section	Comment	Response to comment
90	EPA	2.5.1	The discussion of first and second-generation anticoagulants on p. 30 is not completely accurate. The "generation" designations for anticoagulants are not strictly "according to when they were first developed as rodenticides" although they relate indirectly to their toxicity.	We have modified the Section to include the explanation the reviewer provided .
91	EPA	2.5.1	Discussion on p. 30 concludes that "any rodenticide can be effectively used to eradicate an entire rodent population if all individuals within the population consume enough bait over an appropriate amount of time." This sentence does not address the possibility of resistant individuals within the population.	We have modified the sentence to include resistance.
92	EPA	2.5	Assessing the weather conditions and prohibiting bait broadcast if rainfall is forecast (Appendix H, p. 12). More detail about effectiveness and implementation of this measure should be included in the FEIS.	Please refer to Sections 2.4.9 and 2.6.3, Table 3.1. We have also included many preliminary operational details in Appendix K, and will post a working draft version of the operations plan at http://www.fws.gov/palmyraatoll/rainforestrestoration.html.
93	EPA	General	Securing a tarp over the drinking water catchment to prevent aerially broadcast bait from entering the drinking water supply. We recommend adding to this measure that the tarp would be inspected (or reinstalled if it was removed) prior to a second aerial application.	We have modified the document to clarify that we would clear all bait pellets off of the tarp covering the catchment system after each bait application.
94	EPA	General	Dying the bait blue to make pellets less attractive to birds. We believe the conclusion that blue dye used in EPA Reg. No. 56228-36 would make pellets less attractive to birds is overdrawn. The degree of repellency would depend upon the shade of blue and the perceptions and food habits of each bird species. Birds that eat fruits or some types of insects might not be predisposed against eating blue things. It is not clear to what extent the factors affecting eat/don't-eat decisions for the types of birds that occur on Palmyra have been studied.	There are no Palmyra-specific studies of which we are aware. Monitoring for this is not a component of this project.
95	EPA	General	Capture and treatment of all sick and moribund shorebirds found during and directly after the eradication, and treatment with Vitamin K, an antidote to anticoagulants (p. 26). The planned collection and Vitamin-K treatments of sick or moribund shorebirds should be evaluated for feasibility and effectiveness in the FEIS. Treatments would likely have to be extensive if experiences with various mammals (including humans) are predictive of what would be needed to save birds.	Please see Shorebird protection protocol in the draft operational details outlined in Appendix K where we have included many preliminary operational details. We will also post a working draft version of the operations plan at http://www.fws.gov/palmyraatoll/rainforestrestoration.html.
96	EPA	General	For Alternative D (bait station alternative), the DEIS indicates that, while mortality risk from toxicants is high for some birds (BTCU, Pacific golden plover, ruddy turnstones, laughing and Franklin's gulls, Northern shoveler and Northern pintail duck), the exposure risk is low (p. 136- 139). This does not fully consider the fact that the bait would be present in the atoll environment for approximately 2 years, which would offer long-term secondary pathway toxicity opportunities.	Comment noted. No response required as Alternative C is our preferred alternative.
97	EPA	General	The issue of preventing rats in the bait station areas of the aerially broadcast alternatives repopulating aerially eradicated areas should be addressed in the project design.	All rats would be exposed to rodenticide during the same time period. There would be no source populations to re-populate other areas.
98	EPA	General	Capturing, holding, and maintaining individuals of the native gecko species should be considered as a mitigation measure.	A tropical gecko specialist is on the monitoring team and will attempt to successfully capture, hold, and maintain native geckos.
99	EPA	General	Reevaluate impacts to soils and water resources from the aerial broadcast alternatives using the quantity of bait expected to be applied for the project. If the active ingredient infiltrates vertically into soils, the Alifano and Wegmann (2010) data likely would overestimate the extent of island-wide contamination, although it is possible that material might congregate in some lower areas due to surface flow resulting from heavy rain events. Due to the composition of the islands, however, puddles tend to be short-lived, even after extensive heavy rains.	We prefer to stay with the precautionary result that overestimating the amounts in the soil is better than underestimating it.
100	EPA	General	For impacts from the bait stations (which are part of all action alternatives), these discussions should note the possibility of bait stations becoming damaged or being dumped, either of which could result in a concentration of several ounces or more of bait at one spot. Describing the bait stations as being "durable enough to stay in place for 2 years and prevent crabs from entering or destroying them" is fine in theory, but realistic assumptions would expect some error. It also is not clear that a specific design of bait station has been selected for use in this project.	Tamper-resistant bait stations would be purchased for use in and around areas of human habitation. For uninhabited areas of the atoll, crab-resistant bait stations would be constructed with off-the-shelf materials (Appendix G.) and placed accordingly. We expect that any bait on the ground would be quickly consumed by crabs.
101	EPA	2.5.2	Last paragraph, running over to p. 36. The characterization that detection of shore birds was consistently higher post-treatment than pre-treatment for the 2005 mini-eradication effort is not consistent with the narrative in, nor "Figure 10" of, the report by Buckelew, et al (2005).	Page 35 of the DEIS repeats a Section of the summary in 'Progress in Palmyra Atoll Restoration: Rat eradication trial 2005' (Appendix 4, page iv), "The frequency of detection of these shorebirds were consistently higher post broadcast and was likely due to migratory influx." The 2005 report states these results in greater detail on page 34, "the numbers of individuals observed during the surveys were higher post bait application than pre application for all species except Ruddy Turnstones on Little East islet and Wandering Tattlers on Whippoorwill, Home, and Little East islets", which is confirmed by the results presented in Table 10. Therefore, the DEIS accurately reports the findings of the Buckelew et al. (2005) report.
102	EPA	2.5.2	"Figure 2.1". The numbers illustrated in this figure are not consistent with those shown in "Fig. 5" in the Wegmann, et al. (2008) report. The narrative on page 37 of the draft EIS is more accurately reflected by Fig. 5" of Wegmann, et al. (2008), than by "Figure 2.1" on page 38 of the Draft EIS.	The values in the FEIS represent an updated version of the figure. The text remains accurate.

Comment Response Matrix
Final Environmental Impact Statement, April 2011:
Palmyra Atoll National Wildlife Refuge Rat Eradication Project

Comment #	Reviewer	Section	Comment	Response to comment
103	EPA	2.5.2	The first line of this paragraph should be corrected factually as well as grammatically.	We have made the correction.
104	EPA	2.6.2	The number (332) given here for "successfully reported island eradication efforts world wide" differs from the number (278) cited from the same reference on page 31. At least one of those numbers must be wrong. The correct number, if known, should be used. "Brodifacoum-25" is not one "specific product". This paragraph itself acknowledges the existence of a "Brodifacoum-25D" and a "Brodifacoum-25W'.	For clarity, one number refers to all eradications, the other to all eradications where the rodendticide used is known. Both numbers are correct.
105	EPA	2.6.4	Table 2.5, and relevant discussions on page 51. The result on Whippoorwill Island is reported as having been "Successful" despite the finding of one or more live rats 8 and 10 days after bait application. All of the localized rat eradication efforts on Palmyra in 2005 would be judged as "Failed" if the standard index of no signs of rat activity for 2 years following treatment were applied. Although reinvasion from very nearby untreated islands might have been the cause of the reappearance of rats on those islands, the standard for successful eradication should be greater than obtaining zero scores for various activity measures shortly after treatment. By the latter standard, the brodifacoum/Bromethalin trials on Palmyra Atoll in 200 1-2003 probably would have been judged "Successful", at least for some of the islands; and the same would have held for some islands in the diphacinone work in the Bay of Islands, Adak, AK, 2003-2004. The 2008 trials on Palmyra involved placebo baits which, presumably, did not directly kill any rats. The "Failed" status is visited upon them because one or more rats live trapped post-treatment showed no evidence of the Pyranine "biomarker", and some others were marked only to a degree like the captive roof rats that were fed only one placebo bait pellet. The two failures for Polynesian rats (R. exulans) might have resulted in part through use of a bait moiety that was less than optimal for controlling that species. The 25W bait was not accepted especially well by captive Polynesian rats in trials conducted on Wake Atoll in 2007.	The Whippoorwill Island rat was lethargic and showed signs of hemorrahage and thus the eradication there was classified as a success.
106	EPA	2.1	"Table 2.7". "Canopy baiting" is mentioned as one of the "Secondary bait delivery methods" that would be used for "Alterative D" [sic] (bait stations), but not for the aerial application options which the narrative to the Draft EIS indicates would be supplemented by baiting trees that overhang water.	We have corrected the error.
107	EPA	4.4.4.1	Whether a single "dose" of brodifacoum would be lethal would depend upon the amount received, through ingestion in this case. The LD50 is not really a "threshold", as some individuals would be expected to die after receiving lower dosages.	We have corrected the error.
108	EPA	4.5.2	Under this alternative, there would not be an eradication effort. Therefore, signs (or "sings", line 17) would not have to be posted.	We have corrected the error.
109	EPA	2.5.1	The last sentence of the first paragraph under "Brodifacoum25WTM bait product" does not follow from the rest of the paragraph. It appears that 14 (7%) of 197 successful eradications using brodifacoum as the "primary rodenticide" were effected using "aerial broadcast supplemented with hand-broadcast" but that technique would have been less "commonly used" than bait stations (47% or ~93 instances), aerial-broadcast alone (29% or ~57 instances), or hand-broadcast (21% or ~41 instances).	We have modified this Section for clarity.
110	EPA	2.3	In approaches dismissed, the DEIS identifies fertility control and discusses oral contraceptives. We are aware that research is being conducted towards the development of chemical sterilants that could offer a less toxic alternative to rodenticides. FWS should monitor this development for possible future use.	Comment noted. No response needed.
111	EPA	4.4.3.1	The DEIS says that successful turtle nesting attempts have not been recorded on Palmyra; but, on p. 83, it says that green turtle nesting has been documented at least twice at Palmyra, primarily on the northwest side of Cooper island.	Nesting attempts have been documented but no "successful" or hatched nests recorded.
112	EPA	4.4.2.1	DEIS states that informal Sect 7 consultation will be conducted "for any case deemed necessary by the FWS". The FEIS should indicate whether informal consultation has occurred.	Informal ESA Section 7 Consultation is currently underway with NMFS Protected Resources Division.
113	EPA	Appx. C	Appendix C pp. 14 and 37 indicate that 2 cats and a dog (and a cat on a boat) were present in 2004. State whether these animals are still present and how they will avoid poisoning.	Domestic animals currently at Palmyra are 2 housecats and a dog. Their care during the operation is included in the draft operational details (Appendix K).
114	EPA		Pages bearing these numbers are missing from the copy of the draft EIS that was reviewed; but, seemingly, with no loss of intended text. Subsection "5.1" appears on page 151; and subsection "5.2" appears on page 189	We have corrected the pagination error.

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Pacific Islands Regional Office
1601 Kapiolani Blvd., Suite 1110
Honolulu, Hawaii 96814-4700
(808) 944-2200 • Fax (808) 973-2941

MAR 3 1 2011

Pacific Reefs National Wildlife Refuge Complex
300 Ala Moana Blvd., Room 5–231
Honolulu, HI 96850

The Protected Resources Division of the NOAA Fisheries Pacific Islands Regional Office (PIRO PRD) provides the following comments on the Palmyra Atoll National Wildlife Refuge Rat Eradication Project Draft Environmental Impact Statement (DEIS).

PRD is the division of PIRO that is responsible for the management and conservation of protected marine species throughout the Pacific Islands Region. Our agency manages several species that are protected under the Endangered Species Act (ESA) as well as the Marine Mammal Protection Act (MMPA). These include the Hawaiian monk seal and all species of sea turtles, whales, and dolphins that are found within the proposed project area.

NOAA Fisheries was recently petitioned under the ESA to list the bumphead parrotfish (*Bolbometopon muricatum*), as well as 82 species of coral, 21 of which are found within waters surrounding Palmyra Atoll. Our agency is currently evaluating the petitions to determine whether any of these species warrant listing under the ESA.

General comment: Appendices are labeled with letters but referred to at times in the text as being numbered (example: pg. 42 refers to Appendix 7 which is actually Appendix G).

The list of marine mammals observed in the pelagic waters surrounding Palmyra on page 83, lines 30-37, does not agree with the list contained on pages 101-102 in Section 4.4.2.2 *Special significance considerations for listed marine mammals under the Marine Mammal Protection Act (MMPA).* It is recommended that all marine mammals known to inhabit the waters surrounding Palmyra be given special significance consideration under the MMPA.

The DEIS incorrectly states that "MMPA regulations prohibit "disturbance" of marine mammals, which is a lower threshold of effect than mortality" (p. 101, lines 27-28). The MMPA prohibits "take" of marine mammals, which is defined as "to harass, hunt, capture, or kill, or attempt to harass, hunt, capture, or kill any marine mammal" (16 U.S.C 1362 Sec. 3(13)). Further, the term "harassment" is defined as "any act of pursuit, torment, or annoyance which – (i) has the potential to injure a marine mammal or marine mammal stock in the wild; or (ii) has the potential to disturb a marine mammal or marine mammal stock in the wild by causing disruption of behavioral patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering" (16 U.S.C. 1362 Sec. 3(18)(A)). The acts described in subparagraphs (A)(i) and (A)(ii) are also referred to as Level A and Level B harassment, respectively (16 U.S.C. 1362, Sec. 3(18)(C) and Sec.3(18)(D).

If your agency determines there is potential for "take" of any marine mammal species resulting from the proposed action, you may be required to apply for an Incidental Harassment Authorization (IHA) or a Letter of Authorization (LOA) through the

NOAA Fisheries Office of Protected Resources. Please refer to the following website for more information on obtaining permits under the MMPA: http://www.nmfs.noaa.gov/pr/permits/types.htm

The DEIS acknowledges that the bumphead parrotfish is designated as a candidate species (p.100, lines 26-27). However, there is no analysis provided in the DEIS on potential impacts to this fish species. We suggest that you provide information on how this species may or may not be at risk of primary or secondary exposure to the toxin.

Given the fact that surveys have documented Palmyra to be a significant chelonian foraging area (DEIS p.83 lines 7-8), PIRO PRD is concerned that potential impacts to sea turtles have not been adequately addressed in the DEIS. The following comments and questions specifically relate to potential impacts to sea turtles.

Pg. 26, lines 25-36: Would measures also be in place to monitor the health of sea turtles potentially exposed to toxicant and is it possible to administer the antidote to reptiles?

Pg. 28, lines 22-28: Sea turtles can be opportunistic feeders, and have been known to ingest pieces of plastic and other debris of varying sizes and colors; therefore, they could very possibly ingest any bait pellets that end up in the marine environment.

Pg. 83, line 2: Green turtles should not be included in the section on reef fishes; they are discussed in the next section on turtles. Lines 16-17: East Pacific greens are also distinguished by different shell morphology but can only be confirmed with genetic analysis. It is recommended you also remove the term 'rare.'

Pg. 84, algae section: McFadden, Sterling, and Naro-Maciel *et al.* may have more info on algal species and abundance on the north and south reef flats as a result of a portion of their research involving algae transects in relation to green turtle food source studies.

Pg. 85, lines 28-29: Green turtle nesting has only rarely been observed at Palmyra so it is difficult to make a connection between rat eradication and the potential to establish or re-establish nesters at this site, especially if there is no evidence that Palmyra was a nesting site used historically with any regularity.

Pg. 115, primary exposure section: There is no mention of potential ingestion by sea turtles if pellets unintentionally end up in the marine environment. While accidental entry into the marine environment will be 'minimized', it can not be eliminated; can you quantify how much of the toxicant is likely to enter the marine environment? Is there any information available on the level of toxicity for sea turtles?

Pg. 124, toxicant risk section: It is reasonable to assume that green or hawksbill turtles would potentially consume bait pellets if they were to come in contact with them in the marine environment. A wide range of life stages are present at Palmyra and juvenile green turtles in particular are more omnivorous and opportunistic feeders. Once they have recruited to nearshore environments like Palmyra, sub-adults and adults tend to primarily feed as herbivores but may still be opportunistic at times. Many necropsies of turtles of all size classes reveal plastic and other types of debris that have been ingested; bait pellets would not appear much different than floating or sunken bits of debris that turtles have been known to ingest. See (among others):

Bugoni, L., L. Krause, and M.V. Petry. 2001. Marine debris and human impacts on sea turtles in Southern Brazil. Marine Pollution Bulletin 42(12): 1330 – 1334.

Bjorndal, K.A., A.B. Bolten, and C.J. Lagueux. 1994. Ingestion of marine debris by juvenile sea turtles in coastal Florida habitats. Marine Pollution Bulletin 28(3): 154-158.

Carr, A. 1987. Impacts of non-biodegradable marine debris on the ecology and survival outlook of sea turtles. Marine Pollution Bulletin 18(6): 352-356.

Thank you for the opportunity to provide comments on the DEIS. Our staff is available to assist you with any questions you may have about this comment letter, or the ESA and MMPA processes. Please contact Kim Maison (Kimberly.Maison@noaa.gov) if necessary. We look forward to working with you to protect our nations living marine resources.

Sincerely,

Alecia VanAtta
Assistant Regional Administrator
for Protected Resources

Best Management Practices (BMPs) for General In-Water Work Including Boat and Diver Operations

January 5, 2011

NMFS Protected Resources Division recommends implementation of the following BMPs to reduce potential adverse affects on protected marine species. These BMPs are in no way intended to supersede or replace measures required by any other agency including, but not limited to the ACOE, USFWS, USEPA, or NMFS Habitat Conservation Division. Compliance with these BMPs is secondary to safety concerns.

A. Constant vigilance shall be kept for the presence of ESA-listed marine species during all aspects of the proposed action, particularly in-water activities such as boat operations, diving, and deployment of anchors and mooring lines.

1. The project manager shall designate an appropriate number of competent observers to survey the marine areas adjacent to the proposed action for ESA-listed marine species.
2. Surveys shall be made prior to the start of work each day, and prior to resumption of work following any break of more than one half hour. Periodic additional surveys throughout the work day are strongly recommended.
3. All in-water work shall be postponed or halted when ESA-listed marine species are within 50 yards of the proposed work, and shall only begin/resume after the animals have voluntarily departed the area. If ESA-listed marine species are noticed within 50 yards after work has already begun, that work may continue only if, in the best judgment of the project supervisor, that there is no way for the activity to adversely affect the animal(s). For example; divers performing surveys or underwater work would likely be permissible, whereas operation of heavy equipment is likely not.
4. When piloting vessels, vessel operators shall alter course to remain at least 100 yards from whales, and at least 50 yards from other marine mammals and sea turtles.
5. Reduce vessel speed to 10 knots or less when piloting vessels at or within the ranges described above from marine mammals and sea turtles. Operators shall be particularly vigilant to watch for turtles at or near the surface in areas of known or suspected turtle activity, and if practicable, reduce vessel speed to 5 knots or less.
6. If despite efforts to maintain the distances and speeds described above, a marine mammal or turtle approaches the vessel, put the engine in neutral until the animal is at least 50 feet away, and then slowly move away to the prescribed distance.
7. Marine mammals and sea turtles should not be encircled or trapped between multiple vessels or between vessels and the shore.
8. Do not attempt to feed, touch, ride, or otherwise intentionally interact with any ESA-listed marine species.

B. No contamination of the marine environment should result from project-related activities.

9. A contingency plan to control toxic materials is required.
10. Appropriate materials to contain and clean potential spills will be stored at the work site, and be readily available.
11. All project-related materials and equipment placed in the water will be free of pollutants. The project manager and heavy equipment operators will perform daily pre-work equipment inspections for cleanliness and leaks. All heavy equipment operations will be postponed or halted should a leak be detected, and will not proceed until the leak is repaired and equipment cleaned.
12. Fueling of land-based vehicles and equipment should take place at least 50 feet away from the water, preferably over an impervious surface. Fueling of vessels should be done at approved fueling facilities.
13. Turbidity and siltation from project-related work should be minimized and contained through the appropriate use of effective silt containment devices and the curtailment of work during adverse tidal and weather conditions.
14. A plan will be developed to prevent debris and other wastes from entering or remaining in the marine environment during the project.

USDA

United States Department of Agriculture

Marketing and Regulatory Programs

Animal and Plant Health Inspection Service

Wildlife Services

Washington, DC 20250

April 8, 2011

Dr. Elizabeth Flint
Pacific Reefs National Wildlife
Refuge Complex
300 Ala Moana Blvd.
Room 5-231
Honolulu, HI 96850.

Dear Dr. Flint:

We have reviewed the draft Environmental Impact Statement, "Palmyra Atoll National Wildlife Refuge Rat Eradication Project" (DEIS) and your intent to pursue island restoration activities on Palmyra Atoll. Wildlife Services shares your interest in using rodent eradication as a means of achieving conservation goals on islands to restore indigenous populations of wildlife. We believe that should rat eradication on Palmyra be achieved, native plants and wildlife, primarily the nesting seabirds and reptiles, will once again flourish as you have described.

As you effectively point out in the DEIS, eradication of invasive rodents on islands has potential for enormous conservation benefits. We agree with you and the larger conservation community that this management technique should be embraced. It may be the single most important conservation tool land managers have to protect native island habitats and their associated faunal communities. However, we also recognize that an eradication project that suffers unacceptable short- or long-term negative impacts could eliminate the use of this tool for future predator management activities. As a result, the U.S. Fish and Wildlife Service (FWS) should proceed cautiously and make every effort to document the impacts of this project. Documentation of environmental impacts should be evaluated by an independent party to ensure absolute transparency.

The project proposed in Alternatives B and C of the DEIS represents the largest application of brodifacoum we are aware of anywhere in the world. The application rates proposed in these options are 4.5 times higher than the currently allowed rate for the first application and nearly 6 times higher than the currently allowed second application rate. If either Alternative B or C is chosen for this project, the total application rate (134 kg/ha) will exceed the current total label allowance (27 kg/ha) by 107 kg/ha. Since the proposed application rates exceed the currently allowed rates, the effects of such application levels on the Palmyra Atoll ecosystem are not fully known.

Wildlife Services is participating in the proposed rodent eradication to the extent that we have worked with FWS and Island Conservation to draft a time-limited, Palmyra Atoll specific, supplemental pesticide label for Brodifacoum 25W:Conservation. This label, if approved, should provide you sufficient latitude in application methods to successfully complete this eradication project. We have also worked cooperatively to draft a post- application monitoring plan to properly document the short-term environmental impacts of this activity.

We concur with the DEIS that the application could result in a massive non-target mortality of shorebirds and other species that directly consume bait. In addition, we believe this project could result in significant secondary exposure and mortality of species consuming dead or dying rats, or other food items incorporating brodifacoum into their tissues. Because this could be interpreted as a direct violation of the Migratory Bird Treaty Act, FWS should secure a take permit under the Act which specifies the number of each species listed in the DEIS allowed to be taken by this project. It should be noted that the range of birds listed page 107 of the DEIS that will likely be lethally taken on do not quite match with the expected lethal take given in the individual accounts discussed starting on page 119. Additionally, we believe that the nontarget lethal take in the DEIS is understated and that marine reptiles, namely sea turtles, need to be included because they will eat pelleted bait and it is anticipated that broadcast bait will wind up in waters where they could be exposed.

We believe that the DEIS should have included a wider range of Alternatives such as an Integrated Rat Eradication Alternative. In particular, we expected to see the use of other rodenticides as considered alternatives analyzed in detail. Worldwide literature strongly supports first generation rodenticide operations more than is indicated in the DEIS, including tropical environments in Australia and Pacific Islands (Varnham 2010). An example of a recent rat eradication success in a tropical environment using an integrated approach included rodent eradication on Cocos Island, Guam (Lujan et al., 24th Vertebr. Pest Conference, 2010, in press). A great uncertainty in the rodent eradication plan is the rats' use of the coconut canopy and the ability to adequately treat the palm canopy. It is our understanding that the Refuge has discussed eradicating coconut palms (potentially another invasive species) from Palmyra Atoll. A viable alternative to one of the alternatives in the DEIS would be to remove the coconut palms prior to the eradication, simplifying the rodent eradication.

The DEIS on page 25 suggests that rodenticide resistance is unlikely because it has been 6 years since the last treatment. This is an incorrect assumption as it is possible to still have some rodenticide resistance in the rats at Palmyra Atoll. The DEIS relies on old information and the reference to Pitt (2010) is erroneous.

Another concern of ours is baiting in and around human habitation because it is unclear exactly what the protocol will be. This should be explicitly stated in the DEIS. Additionally, if baits are currently being used in these areas, the type of bait, active ingredient, application rate, and duration of baiting being used should be documented.

A clarification/correction needs to be made in the DEIS regarding Diphacinone 50:Conservation and Ramik Green (DEIS Section 2.3.6). In numerous places in the DEIS reference is made to differences in the performance of Diphacinone 50:Conservation and Ramik Green when used in rodent eradication or control projects. These two products are exactly the same formulation. Diphacinone 50:Conservation is simply a repack of Ramik Green. Consequently, questions raised in the DEIS regarding the uncertainty about relating the performance of the two products is nullified because they are directly comparable.

We feel ideas presented on page 97of the DEIS regarding the potential residues in surface water mislead the reader. On this page you present a summary of an aquatic risk assessment conducted by Syngenta Crop Protection Inc. (2003). This risk assessment reported residues resulting in surface water from an application of 18 kg/ha brodifacoum. No risk is indicated for fish in this assessment. The proposed application rate in Alternatives B and C are 4.6 times higher than 18 kg/ha. Even at this higher application rate, no risk is indicated for fish. However, it is critical to point out in this section that the application rate proposed on Palmyra Atoll will be much higher than that used by Syngenta and, thus, may not result in similar conclusions as suggested.

The DEIS predicts the impact of brodifacoum on nontarget species, especially birds and reptiles. However, the true extent of impacts on nontarget species are largely unknown because many facets of the persistence of brodifacoum are unknown, such as the length of time it remains intact in soils and other environmental compartments and the duration of primary and secondary impacts to aquatic and terrestrial organisms. The longevity of active brodifacoum could become a great concern beyond the 2-month window when birds are relatively rare on the island and potentially long beyond the 1-month monitoring proposed in the included monitoring plan. As a result of the unknowns, monitoring will be extremely important and valuable. We understand the logistical difficulties of keeping a monitoring crew on the atoll beyond one month. However, collection of environmental samples during follow-up visits on day 56, 6 months, 1 and 2 years are important to document the residue decline in the environment.

We believe that the DEIS should include a discussion of professional wildlife damage management principals which guide agency decision making beyond efficacy, such as the intent to minimize adverse effects on non-target animals, and economic (e.g. program cost/benefit) and social factors (public acceptance of various alternatives). In addition, the DEIS should include lessons learned from Rat Island, with recommendations made by FWS and the Ornithological Council (Paul and Salmon 2010) as they may apply to Palmyra. For disclosure, the label should be included in the Final EIS to ensure that the proposed action is in conformance with label restrictions. Additionally, the DEIS did not cite literature that included pertinent information relevant to the analysis of the effects of brodifacoum and diphacinone that should be considered in an objective analysis of both toxicants including information on the effects to nontargets (Cox and Smith 1992, Dowding et al. 2006, Paul and Salmon 2010), effectiveness of formulations on targets (Swift 1998), registration/environmental concerns (U.S. Environmental Protection Agency 1998), and rat ecology (Varnham 2010).

As the registrant of the only brodifacoum labels currently approved for using broadcast application to undertake this type of a project, WS is very interested in the short- and long-term effects from this rodenticide. We have a great interest in ensuring the availability and safe use of this important management tool.

We look forward to providing you with continued assistance as needed for the project.

Sincerely,

William H. Clay

William H. Clay
Deputy Administrator

Literature Cited

Cox, P. R. and R. H. Smith. 1990. Rodenticide ecotoxicology: Assessing non-target population effects. Functional Ecology 4:315-320.

Dowding, J. E., T. G. Lovegrove, J. Ritchie, S. N. Kast, and M. Puckett. 2006. Mortality of northern New Zealand dotterels (*Charadrius obscurus aquilonius*) following an aerial poisoning operation. Notornis 53:235-239.

Nelson, J.T., L. Bethany, S.G. Fancy, G.D. Lindsey, and E.J. Tweed. 2002. Effectiveness of rodent control and monitoring techniques for a montane forest. Wildlife Society Bulletin 30(1):82-92.

Paul, E. and T. Salmon. 2010. The rat island rat eradication project: A critical evaluation of nontarget mortality. The Ornithological Council final report. December. 85 pp.

Swift, C.E. 1998. Laboratory bioassays with wild-caught black (*Rattus rattus*) and Polynesian (*R. exulans*) rats to determine minimum amounts of Ramik Green (0.005% diphacinone) and exposure times for field broadcast applications in Hawai'i. M.S. Thesis, University of Hawai'i Manoa, Honolulu, HI. 92 pp.

U.S. Environmental Protection Agency. 1998. Reregistration Eligibility Decision (RED): Rodenticide Cluster. EPA 738-R-98-007. 319 pp.

Varnham, K. 2010. Invasive rats on tropical islands: Their history, ecology, impacts and eradication. RSPB Research Report No. 41. Royal Society for the Protection of Birds, Sandy, Bedfordshire, UK. ISBN 978-1-905601-28-8.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, CA 94105

April 8, 2011

Dr. Elizabeth Flint
Pacific Reefs National Wildlife Refuge Complex
300 Ala Moana Blvd., Room 5-231
Honolulu, HI 96850

Subject: Draft Environmental Impact Statement (DEIS), Palmyra Atoll National Wildlife Refuge Rat Eradication Project (CEQ # 20110049)

Dear Ms. Flint:

The U.S. Environmental Protection Agency (EPA) has reviewed the above-referenced document pursuant to the National Environmental Policy Act (NEPA), Council on Environmental Quality (CEQ) regulations (40 CFR Parts 1500-1508), and our NEPA review authority under Section 309 of the Clean Air Act. Our detailed comments are enclosed.

The Fish and Wildlife Service (FWS) proposes to eradicate non-native black (roof) rats on Palmyra Atoll National Wildlife Refuge to help restore this important center of biodiversity and species abundance in the Central Pacific. It evaluates four alternatives: aerial broadcast of the rodenticide brodifacoum (Alternative B), aerial broadcast of the rodenticide brodifacoum with the addition of bird capture to avoid poisoning (Alternative C), bait stations using brodifacoum (Alternative D) and No Action (Alternative A). The DEIS does not identify a preferred alternative.

We note that the use of the rodenticide diphacinone was not evaluated as a NEPA alternative in the DEIS. Diphacinone is less persistent and virtually non-toxic to birds when compared to brodifacoum (Appendix H, p. 13). The rationale for dismissing diphacinone from further analysis did not demonstrate that it was an unreasonable alternative[1], and without this analysis, the decision-maker and the public are deprived of valuable information regarding its comparative impacts and efficacy. The DEIS does retain apparently less feasible alternatives for full NEPA analysis. This, coupled with a description in Appendix A that describes the action as imminent (taking place in June of 2011 and consisting of an aerial broadcast of brodifacoum) seem to imply that the decision has already been made. NEPA requires that environmental

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[1] Under NEPA, reasonable alternatives are those that are practical or feasible from a technical and economic perspective and that are based on common sense (Council on Environmental Quality's 40 Most Asked Questions about NEPA, # 2a)

information be available to public officials and citizens before decisions are made (40 CFR 1500.1(b)), and that EISs serve as the means of assessing the environmental impact of proposed agency actions, rather than justifying decisions already made (40 CFR 1502.2(g)).

Despite the apparent preference for aerial broadcast of brodifacoum, the DEIS does not identify a preferred alternative(s). Therefore, pursuant to EPA's *Policy and Procedures for the Review of Federal Actions Impacting the Environment*, we must rate each of the alternatives listed in the DEIS. We have rated Alternative A (No Action) as Environmental Concerns – Insufficient Information (EC-2) (see enclosed "Summary of Rating Definitions"). The DEIS describes the impacts that rats are having on island ecosystems in general, and the likely effects on the Palmyra ecosystem in particular. It documents the benefits of rat eradications worldwide as well as the expected biodiversity benefits to Palmyra. Specific rat impacts on biological resources are largely speculative for most species; however, and additional information is needed to fully document and predict how no action will affect population trends. This rating also considers the concerns identified below regarding the aerial broadcast alternatives, to which the No Action alternative is compared.

We have rated Alternative B (aerial broadcast of brodifacoum) and Alternative C (Alternative B with added bird capture to avoid poisoning) as Environmental Objections - Insufficient Information (EO-2). We are concerned that proceeding with these alternatives, without sufficient consideration of a less-toxic and less-persistent rodenticide, would set a precedent for future eradication projects that collectively could result in significant impacts to non-target species. In addition, the DEIS, as written, does not provide sufficient assurances that all contingencies have been planned for to avoid mistakes made during previous rat eradications on Palmyra and elsewhere. Alternatives B and C would deposit tremendous quantities of bait on Palmyra that would go into alternative food chains. This may be justified for a potential long-term benefit to shorebirds; however, if such quantities would be used, it is important that the project be designed to ensure the best possibility of success, lest impacts to non-target species occur without the benefit of a complete eradication.

While there is ample evidence of pre-operation research and planning, the DEIS does not demonstrate how the causes of a previous rat eradication failure on Palmyra (ineffective management structure, staff and volunteers with no expertise in rat eradication, poor communication between the involved parties, and an inadequate budget) will be avoided for the proposed project. It also is not clear that the project has incorporated lessons learned from the high non-target mortality from the Rat Island aerial eradication, the causes of which are attributed, in part, to the upward adjustment of bait application rates during the operation, disposal of extra or contingency bait by application, and poor communication. Our objections also pertain to insufficient post-treatment monitoring proposed for Alternatives B and C, and a scope of the biosecurity plan that does not appear commensurate with the high risk of rat repopulation identified. Regarding Alternative C, the bird capture component does not appear feasible and was not recommended by bird experts who were consulted on the matter, some of whom described it as difficult if not impossible. Capture and retention would be very labor and resource intensive, and would stress and cause death, injury, and suffering to birds. The DEIS does not provide any indication that capture and retention would provide a substantial benefit.

We have rated Alternative D (bait stations using Brodifacoum) as Environmental Concerns – Insufficient Information (EC-2). Although this alternative would result in far fewer impacts to non-target species, our rating reflects the potentially lower probability of success, considering the increased likelihood that not all rats present would be exposed to bait, the lack of information regarding its feasibility, the availability of bait stations, and manpower and funding requirements. There is also insufficient information regarding the difficulty of installing bait stations on islands with unexploded ordnance. If additional information is provided to address these concerns and the alternative can be established as feasible, we would have no objections to this alternative.

EPA appreciates the opportunity to review this DEIS. When the Final EIS is released for public review, please send one copy to the address above (mail code: CED-2). If you have any questions, please contact me at (415) 972-3521, or contact Karen Vitulano, the lead reviewer for this project, at 415-947-4178 or vitulano.karen@epa.gov.

Sincerely,

Enrique Manzanilla, Director
Communities and Ecosystems Division

Enclosure: Summary of EPA Rating Definitions
EPA's Detailed Comments

cc: William W. Jacobs, Registration Division, EPA HQ, Office of Pesticide Programs
Jennifer Gaines, Registration Division, EPA HQ, Office of Pesticide Programs
Patti TenBrook, EPA Region 9 Pesticides Office

SUMMARY OF EPA RATING DEFINITIONS*

This rating system was developed as a means to summarize the U.S. Environmental Protection Agency's (EPA) level of concern with a proposed action. The ratings are a combination of alphabetical categories for evaluation of the environmental impacts of the proposal and numerical categories for evaluation of the adequacy of the Environmental Impact Statement (EIS).

ENVIRONMENTAL IMPACT OF THE ACTION

"LO" (Lack of Objections)

The EPA review has not identified any potential environmental impacts requiring substantive changes to the proposal. The review may have disclosed opportunities for application of mitigation measures that could be accomplished with no more than minor changes to the proposal.

"EC" (Environmental Concerns)

The EPA review has identified environmental impacts that should be avoided in order to fully protect the environment. Corrective measures may require changes to the preferred alternative or application of mitigation measures that can reduce the environmental impact. EPA would like to work with the lead agency to reduce these impacts.

"EO" (Environmental Objections)

The EPA review has identified significant environmental impacts that should be avoided in order to provide adequate protection for the environment. Corrective measures may require substantial changes to the preferred alternative or consideration of some other project alternative (including the no action alternative or a new alternative). EPA intends to work with the lead agency to reduce these impacts.

"EU" (Environmentally Unsatisfactory)

The EPA review has identified adverse environmental impacts that are of sufficient magnitude that they are unsatisfactory from the standpoint of public health or welfare or environmental quality. EPA intends to work with the lead agency to reduce these impacts. If the potentially unsatisfactory impacts are not corrected at the final EIS stage, this proposal will be recommended for referral to the Council on Environmental Quality (CEQ).

ADEQUACY OF THE IMPACT STATEMENT

Category "1" (Adequate)

EPA believes the draft EIS adequately sets forth the environmental impact(s) of the preferred alternative and those of the alternatives reasonably available to the project or action. No further analysis or data collection is necessary, but the reviewer may suggest the addition of clarifying language or information.

Category "2" (Insufficient Information)

The draft EIS does not contain sufficient information for EPA to fully assess environmental impacts that should be avoided in order to fully protect the environment, or the EPA reviewer has identified new reasonably available alternatives that are within the spectrum of alternatives analyzed in the draft EIS, which could reduce the environmental impacts of the action. The identified additional information, data, analyses, or discussion should be included in the final EIS.

Category "3" (Inadequate)

EPA does not believe that the draft EIS adequately assesses potentially significant environmental impacts of the action, or the EPA reviewer has identified new, reasonably available alternatives that are outside of the spectrum of alternatives analyzed in the draft EIS, which should be analyzed in order to reduce the potentially significant environmental impacts. EPA believes that the identified additional information, data, analyses, or discussions are of such a magnitude that they should have full public review at a draft stage. EPA does not believe that the draft EIS is adequate for the purposes of the NEPA and/or Section 309 review, and thus should be formally revised and made available for public comment in a supplemental or revised draft EIS. On the basis of the potential significant impacts involved, this proposal could be a candidate for referral to the CEQ.

*From EPA Manual 1640, Policy and Procedures for the Review of Federal Actions Impacting the Environment.

EPA DETAILED COMMENTS ON THE DRAFT ENVIRONMENTAL IMPACT STATEMENT, PALMYRA ATOLL NATIONAL WILDLIFE REFUGE RAT ERADICATION PROJECT, APRIL 8, 2011

Alternatives Analysis
The rationale for the limited scope of the alternatives analysis in the DEIS is unclear. The very high toxicity, persistence in animal tissues, and risk of primary poisoning to shorebirds from using brodifacoum is well known (p. 108, 109), as is the high secondary exposure from eating crabs or other animals that have been exposed, yet use of the much less toxic diphacinone rodenticide bait was not brought forward as a NEPA alternative for evaluation. This omission is especially confusing considering that the alternatives that were brought forward for full NEPA analysis appear to either have significant barriers to feasibility, or lack information to determine feasibility. Finally, the criteria for eliminating alternatives in the DEIS do not appear to be consistently applied. See below.

Elimination of Diphacinone

Factors for screening alternatives
Diphacinone, the other bait product besides brodifacoum that is registered with EPA for conservation-based rodent eradications on islands, has a low toxicity to birds when compared with brodifacoum (p. 18), yet was dismissed from detailed analysis in the DEIS. The DEIS identifies the factors used in this decision as:

1. the toxicity of the product
2. the efficacy of the product (including palatability)
3. the extremely dense vegetation at Palmyra inhibiting distribution of the product
4. Palmyra's series of large and small islands that challenge dispersal of product and the feasibility of applying product to required concentrations and replicates,
5. the safety of personnel in applying product, including consideration of unknown but documented unexploded ordnance in the atoll, and
6. the inordinately dense population of land crabs, their extreme ability to penetrate enclosures, and their voracity of consumption.

Discussion of these factors does not seem to support removal of this alternative from study. The toxicity of the product, in relation to non-target species at least, would favor diphacinone. Considering that the stated project purpose and need is to deliver toxicant in a way that "minimizes harm to the ecosystem" (p. 24), it is not clear how this factor would eliminate diphacinone alternatives.

The discussion on page 17 does not address bait palatability. As the palatability study performed in 2010 found both brodifacoum and diphacinone to be highly palatable in comparison to commonly available food items (Appendix F, p. 39), this factor does not support elimination of diphacinone alternatives. The palatability and general suitability of anticoagulant rodenticide bait formulations for use in specific situations is governed more by the nature of the "inert" components of the bait than by the specific anticoagulant used.

The dense vegetation at Palmyra would inhibit distribution of any bait product. Since cost effectiveness or funding limitations are not discussed, this factor does not explain dismissal of diphacinone alternatives. The feasibility of applying product to required concentrations and replicates is not discussed in the DEIS for diphacinone. Since diphacinone has been used successfully in rat eradications, it is not clear how this factor was evaluated. The safety of personnel from unexploded ordnance while installing bait stations would be a factor in any bait station alternative, and would require initial clearing or marking regardless of the bait used or refill frequency. Consequently, this factor would not preclude use of diphacinone nor distinguish it in a significant manner from brodifacoum regarding safety such that all options involving diphacinone would have to be eliminated.

<u>Bait Efficacy</u>
Bait efficacy appears to be the most important factor considering the objective is to eradicate rats. The DEIS discusses risks associated with using diphacinone, especially in relation to the perceived need for rats to feed on it multiple times in order to be be killed (whereas, with brodifacoum, a rat would be more likely than with diphacinone to consume a lethal amount of bait in one night's feeding). However, these are probabilities rather than hard-and-fast rules as the DEIS seems to imply. Some rats could ingest enough diphacinone bait in one night to cause mortality, while reluctant feeders on a brodifacoum bait might need several nights of opportunity before they consume a lethal dose. With any anticoagulant, the time to death from the onset of bait ingestion follows a similar course. The animals feed and behave normally for several days and then gradually weaken and die. Even rats that have consumed a lethal dose during the first night of feeding will ingest more bait until the symptoms of anticoagulant poisoning set in. It is not clear, then, that twice as many rounds of treatment, or twice as much bait, would be needed for a diphacinone project vs. a brodifacoum project.

The DEIS states that the Fish and Wildlife Service (FWS) does not have enough information on the efficacy of diphacinone within Palmyra's rat eradication environment to proceed with analysis of this bait (p. 17). Diphacinone has been used successfully in 10 island rodent eradications. Substantially more experience has occurred using brodifacoum (197 successful applications, p. 31), with almost half using bait stations alone, and 29% using aerial broadcast primarily[2]. The DEIS concludes that additional successful rat eradications using diphacinone would be needed (p. 18), but it is unclear what number would be sufficient to allow for full analysis as a NEPA alternative. Some criteria should be established and discussed to elaborate on this conclusion.

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[2] There is some confusion regarding these numbers – 29% of the 197 applications would translate to 57 successful aerial applications, but the DEIS also states that compressed cereal products containing brodifacoum 25 ppm have been used to successfully eradicate rats from at least 5 islands using aerial broadcast as the primary technique (p. 31, line 30)

We note that the report *The Rat Island Rat Eradication Project: A Critical Evaluation of Nontarget Mortality* (herein Rat Island critical evaluation) prepared by the Ornithological Council concluded that "the basic operating principle [for rat eradications] should be to always use the lower-risk bait unless there is strong justification to do otherwise". The report concludes that "the track record of brodifacoum alone is not a sufficient basis to justify the choice of brodifacoum" (p. 69). It also concludes that the island restoration community has not made sufficient efforts to develop successful methodology for the use of diphacinone (p. 35).

The DEIS' apparent bias toward use of brodifacoum is likely attributable to the fact that most successful eradications, to date, involved use of brodifacoum; however, CEQ's NEPA regulations require agencies to "rigorously explore and objectively evaluate all reasonable alternatives" (40 CFR 1502.14a), and the DEIS has not demonstrated that an alternative involving use of diphacinone is unreasonable. The claim that, prior to 2004, diphacinone had not proven "to be an effective tool for eradication of rats from tropical islands" (p. 17) is incorrect, since the Buck Island eradication was successful. The DEIS highlights the failure of diphacinone on Lehua (p. 17, 21) without discussing the fact that the failure could well have resulted from the need to keep bait well back from the shoreline, in response to a requirement imposed by the State of Hawaii. This use limitation is mentioned on page 22, but text there does not address whether brodifacoum might also have failed if subjected to the same limitations. Additionally, as discussed above, the inference that more treatment and more bait would be needed for diphacinone vs. brodifacoum applications is not fully supported.

Resistence to rodenticides was not discussed in the efficacy evaluation that eliminated diphacinone as a NEPA alternative. Appendix C notes that feeding trials with captive rats suggested that there is some tolerance or resistence to brodifacoum in the rat population on Palmyra. The inference that absence of brodifacoum use on Palmyra for 6 years means "that it is highly likely that any rats that supported rodenticide resistance have been selected against and are no longer present in the population" (p. 25) is not fully supported. Individual rats alive in 2005 almost certainly have died, but they have reproduced and probably passed any resistance-conferring alleles on to some of their descendents. Rather than its complete disappearance, one might predict reversion to a low frequency for a somewhat disadvantageous (relatively low affinity for Vitamin K) allele in the absence of selective pressure favoring it. Alleles conferring resistance to anticoagulants seem to have been present in murid rodent populations well before warfarin was discovered and first used as a rodenticide. Consequently, they were available for selection when anticoagulant rodenticides first came into use and did not disappear from rodent populations despite no obvious selective pressure favoring them until the advent of anticoagulant rodenticides.

The DEIS states that the decision to not evaluate a diphacinone alternative also stems from a collaborative report that followed the 2004 rat eradication feasibility study conducted at Palmyra (Howard et al 2004) (p. 17); however, there was no discussion of diphacinone in that report, presented in Appendix C. The limited consideration of diphacinone in that study was based on preliminary results with two bait preparations, rather than consideration of other existing and possible diphacinone formulations. What did emerge from that research effort was a recommendation for development of a new brodifacoum formulation – one that would withstand the elements on Palmyra better than did the bait used in the Anacapa Island project.

Aerial broadcast as screening factor

Suitability for aerial broadcast appears to be used as a screening factor, but this is not identified as such nor is it consistently applied. For example, in the discussion on page 21 dismissing a diphacinone alternative, the DEIS states that a strategy for aerial application of diphacinone "has not been extensively tested" (p. 21). Similarly, one of the reasons given for eliminating use of other toxicants is the lack of EPA registration for aerial broadcast (p. 23). The purpose and need does not establish aerial application as a condition for the action; indeed, a bait station alternative using brodifacoum was brought forward for analysis. If aerial application is deemed necessary for an alternative to be considered feasible, this should have been identified in the purpose and need statement and applied to the screening of all potential alternatives. The FEIS should explain how and why aerial broadcast suitability was factored into the assessment of rodenticide alternatives.

Feasibility of Alternatives

Alternative C

The elimination of a diphacinone alternative is especially confusing considering that the other two alternatives that were brought forward for full NEPA analysis have questionable feasibility. Alternative C is comprised of Alternative B (brodifacoum aerial application) with additional mitigation of risk for shorebirds that could be poisoned by bait broadcast. This alternative proposes to capture and hold shorebirds prior to and during the period when they would be at risk of lethal exposure to rodenticide. We commend the good intentions of this alternative; however, there is no indication in the DEIS that successful capture of shorebirds -- primarily bristle-thigh curlews (BTCU) and Pacific golden plovers (PGPL) -- would be expected. Shorebird experts maintain that it would be very difficult to capture BTCU (p. 58), and capturing birds and holding them for the required period[3] (until land crabs consumed by the birds have low

[3] The DEIS does not identify the required period of time, requiring the reader to attempt to calculate it. Our estimate: to allow for two applications 10-14 days apart, 10 days for all phases of bait application (including trees overhanging water) associated with the second round of treatment to be completed, 7 days for disappearance of nearly all bait after the second application, and reductions in residues in terrestrial crabs and other invertebrates would take an additional 2+ weeks at least. The minimum holding period would have to extend >3 weeks beyond the date of the completion of the last component of second treatment round on any island. Measured from the date of first application, a semi-conservative calculation would put the minimum holding period at ~7 weeks, plus any holding time prior to the initiation of bait applications. With bait stations being used in the camp area, there would be extended potential for secondary exposure to curlews that congregate on the runway (which is close to the camp area).

brodifacoum residue levels) presents risk of injury, deterioration in body condition, death, behavior changes, and disease outbreak (p. 56). Appendix F documents several unsuccessful attempts to capture BTCU on the runway at Palmyra (App. F p. 36). The study in Appendix H indicates this capture is feasible, but it is not clear how this was determined or defined. Almost all of the BTCU expert opinions in its appendix clearly indicate that such an effort would be difficult, if not impossible, with one expert stating, "catching and holding the birds seems to me like a very labor intensive and resource intensive way to achieve the ultimate goal" (App. H, p. 28).

Alternative D
It is not clear whether FWS believes this alternative is feasible. Because of the rat's small range, due to its use of tree canopies and abundant year round food sources, a large number of bait stations would be needed. The DEIS estimates that 1,862 bait stations[4] plus an additional 20% would be used for Alternative D, and that every 3rd palm tree would be baited, presumably by launching bait filled sacks or "bolas" into them, 4 times (DEIS p. 60, Appendix G). An evaluation of effort was included for the alternatives and revealed that Alternative D would be four times more effort intensive (2,475 person-days versus 616 or 684 person-days for Alternatives B and C respectively). Because no information regarding funding for the project was included, it is unclear whether this substantially larger effort would render the alternative infeasible. Additionally, the presence of unexploded ordnance on Quail and Barren islands would require clearance or marking by qualified personnel (p. 60). No further information is provided, and it is not clear if these qualified personnel were included in the person-hours determination in Table 2.4, nor whether this aspect of the project would present insurmountable logistical difficulties. Because a lack of manpower contributed to previous eradication failures, the availability of the workforce for the alternatives should be discussed, as should any funding limitations.

The availability of the bait stations is also unclear. The DEIS references development of a bait station by U.S. Department of Agriculture - Animal and Plant Health Inspection Service - Wildlife Services (p. 29) that would be used for Palmyra, but its availability is not discussed. Elsewhere, the DEIS references bait stations being "purchased" (p. 59), and it is unclear whether these stations would be available for purchase in the quantities needed or if they would have to be constructed by project personnel or modified by them so as to be rendered crab-resistant and otherwise suitable for use on Palmyra.

Cost considerations, objective decision-making
In the discussion on page 21 dismissing a diphacinone alternative, the DEIS describes aerial broadcast of brodifacoum as more cost-effective and effort efficient. These criteria were not identified as factors to be considered in screening potential alternatives. In fact, the DEIS states

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[4] Appendix C, p. 27 states that over 15,000 bait stations would be needed

that an integrated pest management approach would be used for the project (p. 14) and cites to the Department of Interior's and FWS's integrated pest management policies. These policies clearly state that cost is not the primary consideration for pest management approach[5]. We understand this is an eradication effort and not simply pest management, but it is unclear how the alternatives are using the IPM approach as stated in the DEIS.

Information regarding costs and the funding available for the project would be helpful in interpreting information in the document. NEPA does not require a cost-benefit analysis, but the Council on Environmental Quality (CEQ) Regulations implementing the National Environmental Policy Act (NEPA) state that an environmental impact statement should at least indicate those considerations, including factors not related to environmental quality, which are likely to be relevant and important to a decision (40 CFR 1502.23).

The monitoring plan in Appendix A describes the action as imminent (taking place in June 2011) and consisting of an aerial broadcast of brodifacoum (Appendix A, p. 1). CEQ's Regulations state that NEPA procedures must ensure that environmental information is available to public officials and citizens before decisions are made (40 CFR 1500.1(b)), and that Environmental Impact Statements shall serve as the means of assessing the environmental impact of proposed agency actions, rather than justifying decisions already made (40 CFR 1502.2(g)). Additionally, the CEQ regulations include a provision in 40 CFR 1506.5(c) that addresses objectivity for any contractors involved in the preparation of the NEPA document, including a lack of financial or other interest in the outcome of the project. Because Island Conservation will be the implementing entity for the project, FWS should ensure that their substantial involvement and contribution of information is incorporated into the document in a way that meets the letter and spirit of 40 CFR 1506.5(c).

> *Recommendations:* The alternatives analysis in the FEIS should clearly identify the criteria used in screening potential alternatives to determine which would be brought forward and evaluated in the NEPA document, and these criteria should be consistently applied to all potential alternatives. An objective evaluation of diphacinone alternatives, in a side-by-side comparison, would be helpful to the public and the decision-maker and is recommended.
>
> Discuss and define feasibility and how it was assessed for the alternatives. Include cost data, which are likely to be relevant and important to the decision, so that an evaluation of the person-hours and mitigation proposals can be made.

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[5] From DOI Directive 517 DM 1: "While management costs are important, they are not the primary deciding factor in selecting a management approach". From FWS's 569 FW 1: 1.7 How does the Service choose which pest management methods to use? We choose pest management methods by considering the following *in this order of importance*: A. Human safety, B. Environmental integrity, C. Effectiveness, and D. Cost.

Project Features Common to All Action Alternatives
The DEIS identifies reasons why a previous rat eradication effort failed on Palmyra. Reasons include an ineffective management structure, use of volunteers and other staff with no expertise in rat eradication, poor communication between the involved parties, and an inadequate budget to complete the eradication. The lack of monitoring and communication plan led to poor data feedback to management and technical support, which contributed to a failed eradication (Appendix C, p. 15).

Although it is clear that far more initial research and planning has preceded the project being proposed now than was the case for the 2001-2003 effort, the project description in the DEIS does not clearly identify how these errors will be avoided in this project. The DEIS does identify adaptive management as a feature common to all alternatives (p. 24) and adaptive management could help address monitoring and communication issues; however, the adaptive management discussion is a presentation of the concept only, with no development of a plan specific to the project. Because avoiding the deficiencies identified above is crucial to project success, it is important that this project element be more fully developed[6].

> *Recommendation:* In Section 2.4 – Features Common to All Action Alternatives, include a discussion of the management structure for project implementation, and the staff who would be involved, including their expertise in rat eradications. Include a communication plan as an appendix to the FEIS. Discuss budget concerns or limitations. This information is relevant to environment impacts and should be included. FWS may choose to include this information in an adaptive management plan. If so, we recommend it be appended to the FEIS.

Bait Application Rate
The DEIS does not identify a preferred alternative; however, we are aware that Alternative B is preferred by the project partners. Alternative B would consist of two rounds of aerial application of brodifacoum, 10-14 days apart, at ≤90 kilograms/hectare (kg/ha) (approximately 80 pounds (lbs)/acre) per treatment, supplemented by hand-broadcast applications and bait station applications in certain locations, and arboreal applications of bait to trees that overhang the marine environment. The proposed maximum rate for broadcast application is five times the maximum rate indicated on the current label for the product (EPA Reg. No. 56228-36) that is intended to be used in the project. The DEIS indicates that the proposed bait application rate is

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[6] The report *Modernizing NEPA Implementation* (the NEPA Task Force report to the Council on Environmental Quality, 2003) suggests that the extent of the discussion of adaptive management in a NEPA document depends on its importance to the proposed action and the impacts being considered. When adaptive management is being used to adjust to unanticipated impacts of project implementation, the extent and detail of the adaptive management action would likely be extensive.

necessitated by the intense and rapid removal of bait by nontarget terrestrial organisms, chiefly 5 species of crabs. Without use of treatment rates of ≤ 90 kg/ha, the DEIS finds that insufficient amounts of bait would be left by crabs to permit rats access to bait for a sufficient period of time (4 days post application) to ensure an opportunity for each rat to ingest a lethal amount of the rodenticide brodifacoum, which is present in the bait pellets at a concentration of 0.0025% or 25 parts per million (ppm).

A specific sowing (broadcast application) rate is not established. The product label has instructions for determining the application rates. It states "The primary method of determining application rate should be calculated on data from onboard bait metering software and GPS flight path data [area treated (acres or ha) and total bait applied (lbs or kg)]. Where feasible, ground truthing should occur to verify application rate." Any proposed increase in maximum rates above current limits set by the label for EPA Reg. No. 56228-36 must be accepted, under the provisions of the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) as amended, by EPA's Office of Pesticide Programs through amendment of the label for that registered product or by some other applicable authorized mechanism.

The DEIS states that, for the project to be successful, an application rate greater than 36 kg/ha would be required (p. 39). There is a substantial difference between 36 kg/ha and 90 kg/ha. In at least one place (p. 47), FWS allows that the second application would be lower than the first ("to account for the reduction in bait consumers – rats that died from the first bait application"). The first treatment would go on at ≤90 kg/ha, while the second would be at ≥60 kg/ha. However, this information is at odds with text on pages 35-39, specifically the conclusion on p. 38 that "the bait application rate for the second broadcast should be as high as the first".

According to the full report for the 2005 visit, the "small juvenile, weanling rat" found alive 8 days after treatment on Whippoorwill Island may or may not have been the "similar sized rat" (Buckelew, et al, 2005) found ("in the same nest") to be "clearly lethargic" and dispatched 2 days later. The fact that one, or a few rats survived an initial hand-broadcast of 25 ppm brodifacoum bait at 95 kg/ha does not, by itself support a second broadcast at the same rate. All evidence assembled thus far indicates that the first broadcast would take most of the rats, even if made at a rate much lower than 90 kg/ha. The highest reported projections for bait take by crabs are well below 90 kg/ha.

The first paragraph on page 39 is not clear, but seems to indicate that making more bait available attracts more crabs, meaning that bait availability might be more important than crab density in determining how much of the applied bait is taken by crabs and how much remains for other organisms, including rats. The argument for making two applications at the same rate is, basically, that such a negligible percentage of what is applied would go to rats that the high rate is driven almost entirely by the need to have some bait not be eaten by crabs. The calculations discussed in Howald, et al, (2004) of potential bait take by crabs, especially the upper limits of it, should be discussed in this EIS, including how this information could inform bait application rates.

As the first planned application at $\leq$90 kg/ha would kill nearly all, if not all, of the resident rats, virtually all of the bait applied in the second planned application at up to the same maximum rate (leaving aside the issue of overlapping helicopter swaths) would be available for consumption by nontarget species. Results from Home Island (Wegman, et al, 2008) indicate that neither treatment at 36 kg/ha resulted in much, if any, bait remaining after 3 days. It does not automatically follow that increasing the application rate to ~90 kg/ha (~2½ times 36 kg/ha) also would result in no bait being left after 3 days. In the 2008 "biomarker" trials, all types of potential primary consumers of bait that were examined showed evidence of the fluorescent dye; and those treatments were at 10%, 20% and 40% of the maximum rate contemplated for use. It seems fairly certain that less bait would be needed in a second round of treatment to reach all individuals in the residual rat population, but it also would be difficult to determine where and at what densities rats remained on the various islands and various areas on those islands, especially without significant activity monitoring between applications.. We understand the proposal to use enough bait for it to be present for 4 days (p. 47) when anything short of full eradication means failure; but that approach would require putting out tremendous quantities of bait that would go into alternative food chains.

> *Recommendation:* The FEIS should clearly present the aerial application rates for both the first and second applications. EPA recommends that the second application rate be lower than the first unless between-treatment monitoring of other evidence indicates the presence of significant rat activity in a particular area. Once rates are established, they should be adhered to during the operation, and changes only made according to a clear protocol. The miscommunications and errors made during the Rat Island eradication, during which Island Conservation applied bait at a rate significantly deviating from the target application rate, should be avoided. Changes to baiting rates in the field should be thoroughly documented. In no case may the limits on application rate established by the label for the product used in the project be exceeded, with some allowances for swath overlap (as covered by the labeling). As recommended in the Rat Island critical evaluation, planning should occur for contingencies that are reasonably foreseeable. For each contingency, that evaluation recommends developing a structured decision-making tool that provides much more detail than did Island Conservation's Rat Island risk and contingency plan. Specifically, "A structured decision-making tool for application of bait other than as planned would require a written assessment of the amount of bait already on the ground, a comparison to the approved label rate and target rates, a written assessment of the additional bait to be applied, a calculation of the total amount of bait that would be applied, and the increase in the potential risk to nontarget species".

Contingency Bait

The DEIS does not reveal whether there will be additional or "contingency" bait for use to replace bait that spoiled or spilled and to fill gaps in coverage from aerial applications, nor does it discuss the disposition of excess bait. A major error that occurred with the Rat Island eradication, according to the Rat Island critical evaluation, was that all the contingency bait was applied to avoid costs of disposal or returning excess bait to the manufacturer. Failures in communication also contributed.

Recommendation: The FEIS should disclose how excess bait will be disposed (or shipped off-island) and whether funding for bait disposal will be included in the project, and should include clear directions for proper excess bait disposal in a communication plan. As mentioned above, decisions regarding disposal of bait should be clearly outlined in a structured decision-making tool.

Post-treatment Monitoring

The DEIS does not document sufficient post-treatment monitoring. "Passive observation by field station staff" (p. 25) would not, as asserted, "be a very effective post-eradication monitoring method". It might indeed detect "a remnant rat population … within 1 year of the eradication effort"; but that would be much too late for any remedial action to influence the outcome of the project. Even planned post-treatment monitoring 4-6 weeks after aerial application (p. 24) would be too late for localized remedial baiting. Monitoring rat activity between treatments would inform adjustment of the application rate for the second aerial broadcast. Monitoring shortly after the second round of baiting might detect residual rat activity which, if localized, might be eliminated via intense additional control activities. Additionally, the areas where bait stations are used, and zones bordering those areas, should be monitored intensively for any signs of rat activity during and for months after the broadcast baiting period, to avoid any rat migration into aerially treated areas to become founders of a rebounding rat population.

Recommendation: The FEIS should document a more appropriate post-treatment monitoring plan. EPA recommends monitoring between aerial treatments and shortly after the 2nd round of baiting. Frequent monitoring should occur in bait station areas.

Biosecurity Plan

The DEIS states that the risk of rat reintroduction is high because Palmyra Atoll is a remote refuge and scientific research station that is maintained through periodic shipments of supplies including consumable and bulk goods, as well as personnel via regular airplane and annual barge service from Honolulu (p. 29). The biosecurity plan included in Appendix B does not appear as comprehensive as is needed for a high reintroduction risk. J.C. Russell, et al[7] recommend that biosecurity plans include quarantine, surveillance, and contingency response components. It is also not clear who would implement the different components.

Recommendation: We strongly recommend that the biosecurity plan be as comprehensive as possible. We recommend that it include quarantine, surveillance, and

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[7] Russell, J.C. et al. 2008. ***Review of rat invasion biology, Implications for island biosecurity***. New Zealand Department of Conservation. Available: http://www.stat.auckland.ac.nz/~jrussell/files/papers/sfc286.pdf

contingency components, and provide references and/or discussion that demonstrate that the plan has thoroughly considered which, of the proven biosecurity approaches available, will work best for Palmyra. The FEIS should also identify who would implement the biosecurity actions, whether their implementation is dependent on funding, and if so, any expectancy of funding deficiencies.

Manpower and logistical concerns

The planned use of "bolo" baiting would not coincide with broadcast baiting but rather would start after 3 days of broadcast-baiting and go on for 7 days, with the first round of bolo baiting ending the day before the second round of broadcast baiting might begin (p. 47). With an estimated 3,546 overhanging palms on the atoll (p. 53), project personnel would have to treat 500 palms/day, which works out to approximately 50 palms/hour (1.2 minutes per palm) if personnel are able to devote 10 person-hours/day to this activity alone. At approximately 6° north latitude, Palmyra's photoperiod varies little over the course of a year. In June and July, there might be 12½ hours between sunrise and sunset, with little usable dusk-and-dawn time outside of that period. Clearly, significant rain events, which happen often there, would further restrict the time available for baiting overhanging palms. This means that several crews would have to be devoted to palm baiting. Non-overhanging palms and other trees in hand-baited and bait-station treated areas would also have to be treated, apparently, but such activities might be concurrent with helicopter broadcasts.

It appears that only 4-5 people would be available for hand-broadcast baiting. That could be a problem in the event of helicopter equipment failure or exhaustion of helicopter fuel (p. 46).

It is not clear that the "Person-Days" of "effort" calculations for the aerial application options in Table 2.4 account for hand-broadcasting, baiting trees that overhang water, and bait station establishment and maintenance in the camp area. Those days may have been included in the 460 "Person-Days" indicated for "Aerial broadcast – 25W" (p. 62).

> *Recommendation*: The FEIS should devote more analysis to logistics and manpower needs of the alternatives, especially since effective canopy baiting is crucial to the success of the project. (See also comment below regarding reducing palms prior to eradication). As recommended above, define and discuss feasibility in relation to the alternatives, and whether sufficient funding is available to meet manpower and all logistical needs.

Restricted Use Pesticide (RUP) Certification

The DEIS does not indicate a clear understanding of EPA's certification requirements for use of Restricted Use Pesticides (RUPs). The DEIS states that "all bait application activities will be conducted under the supervision of a Pesticide Applicator certified by the EPA" (p. 25), and that "the product may only be applied by Certified Pesticide Applicators (a certification for Palmyra generally provided by the State or Territory in which the bait is to be applied) or persons under their direct supervision" (p. 30). These statements are not correct.

RUP certification is required under the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) for the Palmyra Rat Eradication. However, EPA would not certify applicator(s) for this project. EPA certifies applicators only under very limited circumstances where there is a federal certification and training (C&T) plan in place per 40 CFR 171. This application is not covered by any currently existing federal plans. Since Palmyra does not fall under the jurisdiction of any state or tribe, there is no state or tribal certification plan that would legally cover applicators for this project.

FWS does not have a plan for certifying applicators for this project. Given the scope and huge quantities of restricted use pesticides used for the rat eradication projects (of which Palmyra is only one), FWS should develop and submit to EPA, for approval, its own certification plan that would cover these applications. We note that, even if FWS did have an EPA-approved certification plan, it would only cover FWS employees, and not contractors (even in an "under-the supervision-of" situation described at 171.2(a)(28).

To be in compliance with FIFRA, no RUPs should be applied; however, in this circumstance, EPA's Office of Pesticide Programs suggests that it would be minimally acceptable for the applicator to be certified as a commercial applicator in an appropriate category by the State of Hawaii. Charles Nagamine, a University of Hawaii Extension agent, suggested that either Category 2 (Forest Pest Control) or Category 7c (General Pest Control) would be appropriate. Please consult with Mr. Nagamine (Phone: 808-956-6007). (Certification by other Pacific Islands such as Guam, CNMI, and American Samoa should not be pursued as their certification programs are not finalized).

> *Recommendation:* Correct the statements regarding RUP certification in the FEIS. The FEIS should document if and how responsible parties are following the record keeping requirements for sale and use of RUP's, including the company selling them and the applicator who is using them. Ensuring that all of the restricted use pesticides are accounted for could be a homeland security issue, especially in the quantities being proposed.

Pesticide Information and Corrections

The name, registrant, and registration number of the product intended to be used on Palmyra are misidentified on page 29 and elsewhere. The product's name is "brodifacoum-25W Conservation", without a trademark symbol. The registrant is the Animal and Plant Health Inspection Service (APHIS), USDA. The registration number is 56228-36. See the product's label (e.g., on page 48 of Appendix F).

The discussion of first and second-generation anticoagulants on p. 30 is not completely accurate. The "generation" designations for anticoagulants are not strictly "according to when they were first developed as rodenticides" although they relate indirectly to their toxicity. Another "first-generation" type of anticoagulant could be developed this year, if anyone were interested in doing so. The term "first generation anticoagulants" was introduced to contrast anticoagulants that were not effective against rodents with genetic resistance to them with anticoagulants that could kill resistant individuals (Dubock and Kaukeinen, 1978). The chemistries that became known as "second-generation anticoagulants" - a term apparently first used in print by Marsh, Howard, and Jackson (1980) - were developed through a search for rodenticides (Hadler and Shadbolt, 1975, cited in DEIS) that would be effective against individual commensal rodents that are resistant to warfarin, pindone, diphacinone, chlorophacinone, and other "first-generation" anticoagulants. See also Jackson and Ashton (1992 – cited in the DEIS). Why the "second-generation" anticoagulants can kill warfarin-resistant individuals (greater affinity for the "Vitamin-K receptor") was fully characterized after the compounds were put into use as rodenticides. The so-called "single-feeding" effect attributed to brodifacoum (Dubock and Kaukeinen, 1978) and other second-generation anticoagulants results from this greater affinity, but is dependent upon the amount of the compound that is ingested on the first day of exposure to it. The amount of anticoagulant ingested on the first day of exposure is determined by the rodent's willingness to consider the bait as a food item; the concentration of the rodenticide in the bait; the palatability of the bait to the rodent; and, in a control situation, the amount of bait available to the rodent. The last of these is an issue on Palmyra due to documented competition for bait with other terrestrial animals, chiefly crabs.

This discussion on page 30 concludes that "any rodenticide can be effectively used to eradicate an entire rodent population if all individuals within the population consume enough bait over an appropriate amount of time." This sentence does not address the possibility of resistant individuals within the population. It has been shown with captive animals that Norway rats genetically resistant to warfarin eventually can be killed by warfarin if consumption continues for many days. It is doubtful, however, whether that would occur in practice before such rodents were able to reproduce and before the baiting program was stopped.

The product (EPA Reg. No. 56228-36) under consideration for the Palmyra project is not labeled for use for "agricultural operations" or "professional pest control operations", apart from conservation uses, as started on page 32 of the DEIS. EPA did not *decide* to make 56228-36 a restricted use pesticide after a period of registration without such designation, as the paragraph implies. Rather, the product was proposed by its applicant to be a restricted use pesticide.

There is reference to "EPA –approved label instructions" in Section 2.4.4 (pp. 24-25) that do not currently exist. As noted above, the existing label for EPA Reg. No. 56228-36 would have to be amended or Palmyra-specific application directions would have to be authorized via another provision of FIFRA.

> *Recommendation:* The information provided above should be used to make the necessary corrections in the FEIS.

Mitigation Measures

Reducing Coconut Palms Prior to Eradication

The coconut palms appear to be especially problematic for the eradication. Not only do they require special baiting methods into canopies, requiring additional manpower, but, as the DEIS indicates, the coconut endosperm was the only food item that scored higher than the bait products in the palatability trials. This suggests that coconut palm reduction may be beneficial to the eradication by reducing the amount of naturally available food that could distract rats from consuming the bait pellets (Appendix F, p. 39).

In its discussion of brodifacoum resistance seen in an eradication trial, the DEIS notes that Vitamin K, which is an antidote to brodifacoum, is contained in coconut fruit. Additionally, to avoid bait drift into the marine environment, the project must hand bait coconut palms that overhang the water if aerial broadcast is selected. Removing coconut palms that extend 100% over the lagoon and ocean would minimize risk of impacting water resources with rodenticide. Removing coconut palms near the marine environment could also benefit green turtles, since one hypothesis for lack of nesting on Palmyra is the extreme abundance of coconut palms close to the beach where turtles might otherwise attempt to dig nesting pits (p. 78).

The DEIS indicates that coconut palm removal is a potential future action (p. 149). It also states that rat eradication is the first step in a series of restoration efforts because it is relatively simple and fast and provides the framework to initiate the palm removal stage of the restoration process (p. 10). The DEIS does not make clear why conducting the rat eradication first is most beneficial (for example, how it sets the framework for the palm removal). Coordinating the timing of the palm removal to precede the rat eradication should be strongly considered, if it would substantially increase the success of the eradication.

> *Recommendation:* As a mitigation measure, the FEIS should discuss the feasibility and benefits of reducing the number of coconut palms on the island prior to the eradication, especially those that extend over the marine environment or are likely to present the greatest problems for the rat eradication. The FEIS should discuss the extent that conducting the palm removal first would increase the effectiveness of the rat eradication effort, and how impacts of the action would change as a result.

Timing of Shorebird Migration

The most important mitigation measure identified is the timing of the eradication to coincide with the period when the least number of migratory shorebirds are present. The DEIS estimates this time to be June and July, when many adult shorebirds return to breeding grounds in the Arctic (p. 28).

Because this is the primary mitigation measure for impacts to shorebirds, it is important that migration timing be confirmed. Shorebirds are affected by the weather (Appendix H discusses the lack of migration of the Sooty Tern from the 2009-2010 El Nino Southern Oscillation) and peak migration dates may vary from year to year. In addition, there is already compelling evidence that birds have been affected by recent climate change, including earlier breeding; changes in timing of migration, etc.[8]. The DEIS does not discuss the effects of climate change on Palmyra's resident shorebirds nor how potential effects could impact the project design.

> *Recommendation:* To improve the effectiveness of this mitigation measure, consider conducting shorebird surveys prior to the eradication to confirm that a low number of shorebirds are present, as predicted in the DEIS. Discuss possible climate change effects on the project in the FEIS.

Mitigation Measures Committed to as Part of the Project

Mitigation measures are mentioned in the DEIS and appendices but it is not clear which will be adopted for the project or incorporated as components of the proposed action. CEQ recently released guidance to federal departments and agencies on the appropriate use of mitigation and monitoring in NEPA documents[9]. In this guidance, CEQ makes clear that mitigation commitments should be carefully specified in terms of measurable performance standards or expected results, so as to establish clear performance expectations. CEQ also states that agencies should not commit to mitigation measures considered in an EIS absent authority or expectation of resources to ensure that mitigation is performed.

> *Recommendation:* Project mitigation measures should be explicitly identified in the FEIS and included in FWS's Record of Decision. A discussion of the effectiveness/expected results of these measures should be included. FWS should discuss funding and indicate whether the resources are available to ensure implementation of proposed mitigation measures, as well as the party responsible for implementation. If an adaptive management plan will be developed, identify mitigation measures that would apply in the event that initial mitigation commitments are not implemented or effective.
>
> The following were identified in the DEIS as possible mitigation measures:
>
> - Assessing the weather conditions and prohibiting bait broadcast if rainfall is forecast (Appendix H, p. 12). More detail about effectiveness and implementation of this measure should be included in the FEIS.
> - Securing a tarp over the drinking water catchment to prevent aerially broadcast bait from entering the drinking water supply (p. 96). We recommend adding to this measure that the tarp would be inspected (or reinstalled if it was removed) prior to a second aerial application.

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[8] Crick, H. Q. P. (2004), The impact of climate change on birds. Ibis, 146: 48–56. doi: 10.1111/j.1474-919X.2004.00327.x

[9] http://ceq.hss.doe.gov/current_developments/docs/Mitigation_and_Monitoring_Guidance_14Jan2011.pdf

- Dying the bait blue to make pellets less attractive to birds. We believe the conclusion that blue dye used in EPA Reg. No. 56228-36 would make pellets less attractive to birds is overdrawn. The degree of repellency would depend upon the shade of blue and the perceptions and food habits of each bird species. Birds that eat fruits or some types of insects might not be predisposed against eating blue things. It is not clear to what extent the factors affecting eat/don't-eat decisions for the types of birds that occur on Palmyra have been studied.
- Capture and treatment of all sick and moribund shorebirds found during and directly after the eradication, and treatment with Vitamin K, an antidote to anticoagulants (p. 26). The planned collection and Vitamin-K treatments of sick or moribund shorebirds should be evaluated for feasibility and effectiveness in the FEIS. Treatments would likely have to be extensive if experiences with various mammals (including humans) are predictive of what would be needed to save birds.

Impact Assessment

Impacts to Biological Resources

<u>Potentially significant impacts from bait station use not considered</u>
For Alternative D (bait station alternative), the DEIS indicates that, while mortality risk from toxicants is high for some birds (BTCU, Pacific golden plover, ruddy turnstones, laughing and Granklin's gulls, Northern shoveler and Northern pintail duck), the exposure risk is low (p. 136-139). This does not fully consider the fact that the bait would be present in the atoll environment for approximately 2 years, which would offer long-term secondary pathway toxicity opportunities.

The aerial broadcast alternatives would also use bait stations; specifically, on Cooper Island on or near the runway and in the camp area, where Nature Conservancy staff and researchers and project personnel reside and where the drinking water and waste treatment facilities are located. A discussion of the efficacy of bait stations should be included. It appears possible that bait stations might not expose all rats due to some individuals not entering bait stations, especially as the units would have to be elevated and otherwise crab-proofed.

In addition, even for the aerial broadcast alternatives, baiting in the areas mentioned above would have to continue for approximately 2 years, and any rats residing in that area that were not taken during the same period of time when broadcast bait was present on the island could emigrate into previously treated areas and become founders of a rebounding rat population on Cooper Island and, eventually, the rest of the atoll.

> *Recommendation:* The above impacts should be included in the impact assessment in the FEIS. The issue of preventing rats in the bait station areas of the aerially broadcast alternatives repopulating aerially eradicated areas should be addressed in the project design.

Impacts to Reptiles

Two rounds of baiting (10 days each, including canopy follow-ups) are planned. As residues would be retained in prey for some time, the suggestion that geckos would only be vulnerable to brodifacoum for 4-7 days (p. 114) underestimates the likely duration.

The DEIS states that the two species of gecko at Palmyra may be at risk of secondary exposure to rodenticide through the consumption of invertebrates that had previously consumed bait, however, it concludes that none of the 50 geckos sampled during the 2008 biomarker study showed any sign of primary or secondary exposure to bait (p. 116). This is not sufficient basis for this conclusion. As pyranine, a biomarker agent, does not appear to be systemic as afluorescent dye, its absence from geckos in the 2008 biomarker trial does not predict non-exposure to brodifacoum. Invertebrates would retain the rodenticide differently than they would pyranine.

> *Recommendation:* The above impacts should be included in the impact assessment in the FEIS. Capturing, holding, and maintaining individuals of the native gecko species should be considered as a mitigation measure.

Impacts to Soils and Water Resources

The DEIS references the rat eradication on Anacapa island to support its conclusion that the aerial alternatives would not have a noticeable effect on soil contamination (p. 98). For the Anacapa Island project, however, bait was not applied at the rate planned for the Palmyra project (two applications at ≤ 90-kg/ha). Consequently, a low likelihood of contaminated soil samples for Palmyra does not necessarily follow from the results on Anacapa. The data from Alifano and Wegmann (2010) came from isolated pellets rather than baits applied according to how they are planned to be used at Palmyra.

The worst-case calculations presented for impacts to water resources (p. 97) are not based upon the proposed application rate of up to 90 kg/ha (~80 lbs/acre), which is 5 times the maximum rate currently indicated on the label for EPA Reg. No. 56228-36 for the first island-wide broadcast application and 10 times the maximum rate indicated for the second broadcast application.

> *Recommendation:* Reevaluate impacts to soils and water resources from the aerial broadcast alternatives using the quantity of bait expected to be applied for the project. If the active ingredient infiltrates vertically into soils, the Alifano and Wegmann (2010) data likely would overestimate the extent of island-wide contamination, although it is possible that material might congregate in some lower areas due to surface flow resulting from heavy rain events. Due to the composition of the islands, however, puddles tend to be short-lived, even after extensive heavy rains.
>
> For impacts from the bait stations (which are part of all action alternatives), these discussions should note the possibility of bait stations becoming damaged or being

dumped, either of which could result in a concentration of several ounces or more of bait at one spot. Describing the bait stations as being "durable enough to stay in place for 2 years and prevent crabs from entering or destroying them" is fine in theory, but realistic assumptions would expect some error. It also is not clear that a specific design of bait station has been selected for use in this project.

Errors in the Document

The following were identified as errors occurring in the document. EPA recommends that these errors be corrected for the FEIS:

- Page 35, last paragraph, running over to page 36. The characterization that detection of shore birds was consistently higher post-treatment than pre-treatment for the 2005 mini-eradication effort is not consistent with the narrative in, nor "Figure 10" of, the report by Buckelew, et al (2005).
- Page 38, "Figure 2.1". The numbers illustrated in this figure are not consistent with those shown in "Fig. 5" in the Wegmann, et al (2008) report. The narrative on page 37 of the draft EIS is more accurately reflected by Fig. 5" of Wegmann, et al (2008), than by "Figure 2.1" on page 38 of the draft EIS.
- Page 39, bottom paragraph. The first line of this paragraph should be corrected factually as well as grammatically.
- Page 45, first "Rationale" paragraph. The number (332) given here for "successfully reported island eradication efforts world wide" differs from the number (278) cited from the same reference on page 31. At least one of those numbers must be wrong. The correct number, if known, should be used. "Brodifacoum-25" is not one "specific product". This paragraph itself acknowledges the existence of a "Brodifacoum-25D" and a "Brodifacoum-25W".
- Page 50, Table 2.5, and relevant discussions on page 51. The result on Whippoorwill Island is reported as having been "Successful" despite the finding of one or more live rats 8 and 10 days after bait application. All of the localized rat eradication efforts on Palmyra in 2005 would be judged as "Failed" if the standard index of no signs of rat activity for 2 years following treatment were applied. Although reinvasion from very nearby untreated islands might have been the cause of the reappearance of rats on those islands, the standard for successful eradication should be greater than obtaining zero scores for various activity measures shortly after treatment. By the latter standard, the brodifacoum/Bromethalin trials on Palmyra Atoll in 2001-2003 probably would have been judged "Successful", at least for some of the islands; and the same would have held for some islands in the diphacinone work in the Bay of Islands, Adak, AK, 2003-2004. The 2008 trials on Palmyra involved placebo baits which, presumably, did not directly kill any rats. The "Failed" status is visited upon them because one or more rats live-trapped post-treatment showed no evidence of the Pyranine "biomarker", and some others were marked only to a degree like the captive roof rats that were fed only one placebo

bait pellet. The two failures for Polynesian rats (*R. exulans*) might have resulted in part through use of a bait moiety that was less than optimal for controlling that species. The 25W bait was not accepted especially well by captive Polynesian rats in trials conducted on Wake Atoll in 2007.

- Page 63, "Table 2.7". "Canopy baiting" is mentioned as one of the "Secondary bait delivery methods" that would be used for "AlternativeD" [sic] (bait stations), but not for the aerial application options which the narrative to the draft EIS indicates would be supplemented by baiting trees that overhang water.
- Page 107, second full paragraph. Whether a single "dose" of brodifacoum would be lethal would depend upon the amount received, through ingestion in this case. The LD_{50} is not really a "threshold", as some individuals would be expected to die after receiving lower dosages.
- Page 145, "Alternative A – No Action" paragraph. Under this alternative, there would not be an eradication effort. Therefore, signs (or "sings", line 17) would not have to be posted.
- Page 31, first full paragraph. The last sentence of the first paragraph under "Brodifacoum-25W™ bait product" does not follow from the rest of the paragraph. It appears that 14 (7%) of 197 successful eradications using brodifacoum as the "primary rodenticide" were effected using "aerial broadcast supplemented with hand-broadcast" but that technique would have been less "commonly used" than bait stations (47% or ~93 instances), aerial-broadcast alone (29% or ~57 instances), or hand-broadcast (21% or ~41 instances).

Minor comments / discrepancies

- In approaches dismissed, the DEIS identifies fertility control (p. 17) and discusses oral contraceptives. We are aware that research is being conducted towards the development of chemical sterilants that could offer a less toxic alternative to rodenticides. FWS should monitor this development for possible future use.
- On p. 103, the DEIS says that successful turtle nesting attempts have not been recorded on Palmyra; but, on p. 83, it says that green turtle nesting has been documented at least twice at Palmyra, primarily on the northwest side of Cooper island.
- The DEIS states that informal Sect 7 consultation will be conducted "for any case deemed necessary by the FWS" (p. 101). The FEIS should indicate whether informal consultation has occurred.
- Appendix C pp. 14 and 37 indicate that 2 cats and a dog (and a cat on a boat) were present in 2004. State whether these animals are still present and how they will avoid poisoning.
- Pages 152-188. Pages bearing these numbers are missing from the copy of the draft EIS that was reviewed; but, seemingly, with no loss of intended text. Subsection "5.1" appears on page 151; and subsection "5.2" appears on page 189
- Some references to appendices in the draft EIS are by number (eg. p, 17), but the

appendices are lettered (e.g., "A") rather than numbered.

- Page 63, line 23 and p. 68 line 9. To preserve its presumably intended meaning, the word (?) "ratpredation" should be replaced by "predation by rats" (here and elsewhere). "Ratpredation" also could mean "predation on rats".
- Table 3.3 has no headings
- There were many typos in the document. A few are:
  - On p. 60, Alternative E should read Alternative D
  - On p. 145, the word "signs" should replace "sings" in lines 25, 33 and 39
  - On p. 150, the last sentences of paragraphs "4.6.1.5" and "4.6.1.6" should correspond to the correct alternative (C and D)

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United States Department of the Interior

NATIONAL PARK SERVICE
Pacific West Region
300 Ala Moana Blvd., Box 50165
Room 6-226
Honolulu, Hawaii 96850

NATIONAL PARK SERVICE

IN REPLY REFER TO
N1427

Hand Delivery

April 11, 2011

U.S. Fish and Wildlife Service
Pacific Reefs National Wildlife Complex
300 Ala Moana Boulevard
Room 5-231
Honolulu, Hawaii 96850

Attention: Dr. Elizabeth Flint

Re: DEC-11/0012: Nonnative Rat Eradication Project, Palmyra Atoll National Wildlife Refuge, U.S. Pacific Island Territory

Dear Dr. Flint:

Thank you for the opportunity to comment on the Palmyra Atoll National Wildlife Refuge Nonnative Rat Eradication Project, Draft Environmental Impact Statement. We support the Refuge's goal of eradicating rats from Palmyra and anticipate that the project also will yield valuable information on refinement of eradication and follow-up monitoring techniques, particularly for equatorial island environments.

We offer a few comments focused mainly on the Refuge's consideration of diphacinone, an alternative toxicant whose use was considered and dismissed. The EIS should more clearly state the reasons that diphacinone was not considered appropriate for this particular project. We feel this specificity and additional supporting information are important in light of possible future rodent eradication attempts where diphacinone could be the more appropriate tool.

In particular, the section beginning on page 17, line 14 would be clearer if the opening paragraph (lines 16-26) was expanded on or otherwise revised—all five factors contributing to the decision not to further consider the use of diphacinone as an alternative need additional supporting or explanatory information as described below:

1) The toxicity of the product (line 20) is confusing in light of later information about the higher toxicity and slower environmental degradation of brodifacoum. The EIS should clarify why and how the lower toxicity of diphacinone (vs brodifacoum) figured into the decision not to use diphacinone.

2) Efficacy, including palatability (line 19) is also mentioned as a consideration, but then later (page 22, lines 15-16 and elsewhere), the EIS judges that the 2 toxicants are of equal and adequate palatability. If efficacy other than palatability is a major issue, this should be more clearly stated in this section, including in this introductory paragraph.

3) "…the extremely dense vegetation at Palmyra inhibiting distribution of product" (line 21) does not appear to be specific to the use of diphacinone. It instead seems a concern that is related to the method of distribution of any bait.

4) "…the safety of personnel in applying product, including consideration of unknown but documented unexploded ordnance in the atoll" (lines 23-24) also is not specific to the use of diphacinone.

5) "…the inordinately dense population of land crabs, their extreme ability to penetrate enclosures, and their voracity of consumption" (lines 24-26) again does not appear to relate specifically to the use of diphacinone.

We also suggest including in this section consideration of the performance of diphacinone if applied at sowage rates comparable to that proposed for brodifacoum in Alternatives B-D. Would this increase change the likely performance of this first generation toxicant and its assessment in the DEIS?

We also are concerned about the potential for Bristle-thighed Curlew mortality. The stated Palmyra resident population of up to 182 birds constitutes roughly 2% of the estimated world population of approximately 10,000 individuals. The DEIS considers population modeling that suggests "…minor decreases in the population growth rate with diminishing impacts on the projected future population," resulting from a theoretical 80% mortality of resident BTCU at Palmyra (page 113, lines 26-30). Because the species is thought to be in decline, we urge caution and prudence in light of other factors outside the control of the FWS that may impact this species now and in the future. We ask the Service to consider additional actions to minimize exposure of curlews to the toxicant; for example, removing crab carcasses and other avenues for secondary poisoning in the days immediately following baiting in areas of high curlew densities, and/or using bait stations rather than aerial broadcast on key curlew islands or in key curlew habitat if feasible.

Lastly, we call your attention to the recent report by Parkes and Fisher (Parkes, J and P Fisher. 2011.) "Review of the Lehua Island Rat Eradication Project", Landcare Research Contract Report LC 129 for the Pacific Cooperative Studies Unit, Honolulu, Hawaii) that evaluates the failed rat eradication attempt on Lehua Island. Their catalog of rodent eradication attempts differs from that of this DEIS and may be more complete. Additionally, their simple statistical evaluations of diphacinone vs brodifacoum provide an additional way of viewing the track record of these two toxicants and emphasize the need for more data. Finally, some of the lessons learned from Lehua may be applicable to the Palmyra project.

We hope our comments are helpful. Thank you for your consideration.

Sincerely,

Melia Lane-Kamahele
Acting Pacific Area Director

ecc: Dale Morlock, NPS Environmental Quality Division
Alan Schmierer, NPS PWR-Oakland
Dr. Darcy Hu, HAVO Ecologist & CESU Coordinator

Pacific Seabird Group

DEDICATED TO THE STUDY AND CONSERVATION OF PACIFIC SEABIRDS AND THEIR ENVIRONMENT

Dr. Patrick Jodice
Chair
South Carolina Cooperative
Fish & Wildlife Research Unit
Clemson University
Clemson, SC 29634
864-656-6190
PJodice@clemson.ed

Craig S. Harrison, Esq.
Vice-Chair for Conservation
4953 Sonoma Mountain Road
Santa Rosa, CA 95404
202-778-2240
charrison@hunton.com

Kim Rivera
Chair-Elect
NOAA Fisheries
709 West 9th, Room 461
Juneau, AK 99802
907- 586-7424
Kim.Rivera@noaa.gov

pacific_reefs@fws.gov

April 4, 2011

Susan White
U.S. Fish and Wildlife Service
Project Leader
Pacific Reefs NWR Complex
300 Ala Moana Blvd.
Honolulu, HI 96850

Re: Draft EIS for Palmyra Rat Eradication Project

Dear Ms. White:

On behalf of the Pacific Seabird Group (PSG), we offer these comments on the draft Environmental Impact Statement (DEIS) for the Palmyra Atoll National Wildlife Refuge Rat Eradication Project. PSG is an international, non-profit organization that was founded in 1972 to promote the knowledge, study, and conservation of Pacific seabirds. It has a membership drawn from the entire Pacific basin, including Canada, Mexico, Russia, Japan, China, Australia, New Zealand, and the USA. PSG's members include biologists who have research interests in Pacific seabirds, government officials who manage seabird refuges and populations, and individuals who are interested in marine conservation. PSG has long been concerned about nonnative creatures such as rodents on seabird breeding islands. We have a history of supporting projects that remove nonnative species to allow indigenous fauna, especially seabirds, to achieve healthy, sustainable populations. For example, in recent years PSG has supported rodent eradication projects on Lehua Island (Hawaii), Rat Island (Alaska) and Anacapa Island (California). Through its conservation fund, PSG has sponsored an eradication project in Fiji.

PSG strongly supports the proposed plan to eradicate ship rats (*Rattus rattus*) at Palmyra to aid in the conservation of seabirds and their habitat. Rats are notorious for their depredations on bird chicks and eggs as well as adults of the smaller species (I. A. E. Atkinson, 1985, The spread of commensal species of *Rattus* to oceanic islands and their effect on island avifaunas. In: P. J. Moors (ed.), Conservation of Island Birds, ICBP Tech. Pub. 3: 35-81). The introduction of rats on Midway during 1943 decreased seabird populations there and caused the extinction of the Laysan rail and Laysan finch (H. I. Fisher and P. H. Baldwin, 1946, War and the Birds of Midway Atoll, Condor 48:1-15). The successful eradication of rats on Midway in the 1990s has had positive impacts on small nesting seabirds such as Bonin petrels and storm-petrels (M. J. Rauzon, Island Restoration: Exploring the Past, Anticipating the Future, Marine Ornithology 35: 97-107, 2007). Restoring the Palmyra ecosystem by removing ship rats will pay huge dividends for seabirds and the island ecosystem. For example, small and vulnerable seabird species such as sooty terns, brown noddies and black noddies will almost immediately benefit from the eradication of rats. Many of the eight seabird species that were apparently extirpated from Palmyra by rats (Audubon's shearwater, Christmas Island shearwater, wedge-tailed shearwater, Phoenix petrel, white-throated storm-petrel, Bulwer's petrel, blue noddy and gray-backed tern) may reappear, some possibly very quickly. Rat predation on bristle-thighed curlews may occur on Palmyra because curlews experience a period of flightlessness while molting there (DEIS, p. 103). It is evident that the restoration of Palmyra will allow many species to reclaim their former ranges.

USFWS' Regional Marine Bird Policy for over 25 years has stated that its goal is to "remove all introduced predators from marine bird colonies on all National Wildlife Refuges and encourage their removal from all other colonies." (November 15, 1985). The proposed rat removal project furthers that policy, and completes the eradication of rats from all the remote refuge islands.

Although PSG recognizes that the elimination of alien predators that devastate natural communities and drive some species to extinction sometimes is controversial, we have supported USFWS and other agencies in the past when groups that are ignorant about wildlife management attempt to thwart projects such as this, sometimes by force of litigation. PSG will gladly lend its name and expertise to joint press releases concerning this project to help educate anyone who may be initially opposed to this project.

PSG believes that the goals of this project must be complete eradication. We want to avoid situations that require perpetual control, perpetual funding and perpetual vigilance. Long-term rodent control projects raise secondary poisoning issues over a long period as well as the risk that rats will develop a resistance to poisons. In our considerable experience, we have learned that half-measures are inefficient and are simply a waste of funds.

PSG supports of the use of brodificoum, which is capable of killing a rat after a single feeding. Palmyra is a challenging three-dimensional environment for rat eradication because of the prevalence of crab bait competitors, 50-foot coconut trees, and almost daily rain showers. Rats may only have a single chance to find the bait under these difficult conditions. There was a failed attempt to remove rats in 2001-2002 on Palmyra, and we urge you to make every effort to make this attempt a success. The techniques of aerial broadcasting of bait has greatly improved since 2001, and recent successes include Rat Island (Alaska) and Anacapa Island (California). In contrast to these examples, we have analyzed the "Review of the Lehua Island Rat Eradication

Project" by Landcare Research, New Zealand (January 2011) where a rat eradication failed. We conclude that the use of a weaker rodenticide (diphacinone, which requires multiple feeds to deliver a lethal dose) and unreasonable restrictions on its use near the shoreline led to failure. Unfortunately, the Lehua project was ultimately a complete waste of funds and human effort. We would like to benefit from lessons learned at Lehua and would object to such restrictions at Palmyra.

The DEIS presents four alternatives: (A) no action; (B) aerial broadcast of brodificoum; (C) aerial broadcast of brodificoum with proactive mitigation of risk for vulnerable bristle-thighed curlews; and (D) bait stations with brodificoum with canopy baiting. We believe that the chances of success will be improved by using large amounts of bait with high toxicity because hermit crabs, not rats, will consume much of the bait. The project may pose a risk to non-target species such as bristle-thighed curlews. During the summer (June-July) window for this operation a small number of young, non-breeding curlews may be present at Palmyra, and significant efforts should be made to protect those birds. For this reason we support Alternative C. We recognize that some curlews may be lost if they eat poisoned hermit crabs, but we believe those losses, while unfortunate, may be a necessary cost to achieve a rat-free environment on Palmyra which will benefit generations of seabirds and shorebirds.

Thank you for the opportunity to comment on the DEIS. Please contact us if we can be of further assistance.

Sincerely,

Craig S. Harrison

Craig S. Harrison
Vice Chair for Conservation

April 11, 2011

Regulatory Public Docket
US Fish and Wildlife Service
Pacific Reefs National Wildlife Refuge Complex
300 Ala Moana Blvd., Room 5-231
Honolulu, HI 96850

Re: Palmyra Atoll National Wildlife Refuge, U.S. Pacific Island Territory; Nonnative Rat Eradication Project, Draft Environmental Impact Statement (FWS-R1-R-2011-N011)

American Bird Conservancy (ABC) welcomes the opportunity to comment on the effort to eradicate rats from Palmyra Atoll (Palmyra), as it is an important center of biodiversity and species abundance in the Central Pacific area. Specifically, we support the Alternative C (aerial broadcast with capture of shorebirds) for the eradication effort to minimize effects on nontarget species.

Capture and holding: As stated above, we support the option with proactive mitigation of risk for shorebirds, both out of specific concern for the birds in question, especially the Bristle-thighed Curlew, which is estimated to have only 2600 breeding pairs and which is listed on the ABC/Audubon WatchList 2007 and is considered Vulnerable by the IUCN Red List. Bristle-thighed Curlews potentially face high mortality if not captured and removed from the island during eradication. We believe it is incumbent on the project to take all possible active measures to avoid non-target mortalities. We also found the experts listed in the Appendix 1 and 2 to be an excellent list of people, which should inspire confidence in the level of planning and outreach that has gone on thus far in the project. We appreciate that the capture methods have not yet been finalized in the Draft EIS.

ABC also believes there are serious risks to the shorebirds under any scenario, and suggest consideration of the following in continued planning:

1) ABC has been in contact with Peter Doherty, Virginia Beach, VA, who produces capture nets specifically designed for shorebirds. We have informed him of this project and he is willing to provide expertise, if needed. Mr. Doherty's expertise in capturing shorebirds could be of value in this project.
2) Long-legged waders are extremely difficult to capture and hold and can be subject to high rates of mortality during capture and in captivity. It may be useful to try to manage expectations by providing a tentative estimate of mortality in both processes, based on available data.
3) There are few shorebirds in captivity, but one of the largest we know of is the flock of about 35 birds in Monterey Bay aquarium, which included a curlew for the past 20 years, and several other large-bodied waders. International Bird Rescue Research in Cordelia, California also has expertise in handling birds for rehabilitation after oil spills, and has developed techniques to house difficult species. The plan may wish to draw on the expertise of those managers.
4) We have concerns about the cement slab on which it is proposed to maintain the birds on Cooper Island, because curlews tend to develop foot problems in uniform substrates without tidal action.

5) We have been in contact with Dr. Lesanna Lahner, School of Veterinary Medicine, Univ. Wisconsin, Madison, who will be the supervising veterinarian monitoring the curlews for physiological effects during their captivity. She has plans to monitor fecal corticosteroids, fecal parasites, and blood for CBC and chemistry profiles. ABC thinks this could be a very useful monitoring program to evaluate these fragile birds in captivity and to develop additional expertise for future captive holding of vulnerable birds during island eradications.
6) We expect the risk of conspecific aggression to be low among these birds, because of the timing of the operation and because most will not yet be of breeding age, but if the birds are held in some sort of aviary, provisions should be made for separating some birds and providing a visual barrier for any aggressive individuals.
7) One interesting option for the capture and holding of the curlews may be to place them on a nearby islet or rock, if such a place were available and not subject to baiting. The birds may be rendered flightless by plucking a few primaries, which would begin to grow back immediately, though the birds may require supplemental feeding. Flightlessness should not provide a huge obstacle for these birds, because they are accustomed to losing their ability to fly during the molt.

The preparations and prior studies provided in the Appendices to the Draft EIA show great attention to detail and extensive planning to overcome the significant obstacles presented by the large number of land crabs on Palmyra Atoll. The field studies to determine the amount of rodenticide bait needed to insure adequate coverage of all rat territories appear to have been well planned and executed. It is indeed unfortunate that such large amounts of rodenticide bait will be needed to overcome the scavenging by land crabs, but the proponents have presented a good case for the need for their recommended applications.

American Bird Conservancy does have concerns as to the fate of rodenticide bait and metabolism by crabs and other organisms on Palmyra, and the level of knowledge of the mass balance of bait and metabolic products produced when ingested and subsequently excreted by crabs. The potential toxicity of excreted metabolic residues of brodifacoum is of particular concern. After the rat eradication successfully completed on Rat Island, AK, residues of difenicoum and bromadialone were detected in tissues of gulls (Ebbert and Huntington 2010). Both of these rodenticides or close analogs appear to be metabolic products of brodifacoum (see Figure 1). Debromination of brodifacoum at position ❶produces difenacoum, which would be a plausible metabolic route in many animals. Similarly, Coumatetralyl would be produced by hydrolytic removal of the bromobiphenyl chain at position❷. Hydrolysis of the -napthyl moiety of brodicacoum at position ❸would produce a close structural analog of bromodialone. Hydroxycoumarin would be produced through hydrolysis at position ❹ of the molecule. Any of these catalytic reactions could be plausible metabolic routes leading to toxic residues in tissues or excreta of crabs or cockroaches. It is equally plausible that crabs metabolize brodifacoum and excrete only a small fraction of any toxic product in their feces, in which case the risk will be minimized.

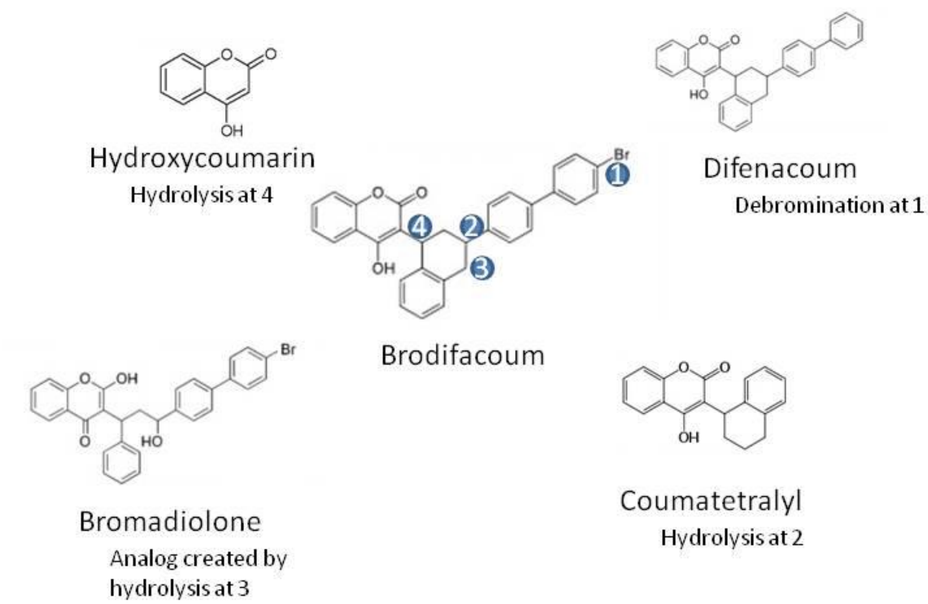

Figure 1: Possible hydrolysis products of brodifacoum which are known active rodenticides or analogs

The metabolic fate of brodifacoum and mass balance of residues were not reported in the prior study given in Appendix F of the Draft EIS. The residue analysis for that study was conducted by the California Animal Health and Food Safety Laboratory at UC Davis, and they may have retained the mass spectrometer reconstructed ion chromatograms, which could identify whether any of these potential metabolic products or other products were present in the crab tissues and excreta analyzed in the 2010 study. We strongly suggest contacting them and trying to have the spectroscopist attempt to determine what metabolic products of brodifacoum were present in the feces in addition to the parent compound. If a mass balance of the rodenticide can be elucidated, it would be very helpful in the risk analysis. Without a study of the fate of brodifacoum ingested by crabs, the fate and residue composition of the large amount of brodufacoum spread over Palmyra Atoll will be unclear. We suggest that when samples are collected and analyzed from the planned Palmyra project, APHIS (and any other lab contracted) report as many residues and metabolic products as possible, and use the information to construct a mass balance. The persistence and toxicity of any identified products should be available from prior studies. We suggest using this data to calculate the expected persistence and toxicity to non-targets (such as curlews) and to hold the curlews in captivity until the toxic residues have dissipated in the Palmyra environment.

ABC also reviewed "Palmyra Atoll Rainforest Restoration Project: Rat Eradication Monitoring Plan for Alternatives B and C", with particular attention to Section 2.3, Impacts to Target and Non-Target Organisms (Rats, Fish, Geckos, Crabs, Birds). We found that the low level of detail in this document precluded a careful evaluation of the bird monitoring protocols, and suggest that further definition be given to the a) statistical design of the pre- and post-eradication bird monitoring 2) the time frame for evaluation of the persistence of bait in the palm canopy, which should be continued until none is detected or some minimal level is reached. Additionally, we would like to see an evaluation of the shorebird population in subsequent years, though we assume this is part of the long term strategy for documenting the effect of the action on the atoll.

The detail given for the foodweb monitoring was minimal, with only a sketchy description given on where pooled samples will be collected. We believe these should be representative of the entire atoll. 84 samples of non-target terrestrial animals and 80 samples of fish appears to be an adequate number of samples to determine the distribution and fate of rodenticide on the atoll. Also, we recommend that a subset of split samples of the rats, fish, gecko, crabs, and bird samples be sent to the U.S. Geological Survey Madison, WI Lab and the USDA National Wildlife Health Center for independent analyses. We urge the project to attempt to determine a mass balance of the fate and residue products to insure residual toxicity does not remain on the atoll. Finally, we believe that directed searches (as opposed to opportunistic searches) for non-target carcasses be conducted in transects for longer than 10 days after the 2nd application in shore bird roosting sites, and that these also concentrate on places where intoxicated curlews might hide to avoid detection. The monitoring plan does not give detail about how often these searches will be conducted.

In conclusion, ABC supports the effort to eradicate rats from Palmyra, as it is an important center of biodiversity and species abundance. Specifically, we support the Alternative C (aerial broadcast with capture of shorebirds) option listed in the Draft EIS. We believe this project has been organized and planned carefully, although we would like to have a more complete analysis of the fate of rodenticide moving through the Palmyra ecosystem. We would be pleased to offer comments on a more detailed draft of the monitoring procedures.

Sincerely,

Michael Fry, PhD
Director of Conservation Advocacy

George Wallace, PhD
Vice President for Oceans and Islands

Jessica Hardesty Norris, PhD
Seabird Program Director

Moira McKernan, PhD
Pesticides and Birds Program Director

1731 Connecticut Avenue, NW, 3rd Floor ● Washington, D.C. 20009
Tel: 202-234-7181 ● Fax: 202-234-7182 ● abc@abcbirds.org ● www.abcbirds.org

Marine Conservation Biology Institute

Lance Morgan, Ph.D., Vice President

April 16, 2011

Dr. Elizabeth Flint
Pacific Reefs National Wildlife Refuge Complex
300 Ala Moana Blvd., Room 5-231
Honolulu, HI 96850

Dear Dr. Flint:

This letter constitutes the comments of Marine Conservation Biology Institute (**MCBI**) on the Palmyra Atoll National Wildlife Refuge, US Pacific Island Territory; Nonnative Rat Eradication Project, Draft Environmental Impact Statement (**DEIS**). MCBI supports the eradication of nonnative rats on Palmyra Atoll in an effort to restore native wildlife populations. After review of the DEIS, MCBI believes Alternative C: Aerial broadcast of brodifacoum, with proactive mitigation of risk for vulnerable shorebird taxa is the most effective option with the least risk of toxicant exposure to non-target wildlife.

Palmyra Atoll National Wildlife Refuge was established in 2001 "to protect and preserve the natural character of fish, wildlife, plants, coral reef communities and other resources associated with the tidal lands, submerged lands, and waters of Palmyra" *(Secretarial Order 3224)*. Palmyra Atoll is among the most pristine coral reefs in the world, supports a diverse selection of nesting seabirds and shorebirds, and is home to many threatened, endangered, and depleted species such as green and hawksbill sea turtles, giant clams, coconut crabs, humphead wrasse, and bumphead parrotfish. In recognition of the importance of this area, MCBI actively supported the designation of the Pacific Remote Islands Marine National Monument (*Presidential Proclamation 8663*) in 2009, which encompasses the ecological significance of Palmyra atoll and other atolls/reefs in the central Pacific Ocean.

The Pacific Remote Islands Marine National Monument is home to some of the healthiest marine ecosystems in the world; they are relatively intact and rich in natural resources. As detailed in the DEIS, these ecosystems have not escaped human impacts. Since discovery, the islands have been explored, exploited for their natural resources, and in some cases inhabited during WWII and the Korean War. As a result, nuisance and invasive species have been introduced to the islands and their surrounding waters. Pacific islands are particularly vulnerable to the introduction of new species due to their isolation and lack of native predators. Thus, it is not surprising that invasive species such as nonnative rats are damaging Palmyra's native ecosystems. To prevent further damage to the ecosystem, MCBI agrees that removal of the invasive rats is necessary.

MCBI believes Alternative C (as outlined in the DEIS): Aerial broadcast of brodifacoum, with proactive mitigation of risk for vulnerable shorebird taxa offers the highest probability of

lance@mcbi.org • (707) 938-3214 • www.mcbi.org
14301 Arnold Drive, Suite 25 • Glen Ellen CA 95442 USA

removing the nonnative rats while also minimizing harm to the marine and terrestrial ecosystems. Specifically we support Alternative C for the following reasons:

1) **USFWS has successfully identified and accounted for the entire rat habitat and has thoroughly evaluated several bait application methods.** The previous failed attempt to remove the rats in 2001 – 2002 was partly attributed to the fact that there was a lack of understanding that rats at Palmyra live in a three-dimensional habitat, including the coconut palm canopy. Now that US Fish and Wildlife Service (**USFWS**) more fully understands the extent of the rats' habitat, we believe aerial broadcast via helicopter with modifications for nearshore application is the best and most efficient method to ensure the palm canopy is baited.

2) **The introduction of bait to the marine environment has been considered and will be minimized.** According to the DEIS, this will be accomplished by distributing the bait through a hopper defector attached to the helicopter when dispensing nearshore, broadcasting bait by hand in narrow land areas and in coconut palms that hang over the marine environment, and placing bait stations near wharf areas and on the support vessel. MCBI believes these measures have adequately minimized the marine environment's exposure.

3) **The disturbance and mortality of non-target biological species has been evaluated and will be minimized.** MCBI does not support alternative D because it allows for a higher duration of exposure of non-target biological species to the toxicant and a higher disturbance risk compared to Alternatives B and C which have a medium to low duration of exposure to the toxicant and a low disturbance risk for the non-target biological species (except the captured shorebirds).

   All alternatives for the rat eradication effort will occur during a time of year when the fewest amount of resident birds (non-target species of most concern) are present and the bait has been modified to minimize uptake after the shorebirds are released back into the environment. MCBI's preferred alternative calls for the capture of the few shorebirds still present on the islands in order to avoid toxicant ingestion. MCBI is a bit concerned about the disturbance and potential harm from capturing and holding shorebirds over a length of time, but the Service seems to have addressed these concerns by having experienced personnel dedicated to capturing and overseeing captive birds. MCBI believes the potential risks associated with the worst case scenario of leaving the remaining bird species free during eradication efforts greatly outweigh the potential risks associated with capture.

4) **Resource efficiency has been considered.** The estimated number of person days for Alternative C is 684 days over 2 months, while Alternative D is 2,476 days over 2 years.

Marine Conservation Biology Institute

Alternative D has been estimated to take substantially more time in order to clear land for bait transects and to monitor bait stations. While Alternative C is 68 person days less, we believe the added days for shorebird captivity is necessary to reduce mortality. MCBI is supportive of the efficient use of resources and time, while also minimizing disturbance.

Overall, MCBI is pleased to learn that little to no impact is expected to the marine environment and inhabitants through the EPA Clean Water Act guidance compliance for aerial pesticide application and varied bait application techniques.

In order to make a more informed decision, a cost comparison of each alternative would have been helpful in determining the efficient use of resources. Regardless of cost, MCBI supports the eradication of nonnative rats on Palmyra Atoll in an effort to restore native wildlife populations.

After eradication, MCBI supports all efforts necessary to prevent future rat infestations. This includes efforts to remove the nonnative coconuts on Palmyra Atoll to help reduce rat habitat.

With the information provided, we believe Alternative C to be the most effective and least disruptive option to the native wildlife.

Thank you for the opportunity to comment on the DEIS. MCBI looks forward to assisting you whenever possible throughout this process.

Sincerely,

Lance Morgan

lance@mcbi.org • (707) 938-3214 • www.mcbi.org
14301 Arnold Drive, Suite 25 • Glen Ellen CA 95442 USA

Individual Comments to DEIS received via email:

<u>March 1-9, 2011</u>

· Wayne Johnson, PhD, Honolulu resident –

Dr. Flint, this plan will cause enormous suffering and agony to living creatures and the blood will be squarely on your hands.

· Eric Barker, individual –

Please extend the contact period for this plan.
Additionally, I would like to attend and encourage others to participate in a public hearing on Oahu for this issue.

· Kim Williams (Aiea), individual –

I strongly OPPOSE The Nature Conservancy and the USFWS using an aerially dispersion of brodifacoum on Palmyra Atoll. The use of poison does more harm to the environment than good. There has to be more better method. Please postpone the start date of this dispersion. And please hold a public hearing in Honolulu before any plan is implemented.

· Anita Wintner, Hawaii resident –

The Nature Conservancy doesn't protect nature. They get $$$ for doing reports and say lets poison, not doing a report that shows what happens to birds, or runoff to the ocean. What a waste of a million dollars!

· Cara Losier, individual –

It has recently come to my attention that rodenticide poison will be dispensed on Palmyra Atoll. I urge you to reconsider this course of action or take steps to halt the progress of this project. This poison causes extremely painful death to the animals who come in contact with it, which is clearly inhumane. Please consider the lives of the animals who will be affected before condoning this project.

· Ursula Heinz, individual –

I am asking for a public hearing in Honolulu and for an extension of the contact period concerning this devastating project which will kill indiscriminately birds and fish in the involved areas. Please provide for time to create a better alternative strategy.

<u>April 10-31, 2011</u>

· Mark Rauzon, Laney College, Geography Department - Chair –

Thank you for the invitation to comment on the Palmyra Atoll National Wildlife Refuge Rat Eradication Project - Draft Environmental Impact Statement. After reviewing the document I would like to nominate Alternative C as the preferred option, for the following reasons.

I am familiar with Palmyra from two prior visits and have surveyed the island for seabirds. I have seen firsthand the potential for seabird restoration and have also witnessed the effects of the failed 2001 rat eradication attempt, both on the island and in the community of eradicators. That is why I advocate pressing forward with rat eradication and especially Alternative C that best copes with the very challenging environment that Palymra presents. The Palmyra rat eradication has had the greatest breadth of research and preparation than any other US eradication. Since the 2001-02 eradication attempt, research into why it failed and what can be learned, has been on-going. Research into bait stations began with the 2001-2002-eradication attempt. Jim Murphy former USDA manager of the rat eradication wrote: "Took 11 weeks …to pound out 36 miles of transects and 1198 bait stations on 34 isles from tabletop size with 1 coconut to rats to 100's of acres with rats. Some were loaded with hermit crabs, some had none, some had lots of coconut crabs, and some had none. I believe some islands are rat free, and rest are 95+% [rat-free]" (J. Murphy, pers. comm.).

Some of these isles remain rat-free today, but given the logistics described by Murphy, there are several ways to fail. The investigation into this effort found the bait station spacing of 50 x 50 m used was placed too far apart. For future eradication projects, it was recommended that a 25 m grid for the placement of bait stations would be needed, but that alone might not be adequate to intercept all rats. Palmyra is a unique challenge with high rainfall and humidity, crabs and coconut trees 50 feet tall. The three-dimensional wet environment, literally crawling with bait competitors in the form of crabs. In 2004, Alex Weggman began crab studies, the large but unknown factor in tropical rat eradications. The 2005 trial eradications demonstrated that rats can be eradicated from islands with high land crab densities when bait is broadcast at rates from 85kg/ha to 95 kg/ha.

Bait in sufficient quantity must be available to all rats for at least one meal, even if the rate appears high, and the bait choice should be of sufficient toxicity that rodents need only one-visit. I am glad to see the bait choice limited to brodificoum. The 2001-02 failure using brodificoum set back the field of eradication substantially, but the risk of second eradication failure in not an option. Using a toxic bait that requires more than one feeding is a recipe for another failure- and as such, an unacceptable risk given the planning and investment.

Past feasible evaluations determined 'exhaustive planning" was required in order to achieve a successful eradication outcome at Palmyra. Apparently this policy has been followed. This project is the culmination of years of research and a beneficiary to all the lessons learned during past eradications and especially builds on the success in the rapidly evolving field of aerial baiting techniques. In 2001, aerial broadcast of bait was in its infancy, now it is state-of-the-art. Helicopter broadcast into the three dimensional habitat would be an equalizer in distributing to bait to all areas, not just those within human reach, which in 2002 was insufficient.

The applicators, Island Conservation, has been involved from the US first aerial drop on Anacapa Island to the latest at the Rat Island, Alaska in 2009. They have join forces with federal and private conservation entities to become the Palmyra Atoll Rainforest Restoration Project (PARRP). The project is also informed by the recent 2011 Galapagos and South Georgia Island aerial bait drops.

Unfortunately, increased bait toxicity poses high non-target risks. The greatest forseeable risks in this effort may be the threat to Bristle-thighed curlews (BTCU). I appreciate the concern expressed by the proposed capture and hold of ‘catchable’ curlews, and all the careful efforts to have minimal effect on the captive birds. While losing a curlew would be most unfortunate, some loss must be expected. Investing in the future ecological health requires the sacrifice of some individuals, and fortunately the loss of summering sub-adult birds is not of population level significance, which is what makes the most biological and ecological sense.

The lamentable non-target loss has recently been brought to the public attention with the loss of eagles and gulls at Rat Island and a call for public discussion. The death of rats, themselves violate Buddhist principals for the sanctity of all sentient life forms. So eradication failures cause needless loss of life (rats) since there is no ecological gain. Thus some overkill involving non-target loss must be seen as investment in complete eradication success measured on an ecological level that justifies all the incipient death that occurs, target and non-target alike. This must be accepted as a fair trade for future curlews may benefit from a rat-free Palmyra in unanticipated ways, such as increased sooty tern egg densities, but other species will clearly benefit in the short term. Palmyra becomes one of the rare few tropical forest island free of rats, as such it become the site to transplant Line Island endemics. With a rapidly changing climate and sea level rising, Palmyra must be rat-free, if only to mitigate the use of the island habitat for a research station with a substantial carbon footprint.

Overall, the completeness of this EIS, the comprehensive appendices that review the past and future options, determine LD’s of toxins, etc. is very remarkable and admirable in scope, showing again how seriously you take your duty to be thorough, responsible and transparent. I say overall, for I did not see what happens if rats are detected after the second drop, but I stopped looking. Nevertheless, your team is to be congratulated on the research effort taken to insure this rat eradication will be successful and allow Palmyra to be all that it can be. I endorse Alternative C as the scenerio most likely to succeed in a cost-effective and efficient manner, recognized some non-target loss will be unavoidable. Good luck.

<u>April 1-6, 2011</u>

· Kevin Lafferty, Marine Ecologist, US Geological Survey –
Having studied black rats on Palmyra Atoll, I can testify to their incredible numbers and the need to remove them from the Atoll to help project the area's rich and valuable native diversity. The level of study and forethought that has gone into this restoration effort is admirable. I support the effect and have high hopes that it will succeed.

· Dr. John D. Collen, Associate Professor in Geology, Victoria University of Wellington –
I have carefully read and reviewed the Draft EIS relating to the Palmyra Restoration Project. From my personal knowledge both of Palmyra Atoll and of the pest eradication projects undertaken in New Zealand (which includes visits to many of NZ's now pest-free offshore and Subantarctic islands), I would like to comment that the proposal is necessary, relevant and well constructed. I fully support the actions outlined in the Draft

EIS and look forward to watching the recovery of the atoll's terrestrial ecosystems in the future.

- Jonathan Gardner, Ph.D., Professor of Marine Biology, Victoria University of Wellington – Having reviewed the draft EIS for the Palmyra Atoll restoration project I am pleased to support the actions described which will help protect Palmyra’s species and habitats. In my view, this is a necessary and important project which will lead to significant beneficial conservation outcomes.

- Chelsea L. Wood, Ph.D. Candidate –
  I am a Ph.D. student at Stanford University and have conducted research in the lagoon sand flats of Palmyra Atoll for two years. I've just reviewed the draft EIS for the proposed rat eradication, and wanted to let you know that I support the proposed actions.

<u>April 7-12, 2011</u>

- John P. McLaughlin, Dept. Ecology, Evolution and Marine Biology, University of California Santa Barbara –
  I have reviewed the Draft EIS for the Palmyra Restoration Project and I support the actions outlined to protect Palmyra’s unique species and habitats.

- Hillary S. Young, Stanford University –
  I have reviewd the Draft EIS for the Palmyra Rat Eradication project and believe the project is likely to succeed and should result in positive net benefits for the seabird community at Palmyra, providing important nest site protection for many species that are globally declining.

- Carl E. Orazio, PhD, Environmental Scientist, USGS Columbia Environmental Research Center –
  I reviewed the Draft EIS for the Palmyra Atoll rat eradication. Based on the science, supporting information, and options presented in the DEIS, I am supportive of the actions described in the DEIS for the rat eradication: The proposed actions support the efforts to protect and restore Palmyra Atoll's ecosystem.

From:	RALPH BLACK
To:	pacific_reefs@fws.gov; RALPH BLACK
Subject:	"Palmyra rat project"/Attn: Dr. Elizabeth Flint
Date:	04/11/2011 10:53 AM

"Palmyra rat project"/Attn: Dr. Elizabeth Flint/
DEAR: Dr. Elizabeth Flint
INFORMATION.

E-mail: pacific_reefs@fws.gov. Include
''Palmyra rat project'' in subject line.
Fax: Attn: Dr. Elizabeth Flint, 808–
792–9586.
U.S. Mail: Pacific Reefs National
Wildlife Refuge Complex, 300 Ala
Moana Blvd., Room 5–231, Honolulu,
HI 96850.
FOR FURTHER INFORMATION CONTACT:
Elizabeth Flint, Supervisory Wildlife
Biologist, (808) 792–9553.
SUPPLEMENTARY INFORMATION:
Introduction
With this notice, we continue the
public involvement process for our
DEIS, in accordance with the National
Environmental Policy Act (NEPA; 42
U.S.C. 4321 *et seq.*), as amended, and its
implementing regulations. We started
the process through RESPONCE TO A a notice in the
Federal Register (75 FR 2158) published AND THIS COPY OF LETTER SENT TO
APRIL/11/2011
Ken Salazar, Secretary of the Interior Robyn Thorson, Regional Director
U.S. Department of the Interior U.S. Fish & Wildlife Service
1849 C Street N.W. Pacific Region
Washington, DC 20240 911 NE 11th Ave
Portland, Oregon 97232

P.S. Dr. Elizabeth Flint/ IF YOU COULD PLEASE SUPPLY ME WITH A E-MAIL ADDRESS OFFICIAL AND AS TO COMMUNICATE ABOUT
"Palmyra rat project"/"Palmyra rat project"/
COPY

PETITION TO LIST THE ATULL ISLANDS Endangered Species ANY AND ALL INFINITE AND THE `I`IWI (*VESTIARIA COCCINEA*) AS
THREATENED OR ENDANGERED UNDER THE U.S. ENDANGERED SPECIES ACT/Endangered Species; Marine Mammals, Hawaii Bottomfish, Seamount Groundfish Fisheries,Endangered Species ANY AND ALL INFINITE AND THE `I`IWI (*VESTIARIA COCCINEA*)
APRIL/11/2011
ATULL ISLANDS Endangered Species ANY AND ALL INFINITE AND THE
ATULL ISLANDS Endangered Species ANY AND ALL INFINITE AND THE
`I`IWI (*VESTIARIA COCCINEA*)

APRIL/11/2011
Ken Salazar, Secretary of the Interior Robyn Thorson, Regional Director
U.S. Department of the Interior U.S. Fish & Wildlife Service
1849 C Street N.W. Pacific Region
Washington, DC 20240 911 NE 11th Ave
Portland, Oregon 97232
Dear Secretary Salazar,
The FRIENDS OF ATULL ISLANDS Marine Mammals, Hawaii Bottom fish, Seamount Groundfish Fisheries Endangered Species ANY AND ALL INFINITE AND THE `I`IWI (*VESTIARIA COCCINEA*) AND BIRDS OF A FEATHER OR FEATHERS.

to list the ATULL ISLANDS Endangered Species ANY AND ALL INFINITE AND THE `I`IWI (*VESTIARIA COCCINEA`I`iwi* (*Vestiaria coccinea*) as a threatened or endangered species pursuant to the Endangered Species Act (ESA), 16 U.S.C. §1531 et seq. This petition is filed under 5 U.S.C. 553(e) and 50 CFR 424.14 (1990), which grant interested parties the right to petition for issuance of a rule from the Secretary of Interior.
Under the ESA, a threatened species includes "any species which is likely to become an endangered species within the foreseeable future throughout all or a signification portion of its

range.” An “endangered species” is one that is in danger of extinction.
The `I`iwi AND ANY OF AND ALL OF threatened species warrants listing because it is imperiled by climate change and disease in combination with other factors, SUCH AS POSSIABLE SPRAYING OF CHEMICALS COULD IMPACT AND ADD TO THE declining OF ANY OF AND ALL OF threatened species in population size and range, and ARE not adequately protected by
existing regulatory mechanisms. With climate AND POSSIABLE RADDS FROM FUKASHIMA DISASTER change forcing the spread of avian malaria and
avian pox, CESIAM 131,137 the `I`iwi AND ANY OF AND ALL OF threatened species is in danger of near term extinction in the western portion of its range (the
islands of Kauai, Oahu, and Molokai, west Maui AND ALL THE ATULL ISLANDS), and severe population declines with
risk of extinction within the foreseeable future across its eastern range (east Maui the island
of Hawaii AND THE ATULL ISLANDS).
Petitioners also request that critical habitat be designated concurrent with the listing, pursuant to
50 CFR 424.12, and pursuant to the Administrative Procedures Act (5 U.S.C. 553).
For the petitioners,
/s/
ROWN PAUL BROWN SR.
Director FOR FREE THE ATULL ISLANDS Endangered Species; Marine Mammals, Hawaii Bottomfish, Seamount Groundfish & ARRADICATE THE RATS

Executive Summary SINCE Current situation after accident in Fukushima, JAPAN (update: 2. April 2011 12:00) status of the radioactivity measurements
the world-wide measurements of the radioactivity in the context of the comprehensive atomic test stop agreement(CTBT) show at present (status of the measurements: 29. March 2011) further that traces of iodine and cesium are to be found at present at nearly all measuring points of the north hemisphere. To Europe the stations point in Freiburg/Germany and Stockholm/Sweden Jod-131 concentrations of 250 and/or 1700 µBqm-3. Such values were registered also The material measured at present was already set free 14 days ago in Japan
advance upslope in response to higher ambient temperatures. FOR THE ATULL ISLANDS Endangered Species ANY AND ALL INFINITE AND The `I`iwi, are iconic surviving native'S of Hawaii, The `I`iwi itself,is recognized by its bright scarlet and
black plumage and long curved beak. Once widespread, the species now occurs only in upper
elevation areas where avian disease is infrequent or absent. Increasing ambient temperature,
driven by global climate change, is facilitating the spread of deadly avian malaria to remaining
occupied habitat. The species is in danger of immediate or near term extinction across the entire
western portion of its geographic range, namely, on the lower elevation islands of Kauai, Oahu,
Molokai, and west Maui. The `I`iwi also faces extinction within the foreseeable future in higher
elevation terrain on east Maui and the island of Hawaii as mosquito-borne avian malaria
advances upslope.
`I`iwi populations are severely reduced on Kauai, Oahu, Molokai, west Maui and THE ATULL ISLANDS and have
declined on all islands. Relatively large populations still occur above 1250 m elevation on east
Maui and the island of Hawaii, where disease incidence is currently low or absent. Climate
change is projected to greatly diminish or eliminate disease free areas for `I`iwi.
We petition to list the `I`iwi as threatened or endangered under the U.S. Endangered Species Act
(ESA). The species `I`iwi and THE ATULL ISLANDS Endangered Species ANY AND ALL INFINITE qualifie for ESA protection as per four statutory factors used by the
Secretary of Interior to determine if listing is warranted:
Present or threatened destruction, modification, or curtailment of habitat or range – `I`iwi
habitat throughout Hawaii is adversely impacted by invasive, non-native animals and plants,
and, on the island of Hawaii, by land development.
Disease or predation – The best available data indicate that the ongoing spread of avian malaria
and avian pox endangers the smaller `I`iwi populations on Kauai, Oahu, Molokai, and West
Maui, and threatens the larger ones on East Maui and Hawaii Island. Population-level resistance
or tolerance to these deadly diseases is lacking. Climate modeling based on a conservative
estimate of a 2° C increase in ambient temperature projects avian malaria to reach elevations up
to or beyond 1900 m, affecting most if not all presently occupied `I`iwi habitat. Hawaii is
experiencing a long-term increase in temperature and an accelerated rate of increase over the past
few decades consistent with global climatic trends. Parasitism by bird lice and predation by alien
rats, mongoose, and feral cats may accelerate the decline of `I`iwi populations subject to higher
disease incidence.
Inadequacy of existing regulatory mechanisms – Under current national and international
policies on greenhouse gas emissions, there is virtually no chance of limiting global heating to 2°
C even with full policy implementation. Moreover, regulatory mechanisms are lacking to protect
and restore forest habitat needed to expand 'I'iwi populations at highest elevations, as a means to
reduce their vulnerability to avian diseases and fragmentation. State and private lands, which
include most existing and potential upper elevation habitat for 'I'iwi, are generally not managed

for forest bird recovery.

Other natural or manmade factors affecting its continued existence – Global warming threatens `I`iwi by increasing the elevation at which regular transmission of avian malaria and avian pox virus

4

occurs. Moreover, evidence suggests that epizootics could in the near term eliminate the small `I`iwi populations on Kauai, Oahu, and Molokai, and diminish and fragment larger populations on East Maui and Hawaii Island. Hurricanes, likely to intensify in a warmer climate, and volcanism may further reduce 'I'iwi habitat. Small `I`iwi populations are at heightened risk of extinction from random demographic fluctuations, localized catastrophes (severe storms, wild fire, disease outbreaks, volcanism, etc.), inbreeding depression, and genetic drift.

This petition includes a request for critical habitat designation for the `I`iwi at the time of listing. Critical habitat should include areas of sufficient forest habitat for viable or potentially viable `I`iwi populations on Kauai, Oahu, Molokai, Maui, and Hawaii Island, as each island represents a significant portion of the species' natural range. Designation would require that federal actions promote conservation of essential `I`iwi habitat, and help resolve conflicts that undermine its protection and restoration. It would provide added impetus to re-establish native trees, remove ungulates, reduce depredation by rats and other introduced predators, control invasive plants, and otherwise manage vital habitat to improve prospects for 'I'iwi survival in a climatically challenged environment.

In conclusion, the spread of avian disease driven by climate change, severe range curtailment, ongoing loss of suitable habitat, and the history of forest bird extinctions on Hawaii are compelling reasons to list the `I`iwi as a threatened or endangered species.

I. Introduction

The `I`iwi is one of 17 surviving Hawaiian honeycreepers (Fringillidae: Drepanidinae) of 37 species known historically and 55 extant prior to human arrival on Hawaii (Pratt 2009). Its closest relative is the extinct Hawaii Mamo (*Drepanis pacifica*) (Pratt 2005). Disease and habitat loss are primary reasons for the decline of Hawaiian honeycreepers and other native forest birds. Extinctions continue to this day, with the most recent being the Poo-uli (*Melamprosops phaeosoma*) in 2004.

The `I`iwi, a scarlet bird with black wings and tail, and a long curved, salmon-colored bill. It is generally placed in the monotypic genus *Vestiaria*. It is a largely nectarivorous species that occurs commonly in closed canopy, high-stature native forests above 1500 m elevation (Fancy and Ralph 1998). `I`iwi breed and winter primarily in mesic and wet forests dominated by native 'ōhi'a (*Metrosideros polymorpha*) and koa (*Acacia koa*) trees (Scott et al. 1986). They often travel widely in search of ʻōhiʻa flowers and are important ʻōhiʻa pollinators (Mitchel et al. 2005). The birds respond to seasonal flowering patterns, often moving to lower elevations where they are exposed to deadly disease (Pratt 2005). The `I`iwi uses its long bill to extract nectar from decurved corollas of Hawaiian lobelioids, which have become far less common on Hawaii over the past century (Smith et al. 1995).

Female `I`iwi typically lay two eggs, and they alone are thought to incubate eggs and brood young (Mitchel et al. 2005). Males provision females with food off the nest. Breeding takes place predominantly from February to June, and is usually associated with peak flowering of 'ōhi'a (Fancy and Ralph 1998).

5

For native Hawaiians, THE ATULL ISLANDS Endangered Species ANY AND ALL INFINITE and`I`iwi and other forest birds have a spiritual nexus. Feathered objects represented gods, ancestors, and divine lineage (Amante-Helweg and Conant 2009) even to this day. Red feathers of clothing, such as cloaks, capes, and helmets, were predominantly from `I`iwi. Once a familiar sight on all main Hawaiian Islands, THE ATULL ISLANDS Endangered Species ANY AND ALL INFINITE remain an icon's of Hawaii's native forests and over all exsitence sea and land.

Today `I`iwi occur in higher elevation habitats largely free of avian disease, to which the species is highly susceptible. With climate change, the recent Fucashima ,JAPAN disaster RADDS,ANY OF AND ALL OF threatened species warrants listing because it is imperiled by climate change and disease in combination with other factors, SUCH AS POSSIABLE SPRAYING OF CHEMICALS COULD IMPACT AND ADD TO THE declining OF ANY OF AND ALL OF threatened species in population size and range these safe refugia may be lost entirely as pathogens vectors AND Current situation after accident in Fukushima (update: 2. April 2011 12:00) status of the radioactivity measurements the world-wide measurements of the radioactivity in the context of the comprehensive atomic test stop agreement(CTBT) show at present (status of the measurements: 29. March 2011) further that traces of iodine and cesium are to be found at present at nearly all measuring points of the north hemisphere. To Europe the stations point in Freiburg/Germany and Stockholm/Sweden Jod-131 concentrations of 250 and/or 1700 µBqm-3. Such values were registered also The material measured at present was already set free 14 days ago in Japan advance upslope in response to higher ambient temperatures.

This petition reflects the needs for swift remedial action under the U.S. Endangered Species Act to preventTHE ATULL ISLANDS Endangered Species ANY AND ALL INFINITE AND `I`iwi from joining the tragically long list of extinct or feared extinct Hawaiian birds (Banko and Banko 2009). It explains how climate change, disease, and other factors threaten the survival of the `I`iwi.

II. Population Status

Distribution, abundance, and trends

The `I`iwi occurs on the Hawaiian islands of Kauai, Oahu, Maui, Molokai, Hawaii AND ATULL ISLANDS Endangered Species ANY AND ALL INFINITE (Gorresen et al. 2009). Once widely distributed in native forests on all major Hawaiian Islands, the species is now mostly restricted to elevations above 1250 m because of avian diseases and habitat loss elsewhere (Warner 1968, Scott et al. 1986, Fancy and Ralph 1998, Pratt 2005). `I`iwi are declining everywhere in Hawaii except at high elevation on East Maui and northeast Hawaii Island (Gorresen et al. 2009) (Table 1). `I`iwi population extinctions are impending throughout Hawaii (Banko and Banko 2009).

Oahu, Molokai, and the isolated western area of Maui have small remnant `I`iwi populations at high risk of extinction (Gorresen et al. 2009). `I`iwi are gone from nearby Lanai. These four areas comprise the central portion of the species' geographic range and are therefore significant. On Kauai, in the western portion of the species' range, the `I`iwi has declined sharply (Table 1). Risk of extirpation from the island is of immediate concern because of severely diminished disease-free habitat.

On east Maui and the Island of Hawaii, forming the eastern part of the species' range, `I`iwi populations are restricted to high elevations (Table 1). While some populations are still large, they are at risk of fragmentation and decimation resulting from the spread of avian disease driven by climate warming (Pratt et al. 2009). Scott et al. (1986) estimated the population of 'I'iwi in high elevation areas of the Island of Hawaii may be as large as 340,000 birds, suggesting that in this area they remain abundant. This estimate, however, is more than two decades old, the species has been declining, and even within the portion of range, which represents a fraction of the species' historic range, the 'I'iwi is threatened by upslope movement of mosquitoes with climate change.

Declines in `I`iwi abundance corresponding with reduced lower elevation range since the early 1970s are consistent with anticipated impacts of mosquito borne disease (Foster et al. 2004).

6

The population trend is downward on all islands, with some stability in high elevation areas (Pratt et al. 2009). Climate change AND Current situation after accident in Fukushima (update: 2. April 2011 12:00) status of the radioactivity measurements

the world-wide measurements of the radioactivity in the context of the comprehensive atomic test stop agreement(CTBT) show at present (status of the measurements: 29. March 2011) further that traces of iodine and cesium are to be found at present at nearly all measuring points of the north hemisphere. To Europe the stations point in Freiburg/Germany and Stockholm/Sweden Jod-131 concentrations of 250 and/or 1700 µBqm-3. Such values were registered also The material measured at present was already set free 14 days ago in Japan
is now setting the stage for widespread disease transmission at
the highest elevations on Maui and Hawaii Island (Benning et al. 2002; LaPointe et al. 2005).

Reproduction and Survivorship

`I`iwi pairs are reported to produce on average only 1.33 chicks per year, reflecting low productivity characteristic of Hawaiian forest birds in general (Woodworth and Pratt 2009). However, the `I`iwi has the lowest annual survivorship reported (55% ± 12 SE for adults and 9% ± 5 for juveniles) for any extant species of honeycreeper, reflecting the impact of malaria and avian pox and/or low re-sighting probabilities (Fancy and Ralph 1998; Pratt 2005).

Table 1. `I`iwi population estimates for Hawaiian islands.

Kauai -- `I`iwi numbers decreased by 62%, from 26,000 + 3,000 to 9,985 + 960, between the 1970s and
2000 (Foster et al. 2004, Gorresen et al. 2009);. `I`iwi range contracted from 140 to 110 sq km, consistent
with a shift in its low elevation boundary from ~900 m to >1,100 m.

Oahu – Few, if any, birds remain; 8 individuals dispersed in 3 isolated locations were reported in 1994-
1996 (VanderWerf and Rohrer 1996).

Molokai -- Few birds (1-3) were detected from 1988-2004 (Reynolds and Snetsinger 2001, Gorresen et
al. 2009), contrasting with 12 in 1979 (Scott et al. 1986).

Maui -- About 19,000 + 2,000 individuals occurred in restricted upper elevation habitats of east Maui
(Scott et al. 1986); ~ 180 + 150 birds were reported in isolated west Maui prior to 1980 (Scott et al.
1986); the west Maui population persists today at a very low number (Gorresen et al. 2009).

Hawaii Island – 340,000 ± 12,000 birds were estimated in higher elevation range; ~1,000 birds in lower
elevation Kohala and Puna areas (Scott et al. 1986). These estimates, however, are over two decades old
and there have been overall downward trends in recent decades (Camp et al. 2009a, Gorresen et al. 2009);
of 10 study locations, `I`iwi appear now absent at one, declining at 5, stable at 3, with no estimate for 1
(Gorresen et al. 2009).

Regional breakout of data for Hawaii Island:

Northeast area: For the Hakalau Forest National Wildlife Refuge (Hakalau Unit; 1,500-2,000 m elevation)
population trend data vary from stable (over a 21-year period) to declining (during a recent 9-year
period), except for increasing numbers in limited newly restored upper elevation habitat (Camp et al.
2009a). Recent `I`iwi numbers were estimated at ~61,000 birds.
Central windward area: `I`iwi frequency decreased 54% between late 1970s and 1986-2000 periods in
National Park and Hamakua areas, with specific study area declines and evidence of upward range
contraction (Gorresen et al. 2005, Camp et al. 2009b);`I`iwi showed pronounced decline at lower
elevations (East Rift, <1,000 m elev., and `Ōla`a, ~1,200-1,400 m, 1977-1994 data); modest declines
(Kūlani-Keauhou, 1,500-2,000 m, 1977-2003 data) or stability (Mauna Loa Strip, ~1,500-2,000 m, 1977-
1994 data) at higher elevations.
7
Southeast area: Lower `I`iwi density in the Ka`û area (2002 and 2005 data) than previously (1976 and
1993 data) (Gorresen et al. 2009); recent estimate of ~ 78,000 bird, with 60% occurring above 1,500 m
(Gorresen et al. 2007).
Leeward (western) area: `I`iwi densities have dramatically declined in the Hualâlai and Kona regions
(1997-2000); they are decreasing at lower elevations (<1,500 m; Kona Forest Unit, Hakalau Forest
National Wildlife Refuge); stable only at upper elevations (Gorresen et al. 2009); `I`iwi range is
contracting upslope, with few occurrences below 1,100 m during the breeding season (Camp et al. 2002).
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III. Five-Factor Analysis

Under the ESA, 16 U.S.C. § 1533(a)(1), The U.S. Fish and Wildlife Service (USFWS) is
required to list an organism for protection if it is in danger of extinction or threatened by possible
extinction in all or a significant portion of its range. In making such a determination, USFWS
must analyze the `I`iwi's status in light of five statutory listing factors:
(A) the present or threatened destruction, modification, or curtailment of its habitat or
range;
(B) overutilization for commercial, recreational, scientific, or educational purposes;
(C) disease or predation;
(D) the inadequacy of existing regulatory mechanisms; and,
(E) other natural or manmade factors affecting its continued existence.
For each factor, we provide the following analysis in support of our petition:

A. The present or threatened destruction, modification, or curtailment of habitat or range.

Climate change AND Current situation after accident in Fukushima , JAPAN (update: 2. April 2011 12:00) status of the radioactivity measurements
the world-wide measurements of the radioactivity in the context of the comprehensive atomic test stop agreement(CTBT) show at present (status of the measurements: 29. March 2011) further that traces of iodine and cesium are to be found at present at nearly all measuring points of the north hemisphere. To Europe the stations point in Freiburg/Germany and Stockholm/Sweden Jod-131 concentrations of 250 and/or 1700 µBqm-3. Such values were registered also The material measured at present was already set free 14 days ago in Japan
advance upslope in response to higher ambient temperatures. facilitating the spread of avian disease threatens severe curtailment of the `I`iwi's current range (see discussion under C below).
Most of the `I`iwi's original forest habitat has been cleared for food crops, livestock grazing, tree

plantations, and land development, with habitat losses since human settlement ranging from 52% on Hawaii Island to 85% on O'ahu (Fancy and Ralph 1998). The amount of habitat available to the 'I'iwi and other forest birds has declined over the past few decades as many areas become dominated by invasive non-native species (Price et al. 2009). On the island of Hawaii, additional forest habitat loss results from land development, logging, and conversion to livestock pasture.
`I`iwi habitat across Hawaii is primarily threatened by destruction and adverse modification by feral pigs and other exotic ungulates (goats, sheep, mouflon, deer, cattle) (USFWS 2006, Pratt et al. 2009). Alien animals destroy forest understory vegetation, eliminate food plants for birds, create mosquito breeding sites through ground disturbances, provide openings on the forest floor for weeds, transport weed seeds to native forests, cause soil erosion, disrupt seedling regeneration of native plants, and girdle young trees (Fancy and Ralph 1998; Pratt 2005; USFWS 2006). Spread of exotic ungulates that are especially difficult to contain (i.e., axis deer on Maui and Molokai, black-tailed deer on Kauai, and mouflon sheep on Hawaii Island) represent a

growing threat to `I`iwi habitat as these high-jumping species invade areas even with fencing designed to exclude feral pigs and goats (Price et al. 2009). Browsing and soil compaction by feral pigs, goats, and deer in Molokai has reduced 'ōhi'a forest to grassy scrubland (Hess 2008).
Hawaiian forests are severely modified by invasive alien plant species that displace native plants used by foraging and nesting birds (Scott et al. 1986; Foster et al. 2004) and increase the frequency of forest fires (Pratt et al. 2009). Herbivory by the introduced black rat on the flowers and fruits of native plants may also reduce food resources for native birds and impact regeneration of native plants (Banko and Banko 1976). Introduced predatory insects also may reduce or eliminate specialized native insects that are needed for pollination of plants important to `I`iwi.

Habitat degradation by non-native mammals, plants, and invertebrates will likely continue to result in loss, modification, and curtailment of `I`iwi habitat and range.

B. Overutilization for commercial, recreational, scientific, or educational purposes.

Not considered a threat at this time.

C. Disease or predation.

Disease

The `I`iwi survives in habitat largely free of avian malaria (*Plasmodium reluctum*) and bird pox (*Aviapoxvirus*). Such habitat is currently limited to 22 acres on Kauai, 6,500 acres on Maui, and 16,000 acres on Hawaii Island (with virtually none on Oahu and Molokai) (Pratt et al. 2009). The best available data indicate that the elevational advance of these pathogens driven by climate change endangers the smaller `I`iwi populations on Kauai, Oahu, Molokai, and west Maui, and threatens the larger ones on east Maui and Hawaii Island.

`I`iwi is highly vulnerable to disease

Avian disease is a primary reason for the decline of I`iwi and other Hawaiian honeycreepers (Pratt 2005, Atkinson and LaPointe 2009). Warner (1968) demonstrated high susceptibility of honeycreepers that died from avian malaria and bird pox after experimental exposure to mosquito infested lower elevations where the birds were absent. Van Ripper et al. (1986) also provided experimental evidence of high susceptibility of I`iwi to avian malaria. More recently, Atkinson et al. (1995) experimentally exposed several species of honeycreepers to a single bite of a malaria infected mosquito and found that effects were most severe in `I`iwi with significantly higher mortality and clear manifestations of malaria disease at death. `I`iwi were infected by either single (low-dose) or multiple (high-dose) mosquito bites. Mortality in both groups was significantly higher than in uninfected controls, reaching 100% of high-dose birds and 90% (9 of 10) in low-dose birds.

While some individual I`iwi are known to have at least temporarily survived malaria, we find no evidence of population level tolerance or resistance to the disease. Atkinson et al. (1995) found

that the one `I`iwi that survived malaria after a single experimental bite from an infected mosquito did not develop new parasitemia after multiple bites from infected mosquitoes. This indicated that `I`iwi are capable of an immunological response at least to the administered strain of malaria. Freed et al. (2005) discovered tolerance to malaria in two wild `I`iwi that successfully bred 2-years post infection. However, broken head feathers in these birds suggested physiological costs of malarial tolerance that could reduce survivorship of wild birds. Studies of experimentally infected birds indicate that tolerant birds likely retain chronic infection for life (Atkinson et al. 2001, Valkiunas 2005). Challenges to the immune system by stress or excessive energy expenditure can result in recrudescence of a chronic infection to higher parasitemia levels (Freed et al. 2005). Infected birds lose weight and suffer malaria related pathologies (Atkinson et al. 2001), and would be expected to be more susceptible than healthy birds to predation, competition, avian pox, unfavorable weather, and other stressors. A comparison of infection incidence in `I`iwi and other Hawaii forest birds suggests that few `I`iwi survive exposure in the wild (Atkinson et al. 2005).

Lethal effects of avian poxvirus have also been experimentally demonstrated in Hawaiian honeycreepers (Jarvi et al. 2008). Freed et al. (2005) found a dead `I`iwi in the field with massive poxvirus sores on its ankles. The bird also tested positive for malaria. A significantly high proportion of Hawaiian forest birds with avian pox also had chronic malaria, suggesting interaction between the two diseases (Atkinson et al. 2005).

The downward trajectory of `I`iwi populations (Table 1) indicates a pattern of decline similar to ESA-listed Hawaiian forest birds vulnerable to disease, and dissimilar to populations of the unlisted Amakihi (*Hemignathus* spp.) (Shehata et al. 2001, Woodworth et al. 2005) and Apapane (Atkinson et al. 2005) which have shown some disease resistance and population persistence at lower elevations.

Among the most endangered Hawaiian bird species, the `Ō`ū, (*Psittirostra psittacea*), like the `I`iwi, was widespread on all main islands across a wide range of habitats a century ago (USFWS 2006). However, Ō`ū primarily inhabited the lower to mid-elevation forests where the impact of introduced mosquito-borne diseases was first manifested. Today, the `Ō`ū is probably extinct. Similar widespread exposure of `I`iwi to avian diseases can be expected in coming

decades as a consequence of climate change.
Disease will spread over `I`iwi range as ambient temperatures rise I.E. AND Current situation after accident in Fukushima (update: 2. April 2011 12:00) status of the radioactivity measurements
the world-wide measurements of the radioactivity in the context of the comprehensive atomic test stop agreement(CTBT) show at present (status of the measurements: 29. March 2011) further that traces of iodine and cesium are to be found at present at nearly all measuring points of the north hemisphere. To Europe the stations point in Freiburg/Germany and Stockholm/Sweden Jod-131 concentrations of 250 and/or 1700 µBqm-3. AND THE KNOWN IF THESE ARE AND ARE CEISIUM 137 MUST BE PRESENT Such values were registered also The material measured at present was already set free 14 days ago in Japan
advance upslope in response to higher ambient temperatures.

Avian malaria in Hawaii has been mostly confined to elevations below 1500 m (van Riper et al. 1986) where cool temperatures limit mosquito presence and development of the malaria parasite (LaPointe 2000). Recent climate modeling, however, has projected avian malaria to reach elevations up to or beyond 1900 m within this century, affecting most if not all remaining forest bird habitat (Benning et al. 2002).

Benning et al. (2002) modeled changes in malaria prevalence for Hawaiian honeycreepers at high quality habitat sites, assuming a 2° Celsius (C) increase in regional temperatures (based on International Panel on Climate Change 2007 projections; see Meehl et al. 2007). Current lowrisk habitat diminished by 57% (665 to 285 ha) at the Hanawi Natural Area Reserve, Maui. Lowrisk habitat at the Hakalau National Wildlife Refuge on Hawaii Island declined by 96% (3,120 to

130 ha). On Kauai (the Alakai Swamp), currently with little or no malaria free habitat, a 2° C warming placed most habitat (84%) at highest risk for malaria infection in native birds. Current mean ambient temperatures are believed to already allow limited disease transmission throughout Kauai as all `I`iwi habitat occurs below 1600 m elevation (LaPointe et al. 2005).

The effects of a 2° C warming would almost certainly eliminate the small `I`iwi populations from the lower-elevation islands of Kauai, Molokai, and Oahu, and from West Maui. Larger populations on East Maui and Hawaii Island would be expected to decline severely in a manner corresponding to decreases (~60-96%) in high elevation, disease-free refuges (Atkinson and LaPointe 2009).

The prognosis for `I`iwi and many other native forest birds appears worse than indicated by the Benning et al. (2002) model. The model assumed an increase of 2° C above current temperature, corresponding to ~2.7° C increase above pre-industrial levels. However, recent analysis of global heating indicates that temperature increases in Hawaii and elsewhere are unlikely to be limited to 2° C in this century. Increases in global temperature are currently on a trajectory to reach 2° C (above pre-industrial levels) by mid-century and about 5° C by 2100 (Meinshausen et al. 2009, Sokolov et al. 2009). Global greenhouse gas emissions would need to be halved by 2050 (from 1990 levels) to keep near the 2° C level with a high probability (55-88%) (Meinshausen et al. 2009). Unfortunately, under current multi-national policies regarding greenhouse gas emissions, there is virtually no chance of limiting heating to 2° C even with full policy implementation (Rogelj et al. 2009). For Hawaii, only a low global emissions scenario would likely keep temperature increases to 2° C (Karl et al. 2009).

An added concern is the risk of abrupt increases in global temperature unaccounted for in most modeled climate projections (Lovelock 2009). For example, a global climate model used by Sokolov et al. (2009) did not fully incorporate positive feedbacks that may occur, for example, if increased temperatures cause a large-scale melting of permafrost in arctic regions and subsequently release large quantities of methane, a very potent greenhouse gas (Rice 2009). If these positive feedback loops should occur, and evidence in mounting that they will (McCarthy 2010), temperatures are likely to increase to an even greater degree in Hawaii.

For Hawaii, Giambelluca et al. (2008) document a long-term increase in temperature and an accelerated rate of increase over the past few decades consistent with global trends (0.04° C C/decade over an 88-year period, and about 0.2° C/decade since 1975). Moreover, since 1975 higher elevation temperatures exceeded average warming (a 0.27° C/decade increase) with steepest increases in minimum (night time) temperature (near 0.5° C/decade), which is likely the most limiting for malaria transmission. The recent surface temperature trend in Hawaii is only slightly lower than the overall global trend. Similar surface warming has been detected elsewhere in the Pacific, and is associated with an increase in sea surface temperatures, upper ocean heat content, and sea level height (Richards and Timmermann 2008).

In Hawaii, the upper limit of mosquito presence appears to have increased substantially, from about 600 m in the late 1960s to 1100-1500 m in recent decades (Pratt 2005). Freed et al. (2005) reported that prevalence of malaria in Hawaiian forest birds at 1900 m on the island of Hawai‘i more than doubled over a decade. A highly significant increase of malaria in `I`iwi was

associated with much warmer summertime air temperatures. The 13° C threshold for malaria development projected for 1900 m sites by the conservative Benning et al. (2002) model was surpassed in 2001 by a wide margin (4.4° C; Freed et al. 2005). Measured temperatures were believed to exceed model expectations because the site was strongly affected by the island’s trade wind inversion layer related to tropical air circulation. The altitude of the inversion has averaged 1900 m, above which cooler, drier conditions prevail (*Atlas of Hawaii*, 3rd edition). The response of the inversion layer to climate heating is uncertain (Pounds et al. 1999, Loope and Giambelluca1998). If the inversion layer rises, disease epizootics could become commonplace at higher elevations with devastating short-term consequences for `I`iwi. If the inversion falls, and higher temperatures become associated with high-elevation drought, the effects would be very damaging to upper elevation Hawaiian forests and ultimately to surviving honeycreepers including the `I`iwi (Benning et al. 2002). Given that scenario, or if the inversion layer remains stable, high-elevation forest bird populations may be squeezed between expanding disease transmission from lower elevations and the upper limits of suitable habitat (Atkinson and LaPointe 2009).

Hawaii may see an increased frequency of heavy rain events and increased rainfall during summer months (Karl et al. 2009), conditions that, along with increased temperature, are likely to facilitate breeding of malaria-carrying mosquitoes (Ahumada et al. 2004). At the same time, overall annual precipitation for the Hawaiian Islands may decline (Chu and Chen 2005) thereby affecting habitat quality (e.g., ‘ōhi‘a forest) for the `I`iwi.

Ectoparasites, particularly chewing lice (Phthiraptera), may impact `I`iwi by increasing morbidity and reducing the ability of birds to survive environmental challenges.

Freed et al. (2008) documented an explosive increase in the prevalence of chewing lice in all bird host species at a study site on Hawaii Island. The number of major fault bars in wing and tail feathers, a sign of nutritive stress, was correlated with intensity of infection, suggesting an indirect cost to parasitized birds. Poorer body condition preceded the outbreak indicating the synergistic effect of multiple stressors on forest birds. At a minimum, chewing lice will increase food requirements of hosts. This indirect cost may be especially relevant because it can affect the ability of birds to mount a sufficient immune defense against diseases like avian malaria and pox. Chewing lice may also directly contribute to bird mortality (Freed et al. 2008).

Additional risks to `I`iwi from disease include potential introductions of West Nile virus, new avian malaria vectors (such as temperate varieties of *Culex quinquefaciatus*), or biting midges (Culicoides) that transmit avian diseases.

Predation

Introduced rats are serious predators on adults and nests of Hawaiian forest birds, and are abundant in high elevation habitats (Atkinson 1977, Scott et al. 1986, Fancy and Ralph 1998, VanderWerf and Smith 2002). Feral cats, introduced small Indian mongoose, and the native Short-eared Owl and introduced Barn Owl may also impact native Hawaiian birds (Scott et al 1986; Kowalsky et al. 2002). Predator control efforts generally have not been conducted over areas large enough to result in significant improvement in the status of imperiled forest birds

(USFWS 2006). Logistical and other obstacles to predator control can be great, especially in rugged bird habitat.

D. Inadequacy of existing regulatory mechanisms.

Existing international and U.S. regulatory mechanisms to reduce global greenhouse gas emissions are clearly inadequate to safeguard the `I`iwi against extinction resulting from climate change, which is expected to cause a severe shrinkage of disease free habitat for the ‘I’iwi.

United States Climate Initiatives are Ineffective

The United States is responsible for over 20% of worldwide carbon dioxide emissions (USEIA 2004), yet does not currently have adequate regulations to reduce greenhouse gas emissions. This was acknowledged by the Department of Interior in the final listing rule for the polar bear, which concluded that regulatory mechanisms in the United States are inadequate to effectively address climate change (73 Fed. Reg. 28287-28288). While existing laws including the Clean Air Act, Energy Policy and Conservation Act, Clean Water Act, Endangered Species Act, and others provide authority to executive branch agencies to require greenhouse gas emissions reductions from virtually all major sources in the U.S., these agencies are either failing to implement or only partially implementing these laws for greenhouse gases. For example, the EPA has recently issued a rulemaking regulating greenhouse gas emissions from automobiles (75 Fed. Reg. 25324, Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards; Final Rule), but has to date failed to implement the majority of other Clean Air Act programs, such as the new source review, the new source pollution standards, or the criteria air pollutant/national ambient air quality standards programs, to address the climate crisis (See, e.g. 75 Fed. Reg. 17004, Reconsideration of Interpretation of Regulations That Determine Pollutants Covered by Clean Air Act Permitting Programs). While full implementation of these flagship environmental laws, particularly the Clean Air Act, would provide an effective and comprehensive greenhouse gas reduction strategy, due to their non-implementation, existing regulatory mechanisms must be considered inadequate to protect the ‘I’iwi from climate change.

International Climate Initiatives are Ineffective

The primary international regulatory mechanisms addressing greenhouse gas emissions are the United Nations Framework Convention on Climate Change and the Kyoto Protocol. As acknowledged by the Department of Interior in the final listing rule for the polar bear, these international initiatives are inadequate to effectively address climate change (73 Fed. Reg. 28287-28288). Additionally, the Kyoto Protocol’s first commitment period only sets targets for action through 2012. Importantly, there is still no international agreement governing greenhouse gas emissions in the years beyond 2012. Thus international regulatory mechanisms must be considered inadequate to protect the ‘I’iwi from climate change.

While the 2009 U.N. Climate Change Conference in Copenhagen called on countries to hold the increase in global temperature below 2 degrees Celsius, the *non-binding* “Copenhagen Accord” that emerged from the conference fails to enact binding regulations that limit emissions to reach this goal. Even if country’s did meet their pledges, a summary by the Pew Center (2010) of four

analytical reviews of the Accord found that collective national pledges to cut greenhouse gas emissions are inadequate to achieve the 2° C goal, and instead suggest emission scenarios leading to a 3 to 3.9° C warming.

Regulations to protect high elevation forests that could serve as refugium for ‘I’iwi are inadequate

Current regulatory mechanisms are inadequate to conserve high elevation forests needed to buffer the `I`iwi and other susceptible forest birds against the upslope advance of avian diseases driven by global heating. While some progress has been made to reforest former upper elevation habitat areas with native trees and reduce or eliminate harmful alien species from existing ones, huge tracts of land needed for forest bird conservation in Hawaii remain degraded or without native tree cover (USFWS 2009). A preponderance of lands intended for forest bird recovery are not managed conservation lands (Pratt et al. 2009). Management actions identified in existing forest bird recovery plans have not been implemented at ecologically relevant scales, and successful efforts to restore higher elevation forests must occur across tens of thousands of areas, not hundreds (Scott 2009). On the Island of Maui, for example, more than half of the lands identified for forest bird recovery remain without native forests, have only remnant forest patches, or are dominated by introduced tree species and other alien vegetation (A. Povilitis, pers. com.). Yet restoration of high elevation koa/`ōhi`a forest to protect native birds is clearly a conservation priority (Scott et al.1986, USFWS 2006)

At current rates, reforestation and forest enhancement efforts for Hawaiian forest birds will not achieve habitat conservation goals in time to build and expand populations robust enough to withstand avian malaria and other consequences of climate change. Of over 140 actions for forest bird recovery relating to reforestation and securing recovery areas (USFWS 2006), 61% have not begun, 37% are ongoing, and only 2% are complete or partially so (USFWS 2009). Likewise, of more than 160 actions designed to reduce or eliminate exotic ungulates and mammalian bird-predators, 71% are not yet underway, 27% are ongoing, and less than 2 % are complete or partially complete.

Poor political and policy decisions are responsible for the current inadequacy of regulatory mechanisms to prevent forest bird extinctions. The problem includes conflicting management goals and policies, most notably involving state forest lands (USFWS 2006, 2009), and failure to provide necessary funding (Leonard 2008).

Leonard (2009) discusses political obstacles to saving Hawaiian forest birds, including a state mandate to provide public hunting opportunities of exotic ungulates even where incompatible with conservation of native birds. Actions such as fencing and ungulate control for bird conservation may result in the loss of hunting areas, which is very controversial within his state agency (Leonard 2008). Even proposals for protecting limited forest in areas of little or no public access receive fierce opposition from local hunters (San Nicolas 2010). Native forest restoration is also hampered by agency decisions favoring exotic tree species or leasing for livestock (USFWS 2006).

The `I`iwi, like all other Hawaiian honeycreepers, is not included on the list of species protected under the Migratory Bird Treaty Act and thus receives no protection under federal law.

E. Other natural or manmade factors affecting its continued existence.

Climate change

Global heating threatens `I`iwi by increasing the elevation at which regular transmission of avian malaria and avian pox virus occurs (Benning et al. 2002, Harvell et al. 2002). It is the primary reason why the species merits listing under ESA at this time (review discussion under section C for details).

Catastrophic events

Epizootics involving avian malaria or other pathogens could eliminate remaining `I`iwi from the lower elevation islands of Kauai, Oahu, and Molokai, and from west Maui in the near term, and could diminish and fragment 'I'iwi populations on higher elevation east Maui and Hawaii Island.

There is currently no habitat on Kauai, Oahu, and Molokai where mean ambient temperature entirely restrict malaria development (Benning et al. 2002). These islands are vulnerable to avian malaria at all elevations on a more or less ongoing basis. A recent avian malaria outbreak on Hawaii Island was associated with increases in summertime temperatures related to tropical inversion layer conditions (Freed et al. 2005). Outbreaks of malaria can be triggered by warm periods linked to inversion layer dynamics or El Niño events, and will likely intensify and persist longer with ongoing climate change.

Hurricanes are known for their devastating effects on island birds (Foster et al. 2004). They reduce habitat by blowing down trees and by creating forest openings that facilitate the spread of invasive alien plants. The `I`iwi decline on Kauai after a 1992 hurricane may have partially resulted from the birds seeking substitute nectar resources at lower elevations where risk of malaria transmission is highest (Foster et al. 2004).

Hurricanes are likely to intensify in a warmer climate (Meehl et al. 2007) in terms of wind speeds and precipitation, though the number of storms may be fewer (Bengtsson et al. 2007). Infectious mosquitoes can be carried upslope in strong winds, a probable factor in malaria outbreaks on Hawaii above 1900 m elevation (Freed et al. 2005).

On Hawaii Island, volcanism presents a potential threat to substantial acreage of forest bird habitat. For example, a large portion of the Upper Waiākea Forest Reserve, location of some of the last observations of `Ō`ū and considered prime habitat for the species, was inundated by the 1984 Mauna Loa lava flow which destroyed thousands of acres of forest and created a treeless corridor over 1 km wide (USFWS 2006).

Introduced Competitors

Introduced species of insects and birds can compete with native birds for food and other resources. `I`iwi may face competition from Japanese White-eye (*Zosterops japonicas*) (Mountainspring and Scott 1985), a malaria resistant species, whose numbers have increased at least on Kauai over the past 30 years (Foster et al. 2004). Negative correlations between `I`iwi

15

and Japanese White-eye densities may stem from competition for limited nectar resources (Fancy and Ralph 1998). There are no current efforts to control competing species within the recovery areas of endangered forest birds (USFWS 2006).

Population fragmentation and isolation

'I'iwi populations have suffered from fragmentation as well as reduced size and range. Small population units are at risk of extinction from random demographic fluctuations, localized catastrophes (severe storms, wild fire, disease outbreaks, volcanism, etc.), inbreeding depression,
and genetic drift (Primack 2006).

IV. Request for Critical Habitat SINCE Current situation after accident in Fukushima, JAPAN (update: 2. April 2011 12:00) status of the radioactivity measurements

the world-wide measurements of the radioactivity in the context of the comprehensive atomic test stop agreement(CTBT) show at present (status of the measurements: 29. March 2011) further that traces of iodine and cesium are to be found at present at nearly all measuring points of the north hemisphere. To Europe the stations point in Freiburg/Germany and Stockholm/Sweden Jod-131 concentrations of 250 and/or 1700 µBqm-3. Such values were registered also The material measured at present was already set free 14 days ago in Japan

advance upslope in response to higher ambient temperatures.

When the USFWS lists a species as endangered or threatened under ESA it must concurrently designate critical habitat for that species “to the maximum extent prudent and determinable.” The ESA defines the term “critical habitat” to mean: i. the specific areas within the geographical area occupied by the species, at the time it is listed . . . on which are found those physical or biological features (I) essential to the conservation of the species and (II) which may require special management considerations or protection; and ii. specific areas outside the geographical area occupied by the species at the time it is listed . . . upon a determination by the Secretary [of Interior] that such areas are essential for the conservation of the species.

Critical habitat for `I`iwi is needed to ensure that federal actions avoid jeopardizing the species and help promote its conservation. Designation would help inform federal and state governments and private landowners on conservation planning, habitat management, and other actions needed to secure habitat, and help address conflicts that undermine its protection and restoration.

To reduce the climate change/disease threat, `I`iwi habitat requires special management including reforestation and forest protection adequate to sustain the species. Specific measures include elimination or control of alien species inimical to the survival of `I`iwi, and special measures to monitor and reduce (or eliminate) occurrence of avian malaria vectors. Programs to re-establish native forests, reduce rat depredation, control weeds, and fence out and remove ungulates are essential for forest bird recovery in high elevation habitats that serve as native bird refugia (Gorresen et al. 2005). Reducing mortality, such as that caused by rodent predation, may lessen the threat from disease by improving survival and reproduction of any birds with disease tolerance or natural immunity (VanderWerf and Smith 2002). The evolutionary acceleration of disease resistance through rodent control is possible (USFWS 2006).

Critical habitat should include all areas needed to provide sufficient forested habitat to support viable or potentially viable `I`iwi populations on Kauai, Oahu, Molokai, Maui, and Hawaii Island, as each island represents a significant portion of the species’ natural range. This should include areas on Maui and Hawaii Island above the current limit of tree growth to accommodate any forest expansion resulting from climate change.

16

Critical habitat designation for `I`iwi will extend habitat protection to other listed endangered Hawaiian birds, where ranges overlap. Unfortunately, most currently listed forest birds do not have critical habitat designations.

V. Conclusion

The best available science indicates that global warming
Current situation after accident in Fukushima, JAPAN (update: 2. April 2011 12:00) status of the radioactivity measurements
the world-wide measurements of the radioactivity in the context of the comprehensive atomic test stop agreement(CTBT) show at present (status of the measurements: 29. March 2011) further that traces of iodine and cesium are to be found at present at nearly all measuring points of the north hemisphere. To Europe the stations point in Freiburg/Germany and Stockholm/Sweden Jod-131 concentrations of 250 and/or 1700 µBqm-3.ALSO CEISIUM 137 Such values were registered also The material measured at present was already set free 14 days ago in Japan
advance upslope in response to higher ambient temperatures.
,RADDS its contribution to future elNINIO EFFECT , AND CHEMICALS will allow avian diseases to spread throughout most or all of the `I`iwi’s geographic range. The `I`iwi is highly vulnerable to avian diseases and cannot sustain itself where disease prevails.

`I`iwi in the central portion of the species' range (Oahu, Molokai, and west Maui AND THE ATULL ISLANDS) are critically endangered because of small population sizes and exposure to malaria. Those to the west (on Kauai) are severely threatened as disease free habitat is fast disappearing. `I`iwi AND THE ATULL ISLANDS Endangered Species ANY AND ALL INFINITE in the eastern portion of the range (east Maui Hawaii Island AND THE ATULL ISLANDS) face further population declines and eventual extinction with ongoing climate change.

The `I`iwi warrants listing under the US Endangered Species Act with concurrent designation of critical habitat.

VI. Literature Cited

Director FOR FREE THE ATULL ISLANDS Endangered Species; Marine Mammals, Hawaii Bottom fish, Seamount Ground fish & ERADICATE THE RATS /DIRECTOR ROWN PAUL BROWN SR.

Current situation after accident in Fukushima, JAPAN (update: 2. April 2011 12:00) status of the radioactivity measurements

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P.S. Dr. Elizabeth Flint/ IF YOU COULD PLEASE SUPPLY ME WITH A E-MAIL ADDRESS OFFICIAL AND AS TO COMMUNICATE ABOUT
''Palmyra rat project''/

From: RALPH BLACK
To: pacific_reefs@fws.gov; RALPH BLACK
Subject: ‘‘Palmyra rat project’’ in subject line/THANKS
Date: 04/12/2011 07:12 AM

DEAR: Dr. Elizabeth Flint THANKS FOR YOUR OFFICE QUICK RESPONSE The FRIENDS OF ATULL ISLANDS Marine Mammals, Hawaii Bottom fish, Seamount Ground fish Fisheries Endangered Species ANY AND ALL INFINITE /PETITION TO LIST THE ATULL ISLANDS Endangered Species ANY AND ALL INFINITE
‘‘Palmyra rat project’’ DEPARTMENT OF THE INTERIOR/PRAYER FOR TIME ‘‘Palmyra rat project’’
WE LOOK FORWARD TO SERVING Endangered Species / PROTECTED AREAS OF ATULL ISLANDS AND YOUR OFFICE / WE WILL BE HERE AND AT PHONE#[209] 985 1257
24/7 AND PLEASE CONTACT US AS SOON AS POSSIBLE AS FUEL COST'S GOING UP AND MARINE DONATIONS FOR SUPPORT ARE HARDER BY THE DAY AS ALSO AVIATION FUEL IF ALLOWED AIR ACCESS FOR THE HELP OF ALL CONCERNED TO ATULL ISLANDS. MY /OUR/ US AND FRIENDS BELIEVE WE HAVE A FREE OF CHEMICAL ERADICATION FOR THE RATS OF ‘‘Palmyra rat project’’ ATULL ISLANDS AND WILL BE WILLING TO WORK ALONG SIDE THE PROVIDERS OR CARETAKERS OF THE PALMS OR ANY AND ALL THAT ARE BEING DECIMATED BY THE RATS OR ANY FOREIGN INVADERS OF ANY NATURE TO THE ATULL ISLANDS. AND ALSO IF EMPOWERED TO PARTIAL CHEMICAL ERADICATIONS WE WOULD CARE TO NOT ASSIST IN THE CHEMICAL PORTION. BUT TO REFEREE AS SAFEGUARD FOR AREAS TOO DELICATE FOR CHEMICAL ERADICATION. AS WE CONTEND NOT EVEN A BIODEGRADABLE IS SAFE FOR ALL THE ATULL ISLANDS WE BELIEVE WE HAVE ALL NATURAL PROCEDURES THAT ALONE OR COMBINED WILL SAFELY ERADICATE BY WELL PROVEN AND LONGSTANDING AMERICAN MEANS WITH PROVEN AND SAFE TRACK RECORD WITH POSITIVE FINAL RESULT.
A.K.A.RALPH BLACK = ROWN PAUL BROWN SR.= @BEARBOOBOO1@LIVE.COM
FOR MODERN DAY ELECTRONIC COMMUNICATION PLEASE NOTIFY THIS E-MAIL ADDRESS & PHONE NUMBER PROVIDED ABOVE FOR ANY LEGAL NECESSITY FOR LEGAL PAPER MOVEING FOR THE SAFE GAURD OF THE ATULL ISLANDS.

E-mail: pacific_reefs@fws.gov. Include
‘‘Palmyra rat project’’ in subject line

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Director FOR FREE THE ATULL ISLANDS Endangered Species; Marine Mammals, Hawaii Bottomfish, Seamount Groundfish & ARRADICATE THE RATS
A.K.A.RALPH BLACK = ROWN PAUL BROWN SR.= @BEARBOOBOO1@LIVE.COM