THE RAT ISLAND RAT ERADICATION PROJECT:

A CRITICAL EVALUATION OF NONTARGET MORTALITY

PREPARED FOR

ISLAND CONSERVATION

THE NATURE CONSERVANCY

U.S. FISH AND WILDLIFE SERVICE, ALASKA MARITIME NATIONAL WILDLIFE REFUGE

PREPARED BY

THE ORNITHOLOGICAL COUNCIL

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EXECUTIVE SUMMARY

As part of a larger program of island habitat restoration in the Aleutians, the U.S. Fish and Wildlife Service Alaska Maritime National Wildlife Refuge decided to undertake a rat eradication project on Rat Island. The Refuge entered into a partnership with Island Conservation, a nonprofit organization that has worked since 1994 to remove invasive species from islands, and with the Alaska state program of The Nature Conservancy.

First conceived of in the mid-1970s, the actual eradication project took place in early October 2008, after several years of intensive planning and studies to determine bait rate and to inform other key aspects of the project. The Island Eradication Advisory Group, a New Zealand-based consulting group comprised of experts who have long experience in the eradication of non-native species from islands, reviewed key aspects of the project, including bait rate and baiting strategy, on three occasions. A member of this Group also served as an on-island advisor during the actual baiting operation.

In October 2008, two helicopters dropped approximately 46 metric tons of Brodifacoum 25-W bait on Rat Island's 2800 hectares, supplemented by hand application of bait around the island's freshwater lakes. This rodenticide is known to be highly toxic to birds. Some nontarget mortality was expected, but the actual mortality exceeded the predicted mortality. Forty six Bald Eagles died (exceeding the known population of 22 Bald Eagles on the island); toxicological analysis revealed lethal levels of brodifacoum in 12 of the sixteen carcasses tested. Of the 320 Glaucous-winged Gull carcasses, toxicology tests implicated brodifacoum in 24 of the 34 tested. Carcasses of another 25 bird species were found; of these 54 individuals, three were determined by necropsy to have died of brodifacoum poisoning. This critical review was commissioned to review the eradication project in-depth to determine:

- Was mortality of Glaucous-winged Gulls and Bald Eagles associated with the rat eradication operations?
- What were the likely pathways of exposure?
- Were assumptions made about nontarget risks valid?
- Were the mitigation considerations or strategies appropriate and effective?

After a detailed review of 29 documents and approximately 170 e-mails relating to project planning and implementation, necropsy and toxicant residue analysis for 91 birds, and after 16 interviews with 12 key individuals, we concluded that:

- the mortality of the Glaucous-winged Gulls and Bald Eagles for which there are necropsy and toxicological reports was not only associated with but was a direct result of the rat eradication operations; that it is reasonable, based on scientific research on the effects of brodifacoum and the facts of this case to conclude that all or nearly all the mortality resulted from the eradication operations; and that the specific aspect of the operation that accounts for this mortality was the amount of bait applied and the timing of the bait applications.
- the likely pathways of exposure were consumption of bait or poisoned rats by the gulls and consumption by eagles of rats and gulls that died of brodifacoum poisoning.
- the assumptions made about nontarget risks were valid to the extent that they drew biologically reasonable conclusions from the information available, but that the available information was insufficient as to the presence and behavior of Bald Eagles;

- the primary mitigation strategies – timing of operation and bait rate – were not effective because of the information gaps and problematic assumptions but the primary reason for the nontarget mortality was the abandonment of the planned bait rates and application strategy; because bait rate was a key aspect of mitigation, this mitigation strategy was destined to fail regardless of the soundness of the underlying assumptions and completeness of the information because it was not followed.

Further, we identified aspects of the planning and implementation process that contributed to the decision-making that in turn led to the application of too much bait, too fast which in turn contributed to the primary and secondary routes of exposure that resulted in the nontarget mortality. These included inadequate documentation of the basis of decisions, an apparent lack of routine processes to verify calculations, and communication gaps. Two of the partners appeared to lack sufficient expertise or did not avail themselves of the expertise of their staffers when evaluating key decisions and there was inadequate follow-up on recommendations made by external reviewers.

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Introduction

In 1780, a Japanese shipwreck brought rats to the Aleutian island of Hawadax. For the bird life on the island, unaccustomed to mammalian predators, these new residents were anything but welcome. These Norway rats (*Rattus norvegicus*) became firmly established, preying on adult birds, nestlings, and eggs. Burrow-nesting seabirds disappeared and other bird species suffered the impact of rat predation. The island even lost its identity to rats when Russian navigator Fyodor Petrovich Litke mapped the Aleutian islands in the 1820s and bestowed the name Rat Island. For the next 230 years, rats held the island. Then, in 2008, helicopters dropped 46 metric tons of bait containing the rodenticide brodifacoum. No rats were found when the island was surveyed in 2009 or 2010. The partners announced the official results on 30 August 2010: Rat Island was free of rats.

It is too soon to tell if burrow-nesting seabirds will return to Rat Island and establish breeding colonies. The impact of rat removal on other breeding birds of the island also remains to be seen. However, the rapid and dramatic recovery of bird populations following rat eradications elsewhere suggests that seabird species will quickly re-establish colonies and populations of other taxa will rebound. For instance, on Langara Island, the colony area and breeding population of Ancient Murrelets (*Synthliboramphus antiquus*) doubled in the nine years after rat eradication, and the discovery of a small number of burrows indicated recolonization by Cassin's Auklets (*Ptychoramphus aleuticus*). In fact, surveys conducted at Rat Island in the late spring of 2010 indicated the Giant Aleutian subspecies of Song Sparrow (*Geospiza melodius maxima*) population had already increased in response to rat removal, and at least one burrow-nesting seabird, the Ancient Murrelet, was more common than before rat removal.

The success of the eradication effort and the likely conservation benefit of the rat eradication was slightly marred by the discovery in 2009 of approximately 422 bird carcasses on the island. Ninety one carcasses were submitted to a laboratory for necropsy and brodifacoum residue analysis. Sixteen of the 43 Bald Eagle (*Haliaeetus leucocephalus*) carcasses were examined and tested. Toxicological analysis determined that twelve had died of brodifacoum poisoning and another was classified as possible brodifacoum poisoning. The remaining three carcasses had deteriorated too much to permit analysis. Necropsy reports and toxicological analysis on 24 Glaucous-winged Gull (*Larus glaucescens*) carcasses (of 320 found) implicated brodifacoum poisoning; ten others were in too poor a condition to assess. Three Lapland Longspurs (*Calcarius lapponicus*) also succumbed to brodifacoum poisoning.

Even when all goes as planned and all reasonable preventive measures are taken, some nontarget mortality is expected when anticoagulants are introduced into the environment, and avian nontarget mortality in particular is expected when brodifacoum is the chosen anticoagulant. Indeed, the Environmental Assessment for the Rat Island rat eradication project predicted some avian nontarget mortality. However, the extent of the observed mortality on Rat Island exceeded the predicted potential mortality. That Bald Eagles would be among the victims in such numbers was particularly surprising to those who planned and implemented this project.

The conservation benefit of rat eradication is clear. The conservation community that rightly champions eradication efforts, however, is also concerned that nontarget mortality be minimized. To facilitate the continued use of this important conservation tool, the Nature Conservancy, Island Conservation, and the Alaska Maritime National Wildlife Refuge (the "partners") commissioned an external review of the Rat Island project to determine if and how the project

planning and implementation were related to the nontarget mortality. Future projects could then use this information to reduce the risk of nontarget mortality.

Ultimately, the partners awarded the contract for the review to the Ornithological Council, a nonprofit scientific organization comprising 11 societies of ornithologists throughout the Western Hemisphere. The Ornithological Council retained Terry Salmon, Ph.D to provide technical expertise regarding rodenticides and rodenticide application and Steve Sheffield, Ph.D to provide technical expertise in the field of wildlife toxicology.

The review process

Focus

The contract called for the review team to determine:

- was mortality of Glaucous-winged Gulls and Bald Eagles associated with the rat eradication operations?
- what were the likely pathways of exposure?
- were assumptions made about nontarget risks valid?
- were the mitigation considerations or strategies appropriate and effective?

Scope

An initial telephone conference between the review team and representatives of Island Conservation and the Nature Conservancy took place on 25 May 2010. It was agreed that beyond answering the specific questions posed in the Request for Proposals, the larger purpose of the review was to learn and to understand what can be done to improve future projects so that island conservation projects that require rodent eradication can continue. The review team conducted an investigation to determine what happened and why. Specifically, this review evaluates aspects of the planning and implementation that contributed to the nontarget mortality, including both methods of implementation and the processes that led to the decisions that contributed to the choice of methods. Therefore, the scope of inquiry necessarily included interactions among participants in the project to the extent necessary to elicit if and how human dynamics played a role in making decisions that led to the outcome.

Methods

Components of the review were as follows:

- Document review

  Project manager Stacey Buckelew (IC) provided a complete set of documents that could be characterized as the official record. These are detailed in Appendix B and served as the basis for findings on the key issues of bait rate and manner of application.

  Refuge biologist Vern Byrd provided a chain of e-mails between and among the partners and others, dating from August 2000 to September 2009. These e-mails were invaluable in constructing a chronology of events. Some e-mails included additional documents that also shed light on the decisions made and the reasons for those decisions. Byrd also provided a copy of the draft Programmatic Environmental Assessment originally intended to satisfy the NEPA requirements pertinent to the Refuge's rat eradication program for the entire Refuge.

  We received reports of necropsy results and toxicological analyses for 16 Bald Eagles, 34 Glaucous-winged Gulls, and 11 carcasses of nine other avian species as well as reports on two rats and one fish.

The USFWS Division of Law Enforcement provided its report, but the review team decided against reading this report prior to the submission of the draft report as we wanted to reach our own conclusions free from the influence of others. Prior to completion of the final report, we reviewed the Law Enforcement report, along with any additional information that was submitted to us after the 1 October 2010 presentation of the report and findings in Homer, Alaska.

- Literature review

Reports and papers resulting from other island rat eradication projects
Avian behavior, absence/presence and abundance particularly in the Aleutians
Toxicology and rodenticide literature

- Interviews

We interviewed key personnel representing each of the partners, project consultants, individuals from other agencies and organizations who participated in the project, and a number of other experts and consultants. To encourage interviewees to answer fully and candidly, we assured them (with the knowledge and approval of the partners) that: " …this is a fact-finding review and not a fault-finding review. The purpose of the review is to identify what, if anything, might be informative for future island habitat restoration projects of a similar nature." We committed to shielding individual identities to the extent possible, though in some cases, the information makes it possible to identify the source. We asked that interviewees not discuss the interviews or the topics discussed in the interviews with one another. We felt it important to obtain each person's individual recollection and perceptions without the influence – deliberate or otherwise – of the views of another. In some cases, that proved to be impractical, particularly with regard to two key elements of the investigation – the interpretation of the spreadsheet recording the amount of bait applied to the island and the visual record (GPS tracks) of the areas covered in each segment of the application. Finally, we sent the interview notes to each interviewee for review and correction. We also offered each interviewee the option to contact us at any time to submit additional information.

- Partner review and comment process

As provided by the contract, subsequent to the submission of the draft report and a presentation by Terry Salmon and Ellen Paul to representatives of each of the three partners (1 October 2010 at the headquarters of the Alaska Maritime National Wildlife Refuge in Homer, Alaska), the partners submitted comments on the draft report. After reviewing the comments, this report was revised. Some revisions were made to the body of the report but most – particularly those requiring longer and more detailed responses – appear in Appendix C.

Limitations

It is impossible to know the full extent of the mortality resulting from brodifacoum exposure. There are limited and not entirely comparable data on carcass persistence and detection

probabilities for similar species in a similar environment. Therefore, it is impossible to know how many other carcasses might have decomposed entirely prior to the May/June or August 2009 surveys. Carcasses on beaches might have washed away and it is possible, though unlikely that some birds – particularly gulls - might have died without reaching land.

In addition, most of the carcasses found on Rat Island in 2009 were not necropsied. It appears that while 422 carcasses were encountered, a total of 91 whole carcasses were collected, including 35 Bald Eagles and 37 Glaucous-winged Gulls. The 2009 eradication efficacy report states that "Ninety-one of the carcasses were submitted by USFWS to a veterinary clinic and/or approved laboratory for necropsy and brodifacoum residue analysis." As noted above, the review team was provided with a total of 16 necropsies for Bald Eagles, 34 for Glaucous-winged Gulls, and 11 for other avian species.

For these reasons, the full extent of the mortality resulting from brodifacoum exposure will always remain uncertain. The partners assumed, even prior to the necropsies, that, "…while the lethal dose of brodifacoum for most native birds on Rat Island is unknown, it is likely that many, if not most, gull and eagle moralities were due to primary and/or secondary poisoning, based on evidence of nontarget mortalities following eradications using brodifacoum-based bait on other islands worldwide (Howald et al. 2009; Eason et al. 2002, Dowding et al. 1999, Eason and Spurr 1995, Empson and Miskelly 1999)."

Further, because there are no data available on the background mortality rates of Aleutian populations of the affected species it is not possible to estimate the extent to which deaths resulted from other causes of mortality. On islands without introduced mammalian predators, carcasses of birds, including gulls, eagles, and a diverse group of marine birds are found regularly in spring when field crews typically arrive.

At the onset of this investigation, the review team and the partners agreed that, "… it is understood by the parties that the report's findings and conclusions will be limited to the evidence that is made available." However, given the necropsy and toxicology results, the reviewers agree with the partners that it is reasonable to assume that many, if not most of the gull and eagle mortalities were due to primary or secondary poisoning.

We limited our evaluation to the questions asked of us but we are of course cognizant that there is another, larger question that emanates from any eradication project and indeed, any conservation project that entails negative impacts to individual animals or even local populations, whether as a result of mortality or changes to habitat. The overall conservation benefit of the project must be considered and the weighing of benefits and costs is, at least in part, a question of values. We were not asked to consider the benefits and costs of this project and we have not done so. The biological benefits are not yet fully realized and so cannot be assessed at this time and we could not and would not attempt to determine whether the conservation community or the public values the restoration of habitat and the elimination of non-native invasive species enough to accept the negative consequences generally or in this particular case.

Applicability

The findings and recommendations of a review intended to inform future island rat eradication projects can and should be considered by any government agency or nongovernmental

organization planning an effort of this nature. For this reason, the review team makes recommendations intended not only for the individual partners involved in the Rat Island project, but for the community at large.

The Rat Island rat eradication project

Background

Over 300 volcanic islands spanning 1800 km comprise the Aleutian Islands. The U.S. Fish and Wildlife Service estimates that this archipelago supports breeding populations of 26 species of seabirds totaling more than 10 million individuals (Byrd et al. 2005). Though these remote islands boast inhospitable weather most of the year, some have supported human populations for about 5,000 years. The pre-European populations relied on the abundant fish and seabird populations found throughout the islands. However, their long presence in the region seemingly left little impact on the composition or abundance of native species. Though many bird bones were found in the middens they left behind, Causey et al. (2005) determined that hunting depleted populations breeding in accessible colonies at small scales of space and time but did not cause widespread or long-term effects.

The earliest scientific surveys described high abundance of numerous bird species, including some that have since been extirpated from the region (Causey et al. 2005). However, human activity in the 19th and 20th centuries – some deliberate, some unintentional – took its toll. Fur trappers introduced Arctic foxes (*Alopex lagopus*) and red foxes (*Vulpes vulpes*) (Bailey 1993, Williams et al. 2003); rats reached the islands via shipwrecks and vessels that docked for exploration and trade.

The Rat Islands, centrally-located in the Aleutian chain, suffered the same fate. Rat Island, one of the smallest of the group, became home to Norway rats in about 1780 when a Japanese ship wrecked on its shores. Later, foxes were introduced. Historical records analyzed by Bailey (1993) suggest that up to 200 pairs of blue foxes (another common name for *Alopex lagopus*) were introduced to each of the Rat Islands in 1820.

There is no direct evidence of the impact of the rat population on the birds and other fauna and flora of Rat Island. There were no baseline censuses and the population declines were not monitored. By the time the island became part of the Aleutian Island Reservation (later a unit of the Alaska Maritime National Wildlife Refuge) as a "preserve and breeding ground for native birds," few burrow-nesting seabirds were present on the island. A 2007 pre-eradication survey undertaken by Island Conservation found no evidence of burrow-nesting seabirds except on an islet off Ayugadak Point. That these species once nested on the island can be inferred from the presence of bones of several seabird species in rat middens and the fact that rat-free islands in the region host nesting seabirds that do not occur on Rat Island. Throughout the late 1970s and early 1980s, scientists systematically surveyed every island in the Aleutian Islands (e.g. Day et al.1978, 1979). Refuge personnel surveyed many of the main seabird colonies in the 1990s (e.g. Byrd and Williams 1996; Byrd et al. 2001). From this survey work, it is apparent that Cassin's Auklets, Ancient Murrelets, and puffins (*Fratercula* spp.), widespread breeding species throughout the Aleutians, are absent or extremely rare on islands with rats. Buldir's 1900 ha support approximately 10,000 Ancient Murrelets while the population on Rat Island's 2800 ha numbered about 125 prior to the eradication. Tens of thousands of Whiskered Auklets (*Aethia pygmaea*) nest at Buldir, and the species was common on the islet off Ayugadak Point, but apparently was absent from Rat Island, where rats were present. The Tufted Puffin (*Fratercula*

cirrhata), which nests in rock crevices on Buldir is estimated at 20,000, but only 210 on Rat Island (Byrd 2005).

Elsewhere in the Aleutians, foxes sharply reduced seabird populations (Williams et al. 2003) but on Rat Island, the rats were present for decades before foxes were introduced. The impact of rats can also be inferred from the demonstrated impact of Norway rats on seabird colonies elsewhere. On Kiska Island, for instance, where hundreds of rat-depredated eggs, chicks, and adults were found throughout the Sirius Point colony, Least Auklet (*Aethia pusilla*) productivity was sharply reduced (in fact, the lowest ever recorded for the species) as compared to that of populations on two rat-free islands (Major et al. 2006). The impact of rats seems to fluctuate; no prey caches were found in 2008, following six years in which rat impact declined. Some hypothesize that the impact of rat predation on auklet productivity fluctuates with the overwinter survival rate of the rats, consistent with the coupled oscillation patterns often seen in predator-prey dynamics. Therefore, it cannot be concluded with certainty that the absence of a particular species on Rat Island is entirely or primarily due to the rat predation pressure. However, the consistent pattern of extirpation or reduced productivity and population density across taxa subject to rat predation supports the conclusion that rat predation has been an important factor in explaining the distribution of birds throughout the Aleutians. Some land birds such as the Giant Aleutian Song Sparrow appeared to be very rare or absent on Rat Island and on other islands in the Rat Island group where Norway rats are present. Rats also seem to restrict the productivity of shorebirds such as Rock Sandpiper (*Calidris ptilocnemis*) and Black Oystercatcher (*Heomatopus bachmani*). One model proposes that shorebirds and other ground-nesting species may be less abundant or even extirpated entirely, either directly through rat predation or indirectly through a reduction in prey base in the rocky intertidal zone that in turn results from a trophic cascade triggered by the decreased number of shorebirds that feed on herbivorous invertebrates (Kurle et al. 2008).

Seabird species observed during the June 2008 biological survey of Rat Island included Ancient Murrelet, Tufted Puffin, Horned Puffin, and Least Auklet in the waters near Ayugadak Point and elsewhere. However, no evidence (nests, chicks, or pairs of adults) of burrow-nesting seabird species was found on the island. The Environmental Assessment reported that ledge-nesting seabirds such as cormorants (*Phalacrocorax* spp.) and crevice-nesting seabirds such as Pigeon Guillemot (*Cepphus columba*), Whiskered Auklet, and Horned Puffin (*Fratercula corniculata*) apparently still nested on Rat Island or on the islet off Ayugadak Point, because numbers were seen in marine waters near the island, where they forage on fish or plankton.

Inland, surface-nesting seabirds at Rat Island included Glaucous-winged Gull, Parasitic Jaeger (*Stercorarius parasiticus*), and Aleutian Cackling Goose (*Branta hutchinsii leucopareia*). Surface-nesting bird species persisted on Rat Island. The 2007 pre-eradication biological survey entailed both visual and automated aural detection and documented the presence of numerous avian species. These included Green-winged Teal (*Anas carolinensis*), Rock Ptarmigan, Black Oystercatcher, Rock Sandpiper, Lapland Longspur, Winter Wren (*Troglodytes troglodytes*), and Gray-crowned Rosy-Finch (*Leucosticte tephrocotis*). Glaucous-winged Gulls and Bald Eagles were observed.

Fortunately for the avifauna of Rat Island, President William Taft in 1913 designated the Aleutian Islands from Unimak west to Attu as the Aleutian Island Reservation. Though the

Executive Order establishing the reservation set the area aside as a preserve and breeding ground for native birds, it also provided for the propagation of reindeer and fur-bearing animals. By 1936, the Biological Survey (then part of the Department of Agriculture) sent biologist Olaus Murie to document the impact of introduced foxes. Accompanying Murie was future Refuge Manager Douglas Gray (Williams et al. 2003). Gray (1939) observed that "...*The entire refuge was operating for one purpose: fox farm production* … In many cases, bird colonies were completely cleaned off as their numbers were too small to survive the depredations of the foxes. In the others, there is no way to determine how much wildlife has suffered. The natives sum up the situation with the terse remark 'foxes come, birds go'." In 1949, the Aleutian Island Reservation began to remove Arctic foxes from Amchitka. By 2002, foxes were gone from about 40 islands (Williams 2003), including Rat Island in 1984. Though the foxes went, seabirds remained absent from Rat Island, where rat predation continued.

Although Refuge manager Bob Jones and Refuge biologist Vern Byrd turned their attention to rat eradication as early as 1975, the notion of removing rats from an island the size of Rat Island (approx. 2800 ha) was all but inconceivable as late as the 1980s. Rat eradications from islands began in 1961 but only very small islands (under 100 ha) were treated prior to 1985. The first successful rat eradication in the United States took place in 1982 on the very small Kalkun Cay in the U.S. Virgin Islands. No large island eradication would be attempted until 1995, when bait traps containing brodifacoum cleared the 3100 ha Langara Island of rats. However, the idea to eradicate rats from the Aleutian Islands took hold. As early as the late 1980s Ed Bailey, then the invasive species biologist for the Refuge and Vern Byrd, the Refuge biologist, began talking about rat eradication. After the successful Langara eradication, the Refuge asked Gary Kaiser and Mark Drever, the Canadian Wildlife Service biologists who had carried out the successful Langara extermination, to evaluate the potential to remove rats from the 16,000 ha Great Sitkin Island. Aerial broadcast application of bait, which is a virtual necessity for large, remote islands where the maintenance of bait stations by a large field crew over several weeks or months (Howald et al. 2007) is highly impractical or impossible, did not begin until 1993. On New Zealand's Campbell Island, the 2001 aerial broadcast of brodifacoum-based rodenticide eliminated rats from 11,300 ha, the largest area successfully cleared of rats to date.

Other islands were evaluated as the evidence of the impact of rats on seabirds grew and the eradication experience evolved. Kiska, at 28,500 ha was far too large; others were even larger than Kiska. Eventually Rat Island became the focus as the smallest of the uninhabited islands in the Refuge in need of rat eradication. Due to its distance from other islands with rats, re-invasion from another island was unlikely.

Meanwhile, the Refuge developed a shipwreck emergency response plan to prevent rat introductions from shipwrecks and continued to interact with rat eradication experts in New Zealand and Canada, becoming familiar with the methods and the underlying science. At one such meeting in New Zealand, a discussion about the impact of rats on auklets led the Refuge to begin monitoring the auklet colony on Kiska. Ornithologist Ian Jones of Memorial University documented the impacts (Jones et al. 2001) including predation on nestlings and adults and the caching of bird carcasses (Major and Jones 2005). Photos taken by Jones depict the carcasses of 115 adult Least Auklets and seven adult Fork-tailed Storm-Petrels taken from one unusually large rat cache on Kiska. Although Kiska's size precluded an island-wide eradication, the

increased understanding of the impact of rats on burrow-nesting seabirds prompted the Refuge to begin to plan an eradication on a smaller island to acquire the experience that might eventually allow an eradication attempt on Kiska.

In early February 2002, Island Conservation prepared a draft feasibility study assessing the potential to remove rats from Rat Island. This study, which was apparently provided to Art Sowls, then the invasive species biologist for the Refuge, recommended the use of brodifacoum. No final feasibility study appears in the records supplied to the reviewer team.

In October 2003, the Refuge had developed a rudimentary outline and a slightly more detailed draft plan of action for an "Invasive Commensal Rodent (ICR) Program" that included shipwreck response and local control as well as the rodenticide registration and NEPA process for several islands. The outline also contemplated the development of criteria to prioritize islands in need of eradication. The refuge invited a number of rat eradication experts, including several from New Zealand Department of Conservation, Gregg Howald and Bernie Tershy from Island Conservation, and John Eisemann from the USDA APHIS National Wildlife Research Center to attend a February 2004 meeting to evaluate this nascent plan.

Outcomes of that workshop pertinent to eradication projects included the identification of several prerequisite research needs:

- Determine feasibility of being able to put entire target populations at risk
- Evaluate the best seasons for baiting
- Do bait palatability and weathering tests
- Evaluate efficacy of several rodenticides
- Evaluate risks to nontarget species
- Document impacts of rodents on native ecosystems

Notes taken by Refuge biologist Laurie Daniel add to this list, "Document critical aspects of rat biology in Aleutians (e.g., home range size to evaluate needed bait station density, timing of breeding and fecundity to evaluate whether rodenticides will kill them faster than they can breed, immigration potential to evaluate whether small satellite islands near larger infested islands can be cleared initially."

In fact, the Refuge had already initiated a project to evaluate Norway rat biology and rat eradication methods. A fine resulting from a Korean ship oil spill funded preliminary work to evaluate rat biology, bait acceptability, and bait preference. The Refuge hired Peter Dunlevy in 2002 to undertake a number of specific components of the invasive species program, including local rat eradication work on Kiska, to undertake this preliminary research, and to seek EPA registration for the rodenticide to be used in the eradication project. The research, which began in 2003, was done on a number of small islets off Adak known as the Bay of Islands. The Refuge intended at that point to eventually test the efficacy of both diphacinone and brodifacoum. However, the studies undertaken by Dunlevy used only diphacinone (in Ramik Green bait), distributed in bait stations and placed by hand into rat burrows. Bait was distributed on two islands in late June 2003 and on the third in early July 2003 and replenished frequently enough to maintain an uninterrupted supply of bait until mid-November. The burrow bags were removed by mid-September. Overall, bait was applied at a rate of 8.6 kg/ha. In 2004, bait was applied only in

bags placed in burrows. The results in terms of rodenticide efficacy were equivocal. On the smaller islets (<0.5 ha) that were at least 95 m from a rat source population, eradication was achieved in under 30 days. A 1.0 ha island was cleared in about 60 days. Rats persisted on two other small islands 30 m or less from a rat source population for 73 days. However, the high rate of rodenticide take on these two islands led Dunlevy to conclude that this was an instance of recolonization. Four larger islands (2.1, 3.8, 11.2 and 17.8 ha) at least 100 m from a rat source population still had rats at the end of the initial treatment period (133, 75, 83 and 106 days, respectively) but appeared to be rat-free by the following spring. Dunlevy attributed this to timing. On three of the four islands baiting started in early July, at the peak of rat abundance and recruitment and at the height of food availability. Given the proximity to rat source populations, reinvasion was also a confounding factor. Two larger islands (4.1 and 6.1 ha) within 70 m of a rat source population also still had rats at the end of the treatment period (79 and 76 days, respectively), but, unlike the more isolated islands, continued to have rats after the following winter, suggesting reinvasion was even more of a confounding factor. Although efficacy monitoring indicated rat abundance declined dramatically on all four islands within 70 m of a rat source population, eradication was never achieved; methods appeared to be effective but undermined by insufficient isolation. By the time of the last follow-up survey in 2005, a few small rocky islets remained rat free (>13 months after the last sign of rats was observed), but there was rat sign on all the other treated islands.

Dunlevy also evaluated nontarget exposure and mortality by assessing bird feces and gurge pellets for rodenticide. Those exposed included large species thought to be Common Raven (*Corvus corax*) but potentially Glaucous-winged Gull, Bald Eagle, Peregrine Falcon (*Falco peregrinus*), or Short-eared Owl (*Asio flammeus*). Rock Ptarmigan (*Lagopus mutus*) feces containing rodenticide were observed. Nontarget species may also have been exposed to rodenticide through secondary consumption: as rats succumbed to the toxicant they became increasingly impaired and ataxic, making them easy targets for predators (eagles, falcons, owls, gulls or ravens), and about three-quarters of all rat carcasses found on treated islands were readily visible to avian scavengers. Apart from one Common Raven and a fledgling Lapland Longspur found in 2004, no dead birds were found on the treated islands during the course of the study, and there was no evidence of mammalian exposure to rodenticide other than the rats.

The other significant aspect of the Bay of Islands study, and that probably most directly relevant to the design of the Rat Island study, was the documentation of different rat densities in different habitats. Using index trapping, Dunlevy found that capture rates were about four times higher in coastal habitats than in upland areas.

Shortly after the February 2004 workshop, Island Conservation approached the Refuge and proposed to enter into a cooperative agreement to plan an eradication attempt for Rat Island, including an island-specific NEPA process. By May 2004, however, the Refuge had prepared a request for bids for a programmatic Environmental Assessment for the entire invasive rodent program.

Soon thereafter, The Nature Conservancy expressed interest in playing a substantive and substantial role in advancing the Refuge's efforts to restore seabird habitat through predator removal and prevention of new introductions. Potential roles included public and private

fundraising, production of outreach material, and public relations. The Refuge continued to discuss a potential cooperative agreement with Island Conservation. The Nature Conservancy proposed a Memorandum of Understanding in September 2005. After a November 2005 meeting in Anchorage, Island Conservation proposed a partnership that would include The Nature Conservancy and two other conservation organizations and that featured a two-year project to eradicate rats on Rat Island. In December 2005, the Refuge contracted with Island Conservation to complete the Rat Island Eradication Plan and to develop an operational plan for a 2007 island rat eradication.

Planning

The Refuge, however, had not yet selected Rat Island. In January 2006, Refuge staff were discussing "initial proposed selection criteria." At the same time, the Refuge entered into a Cooperative Cost Share agreement with Island Conservation and the Nature Conservancy. At that point, Island Conservation moved rapidly to plan a trial eradication project on Bay of Islands to take place in August 2006. Logistical planning, rodenticide application certification, and the application for an EPA Experimental Use Permit got underway in late March 2006. The trial would test the efficacy of brodifacoum and determine the uptake rate of the bait. In July 2006, Island Conservation drafted a rat eradication implementation plan that included a number of preliminary studies, including trials of broadcast methods, rat attraction to and palatability of bait, bait uptake rates, and risk to nontarget mortality. This draft plan contemplated only the use of brodifacoum, notwithstanding the Refuge's own plan to test the efficacy of several rodenticides.

Meanwhile, work continued on the draft Programmatic Environmental Assessment. Refuge staff commented on the draft as late as November 2006. However, in January 2007, then-Refuge manager Greg Siekaniec decided to cease work on the Programmatic Environmental Assessment. Over time, he had determined that it would be difficult to satisfy the NEPA requirements with a programmatic approach primarily because it would be easier to address the concerns of communities on the islands with site-specific plans. Both the National Marine Fisheries Service and the U.S. Fish and Wildlife Service's Division of Ecological Services told the Refuge that site-specific analyses were needed due to the different faunal composition on and around each island. He was also concerned that the initial research on Bay of Islands was not sufficient to support a decision to use either brodifacoum or diphacinone. It was also the case that the Refuge realized that eradications would not take place on every island in the Refuge, so there was no need to consider potential impacts for every island in the Refuge. The draft Programmatic Environmental Assessment presented a very comprehensive discussion of the potential use of diphacinone. At least in written documents, then, the termination of the Programmatic Environmental Assessment seems to have ended comprehensive discussion of the potential use of diphacinone. The eradication project moved forward based on the July 2006 draft implementation plan prepared by Island Conservation which stated that brodifacoum would be used for both for the Bay of Islands trial and the Rat Island Eradication. One member of Refuge staff felt that the Programmatic Environmental Assessment was too biased in favor of diphacinone and that the Refuge wanted both rodenticides "to be fairly evaluated but they were not." There was no further discussion of additional field trials to test the relative efficacy of

brodifacoum and diphacinone, and no trials to determine an effective application strategy for diphacinone. The project would move forward on this principle: "In understanding the probability of removal success balanced against the potential risks, the decision to implement a large island eradication project can be made if risks are negligible or can be effectively mitigated."

Although it is not reflected in documents provided to these reviewers, the Refuge apparently chose Rat Island for the eradication project sometime in mid-to-late February 2007. By mid-February, Island Conservation and the Refuge initiated an Environmental Assessment for Rat Island.

Pre-eradication studies, 2006

Island Conservation had conducted its rat eradication trial in the Bay of Islands in August 2006. The purpose of this study was to test methods of rat removal and to structure future operational and logistical plans for rat eradication in the Aleutian Islands Unit of the Alaska Maritime National Wildlife Refuge. According to the report entitled *Progress in restoration of the Aleutian Islands: Trial Rat Eradication, Bay of Islands, Adak Island, Alaska 2006*, the main objectives of the trial were to:

1. Study rat attraction and susceptibility to the proposed bait (*Brodifacoum 25 Conservation*).
2. Validate the bait application rate.
3. Mimic an aerial application of bait using hand broadcast.
4. Measure baiting efficacy on the rat population.
5. Study the movement of the rodenticide brodifacoum into the ecosystem.
6. Evaluate potential risks to nontarget species.

The study assessing bait palatability used paired feeding preference trials against natural food sources common in the Aleutian archipelago. Captured rats were offered fresh samples of the conservation bait Brodifacoum 25 Conservation and one of three alternative food sources:

1) Ramik Green, a competing pelleted conservation bait; 2) abundant food sources known to be common in rat diet; and 3) Brodifacoum 25 Conservation bait that had been exposed to ambient environmental conditions ("weathered") for 10 days. In this test of preference (for the pelleted formulations), Brodifacoum 25 Conservation was chosen significantly more often than natural food choices ($\chi 2$ 2.05,1 = 304.0, $p < 0.001$). However, Ramik Green was preferred over fresh Brodifacoum 25 Conservation during the trials ($\chi 2$ 2.05,1 = 8.0, $p = 0.05$). In all of the feeding trials, when fresh Brodifacoum 25 Conservation was not the first food choice, 71% of the rats switched to fresh Brodifacoum 25 Conservation within 30 minutes of presentation. Nonetheless, Island Conservation decided to use Brodifacoum 25 on Rat Island because "Although the competing conservation bait, Ramik Green, was initially selected more frequently than Brodifacoum 25 Conservation bait, diphacinone, the active ingredient in Ramik Green may not be effective in complete eradication in the Aleutian environment. Diphacinone efficacy has not been proven internationally for eradication purposes (it has no track record in eradications; Howald et al. in press), it is a multi- feed anticoagulant requiring rats to feed on the bait for up to one week before succumbing to symptoms of exposure, and the results from previous trials in the Bay of Islands were equivocal." However, this bait preference trial tested only the preference of rats for one pelleted bait over another and did not yield information pertaining to efficacy; the

results should have been the same had placebo bait been used. Island Conservation did not attempt an efficacy trial for diphacinone in the Aleutian Islands.

Bait efficacy (of the Brodifacoum 25 Conservation bait) was assessed with radio tracking, live-trapping, and the use of chew blocks in baiting stations. Ten of the 44 radio collars failed, but all 34 rats with working radio collars were recovered dead. No rats were live-trapped after bait application; one dead rat was found in a live trap thirteen days after bait application. Two chew blocks on one of the treated islands showed signs of rat activity, which was attributed to reinvasion. All monitoring efforts were concluded within 20 days of the bait application; reportedly, rats have since been found on all treated islands. No information about the origin of these rats has been provided.

By measuring the extent of uptake of a placebo bait replica of Brodifacoum 25W, Island Conservation established the bait application rate to be used on Rat Island. Bait was applied at the rate of 24 kg/ha and each pellet was marked with a flag. After four days, the remaining pellets were counted. Mean uptake - which could have included caching by rats or consumption or caching by other animals such as the sparrows that succumbed to brodifacoum poisoning in the active bait validation trial - in the 16 coastal plots was 10.9 $\pm$ 7.4 kg/ha. In the 14 upland plots, mean uptake was 4.0 $\pm$ 4.5 kg/ha. Using these means and variances to calculate the upper 99.9% confidence limit, Island Conservation determined that bait on Rat Island should be applied at 18 kg/ha on the coastal areas and 12 kg/ha inland to ensure availability to all rats for a minimum of four days.

A second trial measured the uptake rate of bait containing brodifacoum to validate the calibrated application rate. Bait was broadcast by hand at a rate of 17 kg/ha on the coastal area and 8 kg/ha on the inland area. On the day of baiting, 100 m^2 plots were randomly established. Pellets were placed within those plots by hand and flagged. Uptake was assessed at 4, 7, 14, and 21 days. The amount of bait taken at 4 days, 7 days, and 14 days was not reported. Overall, however, in the coastal plots, mean consumption ranged from 12.4% (2.1 kg/ha) to 34.2% (5.8 kg/ha) of total bait available. On three of the five inland plots, no bait was taken; on the other two plots, the rate of consumption was only 1.6% (0.13 kg/ha) and 2.0% (0.16 kg/ha). After 21 days, at least 15% of the bait remained across the island. Nontarget mortality was assessed using radio tracking and carcass searches. Six radio-tagged Song Sparrows (66% of 15)[1] and sixteen unmarked Song Sparrow carcasses were found. A Gray-crowned Rosy-Finch was found dead inside a rat trap but had no detectible level of brodifacoum. The results, as determined by radio-tracking, live-trapping, and chew-blocks, supported the conclusion that the calibrated baiting rate was sufficient to provide a lethal dose of rodenticide to all rats on the treated islands. A key finding that that 60% of the 34 rat carcasses with working radio collars were found in burrows (another 28% were found under vegetation) would influence the mitigation strategy on Rat Island.

The report itself was issued in June 2007.

[1] Six of the 15 birds included in the analysis died; this is a mortality rate of 40%, not 66% as stated in the Bay of Islands report (at p.30).

The Environmental Assessment

By the time the Bay of Islands report was issued, the Rat Island Environmental Assessment was well underway. Three of four sections (purpose and need, affected environment, and alternatives) had already been drafted. The alternatives section, with its discussion of diphacinone, had already been drafted by the time the Bay of Islands 2006 report was released. Of course, Island Conservation drafted the Environmental Assessment and had the underlying data from its Bay of Islands trial, including the bait preference trials that showed a preference for Ramik Green and an uptake trial that would indicate a lack of bait shyness, two considerations that influenced bait choice and baiting strategy. However, the discussion of diphacinone in the Environmental Assessment did not mention the preference trial or the fact that the rats preferred Ramik Green bait with the active ingredient diphacinone to the Brodifacoum 25 Conservation bait.

The Environmental Assessment also stated that "If diphacinone were used as the primary toxin for rat eradication from Rat Island, every potential rat territory on the island would need to have bait available for consumption continuously for a period of up to four days." However, the draft version of the Environmental Assessment stated that, "Every potential rat territory on the island would need to have bait available for consumption continuously for a period of up to 10 days." The Bay of Islands report stated that, "[diphacinone] is a multi feed anticoagulant requiring rats to feed on the bait for up to one week before succumbing to symptoms of exposure." These discrepancies suggest some uncertainty about the field application of diphacinone.

The Environmental Assessment, when released in December 2007, did not state the planned bait rates. By this time, the calibration trials on Bay of Islands (2006) and on Rat Island (July 2007) had been completed. The Island Eradication Advisory Group review of the alternative baiting strategies appears to have been completed on or about 10 December 2007. Presumably, Island Conservation's decision regarding the bait rate was made after the Island Eradication Advisory Group review was received and after the Environmental Assessment was released. The conclusions reached in the Environmental Assessment about the likelihood of exposure to the brodifacoum-laden bait via primary or secondary exposure would have to have been made based on the rates calibrated in the 2006 Bay of Islands trial (17 kg/ha for coastal areas and 8 kg/ha for upland areas).

Pre-eradication studies, 2007

Island Conservation conducted a suite of pre-eradication studies on Rat Island in 2007. The stated purposes were to index the biological populations of native species on the island prior to eradication and assess operational constraints associated with the eradication operation. Visual observation and the use of autonomous recording units served to document the presence and abundance of avian species. Marine mammals and plant species were also surveyed.

The 2007 studies included a calibration of the bait consumption rate. Using methodology similar to that used for the 2006 Bay of Islands study, Island Conservation broadcast a non-toxic, placebo bait replica of Brodifacoum 25 Conservation. Because densities of rats are known to be concentrated on the coastal areas of Aleutian Islands, the bait rate was stratified between inland and coastal habitats at 12 kg/ha and 24 kg/ha, respectively. Bait was applied to a total of 11.3 ha at the specified rates and consumption was monitored for 4 days in randomly placed 100 m^2 plots (four coastal and four inland). The number of pellets consumed from each plot was used to

extrapolate an application rate suitable for the whole-island eradication. The cumulative number of pellets consumed in each plot was converted to kg/ha by multiplying the number of missing pellets by mean weight of dry pellets, then dividing that product by the area of the plot (in ha or acres) (hence forth referred to as consumption rate). The means and standard deviations of the consumption rates for coastal and inland plots were taken, and the upper 99.9% confidence limit of the mean values used as the target application rate for the scheduled eradication. Using the 99.9% confidence limit of mean bait consumption, the calibrated application rate was 13.5 kg/ha in coastal habitat and 7.2 kg/ha in inland habitat. The pattern of consumption was much like that observed in the Bay of Islands trial. On the first day, the rates of take were approximately 11 kg/ha coastal, followed by less than 1 kg/ha on each of the following three days. Inland, the pattern was slightly different. Take the first night was very low – under 1 kg/ha. It increased to 2 kg/ha the second night and there was virtually no take on the two remaining nights. The report concludes that, "Four days after the initial bait application, less than 15% of the bait initially broadcast remained in two of the coastal plots, suggesting that the targeted goal of putting out sufficient, but not excessive quantities of bait, had been met." The actual per-plot consumption rates are not reported, but whatever the consumption rate in these two of four coastal plots, the data in the bar graph suggest that overall, the consumption in the coastal plots was at most 14 of the 24 kg/ha and in the inland plots, it was at most half of the 12 kg/ha applied to each area.

External review

A November 2007 request from Island Conservation to the Island Eradication Advisory Group for a review of the tentative baiting strategy presented three alternate baiting strategies, none of which were actually used on Rat Island. The first of these called for a single application of 16 kg/ha on the coasts and 8 kg/ha inland, based on the surface area of the island, for a total of 46 metric tons of bait. The other two strategies called for a total of 24 kg/ha. Each of the strategies also called for contingency bait in the amount of 20% (the base is not stated). The Island Eradication Advisory Group suggested that even the lowest of the rates was "prodigious" and noted that on Campbell Island – said to have had the highest rat density in the world – the bait was applied at 12 kg/ha on the cliff areas and 6 kg/ha elsewhere and that 6 kg/ha was sufficient in high rat density areas. It is not evident that the Island Eradication Advisory Group reviewed the data from the Bay of Islands calibration trial or the subsequent uptake trial used to validate those rates. However, the review expressly questioned the validity of the basic methodology:

> You obviously have this very conservatively covered in that all 3 strategies include prodigious quantities of bait. The lowest proposed sowing rate is 16 kg/h for coastal and 8kg/h for inland. The highest is a total of 24kg coastal and 12kg for inland. Compare this with Campbell at 12kg/h for cliffs and 6kg/h for the rest. Putting extra bait on is conservative over engineering so in principle is a good thing. We have questioned IC's method of determining bait rates in the past (bait available after 3 nights) Rat Island would seem the best case study to further this discussion. We have rat index data from Campbell so can compare with a roughly similar island. If the index data is not too dissimilar why not rely on the proven success of a real operation compared to a standard (the 3 nights) that is an entirely arbitrary measure?

A second review took place in February 2008 at a meeting of the Island Eradication Group in Wellington, New Zealand. Minutes of the meeting reveal that consultants noted that the overall

bait calculations appeared to be based on "3-D" (i.e., surface area) rather than on the planar area, as is done in New Zealand. Notes apparently taken by Island Conservation staff also state that, "Application rate is high, especially when considering based on surface area, and not planar. Suggested drop the surface area calculations." There was, however, no discussion of reducing the actual bait rate reflected in either the minutes or the notes.

Ultimately, Island Conservation chose to recalculate the overall amount of bait based on planar area rather than surface area, a difference of approximately 100 ha, but did not elect to reduce the kg/ha, notwithstanding the advice from the Island Eradication Advisory Group and the extensive experience of that group with island eradications. It is unclear how the decision to apply this quantity of bait (18 kg/ha coastal and 9 kg/ha inland split into two applications at the rates of 12/6 kg/ha coastal and 6/3 kg/ha inland) was made. One Island Conservation staffer suggested that this decision might have been based on the fact that rat densities on Bay of Islands and Rat Island were similar. However, there was no evaluation of rat density in the 2006 Bay of Islands trial. In the 2007 Rat Island study, the results of the rat trapping effort were used to assess productivity, age class, and relative abundance by habitat but there was no estimate of rat density.

Implementation

A massive planning exercise preceded the baiting operation. In addition to the lengthy permitting processes required at the state and federal level, the logistical planning entailed the choice of helicopters and pilots, the amassing and transportation of gear to support the on-island team, the selection of team members and the development of a command chain, and the calibration of the rate of flow of bait from the bucket and the swath width.

Overall bait quantity

Determining the amount of bait to purchase was a key element in terms of the logistical planning for the actual bait application. The amount of bait ordered seems not to be supported by the planning of the bait application rate or by the documents provided to the review team. An order was placed for 102,000 pounds of bait (46.27 metric tons) on 29 May 2008. The review team has found no documents showing the calculations for the bait order. The Rat Island operational plan called for 18 kg/ha to be applied on the coast and 9 kg/ha to be applied inland (as calibrated on Bay of Islands, but higher than as calibrated on Rat Island), with a contingency of 30% (base not stated). Table 9 of the August 2008 operational report delineates the total amount of bait ordered. The bait said to be needed just for the first and second applications, the offshore islets and a 10% allowance for "expected repeats" comes to 33.1 metric tons. Adding another 2 metric tons for the "expected repeats" (not explained in the text) would bring the total to 35.1 metric tons. The remaining 11.17 metric tons would comprise contingency bait, although the table states that the contingency bait will be 10 metric tons. There are numerous discrepancies in the August 2008 operational plan pertaining to the contingency bait. The first discussion of bait on page 24 states that the contingency bait will be 25% (although it does not say 25% of what). Both Table 9 in that plan and the project manager stated that the contingency bait was to have been 30%; Buckelew stated that this meant 30% of the planar land area assuming an application rate of 6 kg/ha but Table 9 does not give an application rate. The operation report gives the planar area of the island as 2810 ha, so the contingency bait at 6 kg/ha should have been 5.62 metric tons, bringing the total to 40.72 metric tons. In any case, it appears that the order actually entailed 30% of the amount of bait allocated to all other applications, combined, and exceeded that 30% by 1.17 metric tons.

Application timetable

Baiting started on 29 September 2008. Thereafter, the picture of the application timetable becomes murky. The four records of the application dates are inconsistent. The first is the project manager's spreadsheet (labeled Bait Application_Main.xls) of the actual helicopter flights, the area covered, and the amount of bait used on each flight. The second is a set of GPS records taken directly from the helicopters, which should correspond to the project manager's spreadsheet. The third is a spreadsheet prepared by a Refuge biologist, based on daily satellite phone reports from the project manager to the Refuge manager. Finally, Table 2 in the Final Operational Report lists the dates and places of application.

Table 1. Timelines of baiting operations

	Project manger spreadsheet (Bait Application_main.xls)	GPS records	Refuge biologist (Daniel) spreadsheet[1]	2008 Final Operational Report[2]
29 September	1st inland	1st application "base" blocks one and two	Island team begins 1st (3) application	East, Mountains blocks
30 September	1st inland, coastal (both) (hand application also took place during this 1st application)	1st application "base" block three and coastal repeat	Island team begins 1st application	West block
1 October	No application	No application	Island team begins 1st application	Hand broadcast Lake Systems 1,4,5,6, 9
2 October	2nd inland	2d application "base" blocks one and two	Tiglax Team begins hand baiting and SSL monitoring at Ayugadak rookery	Mountains block Hand broadcast Lake Systems 2,4,6,8,9,10 Ayugadak Islet
3 October	Lake exclusion zones with helicopter (dribble)	Lake exclusion zones, several drainages in block 3	Island Team aerially baits Ayugadak islet; Island Team continues 1st bait application, focused inland in mtns	No baiting operations shown for this date
4 October	2nd inland	2d application, blocks 1 and 3 and south coast from near Kyrsi Point east to cove near the midpoint of the coast, sea stacks	Island Team continues 1st bait application, focused inland in mtns; Island Team completes baiting freshwater exclusion zones, ending 1st bait application	East block
5 October	2nd inland, coastal, lakes with helicopter, contingency application	Kyrsi point, dribble on lake exclusion zones, drainages, and coastal (1 for second application and 2 for contingent for internal perimeter and deflector)	Island Team conducts a complete 2nd bait application island-wide; Island team completes all contingency baiting	West block

[1] Data consisted of a timeline kept at refuge headquarters in Homer using daily communications with Rat Island field crews.
[2] The application of the contingency bait is not reflected in Table 2 of the Final Operational Report.
[3] The spreadsheet marked a three-day block "island team begins first application." Presumably, this means the first application on each of the three blocks, each one starting on successive days.

Information from interviews suggested that an off-island advisor from Island Conservation instructed the team to wait a day between the first and second application; two of the four records suggest that the team did so on October 1 but the final operational report suggests that hand-baiting in the lake exclusion zone took place that day. According to the project manager's spreadsheet, that occurred on 1 October 2008. According to the Daniel spreadsheet, baiting "focused inland on mountains" occurred that day. At most, however, the interval between the first and second application for any particular part of the island was two days, and not the

"typically 5-7 days after the first application" directed by the label. In any case, by 5 October 2008, when the second application had been completed, bait in at least the calibrated and planned quantities (see analysis of actual bait rate, below) had been available to rats on all parts of the island for at least four days, assuming no gaps in coverage. We found no conclusive evidence of gaps by examining the baiting maps generated by the GPS TracMap. The project manager recalled there being "a few gaps confirmed by the GPS technology, where the flight paths were not overlapping or around the aerial exclusion zones. If you look at the three application tracks, there were a few gaps of 10s or 100s of meters." However, the GPS specialist recalled finding no gaps. The contingency bait, applied immediately after the second application, was applied to the entire coast, the freshwater drainages (but not the lake exclusion zones); nothing identified on the bait monitoring spreadsheet as a gap was treated with contingency bait. Pete McClelland also reported in his post-operations review that "John V [Vogel] did an excellent job with the GIS- and worked well with the pilots to ensure that there were no gaps and also to show that there were no gaps!"

Prior to the application of the contingency bait no effort was made to "Assess baited areas for signs of residual rodent activity (typically 7 to 10 days post-treatment)" as required by the label. According to Island Conservation's off-island advisor, USDA Wildlife Services (which holds the registration label for bait used on the Rat Island project) was not consulted to determine if it was appropriate to apply the contingency bait under the circumstances. The Refuge Manager, however, told the off-island advisor that the contingent bait should be returned from the island. The off-island advisor called the project manager to tell her to bring the contingency bait back, but by that time, the contingency bait had been applied. The project manager stated emphatically that there was an agreement that no bait would be returned from the island. Indeed, the operational plan makes no provision for the return of unused bait. It states very clearly that, "All bait remaining following two complete applications on the island will be strategically applied to areas perceived to not have received optimal bait coverage during the aerial baiting operations. Priority areas to be supplemented with additional bait are coastal cliffs, coastal bluffs, and coastal zones boundaries between adjacent baiting blocks. Prior to commencing aerial baiting operations the Project Manager will consult with the baiting pilots during an island overflight to determine which areas of the island will be prioritized for supplement with any excess baiting remaining."

The GPS tracks show that the contingency was applied to the drainages and that four flights were made around the coastal perimeter – 2 each around the inner coastal perimeter and the "deflector" zone, i.e., the coastal area between the mean high tide line and 45 m inward from the mean high tide line. The entire baiting operation took a total of six days. The field crew packed the gear, broke down the bait pods, and moved everything to the Tiglax on 6 October 2008, which departed for Adak later that day.

The operational plan called for a stay on the island of up to 45 days, in anticipation of bad weather that would prevent the helicopters from flying for several days at a time. In fact, the operational plan contemplated having the helicopters take shelter on a nearby island in the event of a major storm, described as " >85 kt." In the face of continual good weather, however, the project manager, in consultation with, or perhaps pressed by, the pilots, decided to apply the contingency bait without first conducting an assessment for rat sign, and despite the fact that the

bait already applied exceeded both the target rate and the label rate in at least some parts of the inner perimeter. Several of those interviewed said that a severe storm was anticipated and that they decided to leave to assure the safety of the team. All confirmed that two very severe storms arrived, one soon after the team left the island. In fact, on 9 October 2008, wind speeds gusting to 63 mph (55 knots) were recorded on Adak (National Weather Service records). Apart from the provision for the helicopters to seek safe shelter, however, no plans were made for the team to leave the island in the event of severe weather and then return to complete operations. To the contrary, the Rat Island Risk and Contingency plan clearly contemplated moving the helicopters off-island, stating "prepare helicopters according to forecast: depart island prior to predicted strong storms (wind > 60 kt)" but just as clearly contemplated having the field team stay on island stating "anchor weatherport floors and frames in positions to sustain high winds; disassemble sleeping tents & take refuge in weatherports, if required." The project manager and on-island advisors (including the pilots) chose to complete the baiting, notwithstanding label restrictions, and leave in advance of a storm rather than riding out the storm, as planned, or leaving to return safe harbor until the storm passed.

Analysis of actual baiting rate

The review team devoted enormous effort to trying to understand the amount of bait actually applied to each part of the island. The following table is based on the rates reported by the project manager in an addendum to the final operational report. The independent and more detailed calculations undertaken by the review team are presented in Appendix A.

The tracks recorded on a GPS TracMap Guidance system in the helicopters make clear that the "base" coverage was a layer of bait applied to the entire island in straight, overlapping flight lines across the island. Although the helicopter pilots closed the bait buckets 45 m from the mean high tide line to prevent bait from entering the water, the buckets throw the bait about 30 m in front of the helicopters. The GPS TracMap system in the helicopter records only when the bucket is open. In fact, then bait was applied coast-to-coast in the base application, with the exception of a 15 m fringe around the coast. The helicopters then flew the coastal rings identified as internal perimeter and deflector in the bait application tracking spreadsheet.

Table 2. Bait rates as reported by the project manager (in bold)[1]

All in kg/ha	Target rate	Label limit	Base[2]	Coastal Perimeter[2]	Amount of bait exceeding target rate	Amount of bait exceeding label limit	Nominal[3]	Adjusted Nominal[3]
First inland	6	18	**5.2**	n/a	n/a	n/a	**5.9**	**6.4**
First coastal	12	18	(5.2)	5.2 + 6.0 = *11.2*	n/a	n/a		
Second inland	3	9	**6.1**	n/a	3.1	n/a	**7.0**	**7.5**
Second coastal	6	9	(6.1)	6.1 + 7.6 = *13.7*	7.7	4.7		
Contingent bait[4]		Qualitative restriction	n/a	**7.76**	7.76	7.76	**7.8**	**7.8**
Totals	18 coast 9 inland	No cumulative limit	*11.3*	*32.66*	*Coast 14.66 Inland 2.3*		*20.7*	*21.7*
Lake exclusion zones[5]	9	18 first, 9 second, no cumulative limit		n/a	Unable to determine	Unable to determine	Not given in spread-sheet	Not given in spread-sheet

[1] These figures were not provided in the Final Operation Report itself. They are the figures provided to the Refuge for inclusion in the 9 December 2009 addendum to the 2008 Final Operation Report. The addition shown in the table (in italics) was done by the review team.

[2] Includes the bait thrown at the end of the line 30 m into the internal perimeter and the bait applied in the circumferential flight.

[3] These figures are taken from the Island Conservation spreadsheet labeled "Rat Is_bait appl summary.xlsx. *In fact, these nominal figures are not accurate and the review team recalculated the rates from the bait application spreadsheet. (Appendix A) comprises a recalculation of the rates.*

[4] Some contingency bait was applied inland, specifically on the drainages.

[5] The final operational report states that the intended rate was 6 kg/ha for the first application and 3 kg/ha for the second application. According to the baiting spreadsheet maintained by the project manager, the first hand broadcast in the lake exclusion zone covered 81 ha but the amount of bait applied by hand is not stated. Apparently, no subsequent hand-broadcast application took place. The 2008 operational report goes into some detail in describing the hand-broadcast operation (Section 4.4.2, at pages 17-18) but does not state the quantity of bait applied by hand. Although the hand application was intended to prevent the bait and the toxicant from entering the water, some brodifacoum was found in lake water samples. In the 2008 operational report (Table 7 at page 26), a calculation was made of the number of pellets needed to produce the observed brodifacoum concentrations in each of the lakes. In one case, the number of pellets needed to produce the observed concentration exceed the target application rate by 27% and in another case, by 280%, but in the other two cases, the number of pellets needed to produce the observed brodifacoum concentration was lower than the intended application rate, by 33% and 31% respectively.

Post eradication surveys

Post-baiting monitoring and efficacy surveys began on 26 May 2009 when seven people arrived to look for signs of rat activity and to take biological measures. On that day, 12 dead Glaucous-winged Gulls and one Common Eider (*Somateria mollissima*) were discovered along 600 m of beach inside the cove where the camp was deployed. Another Glaucous-winged Gull carcass was found above this beach near the former bait loading zone. The carcasses varied in states of decomposition and scavenging damage. Eight of these carcasses were collected that day and later shipped to the USGS National Wildlife Health Center in Madison, Wisconsin for necropsy and further analysis.

Over the coming days, the monitoring and efficacy crew encountered 270 bird carcasses on and around the island, including 43 Bald Eagles, 213 gulls, one Peregrine Falcon, two Rock Sandpipers, an Emperor Goose (*Chen canagica*) and one or few individuals of other species. The crew collected a random sample of these carcasses for further examination. To reduce risks of further mortality, the remaining carcasses were buried on the island. The crew saw no birds exhibiting abnormal behavior suggestive of exposure to rodenticide. The collected carcasses were sent to Adak via the M/V Tiglax when the ship stopped at Rat Island on 10 June 2009. They were transferred to a USFWS Division of Law Enforcement freezer. Of these, the remains of five Bald Eagles, one Peregrine Falcon, and one Rock Sandpiper were sent to the USGS National Wildlife Health Center for necropsy and toxicant residue analysis. The remaining samples stayed in the Division of Law Enforcement freezer in Anchorage, Alaska for the time being. The monitoring and efficacy crew left the island 18 June 2009. Additional bird specimens were transferred to the Division of Law Enforcement on 21 June 20009 as the Rat Island crew traveled through Anchorage.

The efficacy and monitoring crew searched for carcasses on all walkable beaches around the island. Seventy beach segments were searched; approximately half were searched repeatedly. Only one gull was found on a beach that had been previously searched. It is unknown whether the carcass was newly deposited or was missed on the previous searches. Surveys of nearby islands in the Rat Island group (Davidoff, Segula, Little Kiska, and Kiska), conducted from skiffs 25-50 m offshore, did not reveal large numbers of dead birds. One Northern Fulmar was found dead in the water off the colony at Davidof Island on 6 June 2009. In addition to coastline surveys, some beaches were walked on Davidof, Segula, Little Kiska, and Kiska. No dead birds were observed. A seabird monitoring crew at Sirius Pt., Kiska Island reported a dead eagle that was collected and placed onboard the M/V Tiglax for later analysis.

In August 2009 two additional teams visited Rat Island to conduct additional searches for carcasses. On 4 August 2009, five crews totaling 15 people surveyed all beaches and lakes on the north coast of the island, from the west end to Ayugadak Point, located on the eastern most point of the island. Two crews checked beaches with support from skiffs, two crews checked all lakes on the north side, and one crew covered some of the interior of the island incidental to botanical surveys. On 27 August 2009, two crews totaling six people surveyed all beaches on the south coast from the west end to Ayugadak Point. All intact or mostly intact carcasses were collected for potential analysis and for disposal. Skeletons of carcasses were left on site. In part because of

the burial of some carcasses, there remains uncertainty about the total number of carcasses found over the course of the three surveys. The 2008 efficacy report submitted by the project manager provides the following numbers (*sua* Table 3 of that report; note that this table reports only carcasses found and *not* the species and numbers of birds poisoned by brodifacoum or even the number of birds tested for brodifacoum):

Table 3. Carcasses found in 2009

Species	May/June	Early August	Late August	Total
Bald Eagle	43	2	1	46
Common Raven	2			2
Emperor Goose	1			1
Grey-crowned Rosy Finch	2	1		3
Green-winged Teal	1			1
Rock Ptarmigan		1	1	2
Lapland Longspur	2			2
Peregrine Falcon	1			1
Snow Bunting	2			2
Common Eider	2			2
Glaucous-winged Gull	222	57	41	320
Black-legged Kittiwake		3		3
Shearwater spp.		1		1
Harlequin Duck	2	2		4
Green-winged Teal		1		1
Northern Fulmar	2	6	1	9
Parakeet Auklet	1			1
Cormorant spp.	2	1	1	4
Pigeon Guillemot	2			2
Tufted Puffin	3			3
Puffin spp.	1		Present, not enumerated	1
Thick-billed Murre		1	1	2
Common Murre		1		1
Murre spp.		1		1
Auklet spp.	1		Present, not enumerated	1
Least Auklet		2		2
Whiskered Auklet	1	1		2
Totals				420

The eagle mortality exceeds all the eagles observed on the island in the 2007 surveys (seven breeding pairs and eight juveniles). Apparently, eagles from other islands arrived at some point after the bait application. According to the 2009 draft biological report, there were no active eagle nests found and only one adult pair was observed on the island.

Discussion

Nontarget mortality

Two nontarget species were significantly affected during and after the period of the Rat Island baiting program. Forty-six (46) Bald Eagle carcasses were found during the surveys, the majority (43) during the first survey period (May/June 2009). Only three carcasses were collected during the August surveys.

Sixteen Bald Eagle carcasses were necropsied. Most (13) were in poor carcass condition and the remaining were mummified. Because of carcass condition, it was impossible to pinpoint the time of death but most, if not all, were likely dead several months before their collection during the summer 2009. This would put death in late fall or early winter 2008, shortly after the baiting program. While some deaths could have occurred during spring 2009, we found no verifiable evidence to support this possibility. Body condition was rated as robust for 2, good for 6 and average for 4, indicating the birds were in fairly good condition prior to death. The rest were either in poor condition or it was not possible to determined. Necropsy reports listed brodifacoum poisoning as likely for 12 and possible for one of the eagles. Cause of death for the remaining three was unknown. The stomach contents for most birds were not determined but two birds had been consuming birds shortly before death.

A total of 320 Glaucous-winged Gulls were discovered during the surveys. Most (222) were found during May/June 2009. Fifty-seven were found in early August with the remaining 41 in late August. Thirty-four gulls were necropsied. Carcass condition ranged from fresh (3), fair (11) to poor (10). Six carcasses were mummified and three were classified as unknown. Body conditions ranged from good (1), fair (9) to poor (17). Three were emaciated and four were listed as ‘condition unknown’. Brodifacoum poisoning was cited as the cause of death of three gulls and likely cause for 19. Brodifacoum poisoning contributed to the deaths of two additional gulls. The cause of death for ten gulls could not be determined. Time of death was not determined for any of the birds examined. More that half the carcasses were in poor or undetermined condition. Only three were in good condition. Necropsy reports did not list stomach contents for most birds. Three had apparently scavenged on birds and one on mammals. Nine carcasses were scavenged by other birds.

From the Bald Eagle and Glaucous-winged Gull necropsy reports, and from the number of carcasses of these species found after the baiting program, it is clear that brodifacoum likely contributed to the death of most of the eagles and gulls found during the nontarget surveys and other activities on Rat Island. The timing of their death relative to the baiting operation, and the route of exposure are not as clear.

Brodifacoum bait was applied throughout Rat Island in late September-early October 2008. Since carcass searches were not conducted until the following summer, most of the deaths occurred sometime during the seven months between baiting and the surveys. The poor or mummified conditions of most carcasses indicated they likely died during the fall after the baiting operation. Even those carcasses in relatively good condition when collected could have been preserved from the cold temperatures during the winter and spring.

The Glaucous-winged Gulls' primary route of exposure was likely from ingesting bait pellets directly. The size and color probably made the pellets easy for gulls to find and consume. And, if bait density was high along beaches and in other more open areas, the gulls could have developed a strong searching behavior for the bait. According to the Environmental Assessment, 1.7 brodifacoum pellets would provide an LD50 to a Glaucous-winged Gull. At the baiting densities used during the eradication it is quite possible that a gull could eat at least 2 bait pellets and possibly many more. Examinations of gull boluses collected in the spring following the baiting the baiting indicated that some gulls had eaten brodifacoum bait. While the numbers were small, it clearly shows primary poisoning as a likely route of ingestion. Secondary poisoning of gulls by consuming poisoned rats is another exposure route. Glaucous-winged Gulls are omnivorous and scavenge rotting carcasses (Trapp 1979). Several gulls necropsied showed consumption of rats prior to death. While most rats were expected to die in burrows, beneath vegetation, or in crevices), some rats would continue moving about the surface after ingesting brodifacoum and many dead rats would die on or near the surface, and thus be available to avian predators and scavengers. These numbers could have been quite high in the rocky coastline, on beaches and around lakes and watercourses. If the island rat population was high, this too could have contributed to the total number of carcasses available to scavenge above ground. While both exposure routes were important, it seems that primary exposure from consuming bait pellets was likely to provide more toxicant than would secondary poisoning, where dilution from the original bait exposure to the rat occurs. If gulls ate many pellets, their toxic load potential for secondary poisoning could have been quite high.

Bald Eagles were likely killed by secondary poisoning. Both rats and Glaucous-winged Gulls are prey items for eagles in the Aleutians and at least two eagles necropsied had eaten birds prior to death. While not confirmed by the eagle necropsies, nine of the 34 gulls necropsied were apparently scavenged by other birds. Eagles could likely have been the scavenger on some of these carcasses, demonstrating a potential secondary poison exposure. Using the figures in the Environmental Assessment, an average Bald Eagle would need to consume the equivalent of 17 brodifacoum pellets to receive an LD50. It is quite possible a gull could have consumed this many or more pellets in areas where pellets were exposed, such as along the beach. If a Bald Eagle consumed a gull shortly after the gull ingested the pellets but before the toxicant had been absorbed into the gull's tissue, the eagle's exposure might be considered direct rather than secondary.

Conclusions:

1. *Bald Eagles and Glaucous-winged Gulls on Rat Island died as a result of brodifacoum poisoning.*
2. *Evidence supports two routes of exposure: primary (consumption of bait) and secondary (consumption of rats and other birds that died of brodifacoum poisoning)*

Bait choice

Generally
Several different toxicants and other control methods were considered for the Rat Island eradication program. Serious consideration was given only to the anticoagulants diphacinone and brodifacoum. While both anticoagulants have similar affect on the body, the primary and

secondary poisoning hazards are quite different. Diphacinone is a first generation anticoagulant that generally requires multiple feedings over several days to be effective. Brodifacoum, on the other hand, is often described as a single-feeding anticoagulant, meaning that multiple feedings over several days are not required to produce death. This single-feeding attribute makes brodifacoum an especially good candidate for eradication programs where exposure to every rodent is difficult and ensuring that they would get multiple feedings - as required for diphacinone - increases the risk of eradication failure. However, brodifacoum residues are retained in the body much longer than diphacinone residues. The single-feeding attribute of brodifacoum and the fact that it stays in the poisoned animal's tissues longer increase its potential to cause secondary poisoning. Both brodifacoum and diphacinone have been used with success for island eradications; brodifacoum has been used in slightly more than half the successful eradications to date. For past eradications using brodifacoum, nontarget poisonings have occurred and this has resulted in increased interest in the use of diphacinone. Prior to the Rat Island project, however, diphacinone had not been used on an island larger than 80 ha, and that was using bait stations maintained for 10 days followed by a second baiting period of 12 days (Witmer 2007).

In light of logistical aspects

The logistics of an eradication program influences the choice of bait. On remote islands with potentially severe weather, the use of bait such as diphacinone would create logistical hurdles that would need to be addressed. It is thought that diphacinone would require at least two applications, generally 2-5 days apart, to ensure access to bait over multiple days. Brodifacoum is also usually applied twice, generally with a short gap between applications, even though a single dose is sufficient to kill a rat. As described in the August 2008 Final Operational plan, the second application of brodifacoum is undertaken to assure complete coverage, both by filling gaps identified by analysis of the GIS records of the flights taken on the first application and also by flying lines at an angle to those flown in the first application. Two applications of also extend the duration of the availability of the bait to rats. Two applications are standard practice, according to the Island Eradication Advisory Group, with the notable exception of Campbell Island, where logistics made a second application impractical. Thus, the plan to undertake two applications when using brodifacoum – albeit for a different reason – suggests that diphacinone could, in fact, be used. There is, however, concern is that if a second application were delayed or canceled entirely due to weather, as might well be the case in the Aleutians, it could jeopardize a diphacinone-based eradication program since some rats might not consume enough bait to accumulate a lethal dose during the time bait was available. Experimental data suggest that delaying the second application of diphacinone might not be problematic. The optimal interval between applications determined in a cage test of ground squirrels was 3-5 days but the mortality rate was not significantly different when the interval was increased to 10 days. (Whisson and Salmon 2002). With either diphacinone or brodifacoum, a failure during eradication – whatever the reason – would mean the entire project would need to be repeated. The cost and logistical challenges of treating a large, remote island are such that the possibility of repeating the project would be unlikely at best.

The potential for nontarget mortality

Using any anticoagulant in large-scale field operations, such as an island eradication, carries a risk of secondary poisoning exposure. Awareness and concern have increased in recent years

because of reported secondary poisonings and exposure for predator and scavenger birds and mammals to the second generation anticoagulants such as brodifacoum. Although secondary poisonings can occur with first generation materials like diphacinone, very few have been reported despite considerable use of these materials in field applications such as California's agricultural cropping systems over the past 50 years.

The Environmental Assessment identified the risk of exposure to brodifacoum from the eradication program as high for both Glaucous-winged Gulls and Bald Eagles. It also identified higher risks from brodifacoum compared to diphacinone. The potential exposure would depend in part on the availability of bait to nontarget species. The belief that 'viable' bait would not survive the harsh winter (later confirmed by examining pellets in May/June 2009) supported the view that primary poisoning would only be a factor during the first 30 days after baiting. As part of the Bay of Islands research, Island Conservation conducted long-term bait persistence trials by monitoring pellets caged enclosures in coastal and upland habitats at 87, 116, 147, 184, 210, and 252 days post placement. In the coastal habitat bait pellets were entirely degraded at Day 87. At Days 116 through 210 bait enclosures in the upland habitat were entirely concealed by snow. On Day 252 remaining bait pellets in the upland enclosures were collected and analyzed for brodifacoum residues. Analysis confirmed that if bait pellets are not consumed or degrade over the winter (due to freezing) the few remaining pellets could contain brodifacoum residues. On Rat Island, by the time the 2009 surveys were conducted, no bait persisted on the coast and inland, an average of one pellet per 100 m^2 persisted but these pellets were in a highly degraded state. The Environmental Assessment predicted that the bait could persist two to eight months, depending on exposure to rain and snow. In this case, the bait was apparently attractive enough for a long enough time in the fall to cause the brodifacoum poisoning of a large number of gulls that consumed the bait directly. Three of the necropsied gull carcasses were characterized as fresh, suggesting that they may have consumed brodifacoum (as bait or from scavenging poisoned animals) in spring 2009, but none showed conclusive presence of either bait or animal consumption.

Secondary mortality resulting from the consumption of rats or other birds that had eaten the bait or other poisoned animals also had to be considered when assessing the potential nontarget mortality. Island Conservation's 2006 Bay of Islands study showing that 66% of rats died below ground during an eradication trial supported the conclusion in the Environmental Assessmentthat secondary exposure would be limited. However, elsewhere in Alaska, Bald Eagles have been observed excavating seabird burrows (DeGange and Nelson 1982). It is possible that Bald Eagles were able to retrieve rats that died near the entrances of burrows or were able to excavate shallow burrows to gain access to rat carcasses. The Environmental Assessment also assumed that eagles would leave Rat Island for more fertile hunting during the fall salmon run on other islands, and most apparently did leave Rat Island before the eradication, as only 6-8 eagles were seen on the island during eradication efforts. If a rich food resource such as dead or dying rats and gulls were present on Rat Island, the eagles may not have needed to leave to exploit the salmon run. The Environmental Assessment notes the study of Bald Eagle diet composition (Anthony et al. 1999) that found that on average, rats accounted for 13% of bald eagles' diet in a two-year study on nearby Kiska and Amchitka Islands. The Environmental Assessment itself acknowledges that Bald Eagles are opportunistic feeders. However, the Environmental Assessment did not consider the possibility that the availability of an abundant and easily

obtained food source might cause the island's resident eagles to remain in the area or return to the island and might attract other eagles passing by.

Bait application strategy

The characteristics of brodifacoum and the lack of experience with diphacinone in situations comparable to Rat Island supported the decision to use brodifacoum over diphacinone. However, once the decision was made, there appeared to be little effort to tailor the baiting program to minimize potential primary and secondary poisoning potential from using this material. The baiting strategy, rates, and application methods used were not altered to reduce these potential hazards. They were more like a strategy that would be appropriate for diphacinone in that bait would be applied twice, with a planned gap of several days between applications. The two-application strategy for brodifacoum is not explained fully in the Environmental Assessment. The short discussion (section 2.2.2.6) justifies the two-application strategy by explaining that bait needs to be available for longer than 10 days after the initial application, to assure that weanlings that survived the first application and emerged from burrow would have bait available to them. The second application is also considered "insurance" because it extends the availability of the bait to both adult rats that survived the first application and to emerging juveniles.

Under the planned baiting strategy, the bait would have been available for at least nine nights, because the application rate for each of the two applications was designed to make bait available for four nights. Data from the Bay of Islands bait uptake trial (with active bait) showed that between 66% and 88% remained on the ground after four days in coastal plots where rat density was the highest. In upland plots, no more than 2% of the bait was consumed over four days. Island Conservation's data from the persistence trials on Bay of Islands showed that unconsumed bait on the ground would maintain its integrity for approximately eight days; it would begin to mold on day nine. Therefore, it could be anticipated that an ample amount of bait would remain unconsumed after four days and that it would maintain its integrity for at least another four days. Thus, each application would actually provide bait for eight days; two applications even one day apart would provide bait for nine days. The Environmental Assessment stated, "If diphacinone were used as the primary toxin for rat eradication from Rat Island, every potential rat territory on the island would need to have bait available for consumption continuously for a period of up to four days." Notwithstanding the fact that Island Conservation's field test data demonstrated that a single application would make sufficient bait available for eight days, the partners in the Rat Island eradication considered the use of diphacinone for a large-scale eradication to be experimental at the time the project was planned. The Refuge made it clear that it did not consider the Rat Island project to be experimental in nature. Therefore, the partners determined to use brodifacoum, notwithstanding the fact that the application strategy was essentially the same strategy that would be used for diphacinone and notwithstanding the fact that a single bait drop at the planned rates could provide sufficient bait for eight days.

In addition, the two-application strategy appears to have been adopted from the practice of the Island Eradication Advisory Group, which in turn is intended to assure that there will be no baiting gaps. The second application is flown at an angle to the first, making it likely that any gaps that occurred, for instance at the ends of lines, will be filled by the next application.

Assuming that the two-application method was based upon the accepted practice and experience of the Island Eradication Working Group members, it is worth noting that on Rat Island, the actual flight lines of the second application were flown at an angle to the flight lines of the first application.

Island eradications are extremely expensive and each program is unique. We recognize the importance of success and that fact that failure could jeopardize the political and financial will to continue with these types of programs. We believe the choice of brodifacoum was appropriate under the circumstances of eradication on Rat Island, especially given the lack of experience with a large-scale application of diphacinone for island eradication at the time and given that the Refuge did not consider this project to be experimental. However, given the genuine scientific debate about using these materials and the known potential for nontarget mortality, more consideration and evaluation of using diphacinone would have been appropriate. Specific application methods, rates and timing should have been developed for a side-by-side comparison with brodifacoum. However, given the single feeding properties of brodifacoum, it would likely prevail as the choice of rodenticide for Rat Island. Nonetheless, the more rigorous analysis could have revealed additional mitigation measures to reduce potential primary and secondary hazards from using brodifacoum. The significant nontarget mortality resulting from the Rat Island operation clearly suggests that a strategy using diphacinone or other toxicants should be developed and tested for future use on islands where predatory and scavenging birds are present. While multiple applications would be required with diphacinone, the accepted practice is to apply two applications of brodifacoum. Except in places where a second application might be precluded by extreme weather or other uncontrollable factors, diphacinone would be a more appropriate choice to minimize nontarget mortality.

Conclusions:

1. The discussion of bait choice, particularly in the Environmental Assessment, was curtailed but this reflected, in part, a dearth of information about the potential for diphacinone in island eradication programs.
2. The information available to the partners regarding the potential for the use of diphacinone was insufficient because the island restoration community has not made sufficient efforts to develop successful methodology for the use of diphacinone, including bait makeup, concentration, pellet type and composition, application rates and timing.
3. The use of a two-application strategy, to assure that there will be no baiting gaps, also happens to be an appropriate strategy for the use of diphacinone. However, the logistical aspects of this particular eradication necessitated an aerial broadcast and presented the possibility that a second application would be precluded by adverse weather. Given these logistical issues and the cost of the operation, the choice of brodifacoum was appropriate.
4. A two-application strategy using diphacinone and brodifacoum, might be feasible. It could reduce the overall amount of brodifacoum. However, we are unaware of any projects that have tested this strategy or any field trials that have used this approach. Any alternate strategy would require small-scale field trials before attempted in an actual eradication project.

Bait rate

Generally
The application rate for Rat Island was established using data from the 2006 Bay of Island (BOI) trials. On islands, rat populations concentrate on the coast and around inland freshwater because food resources are most abundant in these areas. The Bay of Island consumption trials determined the application rate, calibrated as the 99% upper confidence limit of the observed mean consumption rate, to be 17.0 kg/ha in coastal habitat and 8.0 kg/ha in inland habitat. This application rate was designed to provide adequate bait for a period of four days to all rats. However, a 2007 consumption trial on Rat Island generated somewhat lower application rates. Again, using the upper 99% confidence limit of the mean bait consumption over four nights, the Rat Island trial suggested that a rate of 13.5 kg/ha in the coastal area and 7.2 kg/ha in the upland region would have been sufficient to supply bait for four days for all rats. No studies were done to directly estimate rat abundance on the two islands.

Both placebo bait consumption trials indicated good acceptance on the first night with a large decrease in take on subsequent days of the trial. This pattern of bait acceptance seems peculiar since there should be no impact on feeding rate from the consumption of placebo bait during the four-day trial, i.e., no reduction in the number of rats. Generally, this pattern would indicate some type of aversion to the bait, perhaps because the bait was not appealing. It could also indicate hoarding, which may have little to do with bait acceptance. In any case, the observed pattern of consumption suggests that the *a priori* premise that bait needed to be available for four nights may be flawed. Additionally, the use of placebo bait to determine consumption rate is problematic. It is true there is latency period of four to five days between consumption and death that occurs when rats eat anticoagulant. That latency period reflects the physiological effects of anticoagulant on rats, but it does not reflect the amount of bait that a rat would need to eat to consume a lethal dose. It also does not measure the length of time it will take for each rat to encounter bait and it does not take into account rat density. The Island Eradication Advisory Group also questioned this method of calculation in its December 2007 review of the baiting strategy, saying, "We have questioned IC's method of determining bait rates in the past (bait available after 3 [sic] nights) Rat Island would seem the best case study to further this discussion. We have rat index data from Campbell so can compare with a roughly similar island. If the index data is not too dissimilar why not rely on the proven success of a real operation compared to a standard (the 3 [sic] nights) that is an entirely arbitrary measure?" The Island Eradication Advisory Group's observation is general in nature and is seemingly based simply on the fact that the Island Eradication Advisory Group baiting rates are much lower and have proved effective; it does not allude to the bait consumption trials.

The relatively high consumption rates seen on the first nights of both trials suggests that there was no bait shyness, one concern that Island Conservation cited in rejecting the use of diphacinone. However, if rats rejected the bait after the first night (bait aversion), then multiple feedings would have been unlikely, suggesting that the use of diphacinone would have been problematic and might have led to failure. Unfortunately, Island Conservation did not conduct consumption trials with Ramik Green or another diphacinone-based bait, notwithstanding the fact that rats showed a preference for Ramik Green over Brodifacoum 25-W Conservation during the 2006 Bay of Islands trial.

We have found no response by Island Conservation to that question raised by the Island Eradication Advisory Group in its December 2007 review of the baiting strategies about the four-night assumption. We have found no explanation in any of the documents provided to us. The Bay of Islands and Rat Island consumption studies are based on the premise that bait must be available for four nights, but the report cites no studies or prior eradication experience that support this premise. Again, the pattern of consumption of bait in the Bay of Islands placebo study suggests that most of the bait taken is consumed the first night. The actual daily consumption rates are not reported but it appears from a bar graph (Fig. 5) that in the coastal areas, the rats consumed eight kg/ha the first night and at most, one kg/ha each of the following three nights. The corresponding inland rates were approximately 5, 1, 0.5, 0.5 respectively. That would mean that of the 24 kg/ha applied on the coastal areas, approximately 13 kg/ha remained uneaten after four nights and inland, approximately 17 of the 24 kg/ha remained uneaten. During the broadcast trial using bait containing brodifacoum at a rate of 17 kg/ha coastal and 8 kg/ha upland, the uptake rate in randomly located plots was measured. In the five coastal plots, the four-day consumption rate ranged from 12.4% to 34.2% and in the upland plots, from 0.0% to 2.0% of the bait applied. Even 21 days after the broadcast, the maximum overall bait consumption was 85%. Whatever the basis for the assumption that bait rate should be calibrated based on availability for four nights, the assumption seems not to be supported by the data.

The Bay of Islands uptake trial, using bait containing brodifacoum to validate the calibration rates, also suggests that the four-night assumption may be flawed. More than that, it suggests that the calibrated rates were too high. The maximum consumption in coastal plots was 34.2% and inland, at most 2% of the bait was consumed. After 21 days, 15% of the bait remained, but this does not mean 85% of the bait was consumed by rats. By that time, some of the bait could have been consumed by other animals or could have disintegrated. The amount remaining after four nights was not reported. No second application – which would have replenished the bait and extended the amount of time bait would have been available – was done to determine how much bait would have been consumed, even though a two-application strategy would be used on Rat Island.

It may be that this assumption results from the concern that dominant rats in a territory will prevent other rats from obtaining bait. This concern makes sense in the context of a strategy using bait stations, in that a single rat could defend a single source of food. However, in the context of aerial baiting, where bait is distributed throughout every territory, it seems unlikely that a dominant rat could defend abundant and highly dispersed food sources.

We are not suggesting that there is no biological reason to assume that bait needs to be available for more than one night. We are suggesting that as a basis for calibrating bait rate, the assumption that consumption over four nights, which was unexplained *a priori*, was not supported by the placebo trials and the uptake trial.

Developing the baiting strategy

Using the rate calibrated from Bay of Islands, the project planners considered three baiting strategies for Rat Island, each involving a different application strategy and bait rate.

The BOI study and many other island eradication programs have demonstrated the need to stratify application rates to ensure adequate bait is applied to areas with higher rat density. On

Rat Island, the entire coastal perimeter, along freshwater drainages and around freshwater lakes were considered prime rat habitat and therefore targeted with a higher application rate.

The record demonstrates considerable effort to develop the baiting strategy. The first potential strategy contemplated a single application of 16 kg/ha on the coast and 8 kg/ha inland. The second entailed a single application of 24 kg/ha on the coast and 12 kg/ha inland. The third strategy called for a first application of 16 kg/ha on the coast followed by a second of 8 kg/ha, and two drops of 8 kg/ha and 4 kg/ha inland. The calculations of total tonnage for each strategy were apparently based on the surface area of 2800 ha, which is said to be the surface area of the island. However, the August 2008 operational plan gives the planar area as 2800 ha and the surface area as 2900 ha. The project planners asked the Island Eradication Advisory Group to comment on each of the three potential strategies. The Island Eradication Advisory Group suggested that a two-application approach was preferred. However, the Island Eradication Advisory Group did express concern about the amount of bait used since it was much higher (24 kg/ha coastal and 12 kg/ha inland) than they had used in the successful Campbell Island eradication program. For Campbell Island, said to have the highest density of rats in the world, Island Eradication Advisory Group used 12 kg/ha on cliffs and 6 kg/ha elsewhere. Ordinarily, Island Eradication Advisory Group uses 8 kg/ha for coastal areas and 4 kg/ha for inland areas, which they consider to be "…more than enough bait to kill all the rats" but because Campbell Island was so remote, only one bait application was possible, so the bait rate was increased. The Island Eradication Advisory Group characterized all three baiting options as "prodigious quantities of bait." They also offered their indexing methodology and data from Campbell Island as an alternative method of determining bait application rates. Specifically, the Island Eradication Advisory Group said, "We have rat index data from Campbell so can compare with a roughly similar island. If the index data is not too dissimilar why not rely on the proven success of a real operation compared to a standard (the 3 nights [sic]) that is an entirely arbitrary measure?"

The strategy review document also stated that contingency bait in the amount of 20% (of what is not said) was included in the total bait calcuations.

Ultimately, Island Conservation decided to apply 18 kg/ha to the coastal area and 9 kg/ha to the inland area, dividing the application into two drops of 12/6 kg/ha and 6/3 kg/ha, respectively. The review team found no documentation explaining this decision. The August 2008 operational plan stated that: "A 25% contingency of bait (will be purchased) to allow for any potential damage and/or other mishaps to bait at any stage during the operation." However, Table 9 of the August 2008 operational plan quantifies the contingency bait as "30% of total" and comprises 10 metric tons. The August 2008 operational plan also contemplated the use of at least some of the contingency bait. Although it was designated as contingency bait in the table detailing the bait application rates for each component part of the application (Table 9), it was also characterized as "excess bait." The plan for this excess bait, i.e., "all bait remaining following two complete applications on the island" was to strategically applied to areas perceived to not have received optimal bait coverage during the aerial baiting.

The label limits

Pesticide use is controlled by a label that sets specific instructions regarding application rate, methods, treatment areas, and target species. The US Environmental Protection Agency approves

these labels as part of the product registration process. The label is the legal guidance for a control program. While some deviation from the label is allowed (applying pesticides at a lower rate in some situations), the overall label is a legal document with significant penalties for violations.

In this case, the label was written by the Wildlife Services program of the USDA National Wildlife Research Center and submitted to the EPA for approval. That program holds a number of nationwide pesticide labels needed for its state-based operations and often allows states and others who hold the appropriate licenses to "use" these registrations, usually under the supervision of the NWRC or other government agencies. The label for the Brodifacoum 25W Conservation was written at the request of the U.S. Fish and Wildlife Service and reflected the anticipated baiting strategy to be used on Rat Island.

The EPA-approved material (Brodifacoum 25W Conservation) used for the Rat Island eradication program had specific application instructions for controlling Norway rats for island conservation. The label allowed for aerial broadcast application from aircraft or hand broadcast using up to 18 kg/ha of bait during the first application. A second application was allowed ("typically 5-7 days after the first application depending on weather conditions") at half the initial rate (9 kg/ha). Subsequent applications were allowed, subject to these conditions:

> Assess baited areas for signs of residual rodent activity (typically 7 to 10 days post-treatment). If rodent activity persists, set up and maintain tamper-resistant bait stations or apply bait directly to rodent burrows in areas where rodents remain active. If terrain does not permit use of bait stations or burrow baiting, continue with broadcast baiting, limiting such treatments to areas where active signs of rodents are seen.

The application rate listed on the label is the maximum amount of material that can be applied to any given area during an application during the eradication program. While it is generally understood that application technology is not precise, the expectation it that the maximum label rate will not be exceeded.

The label as written has some ambiguity. First, it directs that the first application be applied "at a rate no greater than 16 lbs of bait per acre (18 kg bait/hectare) *per application* (*emphasis added*)." A specific, and lower, limit is prescribed for the second application. Therefore, the limit of 18 kg/ha is not allowed "per application" but only for the first application. This is confusing, the label should be re-written to eliminate this apparent contradiction. It is also unclear what the appropriate rate should be when additional applications by signs of continuing rat activity. Second, the second application is to be applied "typically 5-7 days after the first" which implies that there should be some temporal break between the first and second applications, but the duration of this break is not specified. It is unclear if the break can be shorter, or as short as the one-day break apparently taken on Rat Island. The use of the word "typically" in describing the break between the first and second applications implies that the duration of the break could be more or less than would generally be the case. The label also makes the timing of the second application conditional on weather conditions. This could be read to address the situation, anticipated on Rat Island, where weather necessitated time gaps longer than 5-7 days. However, it could also be read to allow a shorter period if, as occurred on Rat Island, the team took

advantage of unexpected favorable weather to continue baiting on a nearly continuous basis. The same ambiguity pertains to the timing provisions on the subsequent applications, but this is moot because the Rat Island team did no assessment for signs of rat activity at any time prior to applying the contingency bait.

The terms of this label are silent as to compensatory increases or decreases in applications rates to adjust for prior applications, assuming that the cumulative rate did not exceed the combined label rate for those applications. Clearly, the applicator can always chose to apply less bait than the maximum rate allowed by the label, but there is no indication that doing so will justify the violation of the label limit on subsequent applications. In this case, the label allowed for 18 kg/ha to be applied on the first application and 9 kg/ha on the second application. The first coastal application was below the limit by 0.8 kg/ha and the second coastal application exceeded the limit for that application by 4.7 kg/ha. Even if compensatory baiting was allowable under the label, the additional bait applied during the second application far exceeded any rate that could be claimed to be compensatory.

There is also a mismatch between the intention of the label in terms of the purpose of additional bait and the intention and plans of the Rat Island team. The label contemplates the use of additional bait only if rat sign persists. However, it was always the stated intention of Island Conservation to use the contingency bait to treat "gaps and cliffs" regardless of the presence of continued rat presence.

The August 2008 operation plan stated:

> **Excess bait**
> All bait remaining following two complete applications on the island will be strategically applied to areas perceived to not have received optimal bait coverage during the aerial baiting operations. Priority areas to be supplemented with additionally bait are coastal cliffs, coastal bluffs, and coastal zones boundaries between adjacent baiting blocks. Prior to commencing aerial baiting operations the Project Manager will consult with the baiting pilots during an island overflight which areas of the island will be prioritized for supplement with any excess baiting remaining.

There was never an intent to search for rat sign before applying bait beyond the second application. We draw attention to the ambiguity in the label, however, to suggest that the label be revised before it is used in an other island eradication project. Although the excessive bait rates were a function of Island Conservation's practice of calculating a nominal rate and not due to any ambiguity in the label, and of applying too much bait too fast, and although the nontarget mortality was not caused by the ambiguities in the label, it is nonetheless important to remove ambiguities and apparent contradictions. It is important that the label allow some flexibility in eradication practices and especially under the conditions that characterize island eradications. However, the label should define the nature and extent of the allowable deviations. In addition, the label does not prescribe an upper or cumulative limit. It is not common practice on the part of the EPA to set a cumulative limit because follow-up applications are often necessary. The practice is to allow additional applications so long as rodent activity persists. Therefore, it cannot be said that the overall amount of bait applied exceeded the label limits but the amount applied in

specific applications violated the label limits. The violation of the label limit was in applying too much bait in the second application and in failing to meet the condition for the application of additional bait in any amount without determining that rats were still active in the treatment area. Given that the application of the contingency bait took place immediately following the completion of the second application and given that the prerequisite assessment never occurred, the application of contingency bait could and probably should be considered part of the second application. With a total of 21.13 kg/ha in the coastal area (see Table 2), this second application exceeded the label limit by 12.13 kg/ha.

In addition, the applications done in the operational program did not follow the operational plan. The second application was actually higher than the first instead of half the first, as planned. Even if the second application had been within the label limits, there is no documentation explaining the decision to increase the rate for the second application. The assessment of nontarget mortality in the Environmental Assessment and the mitigation strategy "no more bait than is necessary to achieve success" were based on a second application at a lower rate: "The environmental impacts analysis in Chapter 4 of this document is based upon two applications of brodifacoum, with the second application conducted at a lower application rate than the first." . The significant deviation, especially the large increases in the overall amount of bait applied in the coastal areas, likely changed the nontarget risk because excess bait was available to rats (so they could eat more than was needed to achieve mortality) and to nontarget species such as gulls.

Actual application rates

The actual amount of bait applied to the island deviated significantly from the target application rate. Data provided were not consistent and the review team found it difficult to determine the actual amount of bait used (see Appendix A). Table 2 (reproduced here for convenience), represents the application rates in the various areas of the island during the first, second and contingency bait applications as reported by Island Conservation. We could not verify them because there is no written documentation explaining the calculations or the several adjustments to the area of different parts of the island when calculating kg/ha. Answers to interview questions and explanations sent by e-mail were not helpful in discerning how these rates were calculated.

Table 2. Bait rates as reported by the project manager (in bold)[1]

All in kg/ha	Target rate	Label limit	Base[2]	Coastal Perimeter[2]	Amount of bait exceeding target rate	Amount of bait exceeding label limit	Nominal[3]	Adjusted Nominal[3]
First inland	6	18	**5.2**	n/a	n/a	n/a	**5.9**	**6.4**
First coastal	12	18	(5.2)	5.2 + 6.0 = *11.2*	n/a	n/a		
Second inland	3	9	**6.1**	n/a	3.1	n/a	**7.0**	**7.5**
Second coastal	6	9	(6.1)	6.1 + 7.6 = *13.7*	7.7	4.7		
Contingent bait[4]		Qualitative restriction	n/a	**7.76**	7.76	7.76	**7.8**	**7.8**

All in kg/ha	Target rate	Label limit	Base[2]	Coastal Perimeter[2]	Amount of bait exceeding target rate	Amount of bait exceeding label limit	Nominal[3]	Adjusted Nominal[3]
Totals	18 coast 9 inland	No cumulative limit	*11.3*	*32.66*	*Coast 14.66 Inland 2.3*		*20.7*	*21.7*
Lake exclusion zones[5]	9	18 first, 9 second, no cumulative limit		n/a	Unable to determine	Unable to determine	Not given in spread-sheet	Not given in spread-sheet

[1] These figures were not provided in the Final Operation Report itself. They are the figures provided to the Refuge for inclusion in the 9 December 2009 addendum to the 2008 Final Operation Report. The addition shown in the table (in italics) was done by the review team.
[2] Includes the bait thrown at the end of the line 30 m into the internal perimeter and the bait applied in the circumferential flight.
[3] These figures are taken from the Island Conservation spreadsheet labeled "Rat Is_bait appl summary.xlsx. *In fact, these nominal figures are not accurate and the review team recalculated the rates from the bait application spreadsheet. (Appendix A) comprises a recalculation of the rates.*
[4] Some contingency bait was applied inland, specifically on the drainages.
[5] The final operational report states that the intended rate was 6 kg/ha for the first application and 3 kg/ha for the second application. According to the baiting spreadsheet maintained by the project manager, the first hand broadcast in the lake exclusion zone covered 81 ha but the amount of bait applied by hand is not stated. Apparently, no subsequent hand-broadcast application took place. The 2008 operational report goes into some detail in describing the hand-broadcast operation (Section 4.4.2, at pages 17-18) but does not state the quantity of bait applied by hand. Although the hand application was intended to prevent the bait and the toxicant from entering the water, some brodifacoum was found in lake water samples. In the 2008 operational report (Table 7 at page 26), a calculation was made of the number of pellets needed to produce the observed brodifacoum concentrations in each of the lakes. In one case, the number of pellets needed to produce the observed concentration exceed the target application rate by 27% and in another case, by 280%, but in the other two cases, the number of pellets needed to produce the observed brodifacoum concentration was lower than the intended application rate, by 33% and 31% respectively.

The absence of reported data on actual hand-baiting application rates prevents a determination of the total kg of bait applied to the island. However, as no bait was returned from the island and there was no reported spillage or spoilage, it is reasonable to conclude that the entire 46,266 kg ordered and brought to the island was applied.

Information derived from interviews suggests that there were discrepancies between the intended rate and the actual application rate of application in the lake exclusion zones, but that this discrepancy might have been corrected in the field. Apparently, when the hand-baiting began, two of the field crew realized that the amount they were told to apply seemed to be applying too much bait. The pilots were flying more bait out to those baiting around the lake because they were using up the cached allotment for the two planned broadcasts on the first day of hand baiting. One of the workers commented on this situation. That night, others calculated the rate at which the bait was being applied in the lake exclusion zones. The following morning, a discussion was had among the field workers that it appeared that too much bait was being applied, perhaps even exceeding label rate. The project manager was informed of the situation.

In response, she stated that it was acceptable to apply more bait in the first application than was planned because it might not be possible to do a second application, so long as the nominal rate did not exceed the label limit. A Refuge staffer suggested that the actual application rate could be reduced by 25% by broadcasting the bait in three directions rather than four, and that a reduction of 25% would result in a rate below the label limit. This revised application practice was adopted by those who were made aware of it, but it is unclear if all field workers who were assigned to the lake exclusion zones were made aware of it. That the application might have been within the label limit does not indicate that it was also within the intended application rate, however, as the intended rate was lower than the label limit.

Throughout the reports, Island Conservation used the term "nominal rate." In interviews, Island Conservation staff gave two different explanations for this term. In one sense, Island Conservation uses this term to reflect the fact that in an aerial baiting, there is variation in the amount of bait that reaches the ground in any one area. It cannot be applied uniformly across all areas. There is inconsistency caused by air flow dynamics, the bait bucket, humidity, and other factors. On any given square meter, the target rate is not what might actually be found on the ground. While understandable, the calibration of the bait bucket takes most of these things under consideration when determining the calibrated application rate. Island Conservation also uses the term to mean an overall rate of application averaging the different area rates. For example, if 1 ha was treated with 12 kg/ha and another 1 ha was treated with 6 kg/ha, the nominal application rate would be reported as 9 kg/ha for the 2 ha area. By using the nominal rate, project operators apparently felt they were within the label amounts while in actuality, they were exceeding the maximum allowable rate for 25w brodifacoum conservation bait on some areas of the island.

Neither the FIFRA regulations nor the EPA Label Review Manual (which covers only agricultural and residential household use) define the word "rate" or address the issue of a nominal rate. The review team consulted with William W. Jacobs of the Registration Division of EPA's Office of Pesticide Programs. Jacobs stated that, "The maximum application rate indicated on the label applies to the per-acre rate of treatment. The label does not authorize using weighted-averages over broad areas to allow the maximum specified rate to be exceeded." The label allows for a second application of bait, usually 5-7 days after the first. On Rat island, the second application in the Mountains block took place three days after the first application on that block, while the second application on the other two blocks took place on the third and fourth days after the first applications on those blocks (Table 1). There was no contemporaneous documentation of the basis for this decision about when to put on the second application of bait. The 2008 final operational report suggests that this occurred "to take advantage of the clear skies and calm weather that were present." Contrary to the GPS records, the final operational report states that "The second application began 5 days after the initiation of the first application on the East and West blocks and the lower elevation of the Mountains block." In fact, this seems not to be the case. According to the GPS files, the second application began on the fourth day of the operation, and on the same block first treated. However, this was not a violation of the label, which allows discretion as to the timing of the second application. The effect of this shortened period either on efficacy or nontarget hazards is unknown. It is likely that the shortened period between the first and second application resulted in excess bait being available for potential primary poisoning over a shorter period of time. In addition, having excess bait could lead to more bait consumption by rats since the toxicological effects of brodifacoum poisoning do not

generally slow down feeding for 3-4 days. Consuming excess bait (beyond the lethal chronic dose) would lead to increased brodifacoum levels in poisoned rats, thereby increasing secondary poisoning potential.

The second application was targeted at half the first application rate (6 kg/ha coastal and 3 kg/ha inland) but actually went on at a higher rate than the first application and double what was planned. While below the label rate for the second inland application, there was no discussion in the documents we reviewed to indicate why this higher rate was used for the second application. The second coastal application rate was more than double that planned and appears to have exceeded the label limit by 4.7 kg/ha. Again, no explanation appears in the documents. Without justification, this is essentially extra and unneeded bait according to the project's planning documents.

When ordering the bait for Rat Island, a 30% (of the planar area at 6 kg/ha; the stated planar area was 2800 ha) contingency was added to the amount needed to treat the island using the target rates. This should have come to 5.7 metric tons but the amount shown on Table 9 of the August 2008 operational plan was 10 metric tons (10,000 kg). The purpose of this contingency is to ensure that enough bait would be available to complete the operation. Bait could have been damaged or spilled, or some areas could need extra bait because of unanticipated suitable rat habitat. It was also on hand to treat any skips or gaps that were identified using the GPS bait tracking system. The planning documents indicated that this contingency bait would be applied to the island. However, there is no provision on the Brodifacoum-25W Conservation label to apply this contingency bait. The label does allow additional baiting (beyond 2 applications) but only if rat activity persists. Since no effort was made to determine rat activity after the second application, no additional bait would be allowed under the Brodifacoum 25-W Conservation label.

Since the contingency bait was applied immediately after the second application was complete, it is appropriate to consider the contingency baiting as part of the second application. Indeed, an advisor from the Island Eradication Advisory Group who was an active participant in the Rat Island planning and implementation said as much: "It was applied as part of the first and second applications because of the spell of good weather – so we just carried on and there was definitely no checking for rat sign. There was no waiting." If this is the case, it eliminates one potential label violation (no additional applications unless rat activity persists) but it means the second application clearly exceeded the maximum label rate. The amount of bait applied also negates the purpose for the three studies to determine application rates, negates the mitigation strategy, and renders meaningless the limits set by the U.S. Environmental Protection Agency and as directed by the label held by USDA Wildlife Services as well as the limits set by the U.S. Fish and Wildlife Service Pesticide Use Proposal.

Most importantly, the use of this contingency bait in this manner makes no sense considering the justification used for brodifacoum and the environmental assessment regarding mitigation for potential primary and secondary hazards ("no more bait than is necessary"). These hazards increase with the amount of bait applied. An important mitigation for using brodifacoum should have been to minimize bait use without compromising the efficacy of the eradication program. The bait application strategy actually used on Rat Island did not appear to minimize bait use. The

target rate exceeded the calibrated rate and the actual rate greatly exceeded the target rate. The stated purpose for the contingent bait was ignored. All the contingent bait was applied, not just to cliffs and gaps (and it seems that there was at most only one small gap found on review of the GPS tracks), but to the entire coastal area and all the drainages. The stated reason – that these were high-risk areas because of the higher rat density – makes biological sense but this factor was already accounted for by the planned doubling of the bait rate on the coast. The justification given by Island Conservation for applying this extra bait in this manner suggests, in essence, that there are no limits to the amount of bait that can be applied so long as the "nominal" rate does not exceed the label rate, regardless of other label restrictions. The principle seemed to be that whatever bait is available can and should be applied. Had there been twice as much contingency bait, it would have all been applied, regardless of the calibrated rates, regardless of the target rates, and regardless of the label limits simply because there is greater rat density in certain areas. Conversely, had there been only half as much contingency bait, it too would all be applied. The mere presence of the bait, regardless of quantity, justified its use. The biological justification is rendered meaningless under this concept because the amount of bait is unrelated to the abundance of rats and the amount of bait needed to kill a rat or ensure adequate coverage to the island.

The conclusion that all the contingency bait was used simply because it was there is supported by two other facts. First, the project manager stated that there was no plan to return excess bait to the manufacturer or to dispose of it, due to the disposal costs and transport issues. In fact, the August 28 operational plan did contemplate the potential need to remove bait from the island:

> No excess bait is anticipated to remain after the baiting operations, however if poor weather conditions prohibit entire application of bait on the island or if the bait becomes spoiled or otherwise unusable, bait will need to be demobilized. Due to the size restrictions of the Tiglax for transporting large amounts of bait, the quantity of remaining bait will define how demobilization occurs. The final decision for disposal will be made by the PM in coordinated with the Tiglax Captain.
>
> *Small qty bait (< 5 ton)*:
>
> - transport by helicopter onto Tiglax and return to Homer, AK
>
> *Large qty bait (> 5 ton)*:
>
> -multiple trips to transport bait by helicopter to Tiglax and Adak Island; excess bait stored in USFWS warehouse on Adak; transport for disposal will occur at a later date using scheduled barge service from Adak to Dutch Harbor or Seattle, WA.
>
> -charter 100 ft crab vessel from Adak to Rat Island to assist in transporting bait; excess bait stored in USFWS warehouse until transport by scheduled barge to Dutch Harbor or Seattle. Any excess bait will be disposed of on the mainland at an approved waste disposal site (Burlington Environmental, Kent, WA). Approximate cost of bait disposal for 5 tons of bait is $35,000.

Although it is true that the budget did not provide for bait disposal, it did include contingency costs of $430,000 for idle time for the boat and helicopters. As there was no idle time, this

funding could have been available for bait removal and disposal. There was also an apparent communications failure with regard to the removal of unused bait. The off-island advisor from Island Conservation stated that removal would have been preferred and that he and the Refuge manager discussed it by phone but by that point in time the contingency baiting operations were underway.

Second, the on-island advisor from the Island Eradication Advisory Group and the pilots advised that all contingency bait be applied, consistent with New Zealand practice for their island eradication programs. The on-island advisor stated that the view of the Island Eradication Advisory Group is if the bait is taken to the island, it should be applied and that there is no point in taking it back. As he explained it, it is applied to priority areas – areas that are light, then likely sites where there are higher numbers of rats or steep areas where the contingency bait is used to be sure all rats have access to enough bait. The August 2008 operational plan essentially adopted this practice, stating that "all bait remaining following two complete applications on the island will be strategically applied to areas perceived to not have received optimal bait coverage during the aerial baiting operations. Priority areas to be supplemented with additional bait are coastal cliffs, coastal bluffs, and coastal zones boundaries between adjacent baiting blocks." Prior to commencing aerial baiting operations the Project Manager was to consult with the baiting pilots during an island overflight which areas of the island will be prioritized for supplement with any excess baiting remaining. In theory, this would have been acceptable provided that the label limits were not exceeded and it was part of the second application. The notion that supplementation should be determined by perception rather than data (i.e., the TracMap data) has its limits. The pilots on Rat Island were exceptionally experienced. Relying on their perception and experience was probably reasonable in this particular instance. However, the New Zealand operations are *planned* to use all the bait and the amount applied during the first and any subsequent applications takes the overall amount of bait under considerations. There are also two significant differences between the New Zealand practice and that used for Rat Island. First, the typical baiting rate in New Zealand is 12 kg/ha on cliffs and 6 kg/ha elsewhere. Second, according to one New Zealand expert, they usually calculate the contingency at 20-25% of this lower overall total. Considering the much higher (50%) application rate for Rat Island and the high amount of contingency bait (30%), it seems that using the New Zealand implementation "method" was not appropriate and contributed to the excessive bait use. The Island Eradication Advisory Group twice raised concerns that the Rat Island bait application rate was higher than they thought necessary. Had Island Conservation used the New Zealand method for planning, much less bait would have been applied, and in that case, the New Zealand implementation practice of using the contingency bait might have been appropriate. However, the New Zealand legal control over bait quantity is quite dissimilar from the EPA restrictions and under the existing label, the contingency bait could not have been applied in this manner.

There is no record, contemporaneous or post-hoc, of the decision to abandon the planned use of the contingency bait and to substitute this alternate strategy of applying all remaining bait to the coastal areas and some drainages. More than just a question of abandoning the plan, however, the consequences of the change seem not to have been discussed. The change negated the critical mitigation strategy to avert or reduce nontarget mortality by putting out no more bait than needed. There is no record, contemporaneous or post-hoc, of discussing the potential increase in nontarget mortality from this change or of the decision made to apply all the bait. In fact, the

Final Operational Report makes no mention of the application of the contingency bait or the amount of bait applied to the different habitats on the island.

Overall the amount of bait used was excessive and exceeded the approved label rate. The main reason for the excess was failure to reduce the application rate for the second application (as was planned and approved) and the application of the contingency bait, mostly in the coastal areas where bait was already applied at a heavy rate. The excess bait likely contributed to the observed nontarget mortality since it increased both primary and secondary poisoning potential. In addition, nontarget exposure to bait probably increased more so in the coastal areas, where gulls typically feed, with the high application rates.

Conclusions:

1. The methodology to calibrate the bait rate was based on an unsupported assumption that bait needs to be available for four nights; the data generated by the two calibration trials (placebo bait) and the uptake trial suggest that the rates exceeded even that standard by at least 15% (based on bait remaining after 21 days when the amount applied was 17 kg/ha and 8 kg/ha rather than the 18 kg/ha and 9 kg/ha applied on Rat Island).
2. The actual bait rate for the coastal area exceeded the target rate and the label rate on the second application whether the second and contingency applications are considered two separate applications or one application.
3. Island Conservation rejected the suggestion by highly experienced island eradication experts to reduce the amount of bait but then made a last-minute, unexplained decision to abandon its own planned bait rate and strategy and to adopt the implementation methods of those experts in applying all available bait. The combination of a planned rate that was too high and an implementation method that entailed the use of all bait, regardless of plan or need, resulted in the application of an excessive amount of bait.
4. The excess bait increased the risk of nontarget mortality in two ways: by leaving too much unconsumed bait on the ground for consumption by nontarget species such as gulls, and by increasing the toxic load of brodifacoum in poisoned rats and other primary feeders such as gulls that were then consumed by scavengers.
5. Stratification is biologically appropriate and fully justified by the results of the Bay of Islands and Rat Island consumption trials. Stratification also results in lower levels of bait being applied to large areas of the island, which is important in reducing the potential for nontarget mortality.
6. The contingency bait should be used to treat areas where the bait was not applied at the rate intended (e.g., gaps) and as directed by the label. It should not be applied simply because it is available and because no plans or intentions by the operational staff on island were made to remove it from the island.
7. The concept of a "nominal rate" is not useful to describe anything other than average rate "out of the bucket" as the actual distribution on the ground is not uniform. Using the term "nominal" to represent the weighted average of bait applied in different strata is confusing and potentially leads to label violations and bait application greater than the target or label rate, which in turn leads to excess bait on the ground and an increased risk of primary and secondary mortality. In addition, it has no biological meaning regarding the rat control program.

Mitigation

Mitigation has two components: prevention and restoration or compensation. Both elements are intended to reduce the overall impact of a project.

The Rat Island plan had little mitigation in terms of impact to wildlife. The stated preventive measures, as described in the Environmental Assessment, entailed:

1. the seasonal timing chosen for the application (post breeding seasons for birds and marine mammals);
2. the use of only enough bait to achieve success
3. the use of a bait that biodegrades and becomes unattractive to nontargets quickly in the fall Aleutian environment; and
4. the use of a grain-based bait to minimize primary hazard to scavengers are all examples of ways the project is designed to minimize impacting native wildlife.

Missing from this list is the post-operation restoration or compensation effort. In fact, none was planned. The Environmental Assessment states only that monitoring will take place to determine if management actions may be needed. Potential management actions contemplated included further habitat improvement or translocation (presumably to supplement populations impacted by the eradication project).

Various representatives of the partner organizations differed in their understanding of the reason for the seasonal timing of the baiting operation. Some thought the reason, or primary reason, was the fact that the rat breeding season would have ended. This would reduce the chances that nursing females or unweaned juveniles would emerge from burrows after the baiting operation and either not encounter or fail to eat bait remaining on the ground. These individuals would go on to repopulate the island. The fact that the operation would take place after the bird breeding and migration seasons was a secondary consideration. It was thought that the greatest number of migratory species would have left the island by late September. However, a key aspect of the timing with regard to Bald Eagles was the observation by Refuge Biologist Vern Byrd that in the fall, Bald Eagles in the region moved to islands with salmon spawning streams. This inter-island movement that occurs in response to food availability has been observed and documented by Byrd and Williams (2010) and Sherrod (1976). Sherrod observed, however, that movement from Amchitka to Rat Island, which is relatively small and normally supports only a few pairs of Bald Eagles, occurred in response to carcass availability. “An October observation revealed 65 eagles (17 adults and 48 subadults) feeding on a beaked whale washed up on Rat Island, a small island 20.9 km northwest of Amchitka. A considerable number of these birds probably flew from Amchitka or other nearby islands since, judging from previous counts, this small island usually does not support more than about 16 adults (eight pairs) and two or three subadults.” Sherrod surmised that subadult birds rely more on carrion than do adult eagles, and because they are not attached to nest sites, are likely to roam. It is possible, then, that the presence of rat and gull carcasses after the baiting operation on Rat Island attracted birds from Amchitka or elsewhere. It was apparently assumed, though not stated in documents provided to the review team, that rat and gull carcasses would have degraded completely by the time the eagles returned to the island in the spring and that therefore, no carcasses would be available to those eagles, or to gulls. No carcass persistence tests were conducted to test this assumption.

No avian surveys were conducted in late September or early October by the U.S. Fish and Wildlife Service or by independent researchers. The pre-eradication surveys by Island Conservation took place in June and August 2007 and late May and mid-June 2008. Although it was not unreasonable for the partners to rely on the decades of observation by an eminent ornithologist, it seems reasonable to suggest that the partners might have conducted surveys at the time of year when the eradication operations would take place. It might also have been reasonable to distribute unpoisoned carcasses or placebo bait on the island to see if Bald Eagles, Glaucous-winged Gulls, and other scavengers might be attracted to the availability of abundant food items on the island.

To minimize the consumption of rat carcasses by eagles, gulls, or other scavengers, a search for dead rats could have been undertaken. The project manager stated that this is standard practice for Island Conservation but that due to the size of Rat Island and the difficulty in walking on the tundra-like vegetation, it could not be done on Rat Island. However, the 2007 biological surveys included transects throughout the island, particularly for the game bird transects and songbird point count transects as well as the rat trapping transects and the bait consumption trials. During baiting operations, teams had to walk to the lake exclusion zones that would be baited by hand. Although walking on the island's maritime tundra was feasible, it could be difficult to find carcasses in the dense vegetation. However, because rat density was highest in the coastal area and areas with freshwater, even searches on or near the beaches and the lakes could have been helpful in removing rat carcasses. It might well have been possible to locate carcasses by observing the gulls and eagles feeding on those carcasses. Even if the storm forced the team to leave the island on or about 7 October 2010, the team could have returned afterwards to conduct carcass searches. These observations could have also identified potential primary exposure by gulls if they were actively searching and feeding on the bait.

The review team considered the possibility that rat carcass removal was not contemplated because it was thought there would be few scavenging birds on the island, given that the timing of the operation was chosen to coincide with a lower bird abundance. This notion seems unlikely. Some 572 Glaucous-winged Gulls were observed during the beach survey and 363 were observed during the circumnavigation surveys and the Environmental Assessment stated that the risk to gulls of secondary exposure would be high. Had the team returned after the storm, gull carcasses, if any, could have been removed.

In fact, preventive measures other than the timing of the bait application were taken. The pellet size was designed to be too large for small passerines such as sparrows to consume easily, but too small to be an object of interest for larger scavengers. Given the consumption by Glaucous-winged Gulls of virtually everything including kelp flies and berries (Trapp 1979), the assumption that the gulls would refuse an abundant food source requiring little to no search or handling time because of its small size seems unwarranted. And, in fact, passerines also ingested the bait. Although it was thought that most longspurs would have migrated from the island, and in fact, most had, carcasses of three Lapland Longspurs tested positive for brodifacoum. This result is not surprising given the results of the Bay of Islands uptake trial. Following the bait application six (66%) of the Song Sparrows tracked with radio transmitters were collected dead on treated islands. In addition, 16 untagged song sparrows were found dead in carcass searches following treatment. All 22 sparrows found dead were analyzed for brodifacoum residues and

confirmed to have been exposed to brodifacoum at a mean detection of 0.82 mg/kg (maximum detected 1.33 mg/kg). The use of a grain-based pellet as a preventive measure was intended to limit the attractiveness of the bait as a food item. It was recognized that granivorous birds and opportunistic omnivorous animals would find this food item attractive. Finally, the bait pellets were dyed blue which was said to make the food less attractive to some birds but seemingly, that was not the case on Rat Island. The Environmental Assessment cited as support for this assertion several papers (Pank 1976; Tershy et al. 1992; Tershy and Breese 1994; Buckle 1994; Island Conservation, unpubl. data). The bait rate has already been discussed; for the purposes of this discussion, we simply reiterate that the rate as planned was higher than calibrated from the Rat Island trials and the rate as applied greatly exceeded what was planned. Given that the planned rate was calculated to be enough to achieve success, this mitigation measure, seems to have been disregarded.

A related mitigation measure was the bait application strategy. The argument for brodifacoum is its single feeding toxicity, which means rats that find and eat the bait one time should die. The bait application rate was established for bait to be available for four days. A second application, flown at an angle to the first application, assures that there will be no unbaited gaps. While not necessary if all rats eat bait one time in the first four days, as seemed to be the case in the Bay of Islands uptake trial, the second application is also insurance in case one or more rats didn't feed on bait during the first four days. However, it also means that there will be little additional feeding during those four days and most of the bait will remain uneaten by rats. Adding the contingency bait to this second application, or doing a third application without evidence it was necessary clearly negated the mitigation of "only use enough bait to achieve success."

Conclusions

1. *The primary reason for the failure of the planned mitigation strategies was the failure to follow the plan to apply no more bait than necessary.*
2. *Mitigation strategies (for Bald Eagle) did not consider the possibility that eagle behavior would change in response to the availability of an abundant food source.*
3. *Mitigation failed because no effort was made to observe bird behavior and to remove rat (and later, gull) carcasses or unconsumed bait where possible.*

Process elements that contributed to the outcome

A number of aspects of the planning and implementation process contributed to the decision-making that affected the outcome of this project. We highlight those aspects and give a limited number of examples of each and suggest procedures that might prevent recurrence in future projects.

Documentation
Of necessity, this project generated an enormous amount of documentation yet key decisions and calculations were either not documented or were documented in an incomplete manner.

Examples include:

- The incomplete and inconsistent calculation of the overall amount of bait needed for the project. The August 2008 operational plan gives two different figures for the amount of contingency bait (25% in one place and "30% of total" in another) and in each case, fails to state the base of that calculation. In Table 9, the percentage is given, but not the application rate. The baiting regime is said to be 3kg/ha with 50% swath overlap, which is a rate of 6 kg/ha. However, if the purpose of the contingency bait is to fill gaps, then presumably the gap should be filled at the rate appropriate to that particular habitat. Further, the total amount of bait is said to be 45 metric tons, but 46.27 metric tons was brought to the island. The table also includes two metric tons for "expected repeats" but this term is not explained in this document or used elsewhere in any of the documentation we received.
- There is no contemporaneous documentation of the decision to apply all the contingency bait immediately following the second application, or the decision to apply it in certain areas. As the plan was to use this bait to fill gaps, there should have been documentation of gaps that were filled. Given how much bait was applied (3.3 metric tons), given that the application of the bait in this manner violated the terms of the label, and given that the application exceeded the target rates, contemporaneous documentation is of great concern. It appears that neither the project manager nor the off-island advisor felt it necessary to document a serious deviation from the planned application strategy, either prior to the application or immediately thereafter. There is no mention of it in the final operational report.
- The final operational report makes no mention of the actual baiting rates. An addendum was issued, reporting the baiting rates, but lacking any explanation of how those rates were calculated.

In contrast, a great deal of attention was devoted to the writing and re-writing of background information in each of several plans and reports. We suggest that a master list of documents be created and that a single background paper pertaining to the location, biota, and general purpose of eradication could suffice.

We also suggest that telephone conversations be confirmed by e-mail, including detailed notes of the conversations.

Deviations from plan
In addition to documenting deviations from the plan, it would be helpful to consider contingencies that are reasonably foreseeable, and for each contingency, develop a structured decision-making tool. Island Conservation had a risk and contingency plan but the remedy for

each potential risk or contingency consists of one or several short phrases. A structured decision-making tool for application of bait other than as planned, for instance, would require a written assessment of the amount of bait already on the ground, a comparison to the label rates and target rates, a written assessment of the additional bait to be applied, a calculation of the total amount of bait that would be applied, and the increase in the potential risk to nontarget species. It would also document the reason for the change and the potential impact of the change on the overall project.

There was also a deviation from plan in terms of weather contingencies. The risk and contingency plan called for the helicopters to leave the island prior to predicted strong storms (wind > 60 kt) but for the team to anchor weatherport floors and frames in positions to sustain high winds; disassemble sleeping tents & take refuge in weatherports, if required. The concern was about delays caused by prolonged periods of bad weather that kept the helicopters from flying. Instead, the weather was mild from the time of arrival on 29 September 2008 to the time the team left the island on 5 October and would continue to be mild for another day or two. However, in anticipation of a strong storm, the project manager elected to expedite baiting and leave the island ahead of the storm. Though this may very well have been a prudent decision in terms of human safety, the decision to deviate from plan and the potential impact of that deviation on the project should have been documented. Otherwise, the plan appears to be replaced by ad hoc decision-making.

Review of calculations

The risk and contingency plan actually alludes to miscalculations and the stated remedy is "review of bait purchase qty by OPT & eradication advisor." The Operational Planning Team comprised Gregg Howald (Island Conservation), Steve Ebbert (U.S. FWS), and Steve MacLean (The Nature Conservancy). We assume that the eradication advisor was the Island Eradication Advisory Group. Island Conservation staff assured us that it is standard procedure to review calculations and one member of the Operational Planning Team recalled a phone discussion with another member of the team, reviewing the baiting rate. However, there is no written documentation of these reviews. Considering that the amount of bait was probably the single most important aspect of this operation, it might have been advisable to have worksheets and sign-off by one or more of the Operational Planning Team members as to both arithmetical accuracy and accuracy of the components of each calculation. For instance, if anyone calculated the "30% of total" said to be the amount of contingency bait, that individual would have had to know the base quantity which is not stated in any document provided to the review team.

The Island Eradication Review Group reviewed the Rat Island project, or components of it, three times. The first review comprised informal written comments on the baiting broadcast strategy. At that point, Island Conservation had not yet determined the baiting rate to be used. For this reason, it would have been impossible for Island Conservation to review the bait purchase quantity at that point. No documentation shows that the bait calculation was reviewed at the February 2008 meeting. A 15 August 2008 readiness report shows no check of the calculations for the bait purchase although it does note a divergence between the extent of the swath overlap and resulting sowing rate as shown in the helicopter contract and the operational plan and states that neither is mathematically correct. No documentation shows that these errors were corrected.

Terminology

The use of a common terminology seems not to have developed within the community of organizations and individuals who work in this field. It would be helpful to have a set of defined terms and to use those terms in a manner consistent with those definitions. Examples include:

- The term "nominal application" as used by Island Conservation varies from the understanding of that term by the EPA, Wildlife Services, and others involved in island eradication, with the possible exception of the Island Eradication Advisory Group. The term has proved to be misleading, particularly in the context of compliance with label limits.
- A key inconsistency in useage is the term "contingency bait." It is sometimes called excess bait, but the real problem is that the meaning of the term varies from one document to the next. In some instances, it is meant to be used in case some bait is damaged or spilled. In other cases, it is meant to fill gaps. In the risk and contingency plan, the contingency bait (also called excess bait, is to be used to supplement these areas likely to receive a lower application with additional bait (if sufficient quantities) and, alternatively, the "30% bait contingency purchase will allow for supplemental baiting and any excess bait to be broadcast on island targeting "problem" areas."

Communications

At a critical juncture in the operation, when a significant deviation from plan was contemplated, the on-island project manager did not contact the off-island advisor or the Refuge. Protocol entailed a daily call each morning before operations began, but there was apparently no requirement for consultation prior to significant deviations from plan. We suggest that written protocols outlining the circumstances under which consultation is needed for deviations from the approved plan be made part of every operation.

External reviews

The reviews conducted (in this case, by the Island Eradication Advisory Group in December 2007 and February 2008) seem to have been very cursory. The document submitted for review itself provided minimal information and no explanation or justification for key elements, such as baiting rate. The review raised serious questions about methodology, but there is no evidence that these questions were ever answered. Apart from questioning the four-night assumption behind the bait rate trials and the overall baiting rate, the Island Eradication Advisory Group also questioned the bucket calibration and swath width data and conclusions. There is no evidence that Island Conservation repeated the bucket calibration and swath width trial.

Recommendations for future rodent eradication projects

1. The conservation community, defined here as all concerned with the eradication of non-native invasive species to achieve habitat restoration and the elimination of non-native predators and competitors, including NGOs, government and private landowners,government wildlife agencies, scientists and research organizations, should make a concerted effort to develop effective methodologies for diphacinone and other toxicants with the goal of reducing nontarget mortality. These efforts to identify, plan, and undertake the necessary research should commence immediately. In cases where the use of brodifacoum may imperil a rare species or subspecies and logistical conditions do not necessitate the use of brodifacoum, a first-generation anticoagulant should be used, notwithstanding the potential cost of and lack of political support for repeated eradication efforts. Consider using short-term control measures until effective methodologies for diphacinone or other low-toxicity rodenticides can be developed. Non-native rats have existed on most of these islands for many decades and most of the damage is already done. Taking the time to develop effective methodologies for a less-toxic rodenticide is a reasonable measure. This is particularly true if the potential project might result in nontarget mortality to rare species or subspecies. In the Aleutians and in Alaska generally, Bald Eagles and Glaucous-winged Gulls are abundant and the populations can sustain a certain level of short-term mortality beyond the expected annual mortality from natural causes. In other situations, where endemism is high and the populations are small, the better option is to delay eradication until methods for the less-toxic rodenticide are available.

2. The conservation community should develop detailed best practices that address:

    a) logistical considerations that affect bait choice and site-specific justification whenever the use of a less-toxic rodenticide is rejected;
    b) site-specific pre-eradication studies including the timing of biological surveys, experimental studies to assess response to change in prey availability,
    c) determination of bait rate
    d) criteria for application of bait over planned rate
    e) baiting strategy (duration, timing)
    f) standard terminology
    g) full and public documentation of planning decisions
    h) full and public documentation of external reviews and the responses to these reviews
    i) Any environmental impact statement or environmental assessment should include the key elements of the planned operation including bait choice, baiting rate, baiting strategy, methods to prevent non-target mortality, and mitigation plans; the plan should not be changed after the environmental assessment or environmental impact statement is published for comment; if the plan does change after the EA or EIS is published for comment, an amended EA/EIS should be published for comment
    j) bait rate reporting standards
    k) mitigation strategies including carcass removal where practical

l) post-eradication efficacy and biological surveys
m) publication and dissemination of results

Detailed consideration of each of these elements should be fully documented in writing, even if the relevant national law requires a written environmental impact statement. All internal and external reviews should consider each of these elements and no project should move forward unless and until questions raised by reviewers are answered fully and in writing.

3. Where implementation deviates from the plan, document in full detail the reason(s) for that change. Include a comprehensive discussion of the potential and likely impacts of the change.

4. All project-related documents, including feasibility studies, reports of field research, biological assessments, operational plans, project reports, environmental assessments and environmental impact studies (whether required by law or not), internal reviews, responses to external reviews, and final reports, should be made available to the public on the websites of all partners at the earliest possible date.

Literature cited

ANTHONY, R. G., A. K. MILES, J. A. ESTES, AND F. B. ISAACS. 1999. Productivity, diets, and environmental contaminants in nesting bald eagles from the Aleutian Archipelago. *Environmental Toxicology and Chemistry* 18:2054-2062.

BAILEY, EDGAR P.1993. Introduction of foxes to Alaskan Islands – History, Effects on Avifauna, and Eradication. United States Department of the Interior, U.S. Fish and Wildlife Service. Resource Publication 1939.

BYRD, VERNON G., HEATHER M. RENNER, AND MARTIN RENNER. 2005. Distribution patterns and population trends of breeding seabirds in the Aleutian Islands. Fisheries Oceanography 14 (Suppl.1):139-159.

BYRD, G. V. AND J. C. WILLIAMS. 1996. Seabird and marine mammal surveys in the central and eastern Aleutian Islands, Alaska, in June 1996. U.S. Fish and Wildlife Service Report AMNWR 96/-06. Alaska: Homer. 31 pp.

BYRD, G. V., J. C. WILLIAMS, D. G. ROSENAU, AND A. B. KETTLE. 2001. Wildlife Surveys at Amak Island, Alaska in June 2001. U.S. Fish and Wildlife Service Report AMNWR 01/03. Alaska: Homer. 10 pp.

CAUSEY, DOUGLAS, DEBRA G. COREBETT, CHRISTINE LEFE‘VRE, DIXIE L. WEST, ARKADY B.SAVINETSKY, NINA K. KISELEVA, AND BULAT F. KHASSANOV**.** 2005. The palaeoenvironment of humans and marine birds of the Aleutian Islands: three millennia of change. Fisheries Oceanography 14 (Suppl.1):259-276.

CROLL, D.A., J. L. MARON, J. A. ESTES, E. M. DANNER, AND G. V. BYRD. 2005. Introduced Predators Transform Subarctic Islands from Grassland to Tundra. Science 307:1959-1961.

DAY, R. H., T. J., EARLY, AND E. P. KNUDTSON. 1978. A bird and mammal survey of the west-central Aleutians, summer 1997. U.S. Fish and Wildlife Service Report. Adak, Alaska. 198 pp.

DAY, R. H., B. E. LAWHEAD, T. J. EARLY, AND E. B. RHODE. 1979. Results of marine bird and mammal surveys of the western Aleutian Islands- summer 1978. U.S. Fish and Wildlife Service Report. Adak, Alaska. 175 pp.

DEGANGE, ANTHONY R. AND JAY W. NELSON. 1982. Bald Eagle predation on nocturnal seabirds. Journal of Field Ornithology 53:407-409.

DOWDING, J. E., E. C. MURPHY, AND C. R. VEITCH. 1999. Brodifacoum residues in target and non-target species following an aerial poisoning operation on Motuihe Island, Hauraki Gulf, New Zealand. New Zealand Journal of Zoology 23:207-214.

EASON, C. T., ELAINE C. MURPHY, GEOFFREY R. G. WRIGHT, AND ERIC B. SPURR. 2002. Assessment of risks of brodifacoum to non-target birds and mammals in New Zealand. Ecotoxicology 11:35-48.

EASON, C. T. AND E. B. SPURR. 1995. Review of the toxicity and impacts of brodifacoum on non-target wildlife in New Zealand. New Zealand Journal of Zoology 22:371-379.

EMPSON, RAEWYN A. AND COLIN M. MISKELLY. 1999. The risks, costs, and benefits of using brodifacoum to eradicate rats from Kapiti Island, New Zealand. New Zealand Journal of Ecology 23:241-254.

GRAY, D. 1939. Report on Aleutian Islands. Unpublished U.S. Fish and Wildlife Service Administrative Report.

HOWALD, GREGG, C. JOSH DONLAN, KATE R. FAULKNER, STEVE ORTEGA, HOLLY GELLERMAN, DONALD A. CROLL, AND BERNIE R. TERSHY. 2009. Eradication of black rats *Rattus rattus* from Anacapa Island. Oryx 44:30-40.

HOWALD, GREGG, C. JOSH DONLAN, JUAN PABLO GALVÁN, JAMES C. RUSSELL, JOHN PARKES, ARACELI SAMANIEGO, YIWEI WANG, DICK VEITCH, PIERO GENOVESI, MICHEL PASCAL, ALAN SAUNDERS, AND BERNIE TERSHY. 2007. Invasive rodent eradication on islands. Conservation Biology 21:1258-1268.

JONES, IAN L., CATHERINE M. GRAY, JOHANNE DUSUREAULT AND ARTHUR L. SOWLS. 2001. Auklet demography and Norway Rat distribution and abundance at Sirius Point, Kiska Island, Aleutian Islands, Alaska in 2001. Project Report. Retrieved on 19 September 2010 from http://www.mun.ca/serg/finalKiskaREP.pdf

KROG, JOHN. 1953. Notes on the birds of Amchitka Island, Alaska. The Condor 55:299-55.

KURLE, CAROLYN M., DONALD A. CROLL, AND BERNIE R. TERSHY. 2008. Introduced rats indirectly change marine rocky intertidal communities from algae- to invertebrate-dominated. Proceedings National Academy of Science 105:3800-3804.

MAJOR, HEATHER L., IAN L. JONES, G. VERNON BYRD, AND JEFFREY C. WILLIAMS. 2006. Assessing the effects of introduced Norway rats (*Rattus norvegicus*) on survival and productivity of Least Auklets (*Aethia Pusilla*). Auk 123(3):681–694.

WHISSON, D. A. AND T. P. SALMON. 2002. Effect of the timing of applications and the amount of 0.01% diphacinone consumed on mortality of California ground squirrels (*Spermophilus beecheyi*). Crop Protection 21:885-889.

WILLIAMS, JEFFREY C., G. VERNON BYRD, AND NIKOLIA B. KONYUKHOV. 2003. Whiskered Auklets *Aethia Pygmaea*, Foxes, Humans, and how to right a wrong. 2003. Marine Ornithology 31:175-180.

WITMER, GARY W., FRANK BOYD, AND ZANDY HILLIS-STARR. 2007. The successful eradication of introduced roof rats (*Rattus rattus*) from Buck Island using diphacinone, followed by an irruption of house mice (*Mus musculus*). Wildlife Research 34:108-115.

Appendix A: Calculating the amount of bait applied to the island

Table 2 is reproduced here to facilitate comparison to the reviewers' calculation of bait rates, below, with those reported in the 15 December 2009 addendum to the final operational report.

Table 2. Bait rates as reported by the project manager (in bold)[1]

All in kg/ha	Target rate	Label limit	Base[2]	Coastal Perimeter[2]	Amount of bait exceeding target rate	Amount of bait exceeding label limit	Nominal[3]	Adjusted Nominal[3]
First inland	6	18	**5.2**	n/a	n/a	n/a	**5.9**	**6.4**
First coastal	12	18	(5.2)	5.2 + 6.0 = *11.2*	n/a	n/a		
Second inland	3	9	**6.1**	n/a	3.1	n/a	**7.0**	**7.5**
Second coastal	6	9	(6.1)	6.1 + 7.6 = *13.7*	7.7	4.7		
Contingent bait[4]		Qualitative restriction	n/a	**7.76**	7.76	7.76	**7.8**	**7.8**
Totals	18 coast 9 inland	No cumulative limit	*11.3*	*32.66*	*Coast 14.66 Inland 2.3*		*20.7*	*21.7*
Lake exclusion zones[5]	9	18 first, 9 second, no cumulative limit		n/a	Unable to determine	Unable to determine	Not given in spread-sheet	Not given in spread-sheet

[1] These figures were not provided in the Final Operation Report itself. They are the figures provided to the Refuge for inclusion in the 9 December 2009 addendum to the 2008 Final Operation Report. The addition shown in the table (in italics) was done by the review team.

[2] Includes the bait thrown at the end of the line 30 m into the internal perimeter and the bait applied in the circumferential flight.

[3] These figures are taken from the Island Conservation spreadsheet labeled "Rat Is_bait appl summary.xlsx. *In fact, these nominal figures are not accurate and the review team recalculated the rates from the bait application spreadsheet. (Appendix A) comprises a recalculation of the rates.*

[4] Some contingency bait was applied inland, specifically on the drainages.

[5] The final operational report states that the intended rate was 6 kg/ha for the first application and 3 kg/ha for the second application. According to the baiting spreadsheet maintained by the project manager, the first hand broadcast in the lake exclusion zone covered 81 ha but the amount of bait applied by hand is not stated. Apparently, no subsequent hand-broadcast application took place. The 2008 operational report goes into some detail in describing the hand-broadcast operation (Section 4.4.2, at pages 17-18) but does not state the quantity of bait applied by hand. Although the hand application was intended to prevent the bait and the toxicant from entering the water, some brodifacoum was found in lake water samples. In the 2008 operational report (Table 7 at page 26), a calculation was made of the number of pellets needed to produce the observed brodifacoum concentrations in each of the lakes. In one case, the number of pellets needed to produce the observed concentration exceed the target application rate by 27% and in another case, by 280%, but in the other two cases, the number of pellets needed to produce the observed brodifacoum concentration was lower than the intended application rate, by 33% and 31% respectively.

We suggest that the bait rates shown in the following table, reporting the arithmetic rates of application as calculated directly from the bait application spreadsheet, are a more accurate estimate of the amount of bait applied to each area of the island. The area and rate figures are taken directly from the bait tracking spreadsheet and the description of the base area is based upon the GPS maps and the description given by the on-island advisor from Island Eradication Advisory Group.

We stress that these estimates are arithmetical calculations, not measured rates on the ground, and there is no intent to indicate a level of precision. Due to variation in flight speed, humidity, and other uncontrollable factors, the bait does not land on the ground at a constant rate and that therefore, the figures given in kg/ha are measures of the amount dropped, and represent an arithmetical average of that amount over the area covered – they are not to be taken as the *actual* amount applied to any specific ha of ground. In addition, the vegetation structure on the island precluded ground-truthing.

All bait and area figures were obtained from the "Rat Is_bait appl summary.xlsx" spreadsheet.

First application	**Bait (in kg)**	**Planar Area (in ha)**	**kg/ha**	**Target rate**	**Label limit**
				kg/ha under/over target rate	**kg/ha under/over label rate**
1st base (entire island stopping 45 m from the mean high tide line)	14789	2506	5.9	6	18
				under target rate by 0.1 kg/ha	*under* label rate by 12.1 kg/ha
Bait is thrown approximately 30 m forward of the bucket, so at the end of each flight line, some bait is applied to the inner perimeter. The rate at which the bait is thrown dissipates over those 30 meters. The approximate rate of dissipation is drawn from the bucket calibration trials. Based on the bucket calibration trials, the approximate amount of bait thrown into the inner perimeter ranges from 5.9 at center point of bucket and 1.5 at outer edge of the 30 m arc.					
Inner perimeter	1794	285	6.3 plus the forward throw from the base application of between 1.5 and 5.9 = 7.8 at outer edge and 12.2 at inner edge	12	18
				At inner edge, *over* target rate by approx 0.2 kg/ha; at the outer edge, *under* target rate by approx. kg/ha. 4.2 kg/ha.	At the inner edge, under label rate by approx 5.8 kg/ha at the outer edge and *under* label rate by approx 10.2 kg/ha

				Target rate	**Label limit**
				kg/ha under/over target rate	**kg/ha under/over label rate**
1st coastal deflector, outmost 15 m of island	1196	209	5.7	12	18
				Approximately 6.3 kg/ha *under* target rate	Approximately 12.3 kg/ha *under* label rate
1st lake exclusion zone – helo	759	166	4.6	unable to calculate	unable to calculate
1st lake exclusion zone – hand	Not given	81	unable to calculate	unable to calculate	unable to calculate

Second application	**Bait (in kg)**	**Area (in ha)**	**kg/ha**	**Target rate**	**Label limit**
				kg/ha over target rate	**kg/ha over label rate**
2nd base (entire island stopping 45 m from the mean high tide line)	18216	2600	7.0	3	9
				4.0 kg/ha *over* target rate	2.0 kg/ ha *under* label limit
Bait is thrown approximately 30 m forward of the bucket, so at the end of each flight line, some bait is applied to the inner perimeter. The rate at which the bait is thrown dissipates over those 30 meters. The approximate rate of dissipation is drawn from the bucket calibration trials. Based on the bucket calibration trials, the approximate amount of bait thrown into the inner perimeter ranges from 7.0 kg/ha at center point of bucket and 1.75 kg/ha at outer edge of the 30 m arc.					
2nd inner perimeter	1748	226	7.73 plus base application of between 1.75 at outer edge and 7.0 at inner edge = between 9.48 at outer edge and and 14.43 at inner edge	6	9
				Between 3.48 kg/ha *over* target at the outer edge and 8.43 kg/ha *over* target at the inner edge	Between 0.48 kg/ha *over* label at outer edge and 5.43 kg/ha *over* label at inner edge
2nd coastal deflector, outermost 15 m of island	1495	204	7.3	6	9
				Approximately 1.3 kg/ha *over* target	Approximately 1.7 kg/ha *under* label

				Target rate	**Label limit**
2nd lake exclusion zone	736	137	5.4	not stated	9
				unknown	Approximately 4.6 k/g *under* label

Application of contingency bait	**Bait (in kg)**	**Area (in ha)**	**kg/ha**	**Target rate**	**Label limit**
				kg/ha over target rate	**kg/ha over label rate**
Contingency bait applied to base area (gullies)	299	14	21.4[1]	n/a	Qualitive restrictions
				n/a	All bait exceeded label limit
The label provided: "Assess baited areas for signs of residual rodent activity (typically 7 to 10 days post-treatment). If rodent activity persists, set up and maintain tamper-resistant bait stations or apply bait directly to rodent burrows in areas where rodents remain active. If terrain does not permit use of bait stations or burrow baiting, continue with broadcast baiting, limiting such treatments to areas where active signs of rodents are seen. Maintain treatments for as long as rodent activity is evident in the area and rodents appear to be accepting bait." These conditions were not met. There was no pause between the end of the second application and the application of the contingency bait. There was no assessement for signs of residual rodent activity. Therefore, the contingency application is considered part of the second application. In that case, all contingency bait applied to the base area exceeds the label limits. If considered a separate application, it violated the qualitative restrictions.					
Contingency bait applied to inner perimeter	1794	227	7.9	n/a (no specific target)	Qualitative restrictions
				n/a	7.9 kg/ha *over* label limit
If the contingent application is considered part of the second application (as above), then the total amount of bait applied to the inner perimeter on the second application was (9.48 and 14.43) + 7.9 = between 17.38 and 22.33 kg/ha, which exceeds the label limit by between 8.38 kg/ha and 13.33 kg/ha					
Contingent coastal deflector	1196	183	6.5	n/a (no specific target)	Qualitative restriction
				n/a	6.5 kg/ha *over* label limit

[1] The project manager informed the reviewers on 1 October 2010 that this area was not correct but no additional information has been provided since that time.

[2] The contingeny bait was intended to fill gaps or add bait to areas perceived to have received too little bait. In fact, there were no gaps found upon examination of the TracMap data and, as noted above, on-island advisor Pete McLellan stated that there were no gaps. There was no evidence that some areas received too little bait but even if that were the case, the manner in which the contingency bait was applied to the inner perimeter and outer perimeter ("coastal deflector") suggests that this bait was applied simply because it was available. The TracMap data show that the contingency bait was applied in four continuous flights around the island's perimeter (two each, inner perimeter and coastal deflector). The continuous nature of these four flights contradicts an inference that the bait was applied to specific areas perceived to have received too little bait.

Appendix B: Documents reviewed (documents noted in bold denote source material for this report)

Files provided by Stacey Buckelew

Documents related to bait

1. **Bait and pod purchase order #SA052408-1 from Island Conservation to Bell Labs dated 5/29/09 (order for 102,000 lbs. Wet Condition brodifacoum pellets)**
2. Bait boxes for Rat Island_prototype (power point photos showing box construction)
3. Bait manufacture ac_Bell NRC.xls (spreadsheet documenting test results for brodifacoum concentration, moisture content)
4. Bait pod construction_Campbell Is.ppt (power point drawings and photos of bait pod specifications for Campbell Island)
5. Bait storage_Rat Island.pdf prepared March 19, 2008 (documentation to support exemption for traditional methods of bait storage under Alaska Dept. of Environmental Conservation regulations)
6. Bait transportation info.xls (spreadsheet of transportation costs)
7. Rat Island Project Bait Method of Analysis.pdf (methods to determine concentration of brodifacoum in a sample of bait).

Bait bucket

1. Heli Otago bucket spare parts list.doc
2. Rat Is calibration_Aug 2008.xls (results of calibration trials and determination of swath width, August 7, 2008)
3. Rat Is_bucket calibration results.doc (narrative summary of bait bucket calibration)

Baiting operations

1. **Bait application_MAIN.xls (spreadsheet recording each helicopter flight line, the amount of area covered, and the amount of bait applied; cumulative kg, ha, and kg/ha also recorded; includes calculations of nominal rates of application)**
2. **Baiting maps (series of .tif files showing Rat Island with place names, the lake systems and the areas to be baited by hand, the baiting paths for each helicopter by day, a map of the aerial baiting blocks, and a satellite image of the island)**
3. **Rat Is_bait appl summary.xlxs (originally created September 23, 2009; modified December 1, 2009; gives bait application chronology, application rates, and nominal application rates for each application by strata)**
4. Rat Island ArcMap Protocol v3.doc (instructions for creating the maps of the areas covered by each helicopter)

Budget and expenses

1. Rat Is final expense report_actual vs. budget.xls (budget analysis)
2. Rat Is_FWS contribution.xlsx (record of USFWS financial contributions)
3. Rat Island_baiting budget 091808.xls (planned budget)
4. Rat Island_implementation budget.xls (itemized budget)

Contracts

1. Airborne Tch_contract.pdf (contract for helicopter consultant)
2. Airborne Tch_Rat Is Helo Budget.pdf (itemized estimate of costs)
3. Cooperative Agreement_Vogel_IC_25 March 2008.doc (contract with USGS for the services of John Vogel as a GIS expert)
4. Island-Vessel Time Charter Agreement (626569_3_SV).pdf (contract for charter fishing vessel Aquila)
5. Island Conservation Rat Island Helicopter Service Agreement (604386_12_SV).pdf (contract with Pathfinder Aviation)
6. NZ pilot contract_Garden_signed.pdf (contract with pilot Peter Garden)
7. P Garden_pilot subcontract.pdf (subcontract between Pathfinder Aviation and Peter Garden)
8. P McCLelland_contract.pdf (contract for consulting services with Pete McClelland)

Field team & camp

1. Rat Is_food order.pdf
2. Rat Island_packing list.doc
3. Rat Island_project action plan.pdf (detailed operational plans including travel, team member assignments, field operations, and organizational structure)
4. Rat Island_team training agenda.doc
5. **Team briefing_8.21.ppt (briefing power point for field operations including: loading of M/V Reliance, operations staging timeline, preparations on Adak, travel to Rat Island, setting up field camp and loading zone, field team organizational chart and responsibilities, baiting timeline, planned flight strategy and baiting rates, baiting blocks, efficacy monitoring, demobilization timeline, personal gear)**

GPS

1. CNAV_global corrections GPS information.pdf (system description and specs)
2. HeliOtagoAg2_b.pdf (helicopter wiring diagram)
3. Rat Is_GPS test protocolv5.pdf
4. Folder – test results
5. TracMap Flight manual

Helicopter EOI (Expression of interest)

1. EOI response information.xls (summary of quotes from various companies)
2. Pathfinder Audit doc.pdf (compliance audit)
3. Rat Is EOI response_summary.xls (summary of companies contacted and responses received)
4. Rat Is_EOI notice.doc (notice inviting expression of interest)
5. Rat Is_EOI bids_top choice.doc (evaluation of three leading companies)
6. Rat Is_EOI notice_short.doc (short form notice inviting expression of interest)
7. Rat Island EOI.pdf (long form notice inviting expression of interest)
8. Rat Island helo contractor criteria.doc
9. Summary of Alaska helo operator_matrix.doc (experience of helicopter companies in Alaska)

Inventory

1. Rat Is_Packing list.xls
2. Rat Island_Master Equipment List.xls

Minutes

1. **IC Rat Island Debrief_minutes.doc (November 20, 2008 debriefing (Island Conservation only)**
2. **McClelland review_DOCDM.doc (comments by Pete McClelland following the Sept./Oct. 2008 operations)**
3. Rat Is_pilot debrief 10 9 09.pdf (debriefing with Graeme Gale, Peter Garden, Spanky Handley, and Mike Fell)
4. **Rat Is_team debrief 10 17 08.pdf**
5. **Rat Island Partner Debrief Nov 10 08.doc**

Monitoring

1. Carcass collections post-erad file (includes map of locations of eagle carcasses; spreadsheet listing eagle locations, gull carcass locations, records of beach walk and beach transect carcasses searches carcasses found by S. Ebbert, summary table; maps of beach walk and beach transect carcass searches)
2. Rat Island 2009_specimen & sample inventory.xls (carcass, biological inventory, soil and water inventory, gull diet study index)
3. **Raw collection data (carcass counts, carcass beach transects)**
4. **Carcass residue analysis file (15 residue analysis reports)**
5. Ecosytem monitoring protocol file (includes standard protocols for biological surveys and data analysis methods)
6. Eradication efficacy monitoring file (standard protocols for surveys to determine efficacy of rat eradication; monitoring protocols)
7. Rat Il biol erad monitoring SOP_Sept. 08.pdf (protocols for monitoring to be conducted during the eradication operations including incidental sightings of birds, radio-tracking of rats, sea lion counts, and carcass collection)

Permits

1. 2009 permits file (USFWS Pesticide Use Permit for 2009; Alaska Dept. of Fish and Game Nuisance Wildlife Permit)
2. ACMP Consistency Determination (determination by refuge manager that the eradication will be undertaken in a manner consistent to the maximum extent practicable with the enforceable policies of the Alaska Coastal Management Program)
3. Endangered Species consultation determination from Ann Rappoport to Will Meeks, March 10, 2008
4. Alaska Board of Game consent to poison rats on Rat Island (May 1 2008)
5. State of Alaska Dept. of Environmental Conservation Pesticide Control Program Certificate of Registration
6. USFWS Division of Migratory Bird Management salvage permit
7. State of Alaska Nuisance Wildlife Permit
8. **USFWS Pesticide Use Permit R7-08-74500-002**
9. Rat Island Incidental Harassment Authorization (issued by NOAA, undated)

10. Rat Island Finding of No Significant Impact (signed by Thomas Melius, Regional Director, March 14, 2008)
11. State of Alaska Dept. of Environmental Conservation Pesticide Permit Application
12. Environmental Assessment December 2007
13. Endangered species consultation March 10, 2008
14. Finding of No Significant Impact (for Supplemental Environmental Assessment)
15. Finding of No Significant Impact (for Supplemental Environmental Assessment), signed copy
16. Supplemental Environmental Assessment (May 2009) for post-eradication monitoring and localized hand-broadcast of Brodifacoum25W Conservation
17. Supplemental Environmental Assessment informal Section 7 consultation
18. The Aleut Corporation letter of support dated February 14, 20008

Pilot

1. Copy of Rat Island Helicopter-Pilot Task list 040-04-08_SB.xls
2. Immigration folder (empty)
3. Metric conversion card
4. NZ Pilot skills evaluation.doc
5. NZ pilot with US immigration ability (announcement)
6. NZ pilot wo visa_advert.doc
7. Pilot & EOI posting sites.xls
8. Pilot Application summary.xls
9. Rat Island_pilot advert responses.xls
10. US Pilot skills evaulation.doc

Project review

1. **Baiting review_IEAG response.doc (Dec. 2007 comments by IEAG on IC proposed baiting strategies)**
2. **DOCDM-243385 – IEAG meeting 27 & 28 Feb 2008.doc (notes of meeting in Wellington, NZ including comments on the Rat Island project)**
3. **IEAG_readiness report_signed.pdf (15 August 2008 readiness audit of Rat Island project by IEAG)**
4. **Rat Is_aerial bait application strategy_IEAG.pdf (November 25, 2007; request to IEAG for review of baiting strategy)**

Rat Island Habitat Restoration Project Overview (short, undated summary with overall project timeline spanning 2000-2013)

Reports

1. Ayugadak 2008 report.pdf (2008 wildlife survey)
2. App8_Rat Island Final IHA report.pdf (Marine Mammal Protection Act Incidental Harassment Authorization Final Report, January 30, 2009)
3. App9_Rat Island HRP_efficacy monitoring.pdf (2009 efficacy monitoring protocol)
4. **Rat Is op plan_Aug 31 2008.pdf (detailed operational plan)**
5. **Rat Island Habitat Restoration Project: 2008 Operational Report**
6. **Rat Island risk & contingency plan.doc**

7. **BOI 2006 Final Report April 2008.pdf**
8. Rat Island 2009 biological report DRAFT VI byrd comments March 8.docx
9. Rat Island biological report DRAFT VI.docx
10. **Rat Island_eradication efficacy report 2009_FINAL.pdf**
11. **Rat Is 2007 pre-erad report appendix.pdf**
12. **Rat Is 2007 pre-erad report FINAL.pdf**
13. **Rat Island Biological Monitoring 2008 Appendices_FINAL.pdf**
14. **Rat Island Biological Monitoring Report_2008_FINAL.pdf**
15. **Rat Island Feasibility DRAFT Report.doc**
16. Report on Rat Islands Surveys 2008.pdf (report by G. Vernon Byrd, Jeffrey C. Williams, and Valerie R. Byrd)

Safety

1. Crisis communication Plan_Final_09-05-08.doc
2. **Daily communications (folder – apparently notes taken by Sarah Abel; "meeting" between Stacey Buckelew, Gregg Howald, Steve Maclean; notes were provided for Sept. 27, Sept. 29, Oct. 1, Oct. 2, Oct.3, Oct. 4, and Oct. 5)**
3. Rat Island field safety manual.pdf
4. Rat Island helo safety plan.doc
5. Rat Island_general communications plan_FINAL.doc

Tasks

1. Rat Island_task monitoring.xls

Vessel

1. IC Aleutians Ship Request.pdf
2. Vessel contract options 5.5.08.doc

Documents provided by Refuge staff

1. **Addendum to 2008 operational report (letter dated 15 December 2009 signed by Steve Delehanty, refuge manger; details application rates and results of freshwater sampling for brodifacoum residue)**
2. Memorandum of Understanding between IC, TNC, and AMNWR dated May 2006)
3. **Programmatic Environmental Assessment (incomplete draft dated 12-04-06)**
4. Programmatic Environmental Assessment comments by S. Ebbert and V. Byrd (December 2006)
5. Necropsy reports
6. 169 e-mails spanning period 8/3/2000 – 9/18/2009

TracMap files provided by J. Vogel

Appendix C: Comments by the Partners on the original draft; analysis and response to comments.

As provided by the contract, subsequent to the submission of the draft report and a presentation by Terry Salmon and Ellen Paul to representatives of each of the three partners (1 October 2010 at the headquarters of the Alaska Maritime National Wildlife Refuge in Homer, Alaska), the partners submitted comments on the draft report. After reviewing the comments, this report was revised. Some revisions were made to the body of the report but most – particularly those requiring longer responses – are addressed here.

Partner comment:

Bait choice
The OC review concludes that brodifacoum was the appropriate choice for the eradication on Rat Island given the logistical challenges and cost of the operation. The OC also cautions that "in those places where it is appropriate, diphacinone would be a more appropriate choice to minimize nontarget mortality". The Nature Conservancy concurs that the lowest risk bait should be used in all eradications, but the review must consider both risks to nontarget species and the risks of eradication failure.

Response:

[The quoted text (since modified) is actually found in the discussion of baiting strategy on p.33, but the baiting strategy and the bait choice are linked because the former influences the latter].

It is because we considered the potential for failure of the operation that we determined that brodifacoum was appropriate in this particular eradication. The cumulative decades of experience of Island Conservation and the Island Eradication Advisory Group have led to the accepted practice of applying rodenticide twice to extend the availability of the bait. In the Aleutians, the possibility of adverse weather may preclude the second application. A single application will not necessarily lead to failure. Indeed, on Campbell Island, where extreme conditions precluded a second application, the eradication effort succeeded (even at a lower baiting rate than that used on Rat Island). Nonetheless, if the strategy entails two applications, circumstances that entail a substantial risk that the strategy will be forestalled justify the use of a rodenticide that has a higher chance of succeeding after only one application.

The point is that if the proposed baiting strategy would also be appropriate or necessary for the lower risk bait, and conditions are such that the second application will not be precluded by adverse weather or other logistical problems, then the lower-risk bait should be used. A case in point is the planned eradication on Palmyra.

The basic operating principle should be to always use the lower-risk bait unless there is strong justification to do otherwise. The track record of brodifacoum alone is not a sufficient basis to justify the choice of brodifacoum.

Finally, we note that failure of eradication projects is attributable to many factors, not just the choice of rodenticide. In the past, brodifacoum eradications have failed and eradications using other rodenticides, including diphacinone and other first generation anticoagulants has succeeded.

Partner comment

Application Rate
As discussed in the OC draft review, calculation of the concentration of bait in any given area is extremely difficult. Actual application is subject to stochastic variation due to wind drift, humidity of the bait, and other factors that affect the flow of bait through the bucket or distribution through the air. The OC recommended a set of "best practices", including better ways to calibrate, measure, and report the concentration of bait in any given area. The Nature Conservancy agrees strongly with these recommendations.

Response

The calculations of bait concentration in Table 2 and in Appendix A refer to the amount of bait out of the bait bucket and *not* the actual amount of bait actually landing on the ground in any square meter (or hectare) or in each square meter (or hectare). It is absolutely correct that wind drift, humidity, and other factors cause an uneven distribution of bait on the ground. Were it possible to ground-truth the bait application rate by counting the number of pieces of bait in each hectare, it would no doubt be rare to find that the amount on the ground in any specific area closely approximates the intended rate. Throughout this report, the amounts calculated, therefore, are based on what was applied and are not intended to indicate precision of distribution on the ground.

The difficulty in calculating the actual application rate resulted from the attempt to understand the calculations provided by the project manager in the spreadsheet used to track the application. These calculations entailed a number of adjustments that were difficult to understand. Eventually, we abandoned those efforts and calculated the rates based on the raw data and with the assistance of the GIS specialist, who explained the TracMap data upon which these raw data were based. That this approach was appropriate was confirmed by senior staff from Island Conservation. We regret that the Partner interpreted the comments made in several conversations to mean that this calculation was inherently difficult. We also note that calculating the bait rate is an essential part of an eradication project. It assures that the correct amount of bait is being applied and project participants should be able to interpret the data and calculate the baiting rate during the project and at the conclusion of the project.

Partner comment

The OC draft review proposes that the "actual" application rates on Rat Island were significantly higher than reported by the Partners.

Response

The rates shown in Table 2 are as published in the 15 December 2009 addendum to the August 2009 Final Operational Report. The rates in Appendix A reflect a more detailed calculation developed from the bait application spreadsheet maintained by the project manager and modified as suggested by the partners at the 1 October 2010 meeting to account for the dissipation of the bait rate at the distant edge of the arc of bait throw from the center point of the bucket. The rates

calculated in Appendix A are lower than those in Table 2, and in any case, the rates are not higher than those reported by the partners.

Partner comment

However, given the uncertainty around all estimates of bait concentration at small spatial scales, the Conservancy recommends that the language in the draft report be amended to avoid use of "actual", and acknowledge the uncertainty and variability in the baiting rate.

Response

As above, the variation of the amount of bait on any specific area is noted. The term "actual" refers the amount of bait as distributed by the bucket and does not imply that each square meter or hectare received exactly that amount of bait. The application spreadsheet reflects variation from one flight line to another. The amounts reported as "actual" are the means for each of three large areas as stratified by the partners to reflect the differential rat densities in different habitat: the approximately 2600 ha upland area, the approximately 285 ha inner perimeter, and the approximately 200 ha outer perimeter.

Partner comment

One of the tasks of the OC review was to assess whether assumptions made about the presence of non-target species on Rat Island were appropriate given the information available to the Partners at the time. Generally, Glaucous-winged gulls and Bald eagles are expected to be aggregated at salmon streams in the fall to feed on the dead and dying post-spawning salmon (Gibson and Byrd 2007).

This predictable and bountiful food source is expected to draw scavenging birds such as Glaucous-winged gulls and Bald eagles away from islands without salmon streams. Gulls and eagles are known to be drawn to marine mammal carcasses, and it is that scavenging behavior that led to assumptions that gulls and eagles would not be on Rat Island during and immediately after the eradication.

Additionally, studies on Langara Island (Kaiser et al. 1997, Howald et al. 1999) investigated secondary pathways of exposure for scavenging birds, including Bald eagles, and concluded that although some individuals were exposed to brodifacoum, none suffered population level impacts.

Given the information available to them, and the concurring opinion of the preeminent seabird biologist in the Aleutians, it seems reasonable that the assumption that scavenging gulls and eagles would not be present was a reasonable assumption, albeit one that turned out to be wrong.

Response

The report notes that Bald Eagles normally congregate at salmon streams in October; as there are no salmon streams on Rat Island, the partners reasoned that the Bald Eagles on Rat Island would move to islands with salmon streams. However, the report also cites literature (Sherrod 1976) that reports that 65 Bald Eagles congregated on Rat Island to feed on a whale carcass that

washed up on a beach. The assumption that Bald Eagles move among the Aleutian Islands in response to changes in food abundance suggests that they would move to Rat Island if an abundant food source became available, particularly after the breeding season when adult birds are not attending nestlings and defending territories. This assumption could have been tested by providing a large number of rat carcasses in late September or early October 2007. Doing so would have added expense to the project as it would have necessitated additional field work. The report also notes that no census or other surveys of the avifauna on Rat Island have taken place in late September or early October.

The presence or absence of Bald Eagles in October, when salmon were spawning on other islands, also overlooks the question of the movements of Bald Eagles over the winter and spring.

While expert opinion is indeed valuable, it is rarely sufficient. The information that was available was not sufficient and no independent efforts to obtain relevant information were undertaken.

The population impact, or lack thereof, demonstrated by the studies on Langara, are not relevant to this discussion. This report does not examine population impact, which was not one of the questions asked by the partners. Indeed, it would have been impossible to assess population impact as the kind of data needed to determine population impact is not available.

Partner comment

On Rat Island, we believe that observed non-target losses would have occurred at the planned, minimum application rates needed for eradication because: (1) the toxicity of brodifacoum, and the pathway of exposure was present, and (2) bait was available across the entire island.

Response

The premise here seems to be that some non-target mortality is to be expected when brodifacoum is used and that non-target mortality is not a function of baiting rate. Indeed, the partners predicted non-target mortality in the Environmental Assessment. It is likely that had the partners had better information about the movements of Bald Eagles, they would have predicted the probable non-target mortality of Bald Eagles as well.

We agree that some non-target mortality is to be expected when brodifacoum is used. We disagree that the extent of the mortality is not a function of baiting rate, though we know of no evidence of the strength of the correlation. However, the basic rule of rat eradication, as the partners have correctly stated, is that bait must be applied to every potential rat territory. The bait must be available to every rat. If a rat doesn't encounter the bait, it can't consume the bait. Therefore, encounter rate is in part a function of bait rate.

The same is true for non-target animals. If an animal doesn't encounter bait, it can't consume bait. More bait increases the probability of an encounter. More bait increases the chance that an animal searching for food will find bait simply because there is more to be found. At a certain point, the abundance of bait probably influences the foraging behavior of the animal, as well. Optimal foraging theory predicts that animals are likely to spend more time foraging in an area

where food is abundant because it reduces search time.

Partner comment

The risk to and loss of non-target species is not taken lightly by IC. We support the idea that the conservation community should develop and test mitigation strategies and evaluate and field test alternative rodenticides with demonstrated high probability for successful removal of the target rodents that have less risk to non-target species. The design of the Rat Island rat eradication followed fundamental principles.

Response

Fundamental principles have been articulated but they seem not to have been developed through scientific study. Rather, they seem to have been developed primarily through trial-and-error. Island Conservation is to be lauded for its efforts on San Jorge, Anacapa, Bay of Islands, and Rat Island to test various components of rat eradication methodology, including bait rate and application strategy. The larger problem seems to be a lack of will (and resources) to attempt to use first generation anticoagulants even where tests show that resistance is not a concern. Partners in these projects regard the use of anything other than brodifacoum by aerial broadcast as "experimental" or assume that the use of first generation anticoagulants will increase the risk of failure, even where conditions are suited to the use of first generation anticoagulants.

Partner comment

The design of the Rat Island rat eradication followed fundamental principles and EPA label instructions.

Response

The design followed EPA label instructions, with one notable exception. Specifically, it appears that Island Conservation intended to interpret the quantitative limits as allowing a weighted average ("nominal rate") of the amount of bait applied to different parts of the island. The August 2008 operational plan, however, suggests that all the bait brought to the island would be applied and interview of field staff and the project manager confirm that the intent was to apply all the bait brought to the island. The result of this plan to apply all the bait raised the likelihood that the label limits would be exceeded in some areas. We stress that we are not alluding to the unevenness of an application from a moving helicopter. Instead, we are referring to the application of an approximately 10 metric tons of bait to areas that had already received the planned amounts of bait. This additional bait, characterized as "contingency" bait, would be used to replace bait that spoiled or spilled and to fill gaps in coverage from the two planned applications. In the absence of spillage, spoilage, and gaps, the contingency bait was not needed. The operational plan seems to be somewhat incomplete in this regard, in that it contemplates that no bait will be returned from the island, but overlooks the possibility that some or all of the contingency bait will not be needed, and if it is applied to the island, it will result in the application of bait in quantities that exceed the label limit.

That the partners intended to use the nominal rate is clear from the operational plan. It could be argued that the label was silent as to the use of a nominal rate, and this is true. However, this report notes that this issue was investigated, and we determined that the USDA Wildlife Services (the label holder) informed the partners that a nominal rate could not be used.

Partner comment

However, the stratification of the application into the coastal perimeter, interior end-to-end flight paths, combined with the restriction against application of bait into the freshwater lakes and marine environment and the requirement that the application leave "no gaps", led to overlap in flight lines which likely resulted in higher than targeted application rates at specific points on the ground.

Response

For clarification, it is important to note that flight lines were intended to overlap. The application design called for 50% overlap of the swaths of bait applied by the helicopters flying straight lines across the island. What is meant by this comment is the overlap of the bait applied at the *ends* of those lines, where the bait bucket was closed 45 m from the mean high tide line to prevent bait from entering the ocean. The bucket throws bait approximately 30 m in all directions, including forward of the bucket, but the rate dissipates with the distance from the bucket. Therefore, some bait entered this 45 m perimeter area. When the circumferential flights were then flown around the 45 m perimeter, the bait applied in the perimeter flights overlapped the bait thrown at the ends of the straight lines flown across the island.

We concur that this flight pattern led to overlap and to some of the observed overage in bait application rates, as noted in the table in Appendix A. We also note that this flight pattern was necessitated by the mandate (imposed by a federal agency) to avoid putting bait into the coastal waters. However, the greater part of the overage resulted from the application of the contingency bait.

Partner comment

Island Conservation takes an adaptive management approach to our projects and is continuously improving the work we do through ongoing modification of procedures and protocols. We are committed to:
1. Conducting risk assessments using the most up to date scientific data in order to make predictions of potential risks at an individual and population level.

Response

It may be necessary to undertake surveys or conduct research to obtain more complete data than are available. Indeed, the partners undertook extensive surveys and conducted several research projects prior to the Rat Island eradication. However, it may be advisable to expand the scope of this work. For instance, it is advisable to conduct surveys at the same time of year as the planned eradication. We have suggested studies to assess the response of non-target predatory animals

and scavengers to the increased availability of readily accessible prey and food items. These are examples of the kind of research needed to make more accurate predictions of potential risk of nontarget mortality.

Partner comment (continued)

2. Continuing to minimize non-target mortality by developing and implementing appropriate mitigation plans that will directly (e.g., restricting non-target species' access to bait) or indirectly (e.g., restricting non-target species access to toxic target carcasses) reduce or where feasible, eliminate, non-target mortality.

Response:

Collecting rat carcasses may be extremely difficult, as was the case on Rat Island. Alternatives include stationing observers on the island after the application to observe the behavior of non-target species. The congregation of birds or other non-target animals around a carcass may facilitate removal of carcasses.

Partner comment

Invasive rodent eradication is a valuable conservation tool, and the use of a bait containing a rodenticide is the only effective tool to remove rats from large or topographically complex islands. In particular, brodifacoum is the most effective and proven rodenticide for rodent eradications (Howald et al. 2007).

Response

Brodifacoum has been used in most of the successful island rodent eradications but growing concern about non-target mortality has led to the increased use of other toxicants including first generation anticoagulants such as diphacinone. Some experts now assert that a diphacinone-based eradication is as likely to succeed as is a brodifacoum-based eradication. The relative lack of experience with diphacinone has been the justification for the use of brodifacoum, but there have been several recent successful eradications using diphacinone.

Partner comment

All three partners (USFWS, TNC, and IC) were fully engaged in the design and planning of the Rat Island eradication, with IC taking the lead on implementing the plan. In addition to the three partners, an array of other government and academic institutions participated in various aspects of the project, with a goal of complete transparency.

Response

To whatever extent transparency was achieved among the partners, it was not achieved with the public, the conservation community, and other federal agencies. For instance, the Environmental Assessment omitted key facts, such as the planned bait application rate and the justification for

that rate. To this day, key documents such as the final operational report have not been made available to the public. Even among the partners, however, some communication gaps occurred. For instance, it was apparent to those who had visited Rat Island that the vegetation structure would virtually preclude a search for rat carcasses, yet the Environmental Assessment does not mention this. In so complex a project, it is inevitable that some miscommunication will occur. However, there was also miscommunication as to major aspects of the operation. The partners, for instance, apparently did not realize that all the bait would be applied, including the contingency bait, regardless of the amount already applied to the ground.

Partner comment

There are fundamental principles applied to rat eradications that maximize the probability of removing 100% of the rat population. In general, for an eradication to succeed (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.
In all of the more than 284 known rodent eradications, all but two small eradication campaigns utilized a rodenticide (Howald et al. 2007). The method of bait delivery (bait station, broadcast – aerial or hand, or a combination) of the rodenticide depends on island topography, habitat characteristics, economics, and vulnerability to non-target species (Howald et al. 2007). In general, these considerations can be rendered down to three fundamentals that are applied in rodent eradications:
1. Deliver a highly palatable bait containing a rodenticide into every potential rat territory on the island.

Response

If a rat does not encounter bait, it cannot eat bait. Therefore, the principle that rodenticide just be delivered into every potential rat territory on the island is sound. Of course, the question is how much bait: one pellet per territory? one hundred pellets per territory? enough bait to blanket the ground?

Island Conservation has answered this question by conducting site-specific studies to determine how much bait is taken by rats in the various habitats on the island. Some areas support higher density of rats than do others, and this differential allows Island Conservation to reduce the overall amount of bait. In contrast to other island eradication projects, which have used a trial-and-error method, Island Conservation develops a scientific basis for its bait rate. They continue to develop new research methods and it is hoped that the same laudable effort will be applied to the development of successful methodologies for the use of baits that are less toxic to non-target species.

Partner comment

IC acknowledges that the approach to calibrating bait application rates for the Aleutian Islands was different from that which is used by the New Zealand Department of Conservation (NZ

DoC). The research to calibrate bait application rates that was carried out in the BOI in 2006 was reviewed by the USEPA and permitted under an Experimental Use Permit. The application rates used on other rodent eradication projects, while useful as a reference point, are not sufficient to determine the rates needed in a novel environment, particularly for a logistically intensive project such as that implemented on Rat Island.

Response

Island Conservation's approach – undertaking site-specific field trials to determine bait rate - is laudable. However, their own Bay of Islands data demonstrated that a very substantial amount of the bait was not consumed in four nights. In the active bait uptake trial to validate the rates calibrated from the placebo bait trial (17kg/ha in coastal habitat and 8 kg/ha in upland habitat), the mean amount of bait consumed over four nights ranged from 12.41% to 24.17% across the five coastal plots. In the upland plots, no more than 2% of the bait was consumed over four nights. Even assuming that all bait was consumed by rats and not by other animals, the data demonstrate that even at 17kg/ha and 8 kg/ha, the amount of bait was ample and perhaps even excessive for inland areas.

A subsequent placebo bait uptake trial on Rat Island measured consumption of bait applied at the rate of 24 kg/ha on coastal plots and 12 kg/ha in upland plots. Mean consumption in the four coastal plots ranged from 10.98 kg/ha to 13.05 kg/ha. In the four upland plots, mean consumption ranged from 1.84 kg/ha to 5.81 kg/ha. Of course, placebo bait does not kill rats, so rat density did not decline over the four nights. The target application rate calculated on the basis of a 99% confidence interval was 13.49 kg/ha for coastal habitat and 7.22 kg/ha for the inland area. Nonetheless, the partners planned to apply 18 kg/ha on the coastal areas of Rat Island and 9 kg/ha on the inland area.

The results of these studies suggest that the Island Eradication Advisory Group's assessment that the planned bait rate of 18 kg/ha on the coast and 9 kg/ha inland was "prodigious" was worthy of more consideration. Though the Island Eradication Advisory Group arrived at its standard rate of 12/6 kg/ha through trial and error, it not only proved successful on Campbell Island, where conditions were similar to Rat Island, but it seems to be more consistent with Island Conservation's own data.

Partner comment

However, the NZ DoC application rates that are routinely used in New Zealand are not necessarily appropriate outside of New Zealand. For example, applying temperate island bait application rates to islands in the deep tropics …

…Interestingly, the OC suggested the 6kg/ha used on Campbell Island in New Zealand as an appropriate application rate for islands in the Aleutians.

Response

We agree that rates used by the New Zealand Department of Conservation are not necessarily

appropriate elsewhere. Our comparison was limited to the Campbell Island eradication, where conditions are quite similar to Rat Island. The sub-Antarctic conditions on the remote Campbell Island are wet and windy, with gusts up to 50 knots on at least 100 days per year. At 11,269 ha, it is substantially larger than Rat Island. The distance to New Zealand's South Island is 700 km, a much greater distance than the 321 km between Rat Island and Adak (the staging area for the Rat Island operation). On Campbell Island, which was said to have the highest density of rats in the world, the bait rate of 12 kg/ha on cliffs and 6 kg/ha upland succeeded in eradicating rats.

This report did not suggest that the 6 kg/ha used on Campbell Island was an appropriate application rate for islands in the Aleutians. This report noted the comments made by the Island Eradication Advisory Group to the effect that the bait rates proposed for Rat Island were prodigious; those comments reported the rates for Campbell. Our analysis simply reports the assessment of the Island Eradication Advisory Group – acknowledged to be the world's most experienced in the eradication of rodents from islands – and compares that rate to the data generated by Island Conservation in its Bay of Islands and Rat Island studies. When interviewed, Pete McClelland stated that the standard rate used in New Zealand eradications is now 8 kg/ha for cliffs and 4 kg/ha for upland areas, plus a contingency of between 20-25% of that amount (for a total of approximately 10 kg/ha for cliffs or coastal areas and 5 kg/ha for upland areas).

Partner comment

This competition for and subsequent loss/degradation of bait over time in a given rat territory could lead to low bait availability to rats, and ultimate failure of the eradication. Correlating bait rates directly with the density of rats does not account for competition for the bait by other species that are attracted to the highly nutritious and energy rich inert bait matrix. Thus, **broadcast bait application rates will not be directly correlated with rat densities on every island.**

Response

Our report does not allege that application rates will or should be directly correlated with rat densities. The report mentions the rat density on Campbell Island only to demonstrate one of the similarities between Campbell Island and Rat Island and that comparison is made only to support the contention that the view of the Island Eradication Advisory Group that the amount of bait planned for Rat Island was "prodigious" was by direct comparison to their experience on Campbell Island.

Partner comment

The BOI trials empirically measured bait uptake and were used to test bait application rates and served as the reference standard for the eradication on Rat Island. The trial was conducted to ensure bait would be available in all potential rat territories for a minimum of 4 days. This benchmark was driven by a combination of biological factors and extrapolated from verbal discussions with eradication experts, in addition to literature reviews (e.g., Cromarty et al. 2002; Merton et al. 2002).

Aerial broadcast of bait containing a rodenticide, targeted for removal of rats from islands, requires that:
1. bait be available to 100% of the rats in *sufficient quantity for all rats to be exposed to a lethal dose*, and,
2. for long enough that all rats *will gain access* to enough bait.
The factors that contributed to the choice for empirically calibrating the bait application rates in the BOI, when taken as a whole, support the need for having bait on the ground for multiple nights, and in adequate density to ensure all rats have access to the bait. The factors or considerations leading to IC's approach to calibrating bait application rates were:
1. The registration of anticoagulant dry baits with the US EPA is based, in part, on laboratory efficacy studies that are 3-day choice trials, with a minimum of 90% mortality as the target threshold for registration purposes (Schneider and Hitch 1982). Some laboratory studies with brodifacoum at 3 day exposures do not result in 100% mortality of rats (e.g. Pitt et al. 2010). In 1998, the US EPA switched to a 24 hour choice test trial for second generation anticoagulants sold with the marketing claim , "can kill in a single nights feeding". Testing conducted under these conditions does not routinely result in 100% mortality of the test population (P. Martin, pers. comm.). Reasons for an inability to achieve mortality include sub-lethal exposure due to rat behavior in cages and complete avoidance of newly introduced objects (neophobia). Clearly, these studies demonstrate that strict reliance upon a 24 hour (or even a three day) bait exposure will almost certainly result in less than a 100% kill of the rodent population, which is essential to the success of these projects.

Response

When the report was prepared, this information – the basis for the four-night standard - was not made available to the reviewers. We appreciate receiving this additional information.

However, the planned baiting application strategy would have resulted in bait being available for a minimum of nine nights. According to Island Conservation's data on short-term bait persistence, the pellets begin to swell and soften at day five but maintain their size and shape for 21 days. At day 12, the pellets begin to grow moldy. Assuming that this means that the bait is palatable for at least 10 days, if the two drops were done in immediate succession, the bait would have been available for at least 11 days. Combined with the data from the placebo bait consumption trials and the active bait uptake trial, this suggests that a lower quantity of bait could have satisfied the condition that bait be available for a minimum of four nights.

Partner comment

The factors or considerations leading to IC's approach to calibrating bait application rates were:
…3. Norway rats are notorious for their neophobic behavior toward new or novel food items. Thus, bait needs to be available for a long enough period so that individual rats will repeatedly encounter bait, identify it as a food resource, and choose to consume it over the available natural foods that they normally seek out. MacDonald and Fenn (1994) have reported rats avoiding a pile of wheat, and treating it with " great caution" for up to 30 days. During a bait station eradication on Lucy Island, British Columbia, rats

avoided bait stations for ~5 days before removing bait, despite the stations having been in place and weathered for at least 6 weeks, and a small offshore rock treated with a single bait station did not see bait removal for over 16 days despite observation of active rat burrows and rats utilizing the islet (Kaiser et al. 1997). **It takes time for rats to overcome their wariness over new food resources,** such as bait placed on the island.

Response

We appreciate the concern for neophobia, as well as the fact that this observation is supported by published research. Of course, the bait station itself may have been the basis for the neophobia, so the Kaiser et al. (1997) may not be applicable here. In any case, Island Conservation's Bay of Islands and Rat Island data demonstrate a lack of neophobia. In paired food trials, "was chosen significantly more often than natural food choices." The Bay of Islands report states unequivocally that, "Brodifacoum 25 Conservation bait appears to be acceptable and palatable to rats, in both fresh and weathered condition. These results suggest that conservation bait will be readily consumed even when natural food sources are present." The results of the placebo bait consumption trial confirm this finding, in that the rats consumed 8 kg/ha on the first night of the trial and approximately 1 kg/ha on each of the following three nights. This pattern is not suggestive of neophobia. The same pattern was observed on Rat Island, "In both Rat Island and Bay of Islands, Adak, consumption was highest in coastal habitats, with consumption peaking the first day following bait application and incrementally decreasing thereafter."

Island Conservation's scientific approach is laudable and the organization is justified in basing its decisions on the results of their studies. However, it is unfortunate that the organization disavows those same studies and resulting data as to this one factor in determining bait application rates.

Partner comment

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

Response

In fact, it is possible that some rats will never consume bait, regardless of the amount applied. In any case, based on Island Conservation's data (the two placebo bait consumption trials and the one active bait uptake trial, combined with the short-term persistence data) the amount applied should have been more than sufficient to make bait available for a minimum of 10 days, even if the second application took place only one day after the first application

Partner comment:

The four points above support and validate the need to ensure bait is available on the ground to all the rats over multiple nights to ensure eradication success. The target application rates planned for the Rat Island project represented the amount necessary to ensure the success of the eradication. However, the targeted application rates necessary for success on Rat Island presented a risk to non-target species, and resulted in the loss of birds on the island. Minimizing the application rates is highly desirable both for reducing the amount of toxicant introduced into the environment, but also from an efficiency standpoint; less bait = less expense for purchase, shipment, and even helicopter flight time to deliver the bait. However, because of the toxicity of brodifacoum, a lower application rate will not likely translate to a similar reduction risk of lethal exposure to non-target species, especially those that are attracted to the bait and/or secondary exposure via poisoned rats.

Response:

A lower application rate means, at least potentially, a lower toxicant load in the tissues of the dead rats that are consumed by non-target animals. It also results in less unconsumed bait on the ground and therefore less bait available to granivorous and omnivorous non-target animals. As explained above, consumption rate is related to encounter rate. The lower the probability of encountering bait, the lower the overall likelihood of consumption.

Partner comment:

Bait Application Strategy
The OC report did not fully acknowledge why the two application strategy on Rat Island was used. To clarify, the two application strategy had two functions:
· To ensure that active bait was available to any weanling rats that survived in the burrow during the first application and emerged after the initial application of bait had been consumed.
· To ensure that any inadvertent bait gaps on the ground following the first application received bait, and any rats in those areas had an opportunity to be exposed to a lethal dose.
Thus, under a diphacinone model, consideration would have to be given to three, or potentially more (4+) applications at a fixed application rate, which we did not consider to be feasible in the Aleutian Islands. There is uncertainty in the number of applications due to the practical limitations of this toxicant having not been used in broad-scale eradication campaigns, and has only been used on some small experimental broadcast eradications where mixed results have been achieved. The most recent aerial broadcast eradication using two applications of a diphacinone bait (Lehua Island, Hawaii) failed to remove all rats from the island.

Response:

We concur that the draft report failed to provide the full explanation for the two-application strategy. We have now revised the report accordingly (see page 32). However, the comment

raises another contention that seems unsupported, namely that under a diphacinone model, consideration would have to be given to three or four applications at a fixed rate. We realize that diphacinone requires multiple feedings before a lethal dose accumulates, but the partner's own Environmental Assessment states that "If diphacinone were used as the primary toxin for rat eradication from Rat Island, every potential rat territory on the island would need to have bait available for consumption continuously for a period of up to four days." No evidence has been provided to suggest that pellets containing diphacinone could not be formulated so as to persist for at least four days in the Aleutian environment. Multiple feedings would entail a higher baiting rate and, in turn, greater expense, but if the goal is to reduce non-target mortality, the cost of additional bait and the additional helicopter flights are worth consideration.

We also recognize the risk that interruption of application of diphacinone would entail, and for that reason, we acknowledged that brodifacoum was appropriate for use on Rat Island. However, as noted in the explanation of the scope of this review, "the larger purpose of the review was to learn and to understand what can be done to improve future projects so that island conservation projects that require rat eradication can continue." In situations where weather is not likely to interrupt bait application or bring it to a premature halt, the cost and time needed to apply more bait or undertake more applications is outweighed by the reduction in nontarget mortality.

Partner comment

Two partners asked the reviewers to make a determination about compliance with the quantitative and qualitative limits of the label.

Response

We decline to do so. We have provided the facts to the best of our ability, but we acknowledge uncertainty in the assessment of the application rates. It is unlikely that the degree of uncertainty is such that the estimates are off by as much as 8 kg/ha let alone 13 kg/ha (the amount by which the bait rate for the inner perimeter appears to have exceeded the label rate). Nonetheless, the determination of this legal question should be left to those who are charged with that responsibility.

Partner comment

To meet the first principle of rat eradication and ensure no bait gaps occurred along the coast, perimeter runs with a deflector mounted on the bucket, and full swath perimeter runs were made along the coast. As a consequence of the coastal perimeter runs, overlap between baiting the coastal zone and the inland zone occurred. This resulted in a greater amount of bait being applied to the areas of overlap, and likely resulted in higher than expected application rates in these areas compared to other parts of the island (as defined by the OC).

Response

The overlap of the inner perimeter application with the bait thrown forward of the bucket at the end of each of the flight lines across the island resulted in some of the overage in the inner perimeter area. However, the application of the contingency bait accounted for most of the

overage. The label makes it clear that any applications after the first two could take place only after the baited areas were assessed for "signs of residual rodent activity (typically 7 to 10 days post-treatment). The TracMap records and the bait application spreadsheet show that immediately after the second application two more flights were made around each of the two perimeter rings and additional bait was applied to the drainages. No effort was made to assess the baited areas for signs of residual rodent activity. Therefore, the application of the contingency bait has to be considered part of the second application. Appendix A provides the estimate of the total amount of bait applied during the second application.

Partner comment

In summary, there is an apparent conflict between the EPA label and the practicality of aerial broadcast rodent eradications. The EPA label requires that bait be uniformly spread over of the entire landmass (at a given application rate), and that bait not be broadcast into the marine environment. This forces the applicator to treat the island according to a block-by-block plan rather than treating it as one cohesive unit. When the fundamental goal of the bait application for rat eradication is to "leave no gaps," higher than anticipated bait application rates can occur when transitioning from baiting one block to the next.

To overcome this apparent conflict that exists in all aerial broadcast rat eradications in the US using aerial broadcast techniques, we propose that:
· End to end island flight paths be allowed to completely cover the entire island, thereby eliminating the need for separate "blocks" and hard bait transition points on the island.
· The US-EPA label be changed to accommodate overlaps in flight paths, and to accommodate the need for higher bait application rates along the coastline in critical rat habitat.

Response

We agree in principle but adherence to the EPA label is a legal issue that should have been addressed with EPA before the eradication project on Rat Island took place. In any case, the excessive baiting in this project was not, in general, the result of the overlap of the base flight lines across the island with the circumferential flights around the perimeter, but rather resulted from the final application of a large amount of bait, intended for contingencies such as spillage, spoilage, and gaps, to the 45 m perimeter of the island.

Appendix D: About the reviewers

Terrell (Terry) P. Salmon, Ph.D, who served as the principal investigator on this project, retired in 2010 after 30 years of a career that combined scientific research with applied practice and outreach in pest control through the cooperative extension system. Salmon earned a bachelor's degree in renewable natural resources at UC Davis in 1972, a master's degree in animal ecology at UC Davis in 1976, and a doctorate in ecology in 1979. He was immediately hired as a Cooperative Extension wildlife specialist on the Davis campus. His research and the Extension program focused on managing vertebrate pests that reduce crop yield or increase expenses on farms and ornamental nurseries. Salmon's first research effort looked at ground squirrel control using the fumigant aluminum phosphide, which was ultimately registered for commercial use and remains a squirrel control tool that farmers use today. Since the early 1980s, Salmon also worked to develop ways to use integrated pest management in the management of damage by birds, rodents, rabbits and deer. In 1989, Salmon cut back on his research to serve as the director of the UC Division of Agriculture and Natural Resources Northern Region, which encompassed the UC Cooperative Extension programs in 21 counties. When the UC Division of Agriculture and Natural Resources was reorganized in 1999, Salmon decided to return full time to agricultural research, focusing his studies on reduction of hazards associated with using rodenticides for ground squirrel control. Four years later, his career took another turn when he became the County Director and Vertebrate Pest Specialist for the UC Cooperative Extension of the County of San Diego. He remained in that job from 2003 until he retired in 2010.

Even though Salmon split his career between academics and administration, he completed a notable body of research on vertebrate pest management, authoring 167 articles and publications. Among these were numerous studies comparing chlorophacinone and brodifacoum in ground squirrel control, ecological risk assessments for agricultural rodenticide use, and the development of methods of use of anticoagulants for vertebrate pest control.

Steven R. Sheffield is recognized as an expert in ecotoxicology, wildlife toxicology, vertebrate zoology, conservation biology, and environmental risk assessment. After earning an undergraduate degree in zoology from the State University of New York in Oswego, he obtained an M.S. in wildlife ecology from the University of Maryland and a Ph.D from the Oklahoma State University. He served as a postdoctoral fellow for the Environmental Protection Agency at the Oak Ridge National Laboratory. After teaching at Clemson University, he served as a wildlife biologist for the U.S. Fish and Wildlife Service where his duties included serving as the US representative on bird/pesticide issues and working closely with Canadian and Mexican scientists on a Western Hemisphere initiative to decrease mortality of migratory birds from pesticides. He next became a consultant on pesticide/wildlife issues to organizations and government agencies, including the Rachel Carson Council, Defenders of Wildlife, the National Pesticide Reform Coalition, the U.S. Forest Service, Environmental Protection Agency), and professional scientific societies such as the Society of Environmental Toxicology and Chemistry (SETAC), the Society for Conservation Biology (SCB), and The Wildlife Society (TWS). He also teaches field biology for a graduate program in Natural Resources at the northern Virginia campus of Virginia Tech and is an assistant professor at Bowie State University. Dr. Sheffield has 52 papers published in refereed journals (including such journals as Environmental Toxicology and Chemistry, Archives and Bulletin of Environmental Contamination and Toxicology, Environmental Health Perspectives, Human and Ecological Risk Assessment, Journal of Mammalogy, and the Journal of Raptor Research), as well as book chapters,

reports/issue papers and symposium proceedings. He also has eight book chapters published, including a chapter in the new 7th edition of the Wildlife Techniques Manual (*in press*) entitled "Identifying and handling contaminant-related wildlife mortality/morbidity incidents.

Ellen Paul is the Executive Director of the Ornithological Council. In that capacity, she has coordinated, co-authored, and edited numerous projects including critical literature reviews, peer reviews of literature and research methodology, and the revision of *Guidelines to the Use of Wild Birds in Research*, a compendium of ethical considerations arising in ornithological research. After she received an undergraduate degree in history from Goucher College, she earned a law degree from Villanova University and practiced law for a decade before returning to school for an M.S. in conservation biology from the University of Maryland.

About the Ornithological Council

The founding premise of the Ornithological Council is that the ability to make sound policy and management decisions regarding birds and their habitat requires the application of impartial scientific data and the continued collection of such data. The Council thus has a mission to facilitate the generation of scientific knowledge and to assure that this knowledge is available to decision-makers whose actions affect wild birds and their habitat. It serves as a conduit between ornithological science and legislators, regulators, land managers, conservation organizations, and private industry to assure tat the scientific information needed for decision making that affects birds is available.

The Council was founded in 1992 by seven ornithological societies in North America: American Ornithologists' Union, Association for Field Ornithology, Cooper Ornithological Society, Pacific Seabird Group, Raptor Research Foundation, Waterbird Society and Wilson Ornithological Society. In recent years, the Society of Canadian Scientists, the Society for the Conservation and Study of Caribbean Birds, the Neotropical Ornithological Society, and CIPAMEX have become members.

Opinions expressed in this report are those of the individual authors and do not necessarily reflect the opinions of the Ornithological Council.