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The Biology of Introduced Norway Rats on Kiska Island, Alaska, and an Evaluation of an Eradication Approach

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Abstract

Introduced, invasive rats can cause substantial damage to native flora and fauna, including ground-nesting seabirds, when they become established on islands. We tested a control method for introduced Norway rats on Kiska Island, Alaska, during April-May, 2004, by hand-broadcasting rodenticide pellets (0.005% diaphacinone) over a 4-ha area at the rate of 28 kg/ha. We also gathered data on aspects of rat ecology and distribution, although rats were difficult to detect and capture. The rodenticide bait pellets seemed to have been effective in reducing the Norway rat population, however, this is based on a limited observation of rat sign and captures. Four rats were captured on elevational transects on the northside of the island, all below 20 m elevation. Twelve rats captured in other aspects of the study also came from lower elevations. Rat stomach contents revealed that vegetation and seabirds were important components of the diet at the north end of Kiska Island, but stomach contents varied by location depending upon the type of food most readily available. All eight females captured were pregnant and bore an average of 10 embryos. Although the control or eradication of rats at remote locations such as the Aleutian Islands is theoretically possible, there are many challenges posed to resource managers. This field study has provided insight into the ecology and management of Norway rats at Kiska Island, but also points out some of the challenges that remain.

Introduction

Introduced, invasive rats pose a serious threat to the native flora and fauna of islands. Rats can be very prolific on islands where there is little mammalian predation and competition for resources. Their omnivorous foraging has led to the endangerment or extinction of many native island species (Moors and Atkinson 1984, Ebbert and Byrd 2002). Most seabirds that nest on islands have not evolved to deal with predation and are very vulnerable to introduced predators, including rats. There has been substantial documentation of the negative impact of introduced Norway rats (*Rattus norvegicus*) on nesting seabirds of the Aleutian Islands of Alaska (Sowls and Rauzon 2001, Ebbert and Byrd 2002, Major and Jones 2004).

There has been a concerted worldwide effort to eradicate introduced rats from islands with numerous successes (Veitch and Clout 2002). USDA Wildlife Services (WS) conducted a successful eradication of roof rats (*Rattus rattus*) from Buck Island in the U.S. Virgin Islands for the National Park Service (Witmer et al. 1998, Witmer et al. 2001), using a grid of elevated bait stations across the 80-ha island. In recent years, WS National Wildlife Research Center (NWRC) personnel in Fort Collins, Colorado, and at the Hilo, Hawaii, Field Station have been providing data sets for the U.S. EPA for the registration of a 0.005% diphacinone bait pellet to be used for aerially broadcast baiting of conservation areas to manage or eliminate rats (John Eisemann, NWRC, personal communication).

The USDI Fish and Wildlife Service (FWS) has proposed to use 0.005% diphacinone bait pellets on the Aleutian Islands of the Alaska Maritime National Wildlife Refuge, but studies are needed to assess the bait efficacy, durability, and non-target hazards. These studies are needed because of the vastly different climate, soils, fauna and flora than what occurs in more tropical settings.

The main objective of this study was to assess the efficacy of a broadcast rodenticide bait pellet (0.005% diphacinone) to reduce or eliminate the presence of Norway rats in the test area on Kiska Island, Alaska. Secondary objectives included an evaluation of bait uptake (acceptability/palatability), an assessment of the elevational distribution of rats at the north end of Kiska Island, and a qualitative assessment of reproduction and food

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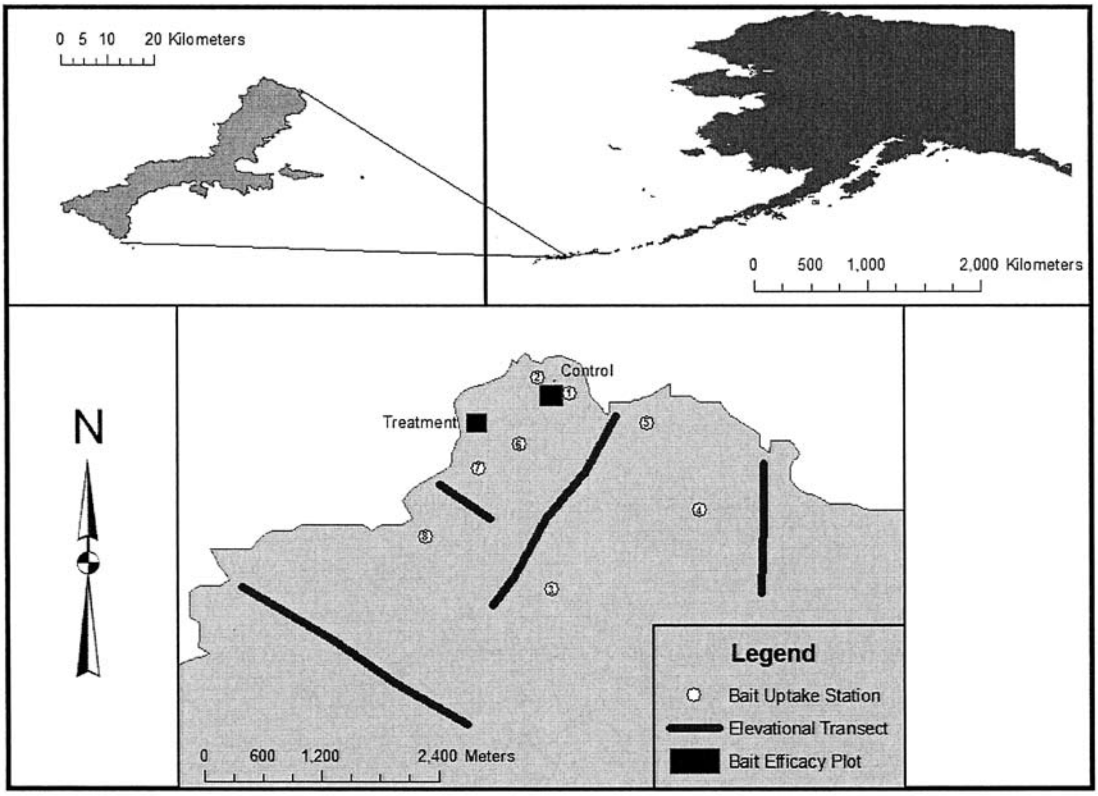

Figure 1. Map of the north end of Kiska Island, Alaska, showing approximate locations of study plots. The two bait efficacy plots and bait uptake stations 1 and 2 are on the 1964-69 new lava field on the northwest edge of Sirius Point, while the old lava field, containing bait uptake stations 3, 4, and 5, is a relatively flat area to the east and slightly south of the new lava field.

habits of rats at the north end of Kiska Island. This paper represents the first published study of Norway rats in the Aleutian Islands.

Study Area

This study was conducted on Sirius Point on the northern end of Kiska Island (52° 08'N, 177° 37'E, part of the Alaska Maritime National Wildlife Refuge (Figure 1). The 278 km^2 Kiska Island is located in the western Aleutian Island chain about 1270 km west-southwest of the tip of the Alaska Peninsula and about 400 km west of Adak Island. The Island is volcanic in origin and has an active volcano near the north end of the Island (Miller at al. 1998). Volcanic activity in 1964-69 created a new lava field on the northwest edge of Sirius Point on the northern end of the island, just west of an older lava field. The new lava field is very rugged with lava boulders varying from small to massive (2-20 m diameter) and crevices varying from small and shallow (0.5 m wide and 2 m deep) to very large and deep (5 m wide and 20+ m deep). Other areas, such as the old lava fields are somewhat less rugged. The new lava field is sparsely vegetated with grasses, sedges, ferns, mosses, and lichens, while the older lava field and other parts of the island have much denser herbaceous vegetation (Jones et al. 2001, Major and Jones 2002). There is little woody vegetation on the north end of the island, although a dwarf shrub, crowberry (*Empetrum nigrum*) can occasionally be found; shrub cover is much more common at Christine Lake to the south. Many bird species occur on Kiska Island and the Island is especially known for the huge nesting colonies containing several million least (*Aethia pusilla*) and crested (*A. cristatella*) auklets (Jones et al. 2001, Major and Jones 2002). Generally, large numbers of auklets nest in the rocks of the new lava field, while fewer nest in older, more densely vegetated areas (Jones et al. 2001). No native, terrestrial mammals occur on Kiska Island. Arctic foxes (*Alopex lagopus*) were introduced in the 1800s, but have since been eradicated (Bailey 1993, Ebbert 2000, Ebbert and Byrd 2002). Norway rats (and probably house mice, *Mus musculus*) probably arrived on ships during World War II and from shipwrecks of freighters and fishing vessels (Bailey 1993, Ebbert and Byrd 2002). We did not detect house mice on the Island, however, nor have they been reported by others conducting seabird research on the Island (e.g., Jones et al. 2004). The geology, climate, floral, and fauna of the Aleutian Islands was described in more detail by Murie (1959).

Methods

Bait Efficacy Trial

Two 4-ha plots (each 200 x 200 m square) were established on the new lava field near Sirius Point on the north end of Kiska Island (Figure 1). The plots were about 30 m above sea level. Plots appeared roughly similar in terms of vegetation, slope, nearness to shore, and rodent activity. The plot on the western side of the new lava dome, and further away from the ongoing auklet study site, was selected to be the treatment plot; the other served as a control plot. At least 200 m separated the closest points of the two plots. An 8 x 8 grid of stations, each 20 m apart, was established in the central area of each plot, leaving a 30 m buffer zone between the stations and the edge of the plot. Each of the 64 stations was marked by a stake or flagging and one track tunnel and one chew stick were placed near each station stake or flag. An inked card that would allow rats to leave tracks, identifying a visit, was scented with a commercial fox lure and was placed in each tracking tunnel. Ink mixed with bacon grease and pieces of auklet flesh were also used as lures. Chew sticks consisted of a wooden dowel approximately 30 cm long soaked in peanut oil.

Bait (Ramik Green pellets; HACCO, Inc., Madison WI) was hand broadcast over the 4-ha treatment plot by FWS and NWRC personnel on 15 April 2004. Bait pellets were uniformly distributed at the maximum label application rate (28 kg/ha). Stations were checked daily for the next 14 days. Rodent activity was recorded by date and station number and inked cards and chew sticks were replaced after a rodent visit. While checking tracking tunnels and chew sticks each day, personnel looked for, and collected, any rat or bird carcasses observed. While this activity was meant to help find target and non-target carcasses, it also located some birds that had struck rocks and died or that had been preyed upon by rats.

Eight days after bait application, a rat snap-trap in a Protecta bait station (Bell Laboratories, Inc., Madison, WI) was placed near each station on the 2 plots. Traps were baited with peanut butter and oatmeal, but left unset, for the next three days. On the fourth day (16 April 2004), the traps were baited, set and checked each day for the next six days. After four days of trapping, the snap-traps were removed from the Protecta bait stations. No rats had been captured and because Norway rats often exhibit neophobia, the bait stations may have caused the rats to avoid the traps. After four days of trapping, the peanut butter and oatmeal bait was replaced with auklet meat obtained from least and crested auklets found dead off the study plots. The snap-traps with auklet meat were placed outside of a bait station and left out for two more nights. The snap-traps were removed on 2 May 2004.

A chi-square goodness of fit test (Sokal and Rohlf 1969) was used to determine if the number of stations with rat sign (maximum possible = 64) differed significantly ($P < 0.05$) between the control plot and the treatment plot. Any evidence of rat presence near the station was used for this calculation: tracks, chewing, fecal pellets, or auklet carcasses with rat feeding marks.

Elevational Distribution of Rats

NWRC personnel established 4 elevational transects to help determine the elevational distribution of rats on the north end of Kiska Island (Figure 1). These transects were at least 200 m from the two trial plots and started from near the shoreline up to 74 m in elevation. The transects then ran upslope to an elevation of 160-242 m depending on the snow levels in that particular area. At about each 50 m of elevation gain along the transect, 10 rat snap-traps were placed without a Protecta bait station, about 10 m apart, along the contour of the slope. After three days of pre-baiting, the traps in these transects were operated for five days (9-14 May 2004) in the same manner as described above, using auklet meat as bait. The snap-traps were removed on 16 May 2004.

Carcasses of all captured rats were bagged and labeled (date, transect, nearest station number) for later necropsy. Data recorded at necropsy included species, sex, weight, morphological measurements, evidence of bait consumption, evidence of internal hemorrhaging, reproductive condition, and stomach contents.

Rat Trapping at Christine Lake

At the end of the elevational transect trial, a 3-day visit was made to Christine Lake, about 6 km south-southwest of Sirius Point and on the other side of Kiska Volcano. Due to the distance of Christine Lake from the base camp at Sirius Point, trapping could only be conducted for two consecutive nights (18-20 May 2004). Five rat snap-traps were used for a total of 10 trap-nights. Dolly Varden trout (*Salvelinus malma*), collected from Christine Lake, was used as bait. The traps were not placed in Protecta bait stations, and traps were not pre-baited. Traps were set out randomly within a 100 m radius of the temporary camp set up on the north end of Christine Lake. Captured rats were processed in the same manner as described above.

Bait Uptake Trial

To assess bait uptake rates by rats, eight bait points were established in varied habitats that included auklet colonies, grassy meadows, and ravines with elevations from 30-165 m. Bait uptake points were at least 200 m from any elevational transect, bait efficacy plot or any other bait uptake point with the exception of two bait uptake points that were placed within 200 m of the bait efficacy control plot (Figure 1). This was allowed since no rats were captured or killed on that plot and therefore the rat population there should have been at its normal level. Bait uptake points consisted of 38 pellets of Ramik Green. Changes in the number of pellets were used as a measure of bait uptake to avoid the influence of moisture gain on changes in weight. To avoid effects due to neophobia, Protecta bait stations were not used. Instead, the bait pellets were placed in cup-shaped depressions under overhanging rocks. The locations were chosen carefully to make sure that bait pellets could not fall down into crevasses and be lost, and that the overhanging rocks prevented rain from falling on the bait pellets. These locations also minimized the chance of pellets being observed or disturbed by non-target species such as birds. Points were checked for 14 days (7-21 May 2004); the remaining pellets were counted and any missing were replaced so that the total remained 38 each day.

Results

Bait Efficacy Trial

Over the course of the study, rat sign was observed at a total of 18 of the 128 stations on the two plots. The rat sign was scattered about the two plots, not clustered. Rat sign was observed at least once at six stations on the treatment plot and at 12 stations on the control plot. This difference in rat sign was not significantly different between plots ($P < 0.127$). However, an interesting pattern was observed when the 17 observation period was split into an early and late periods. During the early period of monitoring, there were six stations with rat sign on the control plot and five on the treatment plot. In the late period of monitoring, however, six stations had rat sign on the control plot, but only one on the treatment plot. This suggests a decline in rat activity or presence on the treatment plot. However, this conclusion is based on rat sign at only 18 of 128 stations and without replication of plots. No rats were found dead on either plot and none were trapped over the six nights in which 128 traps were baited and set.

Due to the difficult terrain on the bait efficacy plots, no quantitative assessments could be made in regards to bait pellet disappearance rate. However, some qualitative observations were made by field personnel monitoring the plots for rat activity. When bait was broadcast on 15 April 2004, bait pellets were commonly seen. On 30 April 2004, the note was made that very little bait remained visible and only occasional pellets could still be found.

Elevational Distribution of Rats

A total of 188 snap-traps were set out on four elevational transects (Figure 1) and four rats were trapped over five nights. All rats were from Steam Beach at about 2 m elevation. There were two other suspected rat captures where the rat was able to escape from the trap and two marker flags were chewed, indicating rat presence. All documented and suspected rat activity was between sea level and 20 m in elevation at Steam Beach and in the cove directly east of the base camp. No recent rat activity was observed elsewhere during elevational trapping, although old rat sign (presumably from the previous year) was occasionally observed at higher elevations.

Rat Trapping at Christine Lake

Five rats were captured in five snap-traps located at about 11 m above sea level during two nights. There were also two suspected rat escapes from the Christine Lake traps. Hence the capture rate at Christine Lake was ≥50%. Rats were observed running around the beach at all times of the day near Christine Lake, while rats were never observed at Sirius Point.

Bait Uptake Trial

A total of 107.5 bait pellets were removed of the total of 412 placed at bait points. Two bait points located on the old lava field at 79 and 165 m above sea level accounted for almost all the pellets removed: bait point #5 accounted for 78.5 (73%) of the pellets removed, while bait point #3 accounted for 22 (21%) of the pellets removed. On two occasions, all available pellets were removed from bait point #5. Three days later, a moribund rat was found within 15 m of that bait point. Upon necropsy, the rat showed evidence of internal hemorrhaging. The other six bait points had ≤3 pellets removed from each.

The fact that most bait stations did not have pellets removed by rats should not be interpreted as the bait being unpalatable to the rats because it appears that the rat population may have been at a very low level at the time of the study. The low levels of rat capture and detection are discussed at greater length in the Discussion section below. Indeed, the results of the bait efficacy trial suggest that the pelleted bait was very acceptable to the rats.

Necropsy Results

Eight male and eight female rats were captured or collected during the study. Four rats (three males and one female) were trapped near the base camp. Five rats were trapped on Steam Beach (two males and three females). Five rats were trapped at Christine Lake (two males and three females). Two rats were collected from the old lava field south and east of the base camp (one male and one female). Fifteen of the rats were classified as adults, based on size and sexual development. Only one rat (a male) was trapped that appeared to be a juvenile/young adult; all female rats trapped were adults. The juvenile/young adult male was 33.8 cm in total length, and weighed 210 g. The adult males averaged 40.4 cm in total length (S.D. = 2.6 cm) and weighed 303 g (S.D. = 66.1 g). Adult female rats averaged 38.5 cm in total length (S.D. = 2.2 cm) and weighed 266.4 g (S.D. = 39.3 g). The smallest individual trapped measured 33.8 cm, the largest was 44.7 cm total length. Two rats were trapped that weighed only 210 g; the heaviest individual captured weighed 420 g. Almost no body fat was observed on 69% of the rats examined, whereas 31% of the rats had little to moderate amounts of body fat. All of the female rats necropsied were pregnant with an average of 9.6 embryos. Pregnancy stages were from early first trimester to one individual with embryos in the third trimester.

Crude stomach content analysis identified nine different food items (Table 1). The most common items observed were vegetation and bird remains (e.g., feathers, what appeared to be auklet meat, and what appeared to be brain matter). However, stomach contents varied greatly by location; for example stomach contents from Christine Lake included no feathers, brain material, or auklet meat; but contained kelp, sand, and fish meat (Table 1).

TABLE 1. Stomach contents of rats by capture location on Kiska Island, Alaska, 2004.

	Camp/Old Lava Field	Steam Beach	Christine Lake
Food Item	Frequency of occurrence (n=4 rats)	Frequency of occurrence (n= 5 rats)	Frequency of occurrence (n= 5 rats)
Feathers	2	2	0
Auklet Meat	3	4	0
Brain Material	2	1	0
Plant Material	2	4	1
Orange Lichen	0	1	0
Egg Shell	0	2	0
Sand	0	0	3
Kelp	0	0	3
Fish Meat	0	0	1

Two necropsied rats showed evidence of bait consumption. Both rats were found still alive, but unable to move near places where bait had been put out. Both rats had discolored, lighter than normal livers. One rat showed considerable internal hemorrhaging with pooled blood inside the body cavity. The other rat had a bright green substance in the stomach that closely resembled the color of the Ramik Green bait pellets used in the study. None of the vegetation on the study area appeared as though it would result in a bright green color in the stomach.

Discussion and Management Implications

While the bait efficacy trial suggested that the rat populations can be reduced by a single broadcast application of the pelleted diphacinone bait, there are a number of considerations that prevent a firm conclusion. The rats proved very difficult to detect or capture. Rat sign was detected at only 18 of 128 stations during the bait efficacy trial. Major and Jones (2004) also noted the difficulties of trapping rats at the seabird breeding colonies of Sirius Point and of accurately assessing rat predation rates on auklets. It is also possible that the rat population had greatly declined, as speculated by Jones et al. (2004). However, there are other possible reasons for low detection rates besides small population size. Norway rats are noted to be neophobic (Jackson 1982, Macdonald et al. 1999), hence they may have avoided the "foreign" objects that we placed in their territories. The abundant seabird prey and carcasses at the time of the study may have reduced the attractiveness of the rodenticide pellets and the bait used with snap-traps. Drever (2004) reported much lower trap capture rates of rats in nesting seabird colonies on the coast of British Columbia, Canada. The rats may make substantial use of underground areas in this volcanic setting. Volcanic activity may provide a thermally-moderated environment in caves and fissures along with water and food sources by way of invertebrates and fungi. Quang and Voisin (2001) noted heavy use of caves in Vietnam by rice rats (*Rattus tanezumi*) that greatly impacted white-nest swiftlet (*Aerodrdamus fuciphagus*) reproduction in the caves. Conditions at Sirius Point are commonly cold, wet, and windy. Perhaps the rats reduce energy expenditure for thermal regulation by spending substantial amounts of time below ground. This strategy would be especially important if abundant, nutritious foods were not readily available which may be the case at Sirius Point during much of the year.

Weather and logistical matters made it difficult to arrive and apply control methods earlier in the year. These constraints precluded determination of the relative similarity of the treatment and control plots in terms of rat density/activity before the application of the rodenticide bait, hence we cannot be sure that the rat densities were very similar at these two sites at the start of the bait efficacy trial. It was also not possible to establish replicate control and treatment plots. Even if the study could have started earlier, it is possible that a relatively accurate density would have been difficult to obtain in this setting of rugged topography and frequent inclement weather.

The elevational transects and other parts of this study suggested that few rats, or only small pockets of rats, occurred above about 165 m and that most rats occurred at--or below--about 20-30 m. Major and Jones (2004) also suggested that rats occurred mainly at low elevations and that rat sign was rarely detected above 150 m. They noted that rats were common in the low-elevation Christine Lake area which we also found to be true. It is possible that the milder weather conditions and topography, along with more abundant and diverse food resources throughout much of the year, support larger rat populations at Christine Lake.

The reproductive rate of the rats at the north end of Kiska Island was high, even in early spring (late-April). Almost all of the rats (15 of 16) that we captured were adults; whereas, when rat trapping has been done in the summer (as by Major and Jones 2004), a larger potion of small and juvenile rats were captured. It is possible that relatively few rats survive the long, inclement winter of northern Kiska Island, but that reproduction initiates rapidly once the seabird prey base arrives. Macdonald et al. (1999) noted the flexible population dynamics of Norway rats and that reproduction could be quickly shut down or rapidly re-initiated.

A portion of the birds consumed by rats were probably not killed, but were found dead and scavenged. It appeared that the frequent, high winds resulted in many birds crashing into rocks and dying. For example, it was common to observe 1-2 dead birds per day when hiking the "trench" along the south-side of the new lava field; after a day of high winds, this number usually increased to 5+ birds (but note, no particular effort was made to find or quantify the number or density of dead birds). About half of the dead birds observed had been fed on by rats. The portion of dead birds that had been fed on by rats appeared to increase as the season progressed. It is interesting to note that these birds had not been cached after being found and fed on by rats. Rats are known to cache food; researchers (Major and Jones 2004, Jones et al. 2004) noted finding a number of rat caches during the years of their auklet study at Sirius Point. They suggest that all those birds were killed by rats, but our findings suggest otherwise.

While the control or eradication of rats at remote locations such as the Aleutian Islands is theoretically possible, there are many technical, logistical, and economic challenges posed to resource managers. While these issues are being addressed, one must also ask whether the introduced rats pose an imminent threat to the nesting birds of Sirius Point. If intrinsic year-around conditions at Sirius Point limit the growth potential of the rat population, perhaps natural mortality of auklets and cyclic patterns of auklet reproductive success (driven by oceanic food availability as suggested by Jones et al. 2004) will be the prevailing determinants of the colony's longevity. Stronger evidence that rat populations are large enough to limit auklet reproductive success may be needed before control measures are implemented.

This field study has provided insight into the ecology and management of Norway rats at Kiska Island, but also points out many of the challenges that remain. Many of the questions posed above perhaps could be best answered by studying the introduced rats of the Aleutian Islands at more accessible and less demanding sites than that presented at Sirius Point.

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Literature Cited

Bailey, E. P. 1993. Introduction of foxes to Alaskan Islands--history, effects on avifauna, and eradication. USDI Fish and Wildlife Service, Resource Publication 193, Washington, D.C.

Drever, M. 2004. Capture rates of Norway rats (*Rattus norvegicus*) in a seabird colony: a caveat for investigators. Northwestern Naturalist 85:111-117.

Ebbert, S. 2000. Successful eradication of introduced arctic foxes from large Aleutian Islands. Proceedings of the Vertebrate Pest Conference 19:127-132.

Ebbert, S.E., and G.V. Byrd. 2002. Eradications of invasive species to restore natural biological diversity on Alaska Maritime National Wildlife Refuge. Pages 102-109 *In* C. Veitch and M. Clout (editors), Turning the Tide: the Eradication of Invasive Species. IUCN SSC Invasive Species Specialist Group. IUCN, Gland, Switzerland and Cambridge, United Kingdom.

Jackson, W. B. 1982. Norway rats and allies. Pages 1077-1088 *In* J. Chapman and G. Feldhamer (editors), Wild Mammals of North America. John Hopkins University Press, Baltimore, Maryland.

Jones, I. L., C. Gray, J. Dusureault, and A. Sowls. 2001. Auklet demography and Norway rat distribution and abundance at Sirius point, Kiska Island, Aleutian Islands, Alaska in 2001. Unpublished Report to the USDI Fish and Wildlife Service, Homer, Alaska.

Jones, I. L., C. Gray, J. Dusureault, and A. Sowls. 2004. Least and crested auklet productivity and survival in relation to introduced Norway rats at Sirius point, Kiska Island, Alaska in 2004, with survey results for the eastern side of the auklet colony. Unpublished Report to the USDI Fish and Wildlife Service, Homer, Alaska.

Macdonald, D. W., F. Mathews, and M. Berdoy. 1999. The behavior and ecology of *Rattus norvegicus*: from opportunism to kamikaze tendencies. Pages 49-80 *In* G. Singleton, L. Hinds, H. Leirs, and Z. Zhang (editors), Ecologically-Based Management of Rodent Pests. ACIAR Monograph No. 59. Canberra, Australia.

Major, H. L., and I. Jones. 2002. Impacts of the Norway rat on the auklet breeding colony at Sirius Point, Kiska Island, Alaska in 2002. Unpublished Report to the USDI Fish and Wildlife Service, Homer, Alaska.

Major, H.L., and I.L. Jones. 2004. Impacts of the Norway rat on the auklet breeding colony at Sirius Point, Kiska Island, Alaska in 2003. Unpublished Report to the USDI Fish and Wildlife Service, Homer, Alaska.

Miller, T. P., R. McGimsey, D. Richter, J. Riehle, C. Nye, M. Yount, and J. Dumoulin. 1998. Catalog of the historically active volcanoes of Alaska. USGS Open-File Report OF 98-0582, Alaska Volcano Observatory, Alaska.

Moors, P.J., and I.A.E. Atkinson. 1984. Predation on seabirds by introduced animals, and factors affecting its severity. ICBP Technical Publication No. 2:667-690.

Murie, O. J. 1959. Fauna of the Aleutian Islands and Alaska Peninsula. North American Fauna No. 61, USDI Fish and Wildlife Service, Washington, D.C.

Quang, P., and J. F. Voisin. 2001. Bats and rodents in swiftlet caves in Vietnam (*Chiroptera* and *Rodentia*). Mammalia 65:253-258.

Sokal, R., and F. Rohlf. 1969. Biometry. W. H. Freeman and Company, San Francisco, California.

Sowls, A., and M. Rauzon. 2001. Can Kiska's auklets survive the rat menace? Pacific Seabirds 28:53-54.

Veitch, C.R., and M.N. Clout, eds. 2002. Turning the Tide: the Eradication of Invasive Species. IUCN SSC Invasive Species Specialist Group. IUCN, Gland, Switzerland and Cambridge, United Kingdom.

Witmer, G. 1998. Rat management for endangered species protection in the U.S. Virgin Islands. Proceedings of the Vertebrate Pest Conference 18:281-286.

Witmer, G., F. Boyd, E. Campbell, J. Wakefield, and Z. Hillis-Starr. 2001. The eradication of introduced rats on Buck Island Reef National Monument, St. Croix, U.S. Virgin Islands: Final Report. USDA/APHIS Wildlife Services, National Wildlife Research Center, Fort Collins, Colorado.

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