***Night Birds Returning*:**

Feasibility Study for Removal of Black Rats from Murchison and Faraday Islands

Gwaii Haanas National Park Reserve,

National Marine Conservation Area Reserve and Haida Heritage Site

Parks Canada Parcs Canada

COASTAL CONSERVATION

ISLAND CONSERVATION Preventing Extinctions

HAIDA NATION

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1.0 INTRODUCTION

The purpose of this document is to weigh the risks and benefits of the available methods for eradicating black rats (*Rattus rattus*) from Murchison and Faraday Islands within Gwaii Haanas National Park Reserve, National Marine Conservation Area Reserve and Haida Heritage Site (referred to hereafter as Gwaii Haanas). The eradication of invasive black rats from these islands is consistent with Parks Canada Agency's direction of active management of invasive species and is part of a larger program of ecological restoration currently being implemented across Canada's national parks and park reserves.

In 2009, Gwaii Haanas launched its *SGin Xaana Sdiihltl'lxa* (translated from the Haida language as *Night Birds Returning*) program. Three main components comprise this project: rat eradication, ecosystem monitoring and active restoration. The *Night Birds Returning* program aims to restore nesting seabird habitat and associated ecosystem processes, on ecologically and culturally significant islands within Gwaii Haanas. In 2011, the first phase of the program involving eradication of Norway rats (*Rattus norvegicus*) from the Bischof Islands and Arichika Island using a bait station approach was completed (Parks Canada, 2010; 2010a; 2011). The second phase of the project is the eradication of black rats from Murchison and Faraday Islands. Our goal is to undertake this eradication in the fall of 2013.

Here, we assess the feasibility of removing introduced black rats (*Rattus rattus*) by:

- Exploring the conservation benefits associated with rat removal;
- Evaluating challenges and risks associated with rat eradication in this region; and
- Determining what actions are likely needed to overcome inherent risks.

Various eradication techniques are assessed and a recommended option that will deliver the highest likelihood of eradication success while balancing risk to non-target species, logistical constraints and cost-effectiveness is presented. A variety of rodenticide options are assessed and an appropriate rodenticide is recommended with suggestion for its adaptation to suit the Gwaii Haanas environmental conditions. Potential impacts to native species are considered and mitigative measures to reduce risk to these species are presented.

1.1 Impacts of Introduced Rats on Island Ecosystems

The impacts of introduced 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 (Towns et al. 2006) have been introduced to 90 percent of the world's islands and have a pronounced impact on island ecosystems. In addition, the extinction of many island mammals, birds, reptiles and invertebrates has 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). It is estimated that 40-60 percent of all recorded bird and reptile extinctions globally have been caused by invasive rats (Atkinson 1985).

Even if species are not extirpated, rats can have negative direct and indirect effects on native species and ecosystem function. For example, comparisons of rat-infested and rat-free islands, and pre- and post-rat rat eradication experiments, have shown that rats depress population size and recruitment of birds (Mulder et al. 2011, 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). Of great public concern, rats have significant negative impacts on seabirds, consuming eggs, chicks and adults and causing seabird population declines, with the most severe impacts on highly vulnerable burrow-nesting seabirds (Atkinson 1985, Kaiser et. al. 1997, Towns et al. 2006, Jones et al. 2008). Ecologically, impacts to colonial nesting seabirds are also of great concern due to potentially large population effects from the invasion of only very small islands.

In addition to direct predation of seabirds, rats feed opportunistically on plants and alter the floral communities of island ecosystems (Campbell and Atkinson 2002), in some cases degrading the quality of nesting habitat for birds that depend on the vegetation. On Tiritiri Matangi Island, New Zealand, ripe fruits, seeds and understory vegetation showed significant increases after rats were eradicated (Graham and Veitch 2002). Rats can also affect the abundance and age structure of intertidal invertebrates (Navarrete and Castilla 1993), directly and indirectly affecting species richness and abundance of a range of invertebrates (Towns et al. 2009). Rats have contributed to the decline of endemic land snails in Hawaii (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 controls (Fukami et al. 2006). In rocky inter-tidal habitats, invasive rats have indirectly affected invertebrate and marine algal abundance, changing intertidal community structure from algae to invertebrate dominated systems (Kurle et al. 2008). Such changes are a result of indirect negative effects of rats causing a 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). Where rats co-exist with other predators (such as cats or predatory birds), the collective direct impact 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 impact on native species, rats are identified as key species for eradication (Howald et al. 2007).

2.0 BACK GROUND

2.1 Eradication Partners

The rat eradication component of Night Birds Returning is a multi-agency partnership between Parks Canada, the Haida Nation, Coastal Conservation and Island Conservation. Financial support is provided by Parks Canada Agency, and the partners are collaborating to raise additional funds from other sources.

The lands and waters of Gwaii Haanas are cooperatively managed by Parks Canada Agency, Fisheries and Oceans Canada and the Council of the Haida Nation which each have delegated authorities from their respective federal ministers or elected council. Representatives from all three organizations sit on the Archipelago Management Board (AMB) which has ultimate authority for both strategic and operational decisions that affect the land and waters of Gwaii Haanas. The AMB is responsible for good governance and appropriate oversight of cooperative management actions within Gwaii Haanas. It was involved in the development of the Night Birds Returning program and will approve this Feasibility Study and related operational plans. The AMB is provided with regular project briefings and updates during project planning and implementation.

2.2 Project Goal

The goal of Night Birds Returning is to restore seabird habitat and associated ecosystem processes through the removal of invasive rats from affected islands.

2.3 Project Objectives

- Complete and permanent eradication of invasive rats (*Rattus rattus*) from Murchison and Faraday Islands with minimal impact to native ecosystems.
- Reduced threat of rat invasion to adjacent rat-free Ramsay Island and consequently enhanced protection of its globally significant seabird colonies.
- Enhanced breeding success of several species of seabird, including the federally listed Ancient Murrelet, a Species-at-Risk
- Restoration of native ecosystem processes and
- Recovery of other floral and faunal populations negatively impacted by rats

2.4 Measuring Success

Success in rat eradication will improve ecosystem integrity and restore ecosystem functioning. Several key metrics will be monitored to evaluate project success, including:

- Rat absence
- Black Oystercatcher breeding pair abundance
- Breeding songbird abundance and species diversity
- Native small mammal presence/abundance
- Intertidal algae & invertebrate abundance
- Abundance of Ancient Murrelets (key species targeted for recovery) and other ground nesting seabirds

All of the above metrics, with the exception of abundance of nesting seabirds, are part of a broader program of long-term monitoring established by Parks Canada to monitor landscape-level indicators of ecological integrity. These metrics are reported on every 5 years through the Parks Canada Agency's State of the Park reports which showcase trends in ecosystem health through the tracking of key ecological indicators.

2.5 Project Site Description

2.5.1 Physical Environment

The project site is within the Gwaii Haanas National Park Reserve, National Marine Conservation Area Reserve and Haida Heritage Site which covers some 5000 km^2 of terrestrial area and marine waters (up to 10km off shore) in the southern portion of the Haida Gwaii archipelago, off the northwest coast of British Columbia. This area is managed cooperatively by Parks Canada Agency, Fisheries and Oceans Canada and the Haida Nation.

Figure 1: Location of Gwaii Haanas National Park Reserve, National Marine Conservation Area Reserve and Haida Heritage Site

Murchison Island and Faraday Islands are located south of Lyell Island and northwest of Ramsay Island. Ramsay Island and the northern Juan Perez Sound islands are recognized by BirdLife International as an International Bird Area, a priority area for the conservation of globally threatened species. Ramsay Island is currently rat-free and supports globally significant breeding populations of ancient murrelets (~20,800 pairs) and Cassin's auklets (~13,000 pairs) and regionally significant populations of Fork-tailed and Leach's storm petrels, pigeon guillemots, and black oystercatchers.

Figure 2: Proximity of Murchison and Faraday Islands to Ramsay Island.

Faraday Island lies closest to Lyell (the nearest island with rats) hence the swimming distance for a rat is 730m at the low tide. The waters here in Faraday Passage are subject to consistently strong currents. Figure 3 shows approximate distances between Faraday and Murchison Islands and their associated islets.

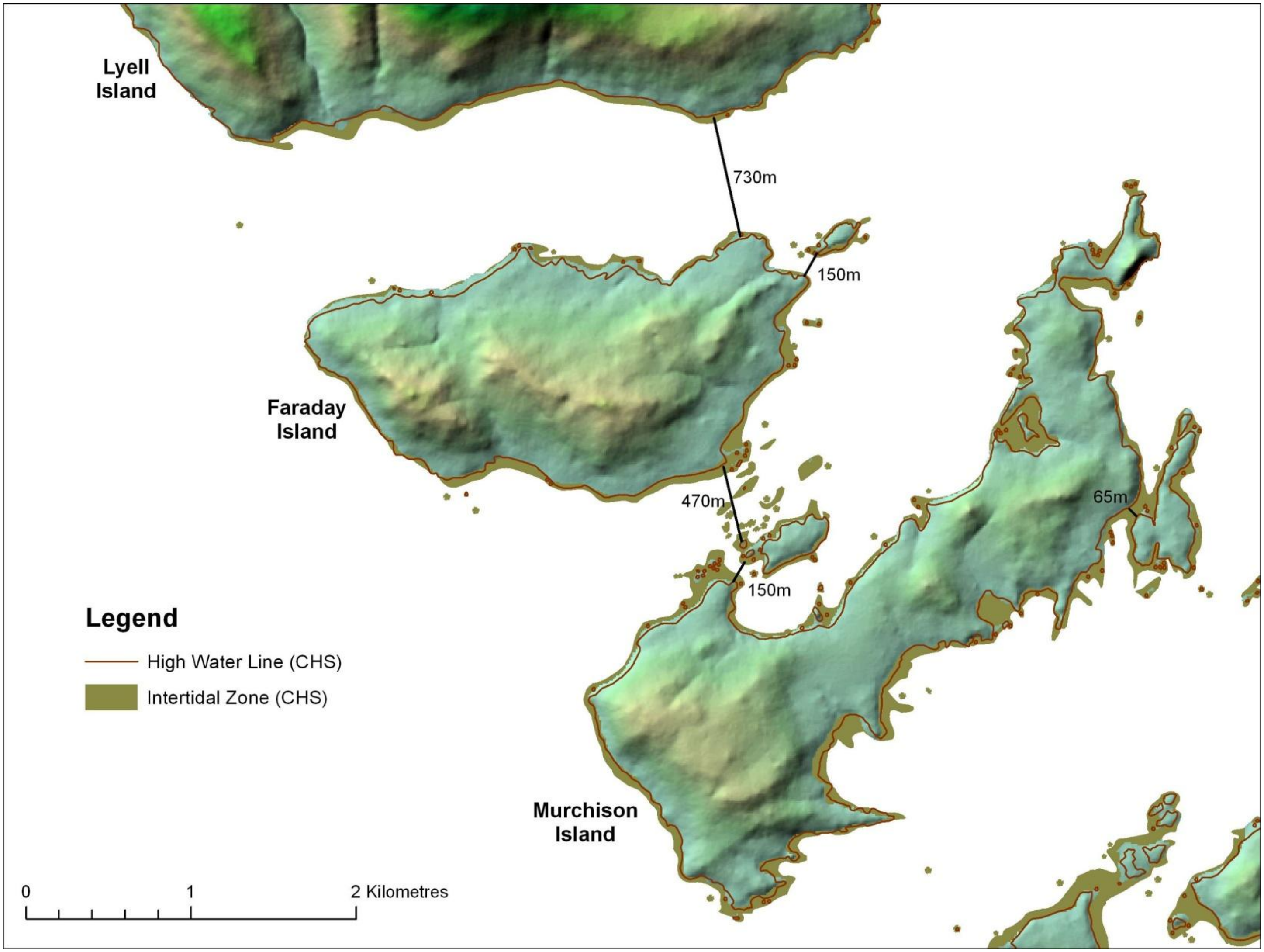

Figure 3: Approximate Distances between Murchison and Faraday Islands and rat-present Lyell Island.

Murchison Island (400 ha) has a maximum elevation of 154m. It has two forested islets on the east and west sides and several rocky islets. There are six streams on the island, although some may run only intermittently in drier months.

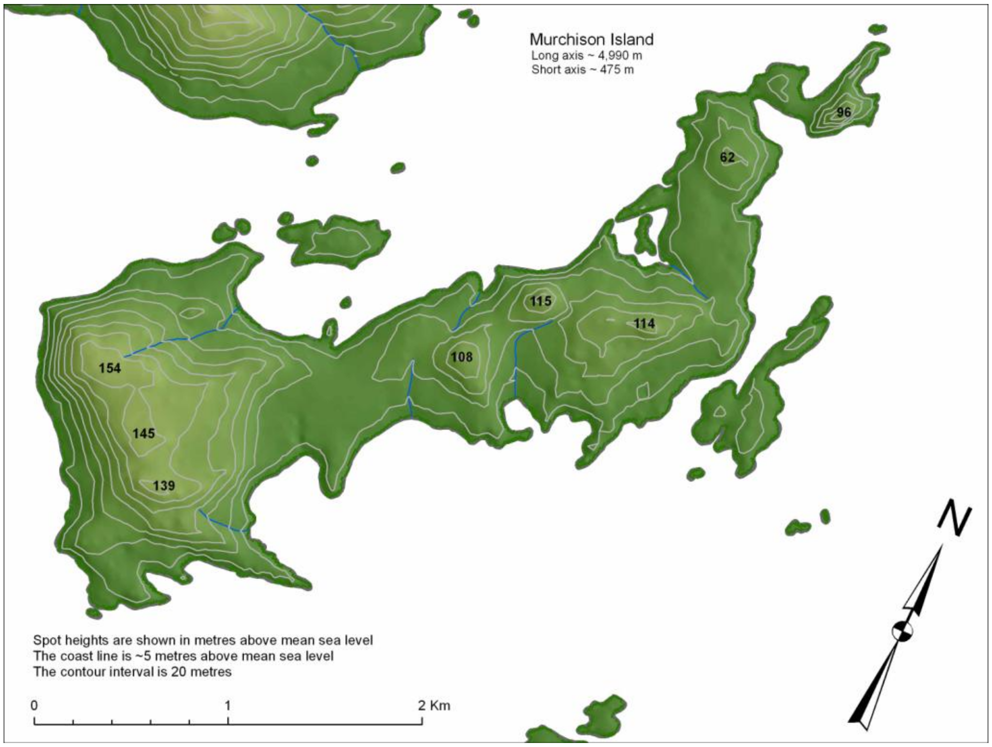

Figure 4: Murchison Island.

Faraday (316ha) has a maximum elevation of 198m. It has one forested islet on the east side and several small rocky islets. Four streams occur on the east and west sides, although in some months these may run intermittently.

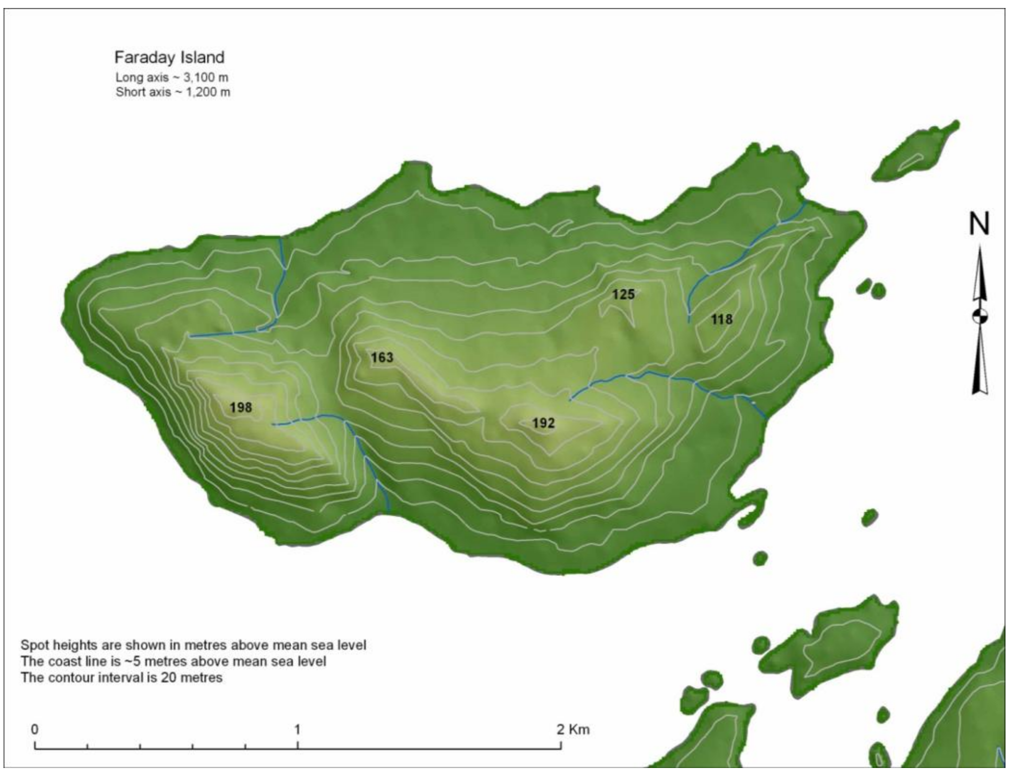

Figure 5: Faraday Island.

2.5.2 Biological Environment

The San Christoval Mountains are the backbone of Moresby Island, rising more than 1000m at Mount de la Touche, on the west side of Gwaii Haanas. The eastern side of Moresby Island descends gradually to sea level, producing many inlets, bays and islets. Haida Gwaii is the most tectonically active area in Canada. Landslides are common due to combinations of steep slopes, intense rainfall, frequent strong winds and seismic activity. Annual precipitation can be in excess of 5000mm per year, however the east coast receives considerably less rain (Cape St. James, at the southern tip of Gwaii Haanas receives a mean annual precipitation of 1610mm). Clouds and fog are common and relative humidity is high throughout the year. Mean annual temperature averages 7.5 C.

Murchison and Faraday Islands fall within the coastal western hemlock wet hypermaritime (CWHwh) biogeoclimatic sub-zone. Here at lower elevations are classic coastal rainforests, dominated by large western hemlock (*Tsuga heterophylla*), Sitka spruce (*Picea sitchensis*) and red cedar (*Thuja plicata*). These forests are quite productive and would normally support common shrubs including salmonberry (*Rubus spectabilis*), black twinberry (*Lonicera involucrata*) and salal, and many herbs. However, browse pressure from introduced Sitka black-tailed deer has greatly reduced understory vegetation, save for that found on a handful of small off-shore islets and islands where deer are absent.

2.5.3 Human Environment

Murchison and Faraday islands were historically inhabited by the Haida. A number of archaeological sites are present on the islands and will require consideration in planning and implementing the eradication. The remains of a settler's cabin are also present on Faraday Island and are considered a historical site. The more recently constructed cabin located on the small island lagoon on the eastern end of Murchison is not a historic site. There are no human inhabitants on these islands presently. There is a Haida Gwaii Watchmen site staffed between May and September on Hotsprings Island located south of Murchison Island.

2.6 Biodiversity Values and Impacts of Rats

Approximately 1.5 million seabirds from 12 species (Table 1) nest on the islands of Haida Gwaii (Rodway et al. 1988). Seabirds are known to nest on more than 200 offshore islands, islets and rocks as well as on the larger islands of Graham and Moresby Islands (Harfenist, 2003). Surrounding marine waters also support millions of migratory and/or non-breeding individuals of species that nest within the Pacific Northwest region and to Alaska and beyond. None of these seabird species nest only on Haida Gwaii, but breeding sites for most of them are confined to the coastlines of the northern Pacific Ocean with the exception of the ancient murrelet for which Haida Gwaii is the only nesting site in Canada. The archipelago supports globally significant nesting populations of ancient murrelets, Cassin's auklets and rhinocerous auklets and nationally or regionally significant nesting populations of Fork-tailed storm-petrels, Leach's storm petrels and pigeon guillemots.

Comprehensive records of seabird nesting are available only from the early 1970s and are incomplete; however they show a marked decline in many seabird populations likely from the effects of introduced predators, including rats. Langara Island historically supported one the world's largest populations of ancient murrelets with more than 200,000 breeding pairs of birds (Gaston, 1992). By 1976, the population had declined to 50,000 pairs (Nelson and Myres, 1976) to 90,000 pairs (Vermeer et al., 1984). Further declines to 21,500 to 24,100 pairs were documented in the 1980s (Rodway et al., 1994) and to less than 15,000 pairs in 1993 (Harfenist, 1994).

Seabird species and their marine habitats are described in Harfenist *et al.* (2002). Oceanographic processes and features that most likely influence the distribution and abundance of seabirds on the ocean, such as currents and seamounts, are briefly reviewed by Burger *et al.* (1997). A review of the distribution and abundance of seabird prey species in the waters around the archipelago can be found in Robinson *et al.* (1999).

Table 1: Breeding seabirds of Haida Gwaii and estimated breeding pairs (adapted from Sloan, 2006).

Species	***IUCN Status***	***COSEWIC Status***	***BC List***	***Estimated Breeding Pop'n (# of pairs)*****	***Notes***
Ancient Murrelet (*Synthliboramphus antiquus)*	*Least concern*	*Special Concern*	*Blue*	*256,000*	*~50% of global pop'n; only breeding location in Canada*
Marbled Murrelet (*Brachyramphus marmoratus)*	*Endangered*	*Threatened*	*Blue*	*5,800**	**estimated; radar surveys underway*
Cassin's auklet (*Ptychoramphus aleuticus)*	*Least Concern*	-	*Blue*	*297,000*	*~18% of global population; ~50% of BC population*
Rhinocerus Auklet (*Cerorhinca monocerata)*	*Least Concern*	-	*Yellow*	*23,900*	*~4% of global population*
Horned Puffin (*Fratercula corniculata)*	*Least Concern*	-	*Red*	*16*	*No confirmed breeding sites (3 probable, 2 suspected)*
Tufted Puffin (*Fratercula cirrhata)*	*Least Concern*	-	*Blue*	*560*	*14 breeding colonies*
Pigeon Guillemot (*Cepphus Columba)*	*Least Concern*	-	*Yellow*	*2500**	**estimated; ~50% of BC pop'n*
Fork-tailed storm-petrel (*Oceanodroma furcata)*	*Least Concern*	-	*Yellow*	*53,000*	*~21% of BC's pop'n*
Leach's storm-petrel (*Oceanodroma leucorhoa)*	*Least Concern*	-	*Yellow*	*103,000*	
Glaucous-winged gull (*Larus glaucescens)*	*Least Concern*	-	*Yellow*	*2,800*	*Underestimated; coast-wide, pop'n has increased ~4 fold since 1940s*
Pelagic cormorant (*Phalacrocorax pelagicus)*	*Least Concern*	-	*Yellow*	*300*	*Underestimated;*
common murre (*Uria aalge inornaata)*	*Least Concern*	-	*Red*	*200*	*Only 1 confirmed breeding site*

** These are rough estimates only and those with an *asterisk are particularly speculative.

In addition to their detrimental impacts on seabirds, invasive rats have impacts on forest songbird diversity and abundance Parks Canada Agency 2011b). In a nest predation study using planted quail eggs, researchers noted significantly higher rates of predation on islands with rats compared to rat-free islands leading to speculation that songbirds on Haida Gwaii exhibit less anti-predator behaviour than their counterparts from elsewhere (Martin et. al., 1994). Rats have caused the disappearance of the Keen's Mouse (*Peromyscus keeni*) on both Langara Island (Cowan (1989) and on the Bischof Islands in Gwaii Haanas (Bergman, unpublished data); a decline in the same species attributed to rats has also been observed on Kungit (Guiget, field notes 1946; Foster 1965; Westland Resource Group, 1994; D. Burles unpublished data) .

Abundance of dusky shrews (*Sorex monticolus*) is also likely impacted by rat presence. Harfenist (1993) found shrews to be present, but at relatively low densities on Langara Island prior to rat eradication.

The recovery of several federally-listed Species-at-Risk that inhabit Haida Gwaii, including the Northern Goshawk (*Accipiter gentilis laingi*), Northern Saw-whet Owl (*Aegolius acadicus brooksi*) and Haida Ermine (*Mustela ermine haidarum*), are threatened by rats. In addition to direct predation on nests and young, rats also compete with these species for prey (Northern Goshawk Recovery Team, 2008; Haida Ermine Recovery Team, 2007).

Table 2: Designated species under Canada's Species-at-Risk Act that may be found on Murchison and Faraday Islands.

Common Name	*Scientific Name*	*Federal SARA status*	*Likelihood of Breeding on Murchison/Faraday*	*Likelihood of Occurrence on Murchison/Faraday*
Northern Goshawk, *laingi* subspecies	*Accipiter gentilis laingi*	Threatened (Schedule 1)	Low	Low
Northern Saw-whet Owl, *brooksi* subspecies	*Aegolius acadicus brooksi*	Threatened (Schedule 1)	Confirmed	Confirmed
Great Blue Heron, *fannini* subspecies	*Ardea herodias fannini*	Special Concern (Schedule 1)	Confirmed	Known Presence
Haida ermine	*Mustela erminea haidarum*	Threatened (Schedule 1)	Unlikely	Unlikely
Western toad	*Anaxyru boreas*	Special Concern (Schedule 1)	Unknown	Unknown

Murchison and Faraday Islands are historically important areas for nesting seabirds. In 1977 Murchison Island supported 800 breeding pairs of ancient murrelets and 200 pairs of Cassin's auklets, as well as pelagic cormorants, glaucous-winged gulls and pigeon guillemots (Campbell and Garrioch, 1979). But by 1985, with signs of rats evident, surveys estimated the breeding population of ancient murrelets at 20 pairs and only 50 pairs of Cassin's auklets (Rodway et al., 1988). More recent surveys in the late 1990s and 2000s have found only black oystercatchers, pelagic cormorants and pigeon guillemots nesting on this island (Parks Canada, unpublished data).

Faraday Island has been the site of less survey activity but one survey (with limited search effort) conducted in 1977 found no signs of burrow nesting seabirds (Rodway et al., 1988). Because of its close proximity to Murchison, it is likely that rats colonizing Murchison have colonized Faraday at the same time.

Murchison and Faraday Islands have also supported at least nine nesting sites for bald eagles and there are a number of additional eagle nest sites on adjacent islands (Parks Canada unpublished data). Monitoring of annual fledging success of bald eagles within Gwaii Haanas indicates that annual fledging success between 1998 and 2011 was higher (94%) on rat-free islands, compared to rat-infested islands (62%); further, it was speculated that this is most likely due to the presence of seabirds which are a low-cost food source for eagles (Bergman and Burles, unpublished data).

2.7 Socio-cultural Values and Impacts of Rats

Seabirds have played a significant cultural role in Haida life pre-contact and throughout the early 20th century. Oral history interviews (Blackman 1979; Ellis, 1991) and archaeological excavations (Acheson, 1998; Fedje et. al, 2001) have documented the use of seabirds by the Haida for the purposes of dietary and ceremonial use. Seabirds feature largely in the story-telling and songs of the Haida people. Historically, seabirds and their eggs provided seasonally abundant food sources. Small alcids such as ancient murrelets and Cassin's auklets dominated the diet during the nesting season, and nesting colony locations were well known. Birds were dug out of the burrows at night, and fires were used to disorient birds (B. Wilson, pers. comm.). Glaucous-winged gulls were of sufficient importance that nesting sites were inherited property of specific lineages. Today, the collection of gull eggs still occurs at some sites in Skidegate (B. Wilson, pers. comm.).

The raven (*Corvus corax*) and the bald eagle (*Haliaeetus leucocephalus*) are culturally significant birds to the Haida. All Haida persons are born into the Raven or the Eagle moiety, which are further divided into lineages or families. Marriage takes place between Eagles and Ravens, rather than within the same moiety. Haida children become members of the same moiety as their mother. Because of the cultural significance of these animals to the Haida, there will be a high level of scrutiny on the well-being of these species during, and as a result of, the eradication.

The Council of the Haida Nation, through the Archipelago Management Board and its involvement in the management of Gwaii Haanas, is supportive of reducing and/or eliminating the negative impacts of rats on culturally significant seabird populations and on other natural and cultural resources of Gwaii Haanas (including totemic animals such as Ravens and Eagles). The Gwaii Haanas Management Plan calls on Parks Canada and the Haida Nation to "*prepare and implement [plans] to manage introduced species in order to minimize their impact on indigenous species and their habitats*" (AMB, 1998).

3.0 REMOVAL OF RATS FROM MURCHISON AND FARADAY ISLANDS

3.1 Global and National Context for Eradications

Removal of invasive species can reverse cascading detrimental ecosystem effects and prevent extirpations and extinctions. Eradications of invasive rodents from islands are technically feasible, and worldwide there have been over 445 successful rodent eradications (Island Conservation 2012). Increasingly, larger islands are being undertaken. For example, in 2011 bait was applied to Macquarie Island, Australia (13,000 ha) to eradicate rabbits, ship rats and mice. To date no sign of rats or mice has been found although it is too early to confirm success (P. McClelland pers. comm.). Currently a Norway rat eradication project is underway on the 375,500 ha sub-Antarctic South Georgia Island where rats are thought to inhabit approximately 90,000 ha of the island that is ice-free. The goal of this project is to prevent extinction of the native South Georgia pipit (*Anthus antarcticus*) and to increase the number of breeding seabirds by the millions.

In Canada, rodent eradications have occurred only on Haida Gwaii. In 1997, the Canadian Wildlife Service successfully eradicated Norway rats from Langara Island and prevented the extirpation of the Ancient Murrelet from its largest breeding colony in the world (Kaiser et.al., 1997). Parks Canada completed a successful eradication of Norway rats from St James Island in 1996 (Golumbia, 2002). In 2011, Parks Canada, Island Conservation and Coastal Conservation undertook a Norway rat eradication from the Bischofs Islands and Arichika Island. Success of these latter eradications will be determined in 2013 although preliminary results suggest that both islands are currently rat-free.

The eradication of black rats from Murchison and Faraday Islands (~800 ha) is well within the standard size range of island eradications and, while these islands have their own unique biological, cultural and logistical challenges, is technically feasible.

3.2 Rodenticides

Currently, the use of bait containing a rodenticide is the only known technique that has a high probability of achieving 100% eradication success (Howald et. al. 2007). The rodenticide used for eradication must have a high likelihood of achieving eradication success while balancing potential negative consequences, such as the risk of non-target poisoning. From an eradication perspective, the rodenticide must:

- contain an active ingredient that is known to be lethal to rats;
- be delivered into the every rat territory on the target island; and
- be consumed in sufficient quantities by every single rat in order to achieve a lethal dosage.

Currently there are eight rodenticides that are registered with the federal Pest Management Regulatory Agency (Table 3). These rodenticides can be divided into the following categories based on their mode of action:

1. Acute action non-anticoagulants: bromethalin and zinc phosphide; and
2. Chronic action anticoagulants, which can be further subdivided into:
    - first-generation anticoagulants: warfarin, chlorophacinone and diphacinone; and
    - second-generation anticoagulants: brodifacoum, bromadiolone and difethialone.

Table 3: Rodenticides registered in Canada and associated properties (Health Canada, 2009. Table adapted from Howald *et. al*., 2007).

Rodenticide	Biological Half-Life in Tissue	Rodenticide Category	Efficacy			Public Health		Non-Target Species		
								Birds		Inverts
			Previous Success in Island Restoration	Activity	Bait Shyness	Danger to Humans	Antidote Available	**Primary**	**Secondary**	Primary
Brodifacoum	Long	Anticoagulant	High	Single-Feed	Low	Low	Yes	Very High	Very High	No
Difethialone	Long?	Anticoagulant	None	Single-Feed	Low	Low	Yes	Very High	Very High	No
Bromadialone	Long	Anticoagulant	Low	Single-Feed	Low	Low	Yes	High	High	No
Chlorophacinone	No Data	Anticoagulant	None	Multi-Dose	Possible	Low	Yes	Moderate	Low to Moderate	No
Diphacinone	No Data	Anticoagulant	None	Multi-Dose	Possible	Low	Yes	Moderate	Moderate	No
Warfarin	Short	Anticoagulant	None	Multi-Dose	Possible	Low	Yes	Very Low	Low	No
Bromethalin	Short	Sub -Acute	None	Single-Feed	Likely	High	No	Very High	Low	Yes
Zinc Phosphide	None	Acute	None	Single-Feed	Likely	High	No	High	Low	No Data

3.2.1 Non-anticoagulant Rodenticides

Acute rodenticides like zinc phosphide, bromethalin, strychnine kill rodents quickly after a single feeding. The major benefit of acute rodenticides is that the animals die quickly before they build up high levels of rodenticide in their tissue, which reduces the risk/incidence of secondary poisoning. However, there are two drawbacks to the use of acute rodenticides. First, they are often extremely toxic to non-target species, including to humans and effective antidotes are not always available. Second, they can induce neophobia (avoidance behaviour) if animals consume a sub-lethal dose. Rodents encountering a new food for the first time will normally test feed and may not take a substantial quantity for many hours, or even days (Buckle et al. 1987). If the bait containing the rodenticide causes distressing symptoms during the test feeding period, the rodent is intelligent enough to recognise cause and effect and becomes 'bait shy'. This was shown during studies with zinc phosphide which demonstrated that rats associate toxic symptoms with a bait if onset of symptoms occurs within 6-7 hours of consumption (Lund 1988). Thus, any individual that survives following the ingestion of a bait containing a non-anticoagulant rodenticide is likely to avoid the bait in the future (Record and Marsh 1988). These characteristics are likely the reasons why non-anticoagulant rodenticides have never been used to eradicate rats from islands.

3.2.2 Anticoagulant Rodenticides

The anticoagulant rodenticides were developed in the 1940s and their advantages of unsurpassed efficacy and safety quickly resulted in their use dominating the practice of rodent control in temperate countries. All anticoagulant rodenticides act by blocking the vitamin K1 dependent oxidation-reduction cycle in the liver. The production of clotting factors is consequently critically reduced and eventually, when the supply of factors already present has degraded, the clotting mechanism fails and internal haemorrhaging begins leading to death (Taylor 1993). Because illness is delayed, rats generally do not develop bait avoidance behaviour and will continue consuming bait until a lethal dose is attained.

Currently six different anticoagulant rodenticides are registered with Health Canada's Pest Management Regulatory Agency (PMRA). These can be further subdivided into first-generation anticoagulants (warfarin, chlorophacinone, and diphacinone) and second-generation anticoagulants (brodifacoum, difethialone, bromadiolone). First generation anticoagulants require multiple feedings over a period of days to reach a lethal dose. The second- generation anticoagulants are able to induce mortality after a single-feed.

3.2.2.1 First Generation Anticoagulants

The primary advantage of first generation anticoagulants (warfarin, chlorophacinone, diphacinone) for eradication operations is the reduced risk[1] they pose to birds in comparison to second generation anticoagulants such as brodifacoum (Fisher 2009, 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), although the overall toxicity of diphacinone still remains low compared with brodifacoum. The disadvantage of this anticoagulant is the requirement for multiple feedings over several days in order to achieve lethality, which decreases the probability of a successful eradication as bait needs to be available for a longer time period and some individual animals may become 'bait shy' possibly resulting in a failed eradication.

A second major disadvantage of first generation anticoagulants is potential for genetic resistance. Warfarin resistance was discovered first in *Rattus norvegicus* in the UK (Boyle 1960). Resistance was also detected in *Mus domesticus* (Rowe and Redfern 1965) and in *Rattus rattus* (Greaves et al. 1976). Concern increased when it was found that cross-resistance

[1] However, the risk is not entirely eliminated.

existed to all first generation anticoagulants (Rowe and Redfern 1965, Greaves and Ayres 1969, Hadler and Shadbolt 1975).

Out of 41 island rat eradication attempts where a first generation anticoagulant was used, 28 were either declared a success or failure (USFWS 2011). Failure was declared in 54% of the cases suggesting that alternative rodenticides or possibly a combination of rodenticides (e.g. diphacinone and brodifacoum)[2] may be better suited to island eradications (Parkes et al. 2011). Diphacinone is the only first generation anticoagulant that has been used for more recent rat eradications from islands (Parkes et al. 2011)

3.2.2.2 Second Generation Anticoagulants

The term 'second generation anticoagulant' was coined to describe compounds (brodifacoum, bromadiolone, difethialone) that were effective against rodents resistant to previously available products (first generation anticoagulants) and considerably more potent (Hadler and Shadbolt 1975). Unlike first generation anticoagulants, second generation anticoagulants such as brodifacoum can induce mortality after a single feeding.

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 haemorrhage, which in turn, causes fatal haemorrhaging usually from a single point or multiple locations. Death typically results from complications due to hypovolemic shock. The major advantage of the second generation anticoagulants is that the onset of poisoning symptoms is delayed until after consumption of a lethal dose. Thus, it is believed that rats do not associate the symptoms of poisoning with the bait containing the rodenticide and bait shyness is avoided.

Brodifacoum is the active ingredient in many off the shelf rodenticide baits that are available to the public and is the most frequently used rodenticide in successful rodent eradication projects. Based on a review of 332 island eradications by Howald et al. (2007), brodifacoum was used in 71% of successful campaigns and on 91% of the total area of islands eradicated of invasive rodents, making it the most widely used rodenticide for island eradications. Brodifacoum has been used in the three largest rat eradications to date (Macquarie, Campbell, and Kapiti, P. McClelland pers. comm.). The largest eradication attempted to date, which is currently underway on sub-Antarctic South Georgia (375,000 ha with 90,000 ha treated) is using aerial applications of brodifacoum to eradicate mice and rats from the island (South Georgia Heritage Trust 2010).
Detailed descriptions of brodifacoum and its effects on non-target species can be found in Taylor (1993), Kaukeinen (1993), and Howald (1997). The following discussion comes primarily from Taylor (1993) unless otherwise cited.

Absorption & Degradation in Soil

The half-life of brodifacoum in soil is from 84-170 days and it is less stable in alkaline soils. Degradation of brodifacoum by soil microbes results in non-toxic metabolites in microorganisms, and eventual reduction to its base components of CO_2 and H_2O.

Half Life in Living Organisms

The half-life of brodifacoum in the tissue of living organisms is about the same as that in soil 150-200 days. However, there is some evidence that it may be somewhat longer. In rats, and perhaps other mammals, 75% of a lethal dose is maintained in the liver, the rest is absorbed into other tissue at a variable rate.

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[2] Using a combination of rodenticides can increase the complexity of a project (P. McClelland pers. comm.).

Soil Mobility of Brodifacoum

Brodifacoum is not soluble in water and will not migrate from the land to the water supply or ocean. Because brodifacoum remains absorbed to soil, only erosion of the soil will result in it reaching the water. However, it would remain absorbed to organic material and settle out into the sediment, which would be widely dispersed and diluted by waves and current action.

Uptake by Plants

Field tests have shown no significant transfer of brodifacoum from soil to grass, even at applications rates 15 times higher than normal rates of application on rangelands. No brodifacoum was detected in samples of grasses collected post eradication on East Anacapa Island (Howald et al. 2010). Plants are not known to be susceptible to toxic effects of brodifacoum.

Effects on Marine and Terrestrial Invertebrates

Anticoagulant rodenticides are not known to affect invertebrates likely because of their different blood clotting systems. Extensive field and lab trials have shown that tinibrionid beetles (Tershy et al. 1992), land crabs (Pain et al. 2000), snails, slugs (Howald 1997), and ants (B. Tershy, unpubl. data) do not show any adverse response to a diet of 20-50 ppm brodifacoum. However, sublethal effects of brodifacoum on invertebrates have not been considered. Studies have reported that the residue levels in marine invertebrates such as crabs exposed to a rodenticide decline rapidly to near non-detectable levels within 2 months of the broadcast, which suggests that either retention time and/or metabolism of the rodenticide is quick (Primus et. al. 2005, Wegman et. al. 2008). For example after the Anacapa Island rat eradication no brodifacoum was detected in shore crabs, hermit crabs, mussels or tide pool sculpins (Howald et. al. 2010).

Effects on Fish

Some fish species may be at risk of both a primary and secondary exposure to the toxicant by eating bait containing the rodenticide directly as it drops through the water column or through the consumption of aquatic invertebrates that have fed on bait containing the rodenticide (Alifano and Wegmann 2010). Little is known about the effect that brodifacoum has on fish. Some studies reported marine fish species eating non-toxic bait pellets dropped into the sea and some mortality was reported in an aquarium trial where marine fish were exposed to relatively high concentrations of bait containing brodifacoum in water (Emperson and Miskelly 1999). P. McClelland (pers. comm.) reported that blue cod (*Parapercis colias*) tested positive for brodifacoum exposure following an aerial eradication operation on Ulva Island, New Zealand in 2011 although no further information was available. However:

- In bait disintegration trials on Desecheo Island (Puerto Rico), placebo Brodifacoum-25D test baits had either disintegrated or been flushed from the immediate environment within 30 minutes, and fish were largely uninterested (Island Conservation 2010b)
- In bait disintegration trials in New Zealand, non-toxic test baits distributed in the sea disintegrated within 15 minutes (Empson and Miskelly 1999).
- In tests in southern California, Alaska, Hawaii and the equatorial Pacific, marine fish species have mostly demonstrated no interest in placebo bait pellets that entered the water nearby (Howald et al. 2005a, Buckelew et al. 2006, Island Conservation unpubl. data). In tests on Palmyra atoll, 20 fish species showed no interest in bait pellets dropped into the water column during the first three trials. However, in subsequent trials, six fish species ‘mouthed’, grabbed or ate bait pellets, indicating that increasing exposure might increase a response in fish (Island Conservation 2010a).

- Surveys of marine fish after rat eradication on Kapiti Island (New Zealand) showed no evidence that fish densities were affected by the operation (Empson and Miskelly 1999).
- After an accidental spill of 20 tonnes of brodifacoum bait into marine waters in New Zealand in 2001, measureable concentrations of brodifacoum were detected in the water 36 hours after the spill, but which were below Mean Level Detector limits (MLD, < 0.02 ppm) by day nine. Residues in fish samples collected 14-16 days after the spill were below MLD (Primus et al. 2005).
- During rat eradication on Anacapa Island divers observed fish behaviour in relation to bait that accidentally entered the marine environment; no fish were observed consuming bait. All fish and seawater samples tested negative for brodifacoum concentration post application (Howald et al. 2010).

If bait does enter the water during an eradication operation on Murchison and Faraday islands, it will be available immediately after entry but disintegrate and disperse rapidly, often within minutes or hours by tidal action (Buckelew et al. 2006). The extent of risk therefore applies only to a limited number of individuals.

Effects on Amphibians & Reptiles

There are, to our knowledge, no published studies on the toxicity of brodifacoum to amphibians. However, amphibians and reptiles may be at risk from consuming insects that have fed on the rodenticide bait. The Western toad (*Bufo boreas*) is the only amphibian native to Haida Gwaii (Matsuda et al. 2006). No reptiles are present on Haida Gwaii.

Effects on Mammals

Terrestrial mammals

Rats are highly susceptible to brodifacoum and usually a single feeding on bait containing the rodenticide can cause mortality. Other animals with similar blood clotting mechanisms are also highly susceptible although the toxicity of brodifacoum varies in mammals and birds. For example, reported LD_{50} values are highly variable for mammals ranging from $\leq$1mg/kg for rodents, 0.25-3.6 mg/kg for dogs, and 5-25mg/kg for sheep (Eason and Spur 1995).

Marine Mammals

Marine mammals of two orders, *Cetacea* and *Pinnipedia* have been observed in Juan Perez Sound, Haida Gwaii. The primary diet of marine mammals found in the waters around Murchison and Faraday or utilizing various haul out points is fish (e.g. harbour seals, stellar sea lions). Therefore, there is no risk of a marine mammal consuming bait or dead and/or dying rats. However, there is a very low risk that marine mammals may consume fish that have been exposed to the bait containing the rodenticide (secondary and tertiary poisoning risk, see *Effects on Fish* section above for more information regarding the probability of fish ingesting bait). Given the size of marine mammals an individual would need to ingest a significant number of fish exposed to the rodenticide within a very short time frame before they would be considered at risk of secondary poisoning (USFWS 2007). This is a very unlikely scenario given the methods that will be in place to minimize bait entering the marine environment during an eradication operation on Murchison and Faraday islands.

Humans

Brodifacoum is potentially toxic to all mammals including humans. Although there may be some skin irritation caused by contact with bait, poisoning is only likely if ingested. The lethal dose of brodifacoum for a human is likely between 0.28 – 25 mg/kg (based on the range of toxic doses in five species of mammals). Even if a person did consume a lethal dose of bait, death is extremely unlikely because brodifacoum is slow acting and the symptoms are treated with the antidote vitamin K1. In fact, there are no recorded cases of accidental poisonings of humans caused by brodifacoum, even though brodifacoum is the most widely used second-generation anticoagulant rodenticide in the world (Taylor 1993).

Effects on Birds

Brodifacoum is highly toxic to birds although the risk is highly variable among species. The bird species present on Murchison and Faraday islands that are most likely to directly consume bait, poisoned rats, or non-target species exposed to the rodenticide are granivorous songbirds, scavengers and predatory birds (see section *3.8 Potential Impacts and Mitigation of Risk to Native Species for more information*). Published LD_{50}'s for the non-target birds found on Murchison and Faraday islands are not available but published LD_{50}'s for several different passerine birds range from 3.0-6.0 mg/kg. For an untested bird species there is a 95% probability that its LD_{50} will be above 0.56mg/kg (Howald 1997).

During the 2008 Rat Island, Alaska eradication project 320 Glaucous-winged Gull carcasses were recovered and toxicology tests implicated brodifacoum in 24 of the 34 tested (Salmon & Paul 2010). It was theorized this species ingested rodenticide bait pellets (primary poisoning pathway) and possibly also dead or dying rats (secondary poisoning pathway). Although possible, it is unlikely that this situation would be replicated on Murchison and Faraday islands due to the significant crown closure, which would limit visibility of the rodenticide bait and dead or dying rats to coastline scavengers such as Glaucous-winged Gulls

3.2.2.3 Brodifacoum vs. Diphacinone from a Rat Eradication Perspective

Two types of anticoagulant rodenticides have proven successful at eradicating invasive rats and mice from islands: brodifacoum and diphacinone (Parkes et al. 2011). When data on attempts to eradicate rats and mice for both aerial and ground-based methods are combined, brodifacoum has a significantly lower failure rate at 17% (54 of 322 attempts) than diphacinone at 33% (13 of 39 attempts, Parks et. al. 2011). However, due to the risk of non-target poisonings associated with brodifacoum, there is interest in the conservation community to investigate the feasibility of using less toxic alternative compounds for rodent eradication purposes (Brakes and Smith 2005; Donlan et al. 2003; DuVall et al. 1989; Fishel 2005; O'Connor and Eason 2000). Diphacinone, a first-generation anticoagulant, is the most commonly considered alternative compound because it presents less risk to non-target birds as compared to brodifacoum (Howald et al. 2007; Erickson and Urban 2004). Because multiple feedings are required to achieve a lethal dosage non-target species that opportunistically or accidentally consume pellets (primary exposure poisoning) are much less likely to ingest a lethal amount of diphacinone (Hoare and Hare 2006)[3]. Furthermore, incidental ingestion or transfer of diphacinone through the food web is significantly reduced. Thus, predatory and scavenger species are also less likely to consume a lethal amount of diphacinone when preying on dead or dying rats exposed to the rodenticide because diphacinone is metabolized much faster than brodifacoum, resulting in low tissue levels. Although the results of diphacinone-based field experiments clearly point to reduced risk to birds, the likelihood of non-target poisoning is not eliminated especially because rats require multiple feedings over several days in order to achieve lethality. The presence of bait containing diphacinone in the environment for an extended period of time, and in sufficient quantities to ensure that all rats receive a lethal dosage, increases the risk of primary non-target poisoning.

The successful eradication of rats on islands using rodenticide baits is dependent upon several factors including overcoming neophobia and ensuring that rats ingest enough bait to die. Although diphacinone generally presents less risk to non-target species compared to brodifacoum, the requirement for multiple-feeding increases the risk of

[3] A rat must eat diphacinone bait every day for up to a week in order to obtain a lethal dose (Parks et. al. 2011).

eradication failure (Donlan et al. 2003). Rats encountering a new food for the first time will normally test feed and may not take a substantial quantity for many hours, or even days. If the bait causes distressing symptoms during the test feeding period, the rat may recognize cause and effect and becomes 'bait shy.' Furthermore, this learned avoidance can be communicated to other rats who will also become bait shy (Jackson 1982). Furthermore, diphacinone at higher concentrations is known to reduce palatability of baits (P. Martin, Bell Laboratories, pers. comm.).

All other operational considerations being equal, the task of ensuring that all rats encounter enough bait to attain 100% mortality is less certain to succeed when using diphacinone than when using brodifacoum. Additionally, rats that survive a diphacinone bait application:

1. could be resistant to, or tolerant of first generation anticoagulants (e.g. diphacinone);
2. may avoid bait after experiencing distressing symptoms or due to bait palatability issues; or
3. may experience a combination of these factors.

These rats, and possibly their offspring, could consequently be more difficult to eradicate from the islands during subsequent eradication attempts.

At a basic level, from the perspective of operational efficacy, brodifacoum is a better choice for rat eradication than diphacinone because the higher toxicity and efficacy of brodifacoum means there is a greater probability of eradication success. In addition, a greater efficacy is more important for bait broadcast delivery than for bait station delivery where bait can be made available for long periods of time. Rat eradication using brodifacoum has proven successful using either one or two aerial bait applications. For diphacinone, only a few eradication projects have used aerial application, meaning a strategy for aerial application has not yet been extensively tested (Parkes et. al. 2011). Given the knowledge that diphacinone is physiologically more effective at low repeated doses and that successful eradications using bait stations have required diphacinone bait to be consistently available for long periods, aerial application of diphacinone would require multiple applications. Therefore, a brodifacoum eradication using aerial techniques is more cost-efficient and more effort-efficient than a diphacinone broadcast, which might demand up to four broadcast applications over a period of 30 days or more in order to make bait consistently available for the required period.

The higher toxicity of brodifacoum also renders the eradication at less risk of failure. Diphacinone delivered by aerial broadcast has successfully eradicated rats only once and failed five times (Parkes et. al. 2011). The multiple-feed requirement of diphacinone as a contributor to operational failure for aerial applications cannot be ruled out. On Lehua Island, Hawaii, where aerial broadcast of diphacinone in 2009 failed to eradicate rats, island managers believed that the success of the operation was compromised by unanticipated regulatory actions that prevented implementers from conducting more than two broadcast applications as well as limited bait broadcast around the coastline. In comparison, brodifacoum delivered by aerial-broadcast has been used successfully for rodent eradications on 137 out of 149 attempts (Parkes et al. 2011)).

Bait palatability is an important aspect that can impact the success of a rat eradication operation. In field trials, the products Brodifacoum-25D™ (Bell Laboratories, Madison, WI) and Ramik Green™ (a diphacinone based product) have both been shown to be preferred by most rats over locally available natural food sources . However, in a recent laboratory free-choice food trial designed to determine the efficacy of different rodent baits, the percentage palatability (bait consumption / total food consumption) of Ramik Green™ diphacinone product was only 60 to 70 percent in black rats and 50 to 54 percent in Polynesian rats (*Rattus exulans*) in a 3-day test (Pitt et al. 2011). In addition, the Ramik Green™ product achieved only 40 percent mortality in black rats and 20 percent mortality in Polynesian rats. Overall, this diphacinone formulation was the only product tested that did not achieve at least 80 percent mortality for a single rodent species in both 3-day and 7-day trials. The low efficacy of this diphacinone-based product was likely the result of low overall product toxicity, limited exposure times, and low palatability compared to other products (Pitt et al. 2011). It is difficult to determine the exact cause of the low efficacy without undertaking additional experiments, therefore, the risk associated with using Ramik Green™ for the Murchison and Faraday islands eradication is significantly high and thus not recommended.

From an operational perspective, the essential difference between application of diphacinone and brodifacoum to eradicate rats from Murchison and Faraday islands would be that quantities of diphacinone must remain relatively consistent over a period of up to 12 days. With a brodifacoum eradication operation, a rat that ingests a lethal dose of bait on day one will likely not need to ingest bait again because brodifacoum has a high binding affinity and is metabolized slowly. With a diphacinone operation, bait must be available to all rats for up to 10 - 12 days; this requires that (a) the bait is highly attractive to rats to ensure that rats prefer it above natural food items, (b) that sufficient bait is available daily to ensure rats frequently encounter bait within their environment, (c) that the consistent bait uptake in the environment through ingestion by rats and other animals, and degradation by invertebrate, microbial and other environmental action does not diminish the amount of bait available to the level at which sufficient bait is no longer daily available for ingestion by rats. More generally, it seems that the tested double-baiting strategy proven for aerial application of brodifacoum baits cannot be simply copied for diphacinone aerial baiting (Parkes et al. 2011).

From the perspective of likelihood of eradication success, brodifacoum is a better choice than diphacinone due to its higher toxicity and extensive proven record. This conclusion does not eliminate diphacinone from full consideration for the proposed action, because diphacinone has also been used successfully to eradicate rats from an island. Furthermore, use of diphacinone imparts a considerably lower risk to non-target species than brodifacoum. Regardless, the difference in the predicted likelihood of success of brodifacoum in comparison to diphacinone should be an important consideration when deciding between the alternatives presented here and should not be overshadowed by concern for any potential non-target impacts, especially non-target impacts that would not affect species at a population level; the need to ensure eradication success is critical. A failed eradication attempt would provide no conservation returns in the long term since rats would quickly re-establish throughout the island (Howald et al. 2005). The most cost-effective conservation returns on rat eradication investment is through a successful eradication on the first attempt.

3.2.2.4 Other Toxins Considered for Rat Eradications

The use of non-anticoagulant rodenticides was dismissed from further consideration for one or more of the following reasons:

1. A lack of proven effectiveness in island rat eradications;
2. The potential for development of bait shyness in the rat population;
3. Potential for genetic resistance (e.g. Marsh 1987); and
4. The unavailability of an antidote in case of human exposure.

The vast majority of rat eradication projects occurring on islands (587 to date, Island Conservation 2012) have used brodifacoum or similar so-called “second-generation” anticoagulants, while only 52 have used “first-generation” anticoagulants such as diphacinone (Island Conservation 2012). Of the nine eradications that have used non-anticoagulant toxins (such as zinc phosphide, strychnine, and cholecalciferol), none have occurred on islands larger than 22 ha, making them untested as effective toxins for larger island eradications (Howald et al. 2007. See section *3.2.1 Non-anticoagulant Rodenticides* for more information on these rodenticides).

3.2.3 Recommended Rodenticide for Murchison and Faraday Islands Eradication

The second generation anticoagulant brodifacoum is recommended for the Murchison and Faraday islands eradication. This is currently the preferred rodenticide for rat eradications around the world given its efficacy compared to a first generation anticoagulant such as diphacinone, which require multiple feedings thus increasing the risk of eradication failure. The potential negative effects of brodifacoum on native species can be minimized through the mitigative activities described in *Section 3.6 Potential Impacts and Mitigation of Risk to Native Species.*

Bait Palatability & Composition

For the Murchison and Faraday islands eradication the brodifacoum-based bait must be palatable and demonstrate low or no bait neophobia. To achieve this, the bait should be comprised of a high-quality grain matrix compressed into ~2 g pellets containing brodifacoum at a concentration of 25 ppm. The bait pellets should maintain their integrity in the wet, maritime conditions. The bait pellet should not contain human or pet taste aversion additives, such as Bitrex, which has been shown to reduce the palatability of the bait to rats.

From a non-target perspective, pellets should also be designed to be too large for small passerines such as sparrows to easily consume. Pellets should also be dyed blue/green, which has been suggested to make pellets less attractive to some birds (Pank 1976, Tershy and Breese 1994, Buckle 1994). Chaff, the dry, scaly protective casings of the seeds of cereal grain should be minimised to further reduce attractiveness of the bait to small birds (P. McClelland pers. comm.).

There are no pelleted bait products matching the requirements available in Canada, however, a US registered Brodifacoum 25W (Bell Laboratories, Inc, Madison, Wisconsin) bait product has been used to successfully to eradicate rats on 11 islands in the US and its territories.

Bait Registration

Pesticides imported into, sold or used in Canada are regulated nationally under the Pest Control Products Act and Regulations (PCPA). Health Canada' s PMRA is responsible for administering this legislation, registering pest control products, re-evaluating registered products and setting maximum residue limits under the Food and Drugs Act.

Companies that wish to have the right to sell a pest control product in Canada must submit detailed information and data that is evaluated by the PMRA. Materials must include scientific studies necessary to determine that the product is acceptable in terms of safety, merit and value. Depending on the complexity of the submission, a complete evaluation can take anywhere from a number of weeks, to a year or more.

Pesticides are classed federally as Domestic (for use around homes), Commercial (for use in agriculture, forestry, landscape, structural and other industries), or Restricted - commercial pesticides with certain limitations on the label. Currently the only rodenticide bait registered by the PMRA for conservation purposes is Brodifacoum Conservation Blox™ manufactured by Bell Laboratories, Madison, WI[4]. The specific usage of Brodifacoum Conservation Blox™, which contains 25ppm of brodifacoum, is for the eradication or control of Norway and black rats and house mice for the protection of threatened nesting seabirds and/or native species and their habitat. The use of this rodenticide bait is permitted only by or under the supervision of the federal or provincial government conservation agencies such as the Canadian Wildlife Service, Parks Canada and/or Ministry of Environment in compliance with recommendations of the

[4] Approved by the PMRA in 2011.

required environmental impact assessment and other provincial or territorial requirements. Brodifacoum Conservation Blox™ must be placed in tamper-resistant bait stations[5] and is not approved for aerial broadcast applications.

Currently, there is no aerially broadcasted rodenticide bait registered under PMRA for conservation purposes. Brodifacoum 25 W[6] bait for use on Murchison and Faraday eradication will need to be registered with PMRA prior to project implementation. There is significant amount of both laboratory and field data from the United States that can be used to support the registration of Brodifacoum 25W in Canada (G. Howald pers. comm.). However, additional field data will likely need to be generated to support the registration and to understand the efficacy and risks to the local environment. Parks Canada will coordinate consultation with both Bell Laboratories and PMRA to understand the process for registration and data requirements. It is likely that an initial field trial on adjacent smaller islands to measure both efficacy and environmental risks (non-target impacts, penetration of the rodenticide into the ecosystem) will be needed to support the registration.

There are two rodenticide bait registration options with PMRA:

Option 1: For product-use approval over a longer time period (e.g. > 8 months), a permanent product registration could be pursued. The product registration requires a company or agency to submit detailed project information and data to Health Canada. This information is used to determine if the health and human risks of the product are acceptable and whether the product has value. In this case, Bell Laboratories would apply as the product registrant with support by and use in association with a federal biological agency (e.g. Parks Canada) for conservation purposes.

The timeline for evaluation depends on the complexity of the application and because an aerial broadcast of rodenticide bait has never occurred in Canada to date it is prudent to assume that the review process would be lengthy (e.g. ≥1 year) and require significant supporting data. Fortunately, rodenticide products with comparable formulations have been approved in the US for several years (e.g. Bell Laboratories Conservation 25W (for wet conditions) and 25D (for dry conditions) bait with brodifacoum) and in New Zealand (Pestoff® Rodent 20R containing brodifacoum). Furthermore, the aerial broadcast technique has been used in numerous successful eradications in the US, New Zealand, Mexico and other parts of the world. Therefore, the data required by PMRA, such as laboratory and field toxicity studies, would be readily available.

Option 2: For product-use approval in a short time period (e.g. <8 months), an application for a Chemical Pesticides Research Permit is the only feasible option. A research permit allows a research establishment (e.g. Parks Canada) to conduct research with an unregistered pest control product.

There are three basic divisions of research[7]:

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[5] Brodifacoum Conservation Blox™ was specifically approved for the Bischof and Arichika Norway rat eradication that was undertaken in 2011.

[6] 25W means 25 ppm brodifacoum with a wet climate formulation of inert components of the rodenticide bait pellet.

[7] Source: Health Canada Regulatory Directive: Chemical Pesticides Research Permit Guidelines (website: http://www.hc-sc.gc.ca/cps-spc/pubs/pest/_pol-guide/dir98-05/index-eng.php#application)

1. new use (new crop, rates, animal host, application method, tank-mix, etc.) for registered products;
2. new formulation and/or new uses for an active ingredient that is currently in a registered product; and
3. new active ingredients. This group is subdivided further into three categories according to type of personnel involved, total area, and available data.

Given that Brodifacoum Conservation Blox™ is already approved for conservation purposes by PMRA, a research permit for aerial application of rodenticide bait with the same concentration of brodifacoum (25 ppm) would fall under division #2 (new formulation and/or new uses for an active ingredient that is currently in a registered product). There are several data requirements for research permits under division 2 (Health Canada 2011) that may or may not apply to rodenticides, including:

1) Acute studies for new formulation;

2) Toxicology data listed as follows if these have not been previously submitted to the PMRA:
   a. Acute studies for technical;
   b. Acute studies for formulation;
   c. Two teratogenicity studies;
   d. 90-day feeding in two species;
   e. Mutagenicity;
   f. Toxicokinetics;
   g. Chronic/oncogenicity and reproduction (interim reports as minimum);
   h. Short-term study of appropriate duration and route of administration for exposure assessment; and
   i. Any other available toxicity studies.

The application is reviewed by the PMRA including an evaluation of the health and environmental risks, the proposed total land area to be treated and, in some cases, the value associated with the proposed research. The timeframe for reviewing a permit for a registered active ingredient (in this case brodifacoum) is approximately 90 days. Parks Canada would be the permit applicant in cooperation with Bell Laboratories. However, before proceeding with either option 1 or option 2 further engagement between Parks Canada Agency, Bell Laboratories and PMRA is required to determine the appropriate registration option for an aerially broadcasted rodenticide bait. The data required by PMRA for the application process is likely available via the rodenticide registrant (Bell Laboratories) as well as from published scientific literature on the active ingredient.

3.3 Rat Eradication Methodologies

Every invasive species eradication operation is different. However, there are three fundamental principles that maximize the probability of removing 100% of the target population (from Cromarty et al. 2002):

1. All rats must be at risk of the eradication technique;
2. Rats must be killed faster than they can breed/replace themselves; and
3. Immigration must be maintained at zero, or is manageable (i.e. be able to respond to and eliminate potential invaders)

In general, these considerations can be broken down into three objectives for eradication operations that use bait containing a rodenticide:

1. Deliver a highly palatable bait containing a highly efficacious rodenticide into every potential rat territory;
2. Whenever possible, time the bait delivery when the rat population is in the declining phase (not breeding) of its annual resource dependent population cycle. Rats are thus more likely to eat the bait presented to them and there is a low likelihood that weanling rats will escape bait exposure and repopulate the island;

3. Minimize the risks of potential non-target species exposure to the rodenticide wherever possible; and
4. Develop a biosecurity plan to minimise the risk of reinvasion.

The best method for the delivery of a rodenticide bait depends on island topography, habitat, economics, socio-political considerations, and vulnerability of non-target species (Howald et al. 2007). The delivery methods currently used for rodent eradications are:

- Bait stations;
- Aerial broadcast by helicopter;
- Hand broadcast; or
- a combination of these techniques.

Bait must be available long enough to ensure that all rats overcome any neophobia towards the bait and/or the delivery methods (for example, bait stations). Bait application rates must account for uptake by both target and non-target species including invertebrates.

A comparison of the characteristics of each bait delivery method is summarized in Table 4.

Table 4: Relative characteristics of bait distribution techniques for rodent eradication.

Eradication Technique	Efficacy	Rodenticide on ground	Quantification of bait uptake	Risk to non-target species		Vegetation impact (trail development, erosion)	Risk to human safety	Cost
				1^0	2^0			
Bait stations	High	Up to 2 years	Yes	Low	Low	High	High	High
Aerial broadcast	High	3 weeks	No	High*	Low*	Low	High**	Low
Hand broadcast	High	2 months	No	High*	Low*	Med	Med	Med

**Risk will depend on the time of year the eradication occurs and also if carcass collection is conducted.*
***Risk includes potential injury or death resulting from working with helicopters although no fatal accidents have occurred during any eradication operations to date.*

3.3.1. Bait stations

Bait stations distributed in a grid pattern on the target island is the oldest technique used in rodent eradication campaigns (Howald et al. 2007). Bait stations are enclosures with small entryways designed to be attractive to rodents but exclude humans and some non-target animals from consuming bait. Unlike the original bait station predecessors, which were made out of corrugated plastic tubing, or other materials, the modern bait station is a commercial grade, tamper-resistant design with a locking lid and an internal baffle to reduce bird access or station raiding by non-target species without compromising rat access (Figure6). However, rats can sometimes exhibit neophobic behaviour towards bait stations even after a long period of habituation (Parks Canada Agency 2012).

Figure 6: Aegis bait station used in Bischof and Arichika islands eradication (Photo: D. Gardiner).

Station placement typically ranges from 25x 25 m to 100 x 100 m, depending on the species of rat targeted and may be filled with four or more ~20 g wax-coated blocks containing 20-50 ppm anticoagulant rodenticide. During an eradication operation bait stations are visited daily to replenish any missing bait until the bait uptake slows or ceases (Figure 7). The stations are then checked every 3-5 days until the eradication enters the monitoring phase, which can last for up to two years (Thomas & Taylor 2002).

Figure 7: Conducting a bait station check on Bischof Islands (Photo: A. Wright).

For Phase I of Night Birds Returning we utilized a bait station approach on Bischof and Arichika Islands to eradicate Norway rats (Parks Canada, 2011). The bait stations appeared to successfully reduce primary bait exposure to some native species (e.g. granivorous, omnivorous, and/or curious birds or mammals, including river otter and deer) that may have been attracted to the bait stations. Using this same technique on Murchison and Faraday Islands would have both advantages and disadvantages.

Advantages

- Minimize primary exposure of the rodenticide bait to non-target species such as granivorous birds, corvids, deer, and raccoon.
- Ability to quantify and monitor/adjust bait application rates during the eradication; and
- Potential to remove the majority of the bait not consumed from the environment.

Disadvantages

- On larger islands, such as Murchison and Faraday a bait station approach is generally labour intensive and cost prohibitive due to the need for extensive infrastructure (trail clearing, multiple base camps) and a large field team (eradication team members as well as support staff);
- Significant potential to prolong direct and indirect exposure period for non-target species given length of time of bait station arming (up to two years);
- Installation and maintenance of bait stations is laborious and expensive;
- Damage caused by trail networks and erosion from frequent bait station checks;
- Regular visits to bait stations can result in disturbance of sensitive species;
- Bait stations cannot be placed on coastal cliffs, bluffs, or steep, rocky areas that are present on both islands. Such inaccessible sites can provide a safe haven for rats during an eradication;
- Bait station placement and arming can be at times dangerous for field personnel, especially for stations placed near cliffs;
- Access to a large number of qualified, dependable workers required for a bait station approach on Murchison and Faraday would be challenging given the small population on Haida Gwaii ;
- Due to the length of the operation it can be challenging to maintain high standards of data collection/analyses and avoid staff complacency over time in the later stages of an eradication;
- Inclement weather can prevent field teams from servicing bait stations (i.e. during the 2011 Bischofs and Arichika eradications, field teams were unable to regularly visit the bait stations during severe storm events due to safety issues);
- Cost is high compared to an aerial application given personnel effort required for large islands such as Murchison and Faraday.

3.3.2 Aerial broadcast

Aerial broadcast of pellet rodenticide bait has become the most common method of rodenticide delivery on large islands (greater than 100 ha) and has been used in the majority of successful eradications globally (Howald et. al. 2007). Over the last 30 years, continued refinements to this technique have increased likelihood of success and have resulted in reduced negative impacts to non-target species. To date more than 75% of the total area treated globally has been accomplished using aerial baiting techniques (Towns and Broome 2003, Howald et al. 2005, Howald et al. 2007).

Aerially broadcasting bait is operationally preferable to bait stations when sections of the target island are steep or otherwise inaccessible to foot traffic (i.e. unsafe to hand-deliver bait), if the island is large (reducing the practicality of hand broadcasting or the use of bait stations), and/or if a regimen of regular foot traffic on the island would likely cause substantial ecosystem or resource damage (through permanent trails, repeated disturbance to sensitive animals, and trampling of sensitive vegetation, Howald et al. 2007). In such cases, an aerial broadcast maximizes the likelihood of bait access to all individuals of the target species, reduces risk of failure, and is generally more cost-effective when treating larger islands. However, because a broadcast application increases the accessibility of the bait, many non-target species face a greater short-term risk of primary rodenticide exposure when compared to bait stations, where bait is less accessible to non-target species. This in turn can increase the risk of secondary poisoning.

Broadcast bait is typically a 1-2 g cereal pellet bait containing 20-25 ppm anticoagulant rodenticide. During an aerial eradication two applications of the bait is spread from a specialized bait hopper (bucket) slung beneath a helicopter (Figure 8). The hopper is 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 device (spinner).

Figure 8: Helicopter and specialized bait hopper for aerial baiting operations (Photo: Island Conservation)

Two applications of rodenticide bait are normally broadcast 7-14 days[8] apart to ensure that bait is on the ground long enough for every rat to encounter it including any young rats that may still be in the nest during the first application. The helicopter flies parallel, overlapping swaths across the island area, and overlapping swaths around the coastal perimeter with a deflector attached to the bait hopper in order to minimize bait spread into the marine environment. Bait application is guided by a precision GPS unit on board the helicopter to ensure the accurate placement of bait at target distribution rates (Figure 9).

Figure 9: Onboard TracMap GPS used to monitor aerial bait broadcast at Rat Island, 2008 (Photo: Island Conservation)

The incorporation of geographic positioning systems (GPS) and geographic information systems (GIS) technologies has increased the effectiveness and efficiency of invasive mammal eradications, including aerial-based rodent eradications (Lavoie et al. 2007). During an aerial eradication operation flight paths are monitored in near-real time from the GPS by GIS experts to ensure there are no gaps or areas free of bait coverage (Figure 10). However, it is Important to note that the GPS only shows the operational flight paths, not where the bait was distributed, which can be affected by wind and the position of the bucket (wind buffeting).

[8] This timing of the two bait broadcasts can vary depending on local environmental conditions as well as other factors.

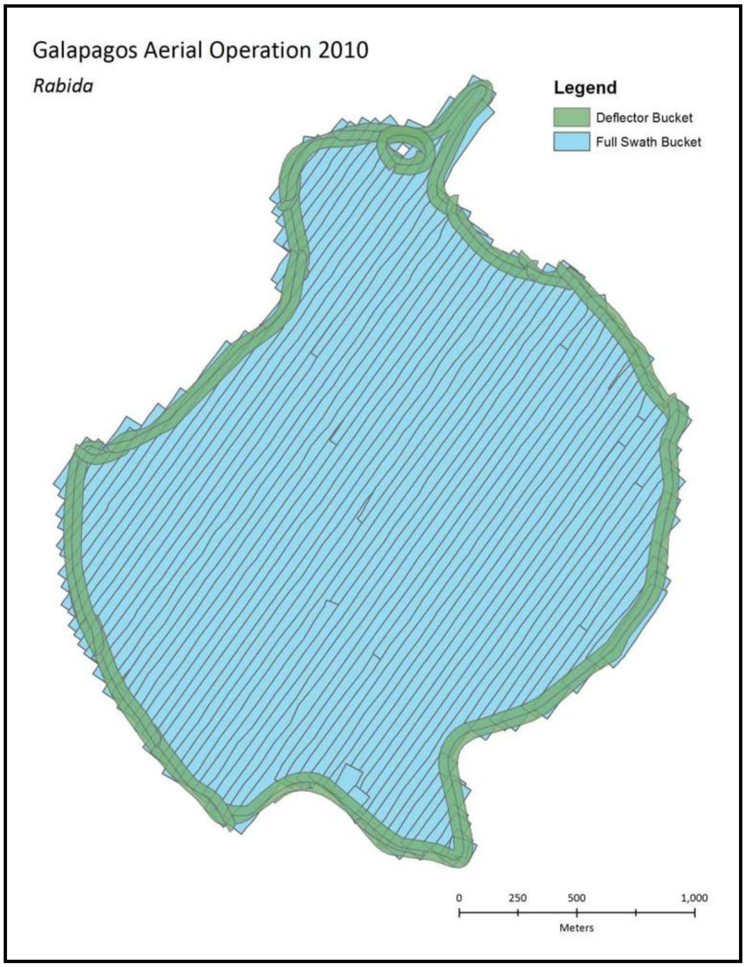

Figure 10: GIS data showing flight lines on Rabada Island, Galapagos (Source: Island Conservation).

The eradication proposed for Murchison and Faraday islands can draw on the experiences of successful eradications in the US and worldwide including the following operational principles:

- Pressed-grain bait pellets (approximately 2 g), containing 25 ppm brodifacoum are applied at the minimum quantity necessary to achieve 100% rat eradication, in accordance with appropriate federal regulations (bait application rate is the minimum necessary to ensure that bait is available to all rats for consumption over a period of at least four days);
- Bait is applied to every potential rat territory on the target island and all vegetated offshore rocks and islets that are within the average swimming distance for rats to the target island; and
- Whole-island coverage is required using bait broadcast aerially by helicopters supplemented by hand broadcast in areas inaccessible by air (e.g. overhanging cliffs) or for smaller islets such as those surrounding both Murchison and Faraday islands. Bait stations may also be used around any temporary buildings used by personnel during the eradication.

Advantages

- On larger islands, such as with Murchison and Faraday, aerial eradications are less labour intensive and less costly than bait stations or hand broadcasting due to the smaller infrastructure and field team size required;

- Aerial broadcast operations maximize bait-exposure probability for every target individual, ensuring bait is present in all potential rat territories on Murchison and Faraday islands including inaccessible coastal cliffs, bluffs, or other steep, rocky areas;
- Bait is readily available to all rats at the same time (thereby reducing inter- and intra-species dominance which can occur when using bait stations when animals defend stations);
- Significantly shorter eradication duration (i.e. two applications, usually 7–14 days apart) compared to a bait station approach;
- Direct and indirect exposure period for non-target species is significantly shorter (i.e. weeks/months vs. up to two years for bait stations);
- Reduced risk of injury to field personnel with the exception of catastrophic injury resulting from a helicopter accident;
- Minimal disturbance to vegetation, soil and wildlife;
- Quality control is more easily maintained as there are fewer personnel involved over a shorter time period;
- Technique is generally not affected by topography or vegetation with the exception of overhanging cliffs; and
- Aerial distribution of rodenticide bait has the highest probability of success compared to the other methods based on the abovementioned factors (Howald et al. 2007, Island Conservation 2012, P. McClelland pers. comm.).

Disadvantages

- Inability to quantify bait uptake or reduce/modify the application rate once bait has been deployed on the islands;
- Bait application rates/total bait used are generally higher than that used for bait station eradications;
- Inability to detect and respond to potential survivors of baiting campaigns. Failure is assessed by waiting until such time as survivors could have produced enough offspring for the population to become easily detectable (Howald et. al. 2005). Thus significant planning of application rates and efficacy is required;
- Increased regulatory scrutiny. Because aerial broadcasts have not been undertaken in Canada, a new, unique bait product must be registered with Health Canada's PMRA;
- Relies heavily on detailed advanced planning and testing because there is little opportunity to modify the methodology during the actual bait application;
- Requires access to highly skilled and experienced pilots as well as specialized baiting equipment including bait buckets and helicopters specifically outfitted for aerial baiting operations;
- The eradication may be delayed or postponed if the helicopter or baiting equipment experiences mechanical failure or due to weather constraints;
- Bait application rates are generally higher than that used for bait station eradications;
- Increased likelihood of bait entering the marine environment although this can be reduced by the use of a deflector on the bucket and skilled helicopter pilots; and
- Greater risk of primary poisoning of non-target species compared to a bait station approach. This can be mitigated by eradication timing, bait pellet size and colouration, and bait pellet matrix to minimize bait availability in the environment (degrades quickly).

3.3.3 Hand broadcast

Hand broadcast is an eradication method similar to aerial broadcast, where rodenticide bait pellets are spread by hand at uniform densities across the entire island area (Figure 11). The effectiveness of hand broadcasting rodenticide bait was first compared with the bait station technique in 1989 during the eradication of *R. exulans* from Double Island, New Zealand (27 ha, McFadden 1992).). During this experiment hand broadcasting rodenticide bait was determined to be more cost effective than bait stations. This in turn led to the development of aerial broadcasting with helicopters, which is currently the most common eradication technique for islands greater than 100 hectares (Howald et. al. 2007, Island Conservation 2012). Hand broadcasting rodenticide bait is now generally limited to smaller islands with mild to moderate topography, sites that do not have ready access to a suitable helicopter, or is used around sensitive areas where an aerial broadcast is not recommended (i.e. fresh water bodies on an island). In the case of the later it is sometimes combined with an aerial broadcast.

Figure 11: Hand broadcast on Palmyra Atoll (Photo: Island Conservation).

During a hand broadcast bait is typically applied at the same rate as an aerial broadcast. The baiting team (usually 4 or 5 individual baiters) forms a line in which broadcasters spaced 5-10 m apart evenly distribute a measured amount of bait pellets to consecutive 50-100m^2 areas (Wegman et. al. 2007). To increase spatial alignment of the team and application accuracy, the person in the inside position of the baiting line places flags along their line so the subsequent baiting swath would abut and slightly overlap the previous swath. An alternative to this approach is using pre-programmed GPS points for each baiting team member to follow.

Each hand broadcaster carries a pre-determined amount of rodenticide bait in a two-pocket tree-planting hip pack (i.e. tree planting bags). A calibrated cup is used to accurately measure the number of pellets necessary to reach the desired application rate. The baiting line moves in unison under the direction of a “line boss” along the pre-flagged baiting lines across the width of the island (or programmed GPS points/lines) while applying bait systematically until the entire island has been treated.

Applying the hand broadcast approach to eradicating black rats from Murchison and Faraday islands has advantages and disadvantages that are outlined below.

Advantages

- Useful for applying bait around sensitive habitats such as freshwater ponds and seasonal creeks when combined with an aerial broadcast for less sensitive areas of an island;

Disadvantages

- Not suitable for larger islands (>35 ha) such as Murchison and Faraday due to challenging terrain and personnel requirements to apply bait to the entire island;
- Inability to quantify bait uptake or modify the application rate once bait has been deployed;

- Unlikely to detect and respond to potential survivors early in the baiting campaign. Failure is assessed by waiting until such time as survivors could have produced enough offspring for the population to become easily detectable (Howald et. al. 2005);
- Bait application rates/total bait used are generally higher than that used for bait station eradications;
- Greater risk of human error in terms of bait distribution (gaps) compared to the bait station approach or aerial broadcast;
- Greater risk of primary poisoning of non-target species due to an unrestricted bait access. This can be mitigated by eradication timing , bait pellet size and colouration, and appropriate bait pellet matrix to minimize bait availability in the environment ;
- Challenges in accessing key rat habitat such as coastal cliffs, bluffs, or steep, rocky areas (i.e. such inaccessible sites provide a safe haven for rats during an eradication);
- A significant number of qualified, dependable workers needed for large islands such as Murchison and Faraday, which would be challenging given the population on Haida Gwaii. One individual can put the project at risk of failure resulting from gaps in bait distribution, which could in turn result in eradication failure;
- Increased risk of injury to personnel in difficult terrain such as cliffs found on both Murchison and Faraday islands;
- Increased regulatory scrutiny for this technique compared to the bait station approach. Registration of a hand-broadcast bait in Canada would require a new, unique bait product to be registered with Health Canada's PMRA;
- Generally high cost compared to aerial broadcast and comparable to a bait station approach given the large number of personnel required (i.e. a large support team required to keep hand baiters in constant supply of bait);
- A high density trail networks may be required (twice the density or higher than that required for a bait station approach) for islands with a relatively thick understory vegetation such as Murchison and Faraday. Development of trail networks is financially costly and can have a significant impact on island ecosystems. There is a significant potential for wildlife disturbance including seabird burrow damage because the field team must access every area of each island on foot.

3.4 Relative Costs of Technical Eradiation Approaches

Estimating the cost of undertaking rat eradication on Murchison and Faraday islands using one of the three proposed eradication techniques is a challenging undertaking. Assumptions made during the budgeting process may result in significant variations to individual line items, and thus total project costs. Table 5 outlines assumptions made in developing relative budgets for each eradication method for consideration for Murchison and Faraday.

Overall a bait station approach for Murchison and Faraday Islands would be approximately two and one half times more costly to implement compared to an aerial eradication (see Table 6). A hand broadcast approach is less costly but is still twice the cost of an aerial eradication. Additionally the size of the eradication team and infrastructure required to implement a bait station or hand broadcast eradication on Murchison and Faraday islands makes these options substantially more costly than an aerial operation approach.

Table 5: Budget assumptions for three eradication methods for Murchison and Faraday Islands.

Bait station approach	***Hand broadcast approach***	***Aerial application approach***
Base operations: Murchison and Faraday (4 on-island camps)	Base operations: Float camp and/or Hotsprings Island	Base operations: Float camp and/or Hotsprings Island
12 welded aluminum vessels for crew transport (3 per camp)	4 welded aluminum vessels, one for each baiting team (4 baiting teams) for crew transport	2 welded aluminum vessels for crew transport
Total field team size: ~76 to account for shift rotations.	Total field team size: ~46	Total field team size: ~19
2,800 stations at 50m grid spacing (rounded up to 3,000 to address any gaps)	Two bait applications 7-14 days apart. Monitoring/carcass searches between the applications and also for two weeks following the second bait application. Estimated total personnel days: 1,380.	Two bait applications approximately 7-14 days apart. Monitoring/carcass searches between the applications and also for ≥three weeks following the second bait application. Estimated total personnel days: 570
56 bait station operators required to check stations every day (50 bait stations per day per bait station operator) for two months. Estimated total personnel days: 3,360.	In between applications all field personnel would be involved in other duties such as carcass searches and monitoring.	In between applications all field personnel would be involved in other duties such as monitoring for target and non-target species; environmental monitoring.
14 bait station operators per camp, one field manager/biologist per camp, one camp cook per camp, 3 boat operators per camp)	Both islands are done simultaneously. It may be possible to stagger the implementation on each island but there is a risk that the eradication on the second island may not be completed before the winter storms arrive.	Both islands done simultaneously or back to back.
Both islands are done simultaneously. It may be possible to stagger the implementation on each island but there is a risk that the eradication on the second island may not be completed before the winter storms arrive.		

Table 6: Relative costs of three eradication methods for Murchison and Faraday Islands.

Eradication Method	Estimated Total
Bait Station Method	
Eradication requirements (incl. bait costs, trail clearing, bait station purchase and installation, computer equipment)	*561,100*
Personnel/operations support (GIS analyst, bait station operators, project manager, program director, field biologist, camp cooks, camp managers, boat operators, support personnel)	*1,829,000*
Camp/Project costs (equipment, supplies, boats, camp outfitting and fuel)	*952,440*
Staging and Personnel shifts (flight and boat support, accommodation costs, travel costs)	*94,000*
Sub-total	*3,436,540*
Contingency (10%)	*343,654*
Total	**3,780,194**
Hand-broadcast Method	
Eradication requirements (incl. bait costs, trail clearing, boats, equipment and supplies, food, field accommodations, computer equipment)	*795,242*
Personnel/operations support (GIS analyst, hand broadcasters, support personnel, project manager, program director, field biologist/camp manager, camp cook and assistant, line boss, boat operators),	*1,224,850*
Bait application training (pre-eradication, GIS support, bait applicators and personnel)	*18,850*
Bait application rate experiment (bait, personnel, food, equip/supplies and staging)	*72,455*
Toxic trial (food, camp cook, field accommodations, staging equipment and personnel)	*203,200*
Travel and staging of personnel	*56,200*
Non-target mitigation (i.e. deer cull incl. personnel, food and accommodation)	*73,360*
Sub-total	*2,444,157*
Contingency (10%)	*244,415*
Total	**2,688,572**
Aerial Application Method	
Eradication requirements (bait, helicopter bait buckets, GPS units, helicopter rental costs, boats, equipment and supplies, food, fuel, staging personnel and equipment)	*630,360*
Personnel/operations support (GIS analyst, support personnel, helicopter pilots and engineer, field manager, cook, project manager, program director)	*421,350*
Bait application rate experiment (bait, personnel, food, equip/supplies and staging)	*72,455*
Toxic trial (food, camp cook, field accommodations, staging equipment and personnel)	*203,200*
Travel and staging of personnel	*29,200*
Non-target mitigation (i.e. deer cull incl. personnel, food and accommodation)	*73,360*
Sub-total	*1,429,925*
Contingency (10%)	*142,992*
Total	**1,572,917**

3.5 Preferred Eradication Method

Based on a review of the three eradication techniques, an aerial broadcast is the preferred option for Murchison and Faraday islands due to eradication efficacy (likelihood of success), cost, personnel safety (weather windows), level of disturbance to vegetation, soil and wildlife, short eradication duration (and thus the time that the bait would be present in the environment), as well as the successful track record for this technique on islands of similar size (or larger).

A two pulse aerial broadcast of bait containing 25 ppm brodifacoum, approximately 7-14 days apart, is recommended. This should be supplemented with hand broadcast of bait as required (i.e. fresh water bodies, overhanging cliffs). This technique is currently used in California, Alaska, Mexico, Hawaii, New Zealand, and elsewhere in the world, including the two largest eradications to date on New Zealand's sub-Antarctic Campbell island (113 km^2; McClelland and Tyree, 2002) and on South Georgia island (90,000 ha treated), which is currently underway (South Georgia Heritage Trust 2010). The two aerial applications of rodenticide bait minimize the likelihood of juvenile rats surviving the first broadcast pulse (USFWS, 2007; 2011; Howald et. al. 2010; ICEG, 2000; G. Howald pers. comm.; P. McClelland, pers. comm.). The second aerial application would likely utilize a lower application rate than the first in order to minimize non-target impacts while still delivering an adequate amount of bait to rats to ensure project success.

Bait would be applied using a commercial bait hopper suspended below a helicopter (see *3.3.2 Aerial Broadcast*). To ensure adequate application, the helicopter would be fitted with an onboard GPS and computer and verified with ground plots, to ensure even bait application on the island. The application rate would be determined prior to eradication implementation during on-island experiments (see *3.5.5 Bait Application Rate and Calibration Trials*).

Prior to bait application each island should be divided into two sections, coastal perimeter and interior. The coastal perimeter and offshore rocks[9] or adjacent small islands will be treated with the bait hopper fitted with a deflector (bait is distributed from the bucket in a ~180 degree pattern, not 360 degrees when the deflector is not fitted) so that the pilot can minimize bait entry into the marine ecosystem (Figure 12)[10]. The helicopter then flies parallel, overlapping swaths across the island area to ensure even bait distribution. For the coastal perimeter of each island/islet bait should be applied at the full application rate above the high water mark with the bait deflector installed. In the interior section bait should be applied with bait deflector removed at the half the application rate used for the perimeter section. Each pass will overlap the previous pass by 50% to achieve the full application rate and to minimize the potential for untreated areas (gaps). The operation is then repeated typically around 7-14 days after the first application to ensure that all rats have access to the bait.

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[9] Small islets and off shore rocks surrounding Murchison and Faraday islands may be hand broadcasted.

[10] An assessment is required prior to eradication implementation to determine if sensitive areas exist that require mitigation, such as on the coastline or near significant freshwater lakes or streams.

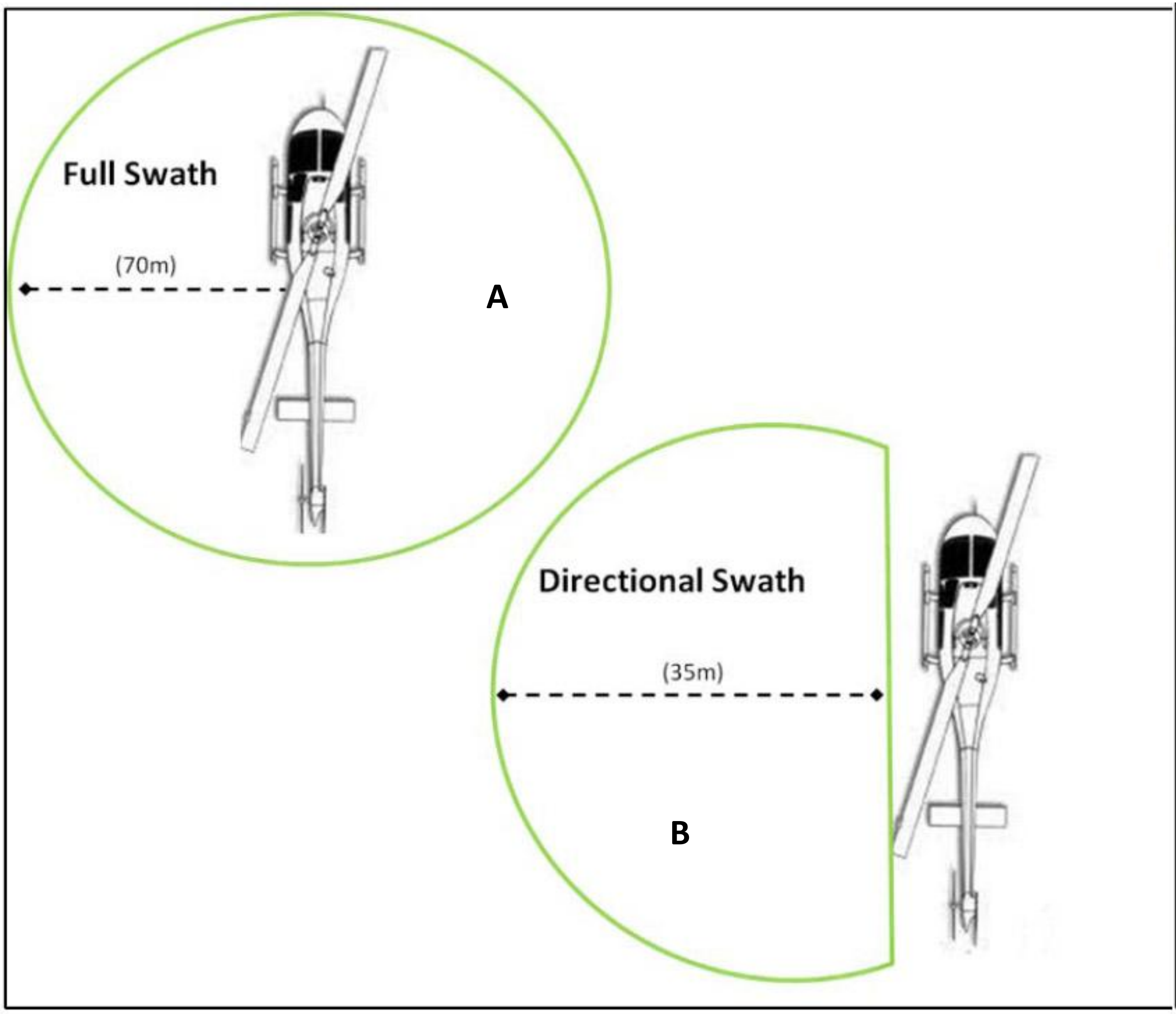

Figure 12: Bait application swath without deflector (A) and with reflector (B) (Adapted from: USFWS 2011).

3.5.1. Flight plan

The bait will be broadcast according to a flight plan that will take into account:

- The need to apply bait evenly as possible and to prevent any gaps in coverage or excessive overlap;
- Island topography;
- The need to minimize disturbance to native wildlife, especially any marine mammals hauled-out on land and resting in near shore waters; and
- The need to minimize the substantial helicopter costs associated with the project.

3.5.2 Monitoring bait application

To ensure complete and uniform application:

- The actual application path will be monitored onboard the helicopter using an onboard GPS and computer to guide the application in order to avoid gaps and unanticipated overlaps in application coverage;
- The application rate will be calculated using the known rate of bait loaded into the bait hopper for a particular aerial application session and the area treated during that session as determined by the onboard GPS; and
- Calibration of the baiting equipment at the target application rate will take place prior to eradication implementation.

Adjustments in bait flow rates, helicopter speed, and flight lines will be made both during the planning and implementation phase as necessary to meet the predetermined application rate as per the PMRA label instructions.

3.5.3 Handling Bait (Personnel Protective Equipment and Training)

When working with the bait in a planned and controlled environment the risks to human health are very low. Personal Protective Equipment (PPE) that meets or exceed all PMRA requirements should be worn by all personnel that handle bait. Furthermore all personnel that will come in contact with the bait or monitor bait application in the field should receive training in bait handling protocols and procedures and successfully obtain their Provincial Pesticide Applicators Certification.

3.5.4 Eradication Timing

Ideal eradication timing is a function of target species biology, non-target species biology, and logistical constraints. Rarely do all factors perfectly align; therefore, eradication timelines are almost invariably a compromise and it is necessary to prioritise the factors for any particular project. Ideally, eradications should be planned for the period in the target species' annual cycle when population sizes are starting to decline or declining due to a natural reduction in seasonal food resources on the target island. A scarcity of natural food items translates to increased foraging effort by the target species and a higher probability of bait encounters and consumption. Secondly, the eradication timing should occur when the risk of non-target species exposure to rodenticide is lowest. Thirdly, in temperate regions seasonal weather patterns often dictate the feasibility and safety of eradication projects, especially when marine or aerial operations are incorporated into the project. Finally, management agendas for cultural resource use and public access often influence when eradications can occur.

For the Murchison and Faraday islands the preferred eradication window occurs during the winter months (January to March) when rat populations are at their lowest (Table 7). Additionally, the winter timeline coincides with:

- the completion of the migratory bird breeding cycle (minimizing disturbance and non-target impacts);
- weather conditions, especially in March that are generally favourable for ground, water, and aerial operations[11].
- the most likely hibernation period for black bears on Haida Gwaii; and
- a low public presence near the project area.

[11] Contingencies would need to be included in the budget to ensure that weather delays are accounted for.

Table 7: An assessment of variables influencing timing of Murchison and Faraday eradication.

	Spring			Summer			Fall			Winter		
	April	May	June	July	August	September	October	November	December	January	February	March
Eradication Success												
Rat breeding (estimated)												
Weather												
Precipitation (mm)	102	63	56	47	58	84	186	198	185	169	139	113
Windspeed (km/h)	21	19	18	16	16	17	20	21	21	22	21	20
Most Frequent Wind Direction	SE	SE	SE	W	W	SE	SE	SE	SE	SE	SE	SE
Maximum Gust Speed (km/h)	140	122	97	93	100	113	148	161	152	161	164	121
Days with Winds >= 52 km/h	4	3	1	1	1	2	5	7	7	7	6	5
Non-target Activity												
Migratory bird breeding cycle												
Bird aggregations during salmon spawning												
Black bear hibernation period (estimated)												
Efficacy (based on rat breeding cycle)												
Risk of delay due to adverse weather												
Non-target presence (migratory birds)												
Non-target presence (black bear)												

**green = low risk, yellow = moderate risk, red=high risk*

3.5.5 Bait Application Rate & Calibration Trials

The amount of bait applied to islands, measured in kg/ha, must be sufficient to provide every individual rat present on an island access to bait for a sufficient time to ensure that it encounters and consumes a lethal dose of rodenticide. Rat eradications can fail from insufficient bait application (Howald et al. 2004). Conversely, while high application rates will ensure enough bait for all rats on the island, excessive bait on the ground for long periods will increase the risk of non-target poisoning. A bait application rate that is sufficient to deliver bait to all rats for a minimum of four days, but not substantially longer, should limit the risk of primary exposure to non-target species while maximizing the probability of eradication success. The appropriate bait application rate must also take into consideration both the uptake of bait by rats and by other non-target species such as Sitka black-tailed deer.

The target application rate[12] used during the Murchison and Faraday island eradications will be determined using on-island experiments prior to the eradication. A non-toxic placebo bait will be broadcast by hand to mimic an aerial broadcast to measure the rate of bait uptake (including both consumption and degradation) at a test site on Murchison or Faraday Island. Application rates will account for some bait being intersected by the forest canopy during the aerial broadcast and consumption by non-target species such as black-tailed deer (*see 3.6 Potential Impacts and Mitigation of Risk to Native Species*).

In addition to determining the bait application rate, the bait hopper used for the eradication must be calibrated to determine flow rate and swath width (how fast and how far the bait is propelled out of the bait hopper). Together, the flow rate and swath width will be used to achieve the pre-determined application rate. During the eradication the field team should monitor the bait application to ensure that the bait hopper is operating correctly.

[12] The application rate will be within the limits of the approved PMRA label.

3.5.6 Toxic Trial

Prior to implementing the aerial eradication on Murchison and Faraday islands a toxic trial should be undertaken on at least two small nearby islands with similar topography and species composition (e.g. black rats, deer). The bait that will be used for the Murchison and Faraday islands eradication will be hand broadcast on the test islands to a mimic an aerial application. Two applications approximately 7-14 days apart will be completed at the application rate determined during the bait uptake study (see *3.5.5 Bait Application Rate and Calibration Trials*).

Field personnel will monitor target and non-target species following the first hand broadcast and also for two weeks following the second hand broadcast to assess ecosystem response to the eradication. This may include conducting formal carcass searches on both test islands, installing remote cameras to monitor rat and non-target species behaviour around the rodenticide bait, and other related experiments. Although a hand broadcast cannot exactly mimic an aerial broadcast it will provide information that can help eradication managers understand the potential issues, risks, and challenges that may arise during the actual aerial eradication operation.

3.6 Potential Impacts and Mitigation of Risk to Native Species of Murchison and Faraday Islands

Conservation practitioners should seek ways to avoid negatively impacting native biological resources whenever practical. However, with most invasive species eradications, the potential for eradication success must be balanced by risks to individual non-target wildlife. Although both sides of this balancing equation are important, the need to maximise the chances of eradication success is particularly acute and some non-target mortality (sub-population level impact) may prove unavoidable. Such negative impacts on individual animals should be outweighed by the expected beneficial effects of rat eradication (e.g. recovery of native species and ecosystems).

Conversely, a failed eradication attempt resulting from prioritizing a desire to avoid or minimize non-target impacts above all else will provide few conservation returns in the long term because surviving rats will reproduce at high rates and quickly re-occupy vacant territories throughout the island. Furthermore, a failed eradication attempt will still put individuals of non-target species at risk with no measurable improvements to the species of interest or the ecosystem. It should be recognized that mitigation of non-target risk can also add significantly to the costs of an eradication attempt (Howald et al. 2010).

While the outcome of the Murchison and Faraday islands eradication will have significant long-term and lasting benefits to native island species and the island ecosystems, there may be associated short-term impacts to non-target species on an individual animal basis. Bait applied by aerial broadcast increases the spatial exposure of certain non-target species compared to a bait station approach. However, aerial broadcast in two concerted applications significantly reduces the temporal availability of bait when compared to bait stations where bait is deployed for significantly longer periods of time (up to two years).

The risk to non-target species during an eradication operation is a function of the toxicological properties of the rodenticide and delivery method as well as the species present on the island, behaviour (e.g. herbivore, scavenger, etc.), susceptibility to the toxin, and the probability of exposure to the toxin either directly by bait consumption (primary poisoning) or indirectly by feeding on animals that have consumed baits (secondary poisoning, Howald et. al. 2007). Although non-target impacts on native species by primary and secondary and tertiary poisoning have been documented for eradication campaigns (Salmon and Paul, 2010), the affected species have recovered quickly to pre-eradication population levels or higher (Empson and Miskelly 1999; Howald et al. 1999; Davidson and Armstrong 2002; Howald et al. 2005, Howald pers. comm.).

Applied research can help eradication operations minimize potential non-target impacts of native wildlife while maximizing probability of eradication success. For example, the use of a toxic trial on two small nearby islands with similar topography and species composition will enable Parks Canada to determine potential exposure pathways for non-target species prior to the Murchison and Faraday islands eradication (see section *3.5.6 Toxic Trial*). However, as stated previously the need to reduce short-term non-target impacts must be balanced with maximizing the probability of eradication success and financial realities.

The islands in Juan Perez Sound, including Murchison and Faraday, support native wildlife that may be at risk of disturbance or incidental poisoning (primary, secondary, or tertiary) as a result of the an aerial broadcast operation. The following sections provide details on these species.

3.6.1 Potential Impacts to Birds

Please refer to Appendix A for a list of bird species breeding in Gwaii Haanas National Park Reserve and Haida Heritage Site.

3.6.1.1 Marine Birds, Shorebirds, Waterfowl, & Kingfishers

Marine birds found near the Murchison and Faraday islands during the winter months when the eradication is proposed include Ancient Murrelet, Marbled Murrelet, Common Murre, and Cassin's Auklet. Fish comprise the diet of these species and because the likelihood of brodifacoum transfer into the marine ecosystem is low the probability of secondary exposure through their prey species, although possible, is likely negligible. Please refer to section *3.2.2.2 Second Generation Anticoagulants, Effects on Fish* for additional information.

Two gulls that may be at significant risk of both primary and secondary poisoning are the Glaucous-winged Gull (*Larus glaucescens*) and Mew Gull (*Larus canus*), which are opportunistic feeders (Verbeek 1993). During the 2008 Rat Island, Alaska eradication project 320 Glaucous-winged Gull[13] carcasses were recovered and toxicology tests implicated brodifacoum in 24 of the 34 tested (Salmon & Paul 2010). It was theorized this species ingested rodenticide bait pellets (primary poisoning pathway) and possibly also dead or dying rats (secondary poisoning pathway). Although possible, it is unlikely that this situation would be replicated on Murchison and Faraday islands due to the significant vegetation cover (crown closure), which would limit visibility of the rodenticide bait and dead or dying rats to coastline scavengers such as Glaucous-winged Gulls or Mew Gulls as well as other species (Figure 13). Even if mortality levels were similar to that reported for Rat Island, it would not result in a population level impact. In addition to rodenticide exposure, there is a minor risk of short term and negligible disturbance to seabirds resulting from helicopter and small boat activity.

[13] Yellow-listed in British Columbia (Not at risk). Not designated under the federal Species at Risk Act (BC Species and Ecosystems Explorer 2011)

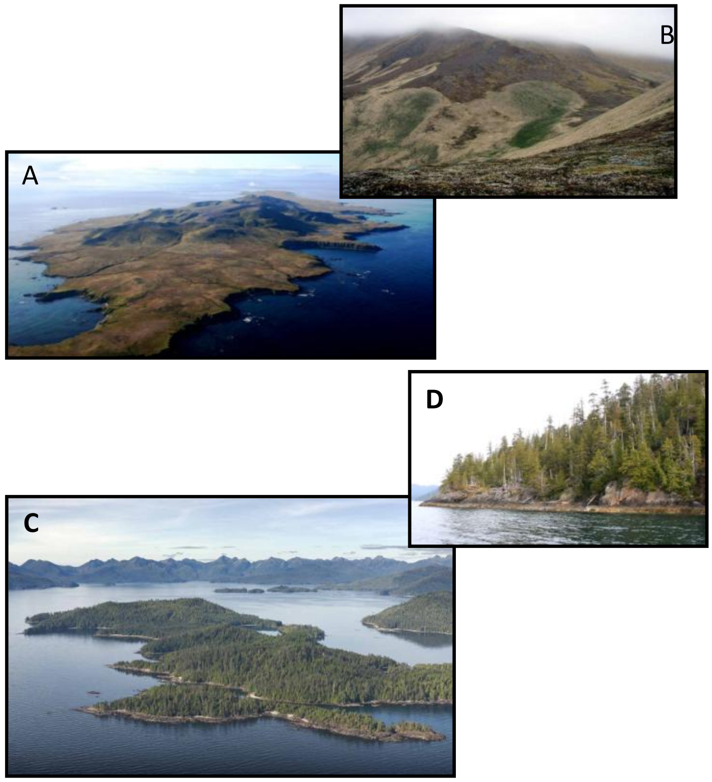

Figure 13: Vegetation composition of Rat Island, Alaska and Murchison and Faraday Islands (Photos: Island Conservation, A. Wright and C. Gill).

Glaucous-winged Gulls or Mew Gulls exposed to the rodenticide may be preyed on or scavenged by Bald Eagles, Common Ravens, and/or Northwestern Crows leading to secondary and /or tertiary poisoning of these species (please refer to section *3.6.1.4 Birds of Prey, Corvids, & Wading Birds*).

In regards to shorebirds and brodifacoum exposure risk, only 5 species have been recorded (*see Appendix: List of resident birds observed in Gwaii Haanas*) and of these only the Black Oystercatcher and Common Snipe are considered residents of the islands[14]. Neither of these species are opportunistic feeders and thus are unlikely to feed directly on the bait. However, it is possible that these species could be exposed to low levels of brodifacoum by consuming aquatic invertebrates that have fed upon bait. This is unlikely because the risk of significant brodifacoum transfer into the marine ecosystem is low, thus the probability of secondary exposure through their prey species is negligible (USFWS 2007).

Therefore, the risk to shorebirds as a result of the eradication is negligible. On Palmyra Atoll National Wildlife Refuge, located in the Line Islands of the central Pacific Ocean and approximately 1,693 kilometres south of the main Hawaiian Islands, a black rat eradication using an aerially broadcast brodifacoum based rodenticide bait was linked to the deaths of eight Bristle-thighed Curlews (A. Wegman pers. comm.). Unlike the Black Oystercatcher and Common Snipe, Bristle-thighed Curlews are an opportunistic feeder (Marks 1993) which resulted in several potential secondary/tertiary brodifacoum exposure pathways identified during the planning phase of the eradication operation including feeding directly on the bait (Pierce et al. 2008).

[14] The remaining shorebirds are considered summer residents or transients.

Only Mallard, Harlequin Duck, Pacific Loon, and Common Merganser are common waterfowl during the winter months. Belted Kingfishers meanwhile are year-round residents. Although unlikely it is possible that these species could be exposed to low levels of brodifacoum by consuming fish (for Pacific Loon, Common Merganser, and Belted Kingfisher) or aquatic invertebrates (for Mallard and Harlequin Duck) that have fed upon bait. However, as stated above, this is unlikely because the risk of significant brodifacoum transfer into the marine ecosystem is low, thus the probability of secondary exposure through their prey species is negligible (USFWS 2007).

Regardless of food habits, these species will only be at risk of exposure to brodifacoum if they are present on Murchison or Faraday Island during bait application or soon after application.

3.6.1.2 Songbirds & Upland Game Birds

All granivorous bird species found on Murchison and Faraday islands during the eradication, such as Song Sparrows (*Melospiza melodia*) , Fox Sparrows (*Passerella iliaca*), and Sooty Grouse (*Dendragapus fuliginosus*) would be at high risk for primary exposure resulting from direct ingestion of the rodenticide bait pellets for a short period of time after each bait application (e.g. Howald et al. 2009). Although not considered at risk either provincially or federally (Conservation Data Centre 2012), Sooty Grouse are of particular concern because of their low dispersal ability from other islands (C. Bergman pers. comm.). However, this species will significantly benefit from rat eradication on Murchison and Faraday islands (because rats predate their nests) and could be re-introduced from nearby islands if the population is negatively impacted by the eradication operation.

Sparrows, wrens, and other passerine birds have been found dead after rodent eradications in New Zealand and California, and estimated mortality rates have varied from very low to nearly 100% (Eason and Spurr 1995, Howald et al. 2005). During the Langara Island rat eradication project researchers confirmed that Song Sparrows were exposed to brodifacoum (Howald et al. 1999). Additionally, insectivorous bird species, such as Winter Wren (*Troglodytes troglodytes*) and Varied Thrush (*Ixoreus naevius*) may be exposed to the rodenticide by eating invertebrates that have fed on the rodenticide baits (secondary poisoning), although no evidence of this was detected on Langara Island in 1995 after two years of rodenticide availability (Kaiser et a;. 1997)[15]. Regardless of food habits, these species will only be at risk of exposure to brodifacoum if they are present on Murchison or Faraday Island during bait application or soon after application.

Based on currently available knowledge, the songbirds or upland game birds found on Murchison and Faraday are not federally or provincially designated as Species at Risk (Conservation Data Centre 2011). Given the global and local abundance of these species, and presence of suitable habitat on nearby islands (e.g. Lyell, Hotsprings, Ramsay, and Moresby island), an aerial eradication would not result in any population level effects even in the unlikely event that significant localized mortalities occur as a result of the operation. Transient birds will quickly occupy any vacant, high quality habitat, hence it is unlikely that any change in the localized population numbers for these species would be observed pre- and post-eradication.

[15] It is important to note that the Langara Island eradication employed bait stations which limit access to the bait by non-target species. Therefore, a direct comparison of potential non-target impacts between bait stations and aerial broadcast should be approached cautiously.

Granivorous or insectivorous birds exposed to the rodenticide may be preyed on or scavenged by Bald Eagles, Common Ravens, Northwestern Crows, Northern Goshawk, *laingi* subspecies (*Accipiter gentilis laingi*), Northern Saw-whet Owl, *brooksi* subspecies (*Aegolius acadicus brooksi*), and/or Sharp-shinned Hawk (*Accipiter striatus*) leading to secondary and /or tertiary poisoning of these species (please refer to section *3.6.1.4 Birds of Prey, Corvids, & Wading Birds*).

3.6.1.3 Wading Birds

The Great Blue Heron, *fannini* subspecies (*Ardea herodias fannini*) is designated under the federal Species at Risk Act as Special Concern (Schedule 1). The best available estimates suggest that the population size in Canada is 4,000-5,000 nesting adults (COSEWIC 2008). The global population is likely between 9,500 and 11,000 nesting adults. During the nesting season the principal diet is small fish which is supplemented with mammals during the winter months (COSEWIC 2008). Because this species is known to prey on rats and other rodents, it is possible that mortalities may occur during an aerial eradication if Great Blue Herons prey on rats that have fed directly on the rodenticide bait. However, it should be noted that Great Blue Herons were regularly observed during the Bischofs eradication in 2011 foraging in intertidal areas but no carcasses were recovered despite over 900 hours of formal and informal carcass searches being conducted during the operation (Parks Canada Agency, 2012)[15].

Three heron nests have been previously located on Murchison Island (D. Burles pers. comm.). Therefore, based on a diet that includes fish and rodents and nesting presence on the island, there is a possibility that some individual mortalities may result from an aerial eradication on Murchison and Faraday islands although this would not result in any long term population level effect or even a local population effect because transient birds would quickly occupy any vacant, high quality foraging habitat.

3.6.1.4 Birds of Prey[16] & Corvids

Initially there will be a high risk of secondary poisoning for bird species that may prey on dead or dying rats, red squirrels (*Tamiasciurus hudsonicus*)[17], dusky shrews (*Sorex monticolus*), deer mice (*Peromyscus keeni*) or granivorous birds that have ingested the bait. There is also a risk of secondary and tertiary poisoning if birds of prey or avian scavengers consume dead or dying non-target species that have been exposed to the rodenticide. For example, on Macquarie Island, New Zealand, researchers reported Giant Petrels (*Macronectes giganteus*) eating gull, rabbit and rat carcases and dying up to 6 months after completion of the aerial eradication (P. McClelland pers. comm.).

There is also risk of attracting avian scavengers to the island as was the case with the Rat Island eradication (Salmon and Paul 2010) although this risk is considered low to moderate based on the significant vegetation cover and degree of crown closure on Murchison and Faraday islands compared to Rat island which would limit visibility of dead or dying rats or non-target species to avian scavengers.

In addition to rodenticide exposure, there is some risk of disturbance resulting from helicopter and small boat activity during the eradication operation. However, the impacts will be minimal and short term, and outside of the breeding season.

3.6.1.4.1 Northern Goshawk, Northern Saw-whet Owl & Sharp-shinned Hawk

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[16] Peregrine Falcon, *pealei* subspecies occurs in Haida Gwaii. However, this species feeds exclusively on seabirds; therefore, there is no risk of rodenticide exposure (COSEWIC 2007).

[17] This species is not native to Haida Gwaii (Golumbia 2000).

Northern Goshawk, *laingi* subspecies and Northern Saw-whet Owl, *brooksi* subspecies are designated under the federal Species at Risk Act as Threatened (Schedule 1). Sharp-shinned Hawk is not designated as a Species at Risk.

British Columbia contains the majority of the Northern Goshawk, *laingi* subspecies population worldwide. It occurs on Vancouver Island, Haida Gwaii, and on the western side of the coastal ranges of British Columbia (COSEWIC 2007). Estimates of population abundance are imprecise, but are thought to be approximately 700 individuals. Based on the best available population estimates approximately 50% of the global population of *A. gentilis laingi* resides within Canada (Northern Goshawk *Accipiter gentilis laingi* Recovery Team 2008). Red Squirrels and various songbirds dominate breeding season diets of Northern Goshawk, *laingi* subspecies (Roberts 1997, Doyle 2003b). This means rats are also potential prey due to the similarity in body size to red squirrels. No information is available on non-breeding season diets. Territory size in Haida Gwaii is estimated at 10.8 ± 0.6 km but there is a high annual variability in territory occupancy (Doyle 2003a). Therefore, based on the size of Murchison and Faraday islands, a maximum of one territory could be present if it is indeed occupied although habitat quality for this species on the islands has not been assessed. Local knowledge of one family who lived on Murchison Island until the 1980's did not contain any reports of goshawks on the island (D. Burles pers. comm.).

The *brooksi* subspecies of the Northern Saw-whet Owl is endemic only to Haida Gwaii and is non-migratory (COSEWIC 2006). Saw-whet Owls are highly territorial of the area near potential nests during the spring breeding season. Males defend core areas approximately 70-100 ha in size. Home ranges are often much larger and are estimated at a mean size of 3.52 $\pm$ 1.3km^2. Applying this estimate to Murchison and Faraday islands (total area: 716 ha) suggests that the islands could support approximately 3 territories although habitat quality for this species has not been assessed on the islands. Rats (especially juveniles) are prey items for this species (C. Bergman, unpublished data), which may further increase their density when rats are abundant. On Haida Gwaii Saw-whet Owls appear to be more generalist taking locally available food items other than rodents, which are thought to be the major food source of Northern Saw-whet Owls elsewhere (COSEWIC 2006). Studies on the diet of birds collected primarily during the fall suggest high levels of marine invertebrate consumption (Hobson and Sealy 1991, Sealy 1999).

The Sharp-shinned Hawk is a common accipiter in British Columbia and not considered at risk (Conservation Data Centre 2011). Birds make up to 90% of this hawk's diet, but they may also take small mammals, frogs, lizards, and insects (Bildstein and Meyer 2000). In Oregon, nest density was estimated as one per 2,750 ha, with mean nearest conspecific neighbour distance of 4.1 km. In Idaho, nest density was estimated at 1.6 pairs of Sharp-shinned Hawks per 10 km^2 (Reynolds et. al. 1978). Based on the size of Murchison and Faraday islands, a maximum of one territory could be present if it is indeed occupied although habitat quality for this species has not been assessed on the islands.

In summary, all three species are present in Juan Perez Sound but are uncommon (D. Burles pers. comm., C. Bergman pers. comm.). For example, during the Bischofs rat eradication field personnel observed only one Northern Goshawk and one Saw-whet Owl[18] but no Sharp Shinned Hawks over the course of two months on the islands (Parks Canada Agency, 2012). All three species are at risk of secondary poisoning resulting from predating rats or passerines that have fed directly on the rodenticide bait. However, given the small number of potential territories on Murchison and Faraday islands for each species the eradication may pose a risk to one or two individual birds but is unlikely to have any long term population level effect because transient birds will quickly occupy any vacant, high quality habitat. It is unlikely

[18] Personnel observed this owl during the eradication and also during a follow up monitoring visit to the islands (L. Wein pers. comm.).

that any change in the Gwaii Haanas Northern Goshawk, Saw-wet Owl, or Sharp-shinned Hawk population sizes would be observed pre- and post-eradication.

3.6.1.4.2 Bald Eagle

Bald Eagles are at risk of secondary and tertiary poisonings resulting from foraging on dead or dying rats, squirrels, dusky shrews, deer mice, or omnivorous, granivorous, or insectivorous birds, Great Blue Heron, Common Raven or Northwestern Crow.

A 1994 inventory estimated that 15,000 Bald Eagles (9,000 on the coast and 6,000 in the interior) breed in BC and 30,000 overwinter in the Georgia Basin (Blood and Anweiler, 1994). Bald Eagles are plentiful in Juan Perez Sound and there are at least nine historical nests on Murchison and Faraday Islands (Bergman 2012). Bald Eagles are opportunistic feeders and their diet includes live prey as well as and carrion. Recent collection of prey remains from nests in the Juan Perez area of Gwaii Haanas included remains of deer, seabirds, corvids, gulls and large intertidal invertebrates (Bergman, unpublished data). This behaviour places Bald Eagles at risk of both secondary and tertiary poisoning during a rat eradication operation. For example, during a rat eradication operation on Langara Island, 3 out of 22 Bald Eagle blood samples obtained from live animals tested positive for brodifacoum exposure. No eagles were found dead during the eradication operation (Kaiser et. al. 1997). Similarly no Bald Eagle carcasses were recovered during the Bischofs and Arichika rat eradication operation completed in 2011 even though each island contains several active territories, including two which successfully fledged young (Bergman, unpublished data; Burles unpublished data).

During the 2008 Rat Island, Alaska eradication project 46 Bald eagle carcasses were recovered and toxicology tests implicated brodifacoum in 12 of the 16 tested (Salmon & Paul 2010). It was theorized eagles had preyed on dead or dying rats and Glaucous-winged Gulls (secondary and tertiary poisoning pathways)[19]. Due to the lack of a forested canopy on Rat Island it was estimated that a large number of rat carcasses were readily visible to avian scavengers (Salmon & Paul 2010). It is unlikely that this situation would be replicated on Murchison and Faraday islands due to the significant crown closure which would limit visibility of the bait and dead or dying rats to coastline scavengers such as Bald Eagles (see Figure 13 for topography comparisons of Rat Island compared to Murchison and Faraday islands). However, there is a possibility that some Bald Eagle mortality may result from an aerial eradication on Murchison and Faraday islands although this would not result in any long term population level effect or even a local population effect because transient birds would quickly occupy any vacant territories since high quality habitat is a limiting factor for this species (C. Bergman pers. comm.). Recently, researchers have reported that both adult and juvenile Bald Eagles have recolonized Rat Island (G. Howald pers. comm.). It is unlikely that any change in the local Bald Eagle population size would be observed pre- and post-eradication on Murchison and Faraday islands.

3.6.1.4.3 Common Raven & Northwestern Crow

In addition to the secondary poisoning risk from feeding on dead or dying rats, squirrels, dusky shrews, deer mice, or omnivorous, granivorous, or insectivorous birds (see section *3.6.1.2 Songbirds & Upland Game Birds* and section *3.6.1.1 Marine Birds, Shorebirds, Waterfowl & Kingfishers*), Common Raven and Northwestern Crow are also at significant risk of primary poisoning as a result of ingesting the rodenticide bait directly (Kaiser et. al. 1997). For example, during a rat eradication operation on Langara Island, 13 Common Raven carcasses tested positive for brodifacoum (Kaiser et. al. 1997). Ravens were observed ingesting the rodenticide bait pellets and also feeding on rat carcasses. During the 2011

[19] Gulls may have fed directly on the rodenticide bait pellets or on rats that had ingested the bait.

Bischofs rat eradication operation one Common Raven carcass was recovered although it has not yet been tested for brodifacoum exposure (Parks Canada Agency, 2012). Kaiser et al. (1997) also reported trace amounts of brodifacoum on liver tissues of Northwestern Crows during a toxic trial on Lucy Island, British Columbia. No crow carcasses were found during the Bischofs and Arichika rat eradications despite over 900 hours of formal and informal carcass searches being conducted and both species being regularly observed during the eradication operation (Parks Canada Agency, 2012). It is anticipated that an aerial eradiation on Murchison and Faraday islands could have a significant, albeit localized impact on the Common Raven and Northwestern Crow populations. It is also possible that corvids exposed to the rodenticide bait on Murchison or Faraday islands may succumb to the poison on nearby islands such as Lyell Island and Hotsprings Island thereby transporting relatively small amounts of brodifacoum into the other ecosystems. However, the consequence of this scenario is not likely to be detectable or of any significance to the wildlife present on those islands (G. Howald pers. comm.).

Any localized corvid mortalities would not result in a long term population level effect or even a local population effect because transient birds would quickly occupy any vacant high quality habitat. It is unlikely that any change in the local corvid population size would be observed pre- and post-eradication. For example, on Langara Island, Common Ravens recolonized the islands within one year after the local population was reduced due to primary and secondary exposure to brodifacoum during the rat eradication operation in 1995 (G. Howald pers. comm.).

3.6.2 Potential Impacts to Mammals

3.6.2.1 Marine Mammals

The waters surrounding Haida Gwaii are home to twenty species of cetaceans (whales and dolphins). Although some of these species are present throughout the year, the vast majority are present from the late winter through until the early summer. Humpback (*Megaptera novaeangliae*), orca (*Orcinus orca*), and minke whales (*Balaenoptera acutorostrata*) are seen regularly in the waters surrounding Gwaii Haanas, along with Pacific white-sided dolphins (*Lagenorhynchus obliquidens*), Dall's porpoises (*Phocoenoides dalli*), Steller's sea lions (*Eumetopias jubatus*), and harbour seals (*Phoca vitulina*, Parks Canada Agency 2011).

Harbour seals and Steller's sea lions are exclusively carnivorous (almost exclusively piscivorous) and do not feed while on land, so the only possible routes for bait ingestion are accidental (G. Ellis pers. comm.). The likelihood of primary exposure is therefore very low and because the likelihood of brodifacoum transfer into the marine ecosystem is low the probability of secondary exposure through their prey species, although possible, is negligible. Please refer to section *3.2.2.2 Second Generation Anticoagulants, Effects on Fish* for additional information regarding potential impacts on marine mammal prey.

The primary risk to marine mammals during the eradication operation is temporary disturbance resulting from helicopter and boating activities. Harbour seals and Steller's sea lions may be hauled out on islets near Murchison and Faraday islands, or on the islands at various times of the day during field operations. Helicopter and boat activity around these sites may temporarily disturb individuals causing them to temporarily relocate to an alternate haul out away from the activity or return to the haul out after the disturbance has passed (G. Ellis pers. comm.).

Potential impacts of rat eradication activities to cetaceans in the waters surrounding Murchison and Faraday islands are thus negligible and limited to disturbance from small boat traffic, which will be limited in duration and concentrated immediately offshore of the island.

3.6.2.2 Terrestrial Mammals

As with birds, initially there will be a high risk of primary poisoning from feeding directly on the rodenticide bait pellets as well as a secondary poisoning risk for terrestrial mammals that may prey on dead or dying rats, red squirrels, dusky shrews, and deer mice that have ingested the rodenticide bait pellets.

3.6.2.2.1 Native Small Mammals (Shrews & Rodents)

Dusky shrews and deer mice are unlikely to be present on Murchison or Faraday islands, likely due to resource competition and direct predation by black rats (Foster 1965). Further studies are recommended to confirm presence/absence of these species on the islands although neither species are considered at risk either provincially or federally (Conservation Data Centre 2011). Red Squirrels are a non-native species (Golumbia 2000).

Initially, all three species would be at high risk for primary poisoning resulting from direct ingestion of the bait and by preying on insects that have fed on the rodenticide bait (secondary poisoning) during an aerial eradication operation on Murchison and Faraday islands. This, in turn, could lead to secondary and tertiary poisoning incidences in a variety of species that may in turn prey on them. Because of their susceptibility to the rodenticide, it is likely that an aerial eradication operation on Murchison and Faraday islands would have a significant, albeit localized (non-population level) impact on dusky shrews, deer mice, and red squirrels. However, it would be feasible to reintroduce dusky shrews and deer mice to the islands if they are indeed extirpated as a result of rat predation pressure combined with the eradication operation (e.g. Howald et al. 2009).

3.6.2.2.2 Herbivores

Sitka black-tailed deer (*Odocoilius hemionus sitkensis*) were first introduced to Haida Gwaii in 1878 and on four occasions between 1911 and 1925. The deer's ability to swim has allowed it to spread to most islands in the archipelago, with only 11 small offshore islands known to be deer free (Sloan, 2007). Current estimates of the deer population throughout Gwaii Haanas are as high as 60,000 individuals (Golumbia 2001a).

Deer have been observed ingesting rodenticide bait pellets in other studies (Stone et. al. 1999, Landcare Research 2010). Therefore, although the LD_{50} value for deer is unknown, it is likely that there is a significant potential for primary poisoning of Sitka deer during the aerial eradication operation on Murchison and Faraday islands. It is possible that the degree of poisoning could either be acute, resulting in mortality, or sub-acute. Sub-acute poisonings with brodifacoum can result in spontaneous abortions in mammalian species (Godfrey 1985). In either case, deer that are exposed to the rodenticide through bait consumption would in turn place scavenging species such as Bald Eagles, Common Ravens, Northwestern Crows, and black bears (*Ursus americanus charlottae*) at risk of secondary poisoning. Furthermore, humans eating deer meat (especially livers and kidneys) from animals exposed to the rodenticide bait would put them at risk of brodifacoum exposure, although the risk window is relatively short[20] and likely with low consequence.

In addition to the risk of primary poisoning of deer on Murchison and Faraday islands (and possible consequent secondary poisoning of other native wildlife through predation and scavenging deer carcasses), there is a risk that deer may outcompete rats for the bait resulting in bait application 'gaps' on the islands. This in turn increases the risk of

[20] Brodifacoum will persist in the meat and livers of sub-lethally poisoned mammals such as sheep for at least 9 months (Laas et. al. 1985).

eradication failure based on the first fundamental principle of rat eradications: all rats must be at risk of the eradication technique (Cromarty et al. 2002).

Prior to implementing the rat eradication operation on Murchison and Faraday islands we therefore recommend either a deer eradication or deer cull to reduce the potential for brodifacoum exposure with this species resulting from direct ingestion of the rodenticide bait pellets. A temporary hunting closure is also recommended for Murchison Island, Faraday Island, Southeast Lyell Island, Hotsprings Island, House Island, and Ramsay to ensure that any deer sub lethally exposed to the rodenticide bait can metabolize the toxin before being potentially consumed by humans. Given that Gwaii Haanas is not open to the public for deer hunting, with the exception of limited Haida First Nations subsistence hunting (as per the 1993 Gwaii Haanas agreement) and deer hunting opportunities are virtually unlimited at other, more easily accessed areas of Haida Gwaii, this temporary closure would have virtually no impact.

3.6.2.2.3 Omnivores

The raccoon (*Procyon lotor*) is an introduced species on Haida Gwaii (Golumbia 2000) while the black bear sub-species is endemic to the islands. The diets of both species are diverse and include vegetable matter, small mammals, carrion, fruit, insects, bird eggs, and fish. Based on diet preferences, and the behaviour of a black bear on the Bischofs islands during the 2011 rat eradication (Parks Canada Agency, 2012), both species are at a considerable risk of primary poisoning (direct ingestion of rodenticide bait pellets) and secondary poisoning (preying or scavenging rats, dusky shrews, deer mice, or Sitka deer, that have ingested the bait) during an aerial eradication on Murchison and Faraday islands. Although LD_{50} values for these species are unknown, it is possible that an aerial eradication operation on Murchison and Faraday islands may have a significant, albeit localized (non-population level) impact on black bears and raccoons. Raccoon carcasses may be scavenged by bears or avian species such as Bald Eagles and Common Ravens thereby presenting a secondary and tertiary poisoning risk. Surveys for both species prior to implementing eradication operation on Murchison and Faraday islands to confirm presence/absence of these species is advised. Black bear surveys should be conducted using remote cameras and hair traps. If black bears are present on the project islands, Parks Canada should ensure that personnel with appropriate training and bear handing experience are on-island to capture and relocate bears if necessary.

3.6.2.2.4 Carnivores

The Haida ermine (*Mustela erminea haidarum*) is recognized as a rare endemic sub-species of ermine and is designated as as Threatened in Schedule 1 of the Federal Species at Risk Act. Sightings are extremely limited (Golumbia 2001a). Ermine *haidarum* have been recorded on only four of the major Haida Gwaii islands: Graham, Moresby, Louise, and Burnaby (Reid et al, 1999).

Although possible, it is highly unlikely that ermine are present on Murchison or Faraday islands because of its current distribution, poor swimming ability, and low population levels of dusky shrews and deer mice on the islands resulting from the presence of black rats and raccoons (D. Burles pers. comm., C. Bergman pers. comm.). However, if this species is present, it would be at risk of secondary poisoning resulting from the aerial eradication operation although impacts would be limited to individual animals.

River otters (*Lontra canadensis*) are exclusively carnivorous (primarily feeding on fish and marine invertebrates such as crab) although this species has been known to infrequently prey on various bird species and small mammals (D. Guertin pers. comm.). Although possible, given the abundance of fish and marine invertebrates in the waters surrounding Murchison and Faraday islands it is unlikely that resident river otters would consume terrestrial species. Furthermore, during the rat eradication operation on the Bischofs and Arichika islands river otters regularly encountered bait stations that were armed with rodenticide bait pellets but did not disturb them (Parks Canada Agency, 2012). The likelihood of primary or secondary exposure of river otter resulting from an aerial eradication operation on Murchison and Faraday islands is believed to be low.

3.6.3 Potential Impacts to Amphibians

The western toad (*Anaxyrus boreas*) is the only native amphibian on Haida Gwaii and is currently designated under the federal Species at Risk act as Special Concern (Conservation Data Centre 2011). Current population estimates for this species is not available. However, COSEWIC (2002) suggests population levels are greater than the critical limits set for listing a species federally as threatened or endangered, (i.e., more than 10,000 individuals occupying an area > 5,000 km^2).

This species is an opportunistic predator exploiting a range of invertebrates including worms, terrestrial and aquatic insects and spiders (COSEWIC 2002). Based on their diet, any western toads present on Murchison and Faraday islands[21] during the eradication would initially be at high risk for secondary poisoning resulting from ingesting invertebrates that have fed on the rodenticide baits. If present on Murchison and Faraday islands, dead or dying toads exposed to the rodenticide may also be preyed on or scavenged by one or more species mentioned in section *3.6.1 Potential Impacts to Birds* and section *3.6.2 Potential Impacts to Mammals* leading to increased tertiary poisoning risk. An aerial eradication operation on Murchison and Faraday islands would likely impact individual animals, if this species is present, but not result in any population level effects even in the unlikely event that significant mortalities occur as a result of the operation.

3.6.4 Potential Impacts to Bats

Four bat species are native to Haida Gwaii: California myotis (*Myotis californicus caurinus*), Keen's myotis (*Myotis keenii*), little brown bat (*Myotis lucifugus alascensis*) and the silver haired bat (*Lasionycteris noctivagans*, Burles, et. al. 2004). These species feed exclusively on flying insects (predominately) although Keen's myotis are also known to prey on spiders (E-Fauna BC 2011, Burles 1999). Little is known about California myotis and little brown bat on Haida Gwaii.

Keen's myotis (*Myotis keenii*), British Columbia's only provincially red-listed bat species (Conservation Data Centre 2011), has one of the most restricted distributions of any North American bat, being found primarily in the coastal temperate rainforests (COSEWIC 2003aa). However, due to their secretive nature, little is known of their distribution and abundance. The limited information available suggests that reproductive Keen's myotis show high fidelity to maternity roosts (Burles 1999). The only maternity colony known for the species is located at Hotsprings Island[22] located southeast of Murchison Island; however there have been reports of bats at Murchison Island (R. Gauthier, pers. comm. 2012).

Based on their diet, any bats present on Murchison and Faraday islands during the eradication would initially be at high risk for primary exposure resulting from ingesting insects that have fed on the rodenticide baits (secondary poisoning). An aerial eradication operation on Murchison and Faraday islands may impact individual animals but not result in any population level effects even in the unlikely event that significant mortalities occur as a result of the operation.

[21] It is unlikely that this species is present due to the relative isolation of the islands size of the islands and presence of a salt water barrier.

[22] Little brown bats also roost at the hot springs (Burles 1999).

However, no bat mortality was detected in previous eradication operations in New Zealand or during any other eradication where bats were studied (Lloyd 1994, Lloyd and McQueen 2002, G. Howald pers. comm.).

In addition to the risk of secondary poisoning, bats roosting on Murchison and Faraday islands may be temporarily disturbed by helicopter activities during the eradication operation. However, the duration of the helicopter activity will be limited thus minimizing any potential disturbance to this species.

3.6.5 Potential Impacts to Marine & Freshwater Ecosystems

During an aerial eradication operation, bait pellets may drift into the marine environment during baiting along the coastline. However, the bait application techniques described in this document include mitigation measures to minimize bait entry into water bodies. Based on previous studies, bait drift into the marine environment will have no measurable long term negative impact to intertidal invertebrates, fish, or water (e.g. Primus et. al. 2005). Furthermore, brodifacoum is not water soluble and will not be detectable in the water column (Olgilvie et al. 1997). The pellets also sink if they drop into the water (G. Howald pers. comm.).

Impacts of an aerial rodenticide broadcast on the marine ecosystem surrounding Murchison and Faraday islands are assumed to be negligible based on the following:

- The number of bait pellets entering the marine environment during the aerial broadcast operation can be minimized by using a deflector on the bait bucket to control the direction of the bait flow and hand baiting in certain areas that cannot be safely and effectively baited by air;
- The bait pellets will disintegrate relatively rapidly upon contact with the water and quickly disperse by currents and tidal action around Murchison and Faraday islands;
- In tests conducted by researchers in the Aleutians, as well as in California, Hawai'i, and the equatorial Pacific, marine fish species demonstrated almost no interest in placebo bait pellets that entered the water nearby (Buckelew et al. 2007a; Howald et al. 2005; USFWS 2005; A. Wegmann, pers. obs.). Although possible, the probability that fish will consume bait pellets is considered to be very low (Please refer to Section *3.2.2.2 Second Generation Anticoagulants: effects on fish* for additional information).

3.6.6 Potential Impacts to Water & Soils

Even if bait enters the marine environment it is unlikely to contribute to detectable levels of brodifacoum in the water column. Brodifacoum has low solubility in water (less than 0.01g/litre at 20°C) but binds strongly to organic material in the soil rendering it relatively immobile. Once in soil, brodifacoum is slowly degraded over weeks to months (half-life of 157 days), breaking down into carbon dioxide and water (WHO, 1995). Degradation time is affected by soil type, temperature, and the presence of soil micro-organisms. Only the erosion of soil itself would result in brodifacoum reaching water. If soil containing brodifacoum reached a waterway, the brodifacoum is likely to remain bound to organic material and settle out in sediments (Fisher and Fairweather, 2005).

The potential for groundwater and surface water contamination from brodifacoum is low (Ogilvie et. al. 1997). Cereal-based bait pellets that fall directly into marine or fresh water bodies will break up rapidly and become dispersed. The brodifacoum, in turn, will bind to organic material and settle out (Eason and Wickstrom, 2001). During previous eradication projects brodifacoum residues have not been recorded in water even when baits were directly deposited into freshwater streams (New Zealand Department of Conservation 2007, Ogilvie et al. 1997, Morgan and Wright, 1996). During the 2004 Hauturu rat eradication, eight water samples were taken directly downstream from baits lying in stream beds within 24 hours of the aerial drop and brodifacoum was not detected in any (Griffiths, 2004). Similarly, no traces of brodifacoum were found in water following trials on Adak Island, Alaska (U.S. Fish and Wildlife Service, 2007). Marine water samples from the intertidal zone of Anacapa Island taken 24 and 48 hours after aerial brodifacoum bait application did not detect any brodifacoum (Howald et al. 2005). In a more extreme example, a truck transporting brodifacoum bait pellets in New Zealand went off a coastal road and spilled more than 20 tons into the nearshore environment. Within nine days of the spill, the marine sediment at the spill site no longer registered a detectable amount of brodifacoum (Primus et. al. 2005).

3.6.7 Measures to Mitigate Risk to Native Species

Mitigative measures can help eradication operations minimize potential non-target impacts of native wildlife. However, the need to reduce short-term non-target impacts must be balanced with maximizing the probability of eradication success and financial realities. The mitigation measures described below are designed to protect individual animals even if expected impacts are not considered significant to the population while still ensuring eradication success. Eradication of rats from Murchison and Faraday islands is anticipated to have long term positive impacts for non-target species, even those populations that may experience some level of mortality as a result of rodenticide bait application.

3.6.7.1 Eradication Timing

The eradication should be timed to occur when most migratory birds have left the islands for their wintering grounds in order to reduce the potential of primary and secondary poisonings. Timing the operation for the late fall will also minimize the potential for physical and noise disturbance of native species including birds and marine mammals.

3.6.7.2 Bait Pellet Design

Pellets should be designed to be too large for small passerines such as sparrows to easily consume, Pellets should also be dyed blue/green, which has been suggested to make pellets less attractive to some birds (Pank 1976, Tershy and Breese 1994, Buckle 1994). Chaff, the dry, scaly protective casings of the seeds of cereal grain should be minimised to further reduce attractiveness of the bait to small birds (P. McClelland pers. comm.).

3.6.7.3 Carcass Searches

During the eradication operation field crews should conduct searches on both islands and remove any target and non-target wildlife carcasses found in order to minimize the risk of secondary poisoning.

Generally, most Norway rats die below ground, which can reduce but not eliminate the risk of secondary poisoning during eradication operations targeting this species (Kaiser et. al. 1997). However, less is known about the behaviour of black rats exposed to lethal or sublethal levels of a rodenticide (P. McClelland pers. comm.). A. Wegman (pers. comm.) suggests that a majority will likely die in their nest based on previous black rat eradication operations. Therefore, if their preferred nesting habitat is in burrows, which is likely the situation with Murchison and Faraday islands, then it is likely that most rats will die underground. If this is not the case with the Murchison and Faraday islands eradication it is possible that a larger number of rat carcasses may be present during and after the eradication operation thereby increasing the risk of secondary poisoning to non-target species. This necessitates the need for thorough carcass searches both during and after the aerial broadcast operation.

3.6.7.4 Supplemental Feeding of Avian Scavengers

Sitka deer carcasses could be placed as a supplemental food source at strategic points of land near Murchison and Faraday islands in order to draw Bald Eagles, Common Ravens, and Northwestern Crows away from the project site during the aerial eradication operation. This mitigative measure was successfully implemented during the Bischofs and Arichika eradications in 2011 (Parks Canada Agency, 2012).

3.6.7.5 Sitka Deer Cull

Prior to eradication implementation a Sitka deer cull on Murchison and Faraday islands could be undertaken in order to reduce the potential for secondary poisoning from scavengers feeding on deer carcasses. The feasibility of this mitigative option should be investigated further prior to implementation.

3.6.7.6 Minimizing Potential for Rodenticide Bait Entering the Marine Environment

A broadcast deflector may be attached to the hopper for all treatment passes of coastal bluffs and cliffs. The deflector directs bait within approximately 180° of the onshore side of the helicopter to minimize the risk of bait entering the ocean on the opposite, or seaward, side. Supplemental hand-broadcasting may be required in areas where aerial application must be limited to minimize accidental bait drift into the marine environments or where helicopter access is limited (e.g. overhanging cliffs).

3.7 Potential Human Health Impacts and Mitigative Measures

When working with the bait in a planned and controlled environment the risks to human health are very low. Personal Protective Equipment (PPE) should be worn by all personnel that handle bait and will meet or exceed all requirements described on the PMRA label for the rodenticide bait. Furthermore all personnel that will come in contact with the bait or monitor bait application in the field should receive training in bait handling protocols and procedures and successfully obtain their Provincial Pesticide Applicators Certification.

A temporary hunting closure should be implemented for Murchison Island, Faraday Island, Southeast Lyell Island, Hotsprings Island, House Island, and Ramsay Island to ensure that any deer sub-lethally exposed to the rodenticide bait can metabolize the toxin before being potentially consumed by humans. Deer on the project islands and adjacent shores of Lyell Island should be tested for brodifacoum exposure before the hunting closure is lifted.

3.8 Regulations and Compliance

Parks Canada Agency will coordinate all permitting and compliance requirements for the eradication. Permitting and compliance activity should be initiated well in advance of the eradication, as some requirements may take more than one year (i.e. bait registration with PMRA). A list of regulatory and compliance requirements is presented below (Table 8), as well as non-regulatory requirements.

Under the Canadian Environmental Assessment Act (CEAA) an Environmental Assessment (EA) is a required process to identify potential adverse environmental effects of the proposed action and to demonstrate that environmental factors have been considered in decision-making. As the eradication will occur within a national park reserve, Parks Canada is the lead federal agency for these lands and is required to undertake an Environmental Assessment. Parks Canada will be required to coordinate input from other appropriate federal agencies, including Environment Canada and Fisheries and Oceans Canada, and to determine what mitigative measures may be required and if additional permits such as Species-at-Risk are required. Based on the findings of the EA, Parks Canada Agency decides if the adverse environmental effects are likely to be significant, and makes a decision if the proposed action should proceed or not. The application and review period for an EA is approximately 180 days.

Parks Canada Agency requires a Research and Collection Permit for the conduct of research, including experimental development, monitoring, surveys, public opinion and related activities within its federal lands. The permit and authorizations period is approximately 60 days. A permit is required for monitoring research associated with this project, and may be required for the toxic bait trials.

As this project poses a small risk to federally-list Species-at-Risk (Schedule 1) species, additional compliance for these species may be required. Agreement and/or permit issuance for eradication activities that affect these species, or any part of their critical habitat, may be required. Both the EA and the Research and Collection Permit take into consideration activities that may impact Species-at-Risk.

Parks Canada will need to undertake an Animal Care Committee review of the proposed eradication and ensure that appropriate Animal Care requirements are adhered to during implementation.

There may also be additional compliance requirements as a result of the bait registration with Pest Management Regulatory Agency.

Table 8: Permits and authorizations required for Murchison and Faraday islands eradication.

Permit/Authorization	Purpose	From	Application Period
Environmental Assessment	A process to predict the environmental effects of proposed initiatives to minimize adverse environmental effects and incorporate environmental factors into decision making.	Canadian Environmental Assessment Agency (on Parks Canada lands, Parks Canada Agency is the lead federal authority to coordinate the EA and must consult with Environment Canada and Fisheries and Oceans Canada).	-
Environmental Assessment decision	Based on the findings of the EA, the federal authority (ies) decides whether adverse environmental effects are likely to be significant. This decision is taken into account when determining whether the proposed project should proceed.	Parks Canada	max 180 days
Research and Collection permit	Permit to conduct both invasive and non-invasive research, such as experimental development, monitoring, surveys, public opinion and related scientific activities in a federal park. Not necessary for management actions, but is required for associated monitoring of native species.	Parks Canada	60 days
Archipelago Management Board approval	Review of any regulations, guidelines or directives to be enacted, having particular regard for the conservation of natural resources and cultural features and the harmonization of visitor use of the Archipelago with these Haida activities	Archipelago Management Board (Parks Canada and the Haida Nation)	monthly
Animal Care	Research and collection permit includes review of animal welfare by Parks Canada Animal Care Task Force. If Research and Collection Permit is not required, Animal Care approval can be sought separately.	Parks Canada	60 days
Species at Risk Act (SARA) permit	A permit authorizing an activity affecting a listed wildlife species, any part of its critical habitat or its residences	Environment Canada; Department of Fisheries and Oceans (for aquatic species)	60 days
Migratory Birds Convention Act exemption	Exemption under the Migratory Birds Convention Act for incidental take of birds for conservation purposes	Environment Canada	

Bait registration	Registration of rodenticide bait for conservation use by federal agencies in Canada. Alternately an emergency registration can be used for short-term rodenticide approval.	Health Canada - Pesticide Management Regulatory Agency (PMRA)	1 year
Provincial Pesticide Applicator License	People applying restricted pesticides must be certified according to the BC Ministry Environment.	BC Ministry of the Environment	1 day exam

3.9 External Relations and Public Engagement

An External Relations Strategy which identifies target audiences and appropriate engagement and outreach tools has been developed by Parks Canada Agency. This strategy aims to increase awareness and understanding of both local communities and national audiences of invasive species management and the need for restoration within Gwaii Haanas. Web-based tools, publications, press releases, information bulletins and photographic and video tools will be used to communicate project activities, and to provide updates on project implementation and results. Information sessions about the project will be held on-island for local communities. A Frequently Asked Questions document has been drafted. More formal community consultation processes may be required under the EA. If formal community consultation processes are required, Parks Canada will coordinate and implement these, as a component of its External Relations Strategy.

Over and above regulatory and permitting consultations, on-going dialogue with other federal and provincial natural resource management agencies and organizations is advised, particularly those agencies on Haida Gwaii. Parks Canada will liaise with British Columbia's Ministry of Environment (MOE) and Ministry of Forests, Lands and Natural Resources Operations (MFLNRO) and local governments during project planning to ensure that any concerns of these agencies are appropriately addressed and that they are apprised of key issues.

The Haida Nation is officially represented in decision-making and management of Gwaii Haanas through the Archipelago Management Board (AMB). As a cooperatively managed national park reserve, the AMB is the ultimate decision-making authority for the management of natural and cultural resources within Gwaii Haanas. Decisions are made by consensus by representatives of the federal Minister of Environment, the federal Minister of Fisheries and Oceans Canada and the Council of the Haida Nation. The AMB has endorsed the Murchison and Faraday islands rat eradication project and was involved in the development of the project proposal. The AMB will need to approve key project components such as this Feasibility Study. On-going briefings and solicitation of input from the AMB regarding the eradication planning are underway.

3.10 Biosecurity Plan

A biosecurity plan is necessary to prevent re-introductions where eradications have been completed and to prevent incursions to currently rat-free islands in Gwaii Haanas. A plan covering all Gwaii Haanas islands, including the recent eradication sites of Bischofs and Arichika Islands, is under development. This comprehensive plan includes biosecurity measures to address potential rat introductions by visitors, researchers, staff and others travelling through Gwaii Haanas, transport of equipment and cargo, early detection measures and appropriate response plans, installation of permanent biosecurity devices (i.e. bait stations) on select islands and on vessels, rat-free education during mandatory orientations and signage. It also includes training for Gwaii Haanas partners such as the Haida Gwaii Watchmen program to assist staff to detect and report rat sign to Parks Canada staff.

3.11 Operational Plan

A detailed operational plan will be developed that takes into consideration the information contained in this feasibility plan. This plan should undergo an internal Parks Canada review as well as an external expert review to maximize the probability of eradication success while minimizing impacts to non-target species.

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APPENDIX: List of resident birds observed in Gwaii Haanas.

Common Name	Scientific Name	Abundance	Resident?	Nesting?
Family Phakacrocoracidae (Cormorants)				
Pelagic Cormorant, *pelagicus* subspecies	*Phalacrocorax pelagicus pelagicus*	common	Yes	yes
Family Ardeidae (Herons, Bitterns)				
Great Blue Heron, *fannini* subspecies	*Ardea herodias fannini*	unusual	Yes	yes
Family Charadriidae (Lapwings, Plovers)				
Semipalmated Plover	*Charadrius semipalmatus*	common	Spring/Summer	yes
Killdeer	*Charadrius vociferus*	uncommon	Transient Spring/Summer	yes
Family Haematopodidae (Oystercatchers)				
Black Oystercatcher	*Haematopus bachmani*	common	Yes	yes
Family Scolopacidae (Sandpipers, Phalaropes)				
Spotted Sandpiper	*Actitis macularia*	uncommon	Summer	yes
Least Sandpiper	*Calidris minutilla*	common	Transient Summer	yes
Short-billed Dowitcher	*Limnodromus griseus*	uncommon/rare	Transient	yes
		rare	Summer	
Common Snipe	*Gallinago gallinano*	uncommon	Yes	yes
Family Laridae (Skuas, Gulls, Terns, Skimmers)				
Mew Gull	*Larus canus*	uncommon	Summer	yes
		common	Winter	
Glaucous-winged Gull	*Larus glaucescens*	common	Summer	yes
		abundant	Winter	
Family Alcidae (Auks, Murres, Puffins)				
Common Murre	*Uria aalge*	common	Spring/Summer/Winter	yes
Pigeon Guillemot	*Cepphus columba*	common	Spring/Summer	yes
		Rare	Winter	
Marbled Murrelet	*Brachyramphus marmoratus*	common	Spring/Summer	yes
Ancient Murrelet	*Synthliboramphus antiquus*	abundant	Spring/summer	yes
		uncommon	Winter	
Cassin's Auklet	*Ptychoramphus aleuticus*	abundant	Spring/Summer	yes
Rhinoceros Auklet	*Cerorhinca monocerata*	abundant	Spring/Summer	yes
		uncommon	Fall, transient	
Horned Puffin	*Fratercula corniculata*	rare	Spring/Summer	yes
Tufted Puffin	*Fratercula cirrhata*	uncommon	Spring/Summer	yes
Family Hydrobatidae (Storm-Petrels)				
Leach's Storm-Petrel	*Oceanodroma leucorhoa*	abundant	Summer	yes
Fork-tailed Storm-Petrel	*Oceanodroma furcata*	abundant	Summer	yes
		rare	Winter	
Family Gaviidae (Loons)				
Common Loon	*Gavia Immer*	uncommon	Summer	yes
		Common	winter	
Family Anatidae (Ducks, Geese, Swans)				
Canada Goose	*Branta canadensis*	Abundant	Summer	yes
		uncommon	Winter	
Mallard	*Anas platyrhynchos*	common	Yes	yes
Green-winged Teal	*Anas crecca*	common	Summer	yes
		uncommon	Winter	
Harlequin Duck	*Histrionicus histrionicus*	uncommon	Summer/Fall	yes
		common	Spring/Winter	
Barrow's Goldeneye	*Bucephala islandica*	uncommon	Winter	yes
Common Merganser	*Mergus merganser*	common	Yes	yes
Red-breasted Merganser	*Mergus serrator*	rare	Yes	yes
		Uncommon	Winter	
Hooded Merganser	*Lophodytes cucullatus*	rare	Yes	yes
		Uncommon	Winter	
Family Accipitridae (Hawks, Kites, Eagles)				
Bald Eagle	*Haliaeetus leucocephalus*	common	Yes	yes
Sharp-Shinned Hawk	*Accipiter striatus*	uncommon	Yes	yes
Northern Goshawk, *laingi* subspecies	*Accipiter gentilis laingi*	rare	Yes	yes
Red-Tailed Hawk	*Buteo jamaicensis*	uncommon	Yes	yes
Family Falconidae (Caracaras, Falcons)				
Peregrine Falcon, *pealei* subspecies	*Falco peregrinus pealei*	uncommon	Yes	yes
Families Tytonidae and Strigidae (owls)				
Northern Saw-whet Owl, *brooksi* subspecies	*Aegolius acadicus brooksi*	uncommon	yes	yes

Common Name	Scientific Name	Abundance	Resident?	Nesting?
Family Corvidae (Crows, Jays)				
Steller's Jay, *carlottae* subspecies	*Cyanocitta stelleri carlottae*	uncommon	yes	yes
Northwestern Crow	*Corvus caurinus*	common	yes	yes
Common Raven	*Corvus corax*	common	yes	yes
Family Alcedinidae (Kingfishers)				
Belted Kingfishers	*Ceryle alcyon*	common	yes	yes
Family Cinclidae (Dippers)				
American Dipper	*Cinclus mexicanus*	uncommon	Yes	yes
Family Phasianidae (Partridges, Grouse, Turkeys)				
Sooty Grouse	*Dendragapus fuliginosus*	uncommon	Yes	yes
Family Picidae (Woodpeckers)				
Red-breasted Sapsucker	*Sphyrapicus ruber*	uncommon	yes	yes
Hairy Woodpecker, *picoideus* subspecies	*Picoides villosus picoideus*	uncommon	yes	yes
Northern Flicker	*Colaptes auratus*	common	Yes	yes
Family Tyrannidae (Tyrant Flycatchers)				
Pacific-slope Flycatcher	*Empidonax difficillis*	common	Summer	yes
Family Trochilidae (Hummingbirds)				
Rufous Hummingbird	*Selasphorus rufus*	common	Spring/Summer	yes
Family Hirundinidae (Swallows)				
Tree Swallow	*Tachycineta bicolor*	common	Spring/Summer	yes
Barn Swallow	*Hirundo rustica*	common	Spring/Summer	yes
Family Paridae (Chickadees, Titmice)				
Chestnut-backed Chickadee	*Poecile rufescens*	common	Yes	yes
Family Certhiidae (Creepers)				
Brown Creeper	*Certhia Americana*	rare	Yes	yes
Family Sittidae (Nuthatches)				
Red-breasted Nuthatch	*Sitta canadensis*	rare	Yes	yes
Family Troglodytidae (Wrens)				
Winter Wren	*Troglodytes troglodytes*	common	Yes	yes
Family Regulidae (Kinglets)				
Golden-crowned Kinglet	*Regulus satrapa*	common	Yes	yes
Family Turdidae (Thrushes)				
Swainson's Thrush	*Catharus ustulatus*	common	Summer	yes
		uncommon	Spring	
		common	Summer	
Hermit Thrush	*Catharus guttatus*	rare	Winter	Yes
Varied Thrush	*Ixoreus naevius*	common	resident	yes
		common	Spring/Summer	
American Robin	*Turdus migratorius*	uncommon	Winter	Yes
Family Bombycillidae (Waxwings)				
Cedar Waxwing	*Bombycilla cedrorum*	rare	Yes	yes
Family Parulidae (Wood-Warblers)				
		uncommon	Spring/Summer	
Orange-crowned Warbler	*Vermivora celata*	rare	Winter	Yes
Townsend's Warbler	*Dendroica townsendi*	common	Spring/Summer	yes
Wilson's Warbler	*Wilsonia pusilla*	uncommon	Summer	yes
Family Emberizidae (Emberizids)				
Fox Sparrow	*Passerella iliaca*	uncommon	Yes	yes
Song Sparrow	*Melospiza melodia*	common	Yes	yes
Dark-eyed Junco	*Junco hyemalis*	common	Yes	yes
Family Fringillidae (Finches)				
Red Crossbill	*Loxia curvirostra*	unusual	Yes	yes
Pine Grosbeak, *carlottae* subspecies	*Pinicola enucleator carlottae*	uncommon	Yes	yes
Pine Siskin	*Carduelis pinus*	common	Yes	yes

Data Sources: 1) the British Columbia Breeding Bird Atlas (accessed online at: http://www.birdatlas.bc.ca/english/index.jsp on 12/14/2011), 2) Birds of Haida Gwaii (accessed online at: http://www.gwaiihaanas.com/WILDLIFE/Birds/BirdFamiliesList.htm on 12/14/2011), and 3) Parks Canada Agency. 2011. A 20-year retrospective on trends in songbird diversity and abundance in Gwaii Haanas. Gwaii Haanas archive, Skidegate, BC. 22p