# Assessing the effects of Norway rats on auklet breeding success and survival at Sirius Point, Kiska Island, Alaska in 2006

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**Introduction**

The presence of introduced Norway rats (*Rattus norvegicus*) has been implicated as a possible threat to the large auklet colony at Sirius Point, Kiska Island, Aleutian Islands, Alaska. Hundreds of rat-depredated auklet eggs, adults and chicks have been documented and observed since the initial sightings of Norway rats at Sirius Point Colony during the late 1980s and early 1990s. Furthermore, incidental sign of rats was particularly high in 2001 and 2002 when overall reproductive success of the Least Auklet was the lowest ever recorded in the Aleutians (Major and Jones 2005). Norway rats are widely known to predate seabirds (Courchamp 2002). Local extinction often results when eggs, chicks and brooding adults are regularly killed such as witnessed at the Sirius Point auklet colony. Least Auklets are especially susceptible to predation by the Norway rat because of their small size (Major 2004). The primary objectives of this sixth year of intensive study by our research group were to continue to assess the impacts that introduced rats may be having on the auklet colony at Sirius Point by measuring auklet productivity and survival, to investigate the spatial arrangement and movements of Norway rats in a lava flow, and develop a method to index rat activity at a seabird colony.

In summary, the objectives of our study were: 1) to assess the impacts of Norway rats on the auklet colony at Sirius Point, Kiska Island by measuring and comparing auklet reproductive success and interannual survival to that at rat-free islands Buldir and Kasatochi and 2) to better understand rat ecology at Kiska by quantifying individual rats' home range area and overlap in the lava flow.

**Methods**

*Auklet productivity*

Least and Crested Auklet breeding crevices were monitored for productivity using USFWS standardized procedures (US Fish and Wildlife Service 1996). Each crevice was carefully checked for signs of rat predation of adults, eggs and nestlings if the crevice failed. The productivity data were also compared with those from other islands (obtained using the same monitoring protocol) without introduced rats (Kasatochi and Buldir) to determine the effects of the rats on the productivity of the auklets at the Sirius Point colony. The three study plots used in 2001 were reused for the productivity estimates in 2006 and are believed to be representative of the entire colony at Sirius Point (Jones et al. 2001). On three productivity study plots (Table 1) 180 Least and 33 Crested Auklet crevices were monitored. The first productivity study plot 'New Lava' was located on the top and east side of the most recent lava dome, which was created during the last eruption of the volcano in 1965-69 (Miller et al. 1998). All of the crevices on this plot were within 60 m of the coastline, at an elevation of 25-30 m in an area sparsely vegetated with lichens. At an elevation of 100m and 520m from the coast, located in the valley between the 1965-69 lava dome and Bob's Plateau (52°07.803'N 177°35.731'E) was the second productivity study plot 'Old Lava Low'. This second plot was in an area densely vegetated with *Carex*, *Calamagrostis* sp. and fern overgrowing basalt blocks. The third plot 'Old Lava High' was moderately vegetated with *Carex* and fern, it was located at an elevation of 180m, 800m from the coastline, and at the top of Bob's Plateau close to the base of a steep talus slope of block lava on the side of Kiska volcano (52°07.699'N 177°36.167'E). Major et al. (2006) reported comparative productivity estimates for Kiska, Buldir and Kasatochi for 2001-2003. Here we update the analysis with data from 2004 and 2006.

*Auklet survival*

Adult interannual survival of Least and Crested auklets was measured using field procedures developed by Jones (1992a) and the MARK (White and Burnham 1999) analysis program. Resightings of Least and Crested auklets banded during the 2001-2003 field seasons were regularly carried out from the blind during the daily activity periods throughout the entire breeding season (May through August 2006). Major et al. (2006) reported comparative survival estimates for Kiska, Buldir and Kasatochi for 2001-2003. Here we update the analysis with data from 2004-2006.

*Norway Rat Activity Indexing*

In order to develop a method of assessing rat activity, ten indexing stations containing a tracking tunnel, wax block and chew stick spaced 25 meters apart were set up on 8 different transect lines encompassing four different habitat types (two lines per habitat type) within the auklet colony at Sirius Point (Figure 1). Tracking tunnel positions were recorded using a Garmin GPSmap 76S and flagged (Appendix 1). Rocks were painted with corresponding tunnel IDs, if possible. The starting points for the eight transect lines were based on environment type and access but the transect direction was randomly chosen using a method described by Gillies and Williams (2004). However, for safety considerations, the transect lines established in the Gullies were based on a safe path and could not be chosen randomly. Tunnels were set at the most suitable spot for maximum protection from severe winter weather in the Aleutians, within two meters of the 25m marker along the line. Ledges, rock crevasses, or caves were chosen in preference to flat open surface area. Also, obstruction of possible auklet nesting sites was avoided. A generalized linear model was used to determine if rat activity was dependent on habitat or if there was a significant increase in activity between June and July. A generalized linear model was also used to test which method is best to detect rat.

*Norway Rat Radio Tracking*

In order to gather information on rat ecology and habitat use at Sirius Point, we quantified rat home ranges and movement using radio-telemetry. This study was conducted in an area that encompassed different habitat types present at Sirius Point: dense vegetation types representative of the old lava flow, bare rock covered with less dense vegetation representative of the new lava flow, intertidal area, and low elevation as well as high elevation (Figure 2). Between 13 June 2006 and 9 July 2006 Norway rats were trapped with Tomahawk live traps (model 201) that were placed in areas with obvious rat sign within the auklet colony. Traps were set at 2100 h and checked at 0700 h. Traps were not set on nights with heavy rain. Captured rats were anaesthetized in a plastic bag using cotton balls soaked in isoflurane, then sexed, weighed, measured and collared. A total of nine adult Norway Rats (5 male and 4 female) weighing a minimum of 140 g were fitted with radio collars (Advanced Telemetry Systems, Michigan, USA).

For this study home range was defined as "the extent of area with a defined probability of occurrence of an animal during a specified time period"

(Millspaugh 2001). The time period of interest was during the auklet breeding season when food resources are abundant and rat behavior would be most detrimental to the auklet colony. Therefore, radio tagged individuals were located using a three-element yagi antenna (ATS) one to three times per night (2200 to 0600) and once during the day (0600 to 2200) from 14 June 2006 to 29 July 2006 (Appendix 2 ). Fifty and ninety-five percent kernel home range estimates were calculated for a more detailed understanding of rat's home range use (Arcview 3.3, animal movement extension). Further analysis of habitat selection and home range overlap will be included in future manuscripts.

At the end of the study (August), a kill-trapping program was carried out in order to estimate population density, using 20 Victor snap traps laid out through the central portion of the study area. This provided a minimum count of rats exposed to the trapping site.

*Other Observations*

A summary of Norway Rat sign found during the 2006 field season is attached in Appendix 4.

A list of bird species identified during field work in 2006 is attached in Appendix 3.

**Results**

*Auklet Productivity*

In 2006 Least Auklet hatching success on the three productivity plots did not differ significantly ($\chi^2$=1.85, df=2, p-value=0.39) and averaged 0.86 (Table 1). The majority of egg loss was due to adult abandonment of the nest (n=12, 46%) although, in the new lava plot the majority of egg loss was due to rat predation (Table 1). Overall hatching success in 2006 differed significantly from both years 2001 and 2002 ($\chi^2$=6.040, df=1, p-value=0.014 ; $\chi^2$=25.20, df=1, p-value=0.000). In 2006 hatching success did not significantly differ between Kiska and Buldir but it was significantly lower at Kasatochi (Table 4).

Similar to hatching success for 2006, Least Auklet fledging success also did not significantly differ between plots at Kiska ($\chi^2$=1.30, df=2, p-value=0.52, and averaged 0.64 (Table 1). The greatest source of breeding failure was due to the disappearance of chicks from breeding sites (n=46, consistent with rat predation of chicks)(Table 1). Fledging success on Kiska was 0.64, which was significantly higher ($\chi^2$=99.7, df=2, p-value<0.001) than the 0.18 and 0.16 found in 2001 and 2002 (Jones *et al.* 2001, Major and Jones 2002). Buldir Island had the highest fledging success in 2006 which was significantly higher than at Kiska (Table 4).

Overall reproductive success at Kiska for 2006 was 54% (Table 1). This is significantly higher than 2001 and 2002 reproductive success ($\chi^2$=125.00, df=2, p-value<0.001). In all years reproductive success was most affected by chick survival. Buldir Island had a successful year in 2006 with 63% reproductive success which was significantly higher than Kiska (Table 2).

In 2006 Crested auklets had the highest reproductive success at Kiska Island when compared to Buldir and Kasatochi (Table 4). Hatching success was also significantly higher at Kiska than at Buldir and Kasatochi (Table 4).

*Auklet Survival*

Program MARK indicated the best model for Least Auklet survival at Kiska was one in which survival rate $\phi$ varied by year as well as recapture rate (Table 5). The survival estimates for Least Auklets at Kiska were 89% (2001-2002), 94% (2002-2003), 79% (2003-2004), and 72% (2004-2005) (Table 6).

*Norway Rat Activity Indexing*

Norway rat's had a significant preference for chewing wax blocks over gnawing on chew sticks or running through tracking tunnels (G= 253.5, df= 5, p-value= .000). There was a significant difference in rat activity between June and July (G= 253.5, df= 5, p-value= 0.00). The odds of rat activity in July were 6.40 times that in June. We did not detect rat activity at index stations set in the old lava flow in June but the lower elevation transects lines did get rat activity in July. The higher elevation transects in the old lava flow only began to show rat activity in August (Appendix. 2).

*Norway Rat Radio Tracking*

The average 95 percent kernel home range estimate for male Norway rats was 1.83 ha. The average 50 percent kernel home range estimate was .33 ha. The average 95 percent kernel home range estimate for female Norway rats was .52 ha. The average 50 percent kernel home range estimate for females was .07 ha (Table 7).

All male Norway rats overlapped home ranges (Figure 4). All female rat home ranges overlapped (Figure 3). Every male rat overlapped all four female rats' that were tracked throughout June and July. Twenty-eight rats were trapped over a 10 day period (2 August – 11 August 2006).

**Discussion**

Our work on Kiska during the summer of 2006 provided the fifth year of intensive monitoring data for auklet productivity and survival for the Sirius Point auklet colony. As found in 2003 and 2004, in 2006 Kiska Island auklet productivity was high and similar to rat-free islands Buldir and Kasatochi. Productivity in 2001 and 2002 at Kiska continue to be the lowest recorded years for auklet productivity in the Aleutians, so taken together we have documented two years of breeding failure (2001 and 2002) and three years of breeding success similar to nearby rat-free auklet colonies (2003, 2004 and 2006). For logistical reasons we were not able to mount a complete study season during 2005 and productivity for that year was not known, although extensive signs of rat activity were observed during brief visits. One of us (ILJ) visited Sirius Point early in the year (late May-early June) in all years (except 2005) and observed abundant rat sign at Tangerine Cove only in 2001 and 2002. Comparable observations made in 2006 were thus consistent with the notion that high early season rat abundance is associated with auklet breeding failure at Kiska, with productivity normal in years with low rat abundance.

Alarmingly, the annual adult local survival estimates declined from normal in 2001-2003 to below 0.8 for 2003-2005. The recently recorded survival rates are lower than required for a stable population. These results need to be interpreted cautiously because we are operating only a single survival monitoring plot (located in a dense and apparently typical part of the colony), but the data do suggest there may be cause for concern. Most interesting was the observation that years with high inter-annual adult survival followed years of breeding failure and high apparent early season rat abundance. With only five years of data it is impossible to confirm a statistically significant negative correlation but if one in fact exists then this would be consistent with a reproductive tradeoff (high reproductive success and investment incurring a survival cost). An explanation linking low auklet survival to rat predation is less plausible, because auklets are most vulnerable to rats during the incubation period when they are in their crevices for long periods of time. None of the years with low survival had low hatching success or apparently abundant rats early in the breeding season. A more detailed investigation of patterns of survival rate variation across islands and years is underway and will be reported elsewhere. In the meantime, we recommend further survival monitoring at Kiska based on a larger sample of marked birds (no new birds were marked in 2004, 2005 or 2006).

Although ILJs anecdotal observations of rat sign abundance at Tangerine Cove have provided some interesting suggestions related to rat-auklet interactions, a rigorous quantitative method of assessing inter year variation in rat abundance is urgently required. Because snap trapping (the usual method used for rat population monitoring) is essentially out of the question at a dense auklet colony site, rat sign detection and measurement is believed to be the most preferable alternative method. Development of such a monitoring method for Norway rat's using sign in the Sirius Point auklet colony has been inhibited by the size of the colony site, by rapid vegetation growth across the season, and by the ruggedness of the lava flow formation. Nevertheless, this year rat activity was measured using wax blocks, chew sticks and tracking tunnels. All three methods were successful in detecting rat presence throughout the auklet colony. Rat activity increased throughout the auklet breeding season as did the extent of the colony site in which the rat presence was detected. It appeared that rats were mainly active at lower elevations in May and gradually moved inland during the auklet breeding season. This is consistent with rats using mainly shoreline low elevation sites for overwintering, only moving inland as the season progressed.

In 2001 and 2002 low reproductive success was observed in all productivity study plots therefore if rats were a cause of low productivity there presence should have been detected early in the season and consistent throughout the entire colony in those years. In as far as was possible given the protocols employed, this is exactly what was found (Jones et al. 2001, Major et al. 2002, 2003, Major 2004).

The spatial arrangement and movements of small mammal groups can give an insight into the size of the population. For example, the intensity of territorial defense by *R. norvegicus* can vary with the size of the population: large groups, according to Telle (1966), are less territorial, and admit strange rats more readily than small ones (Barnett 1975). Radio collared rats at Sirius Point had a large amount of overlapping of their home ranges and therefore appeared to exhibit a lack of territorial defense. This is a good indication that there was a large population of rats inhabiting an area of optimal habitat and abundant food resources from May to August to allow the Norway rat populations to increase during the season. Presumably the Aleutian winter returns rat populations to the low levels documented in three of the five years of our study. One of us (CE) is currently writing a detailed MSc thesis that will contain further analysis of data on rat ecology at Kiska.

**Conclusions and recommendations**

1. The Least Auklet population at Sirius Point experienced near failure of breeding during 2001-2002 when rat sign was abundant at the colony site throughout the auklet breeding seasons. In 2003, 2004 and 2006 when rat sign was relatively scarce, auklets experienced levels of productivity similar to rat free Buldir and Kasatochi Islands.
2. The results of six years of monitoring at Kiska are consistent with the idea that in some years introduced Norway rats cause auklet breeding failure at Kiska, but the link is inferred only from a weak correlation and further study of cause and effect is required.
3. Adult auklet survival rates were high in two years when rat sign was abundant and productivity low, suggesting that rat predation does not have a significant effect on auklet annual survival at Sirius Point.

Nevertheless, the recent low survival estimates are troubling and require further investigation.

4. Wax blocks placed on transects showed the best ability to obtain detections of rats. This indexing method should be continued in 2007. A protocol for standardize rat monitoring will be submitted with our 2007 research proposal.
5. Foraging ecology of auklets at Sirius Point and nearby Buldir should be investigated more closely to evaluate the possibility that Kiska auklets are food-stressed in some years.
6. Further years of monitoring of auklet productivity and survival and rat activity should be considered because both auklet and rat demography fluctuate and few generalizations can be made from only five years of data.

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Table 1. Least Auklet productivity and known causes of breeding failure at three study areas near Sirius Point, Kiska Island in 2006.

| | *Lava Dome* | *Old Lava low* | *Old Lava high* | *Total* |
|---|---|---|---|---|
| Crevices monitored, n (a) | 70 | 47 | 63 | 180 |
| Number hatched (b) | 58 | 43 | 53 | 154 |
| Egg abandoned | 3 | 3 | 6 | 12 |
| Egg disappeared | 1 | 1 | 2 | 4 |
| Egg broken | 0 | 0 | 1 | 1 |
| Egg predated | 5 | 0 | 0 | 5 |
| Egg displaced | 0 | 0 | 1 | 1 |
| Crevice collapsed | 2 | 0 | 0 | 2 |
| Dead adult in crevice | 1 | 0 | 0 | 1 |
| Number fledged (c) | 37 | 30 | 31 | 98 |
| Small dead chick | 0 | 0 | 0 | 0 |
| Chick disappeared | 15 | 13 | 18 | 46 |
| Chick predation | 2 | 0 | 0 | 2 |
| Dead chick | 4 | 0 | 4 | 8 |
| Hatching success (b/a)% | .8286 | .9149 | .8413 | .8556 |
| Fledging success (c/b)% | .6379 | .6977 | .5849 | .6364 |
| Reproductive success (c/a)% | .5286 | .6383 | .4921 | .5444 |

Table 2. Least Auklet productivity at representative study plots at Kiska, Buldir and Kasatochi Islands in 2006.

| | *Kiska dome* | *old low* | *old high* | *Kiska Total* | *Buldir*[1] | *Kasatochi*[2] |
|---|---|---|---|---|---|---|
| n(a) | 70 | 47 | 63 | 180 | 84 | 77 |
| Number hatched (b) | 58 | 43 | 53 | 154 | 75 | 55 |
| Number fledged (c) | 37 | 30 | 31 | 98 | 63 | 34 |
| Hatching success (b/a) | .8286 | .9149 | .8413 | .8556 | .84 | .71 |
| Fledging success (c/b) | .6379 | .6977 | .5849 | .6364 | .75 | .62 |
| Reproductive success (c/a) | .5286 | .6383 | .4921 | .5444 | .63 | .44 |

[1]Orben *et al*. 2006

[2] Drummond 2006

Table 3. Crested Auklet productivity at representative study plots at Kiska, Buldir and Kasatochi Islands in 2006.

| | *Kiska dome* | *old low* | *old high* | *Kiska All* | *Buldir*[1] | *Kasatochi*[2] |
|---|---|---|---|---|---|---|
| n(a) | 5 | 18 | 11 | 34 | 73 | 88 |
| Number hatched (b) | 4 | 18 | 11 | 33 | 58 | 76 |
| Number fledged (c) | 3 | 15 | 11 | 29 | 47 | 58 |
| Hatching success (b/a) | .8 | 1 | 1 | .9706 | .79 | .8 |
| Fledging success (c/b) | .75 | .8333 | 1 | .8788 | .81 | .76 |
| Reproductive success (c/a) | .6 | .8333 | 1 | .8529 | .64 | .66 |

[1]Orben et al. 2006

[2]Drummond 2006

Table 4. Chi-square tests for statistical differences in hatching, fledging and overall reproductive success between, Kiska, Buldir and Kasatochi Islands for Least (LeAu) and Crested (CrAu) auklets.

| **Species** | | *Hatching Success* | | | *Fledging Success* | | | *Reproductive Success* | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | $\chi^2$ | df | p-value | $\chi^2$ | df | p-value | $\chi^2$ | df | p-value |
| LeAu | Kiska – Buldir | 1.78 | 1 | .18 | 4.29 | 1 | .038 | 10.17 | 1 | .001 |
| | Kiska – Kasatochi | 7.08 | 1 | .008 | .058 | 1 | .810 | 2.28 | 1 | .131 |
| CrAu | Kiska – Buldir | 5.65 | 1 | .017 | .716 | 1 | .398 | 4.92 | 1 | .026 |
| | Kiska – Kasatochi | 2.68 | 1 | .101 | 1.91 | 1 | .167 | 4.50 | 1 | .034 |

Table 5. Comparison of the different survival-recapture models for Least Auklets marked at one study plot near Sirius Point, Kiska Island in 2001-2006, where $\phi$ is survival, p is the recapture probability and t is time.

| *Model* | *AICc* | *Δ AICc* | *AICc Weight* | *# Parameters* | *Deviance* |
|---|---|---|---|---|---|
| $\phi_{(t)}\ p_{(t)}$ | 569.590 | 0.00 | .60511 | 9 | 29.379 |
| $\phi_{(Year1*t)}\ p(_t)$ | 570.569 | 0.98 | 0.37093 | 9 | 30.358 |
| $\phi_{(.)}\ p_{(t)}$ | 576.048 | 6.46 | 0.02397 | 6 | 41.965 |
| $\phi_{(t)}\ p_{(.)}$ | 609.349 | 39.76 | 0 | 6 | 75.266 |
| $\phi_{(.)}\ p_{(.)}$ | 639.965 | 70.37 | 0 | 2 | 113.979 |

Table 6. Least Auklet survival estimate for one study plot at Sirius Point, Kiska Island, Alaska for 2001-2005 as determined by the model: $\phi_{(Year)}$ $p_{(group)}$ from the Program MARK, where ϕ is survival, p is the recapture probability, t is time.

| Parameter | Estimate | Standard Error | 95% Confidence Interval Lower | 95% Confidence Interval Upper |
|---|---|---|---|---|
| ϕ (2001 – 2002) | 0.895 | 0.030 | 0.821 | 0.941 |
| ϕ (2002 – 2003) | 0.941 | 0.025 | 0.867 | 0.975 |
| ϕ (2003 – 2004) | 0.791 | 0.043 | 0.696 | 0.862 |
| ϕ (2004 – 2005) | 0.723 | 0.081 | 0.541 | 0.853 |
| p (2001-2002) | 0.926 | 0.027 | 0.851 | 0.964 |
| p (2002-2003) | 0.965 | 0.021 | 0.893 | 0.989 |
| p (2003-2004) | 0.956 | 0.028 | 0.851 | 0.988 |
| p (2004-2005) | 0.514 | 0.078 | 0.364 | 0.661 |

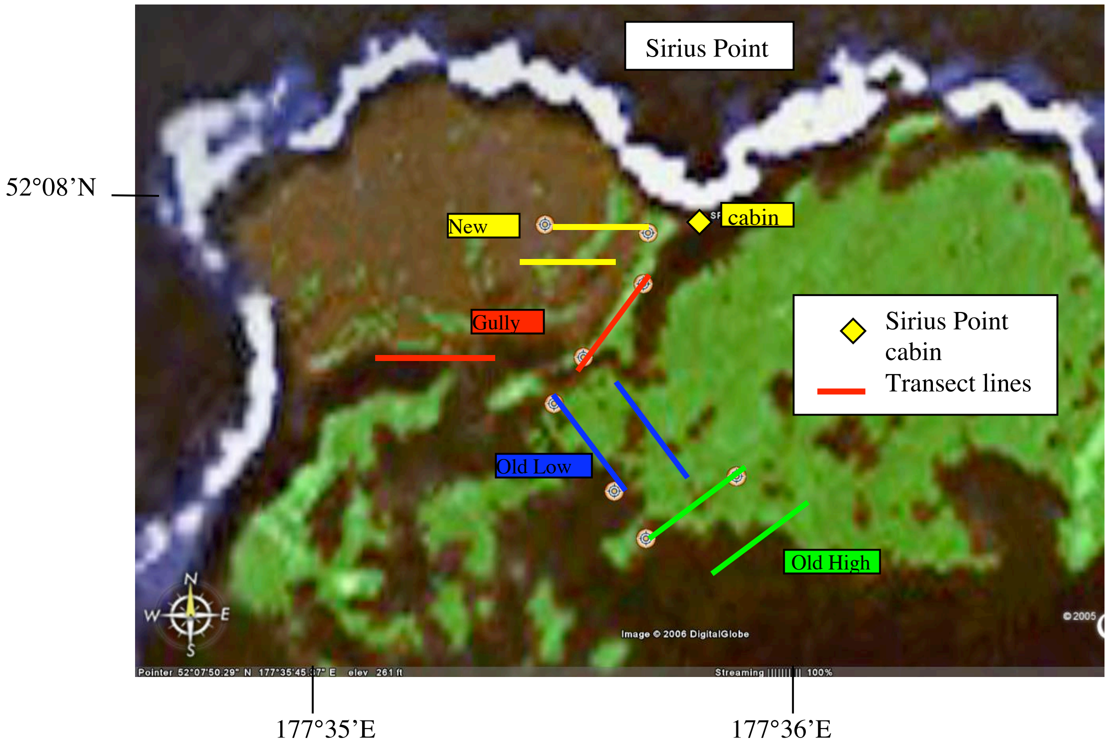


Figure 1. Map of Sirius Point, Kiska Island showing approximate location of transect lines set-up in 2006 for rat activity indexing.


Figure 2. Ma[illegible]oximate area and ha[illegible]ompassed by radio tracking study of Norway rats at Sirius Point, Kiska Island in 2006.

Table 7. Home range estimates (m^2) for male and female Norway rats tracked at Sirius Point from June-July 2006 (50% and 95% kernel estimates). Colors correspond to individual rat home ranges presented in Figures 3 and 4.

| Frequency | Sex | Color | 50% | 95% |
|---|---|---|---|---|
| 156.062 | Female | | 794.02 | 5751.43 |
| 156.105 | Female | | 761.01 | 4592.9 |
| 156.121 | Female | | 1060.97 | 7110.61 |
| 156.161 | Female | | 303.07 | 3567.79 |
| | | Female average | 729.76 | 5255.68 |
| 156.020 | Male | | 1571.09 | 7941.01 |
| 156.083 | Male | | 1198.58 | 9333.25 |
| 156.141 | Male | | 1704.97 | 14047.57 |
| 156.182 | Male | | 7463.44 | 38766.48 |
| 156.220 | Male | | 4762.45 | 21865.23 |
| | | Male average | 3340.10 | 18390.70 |

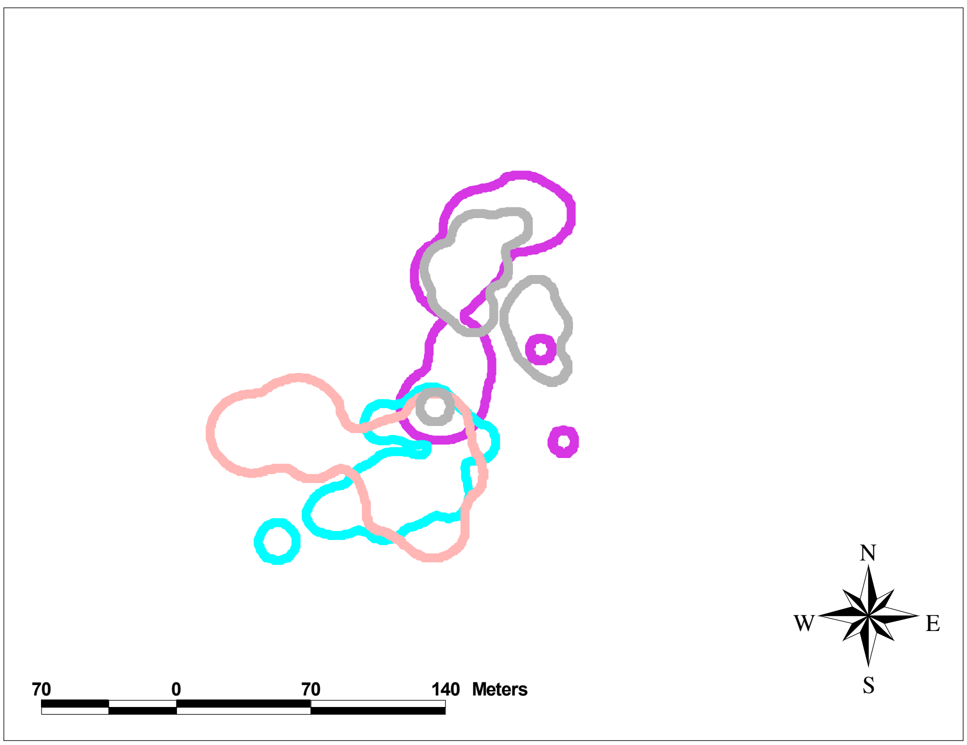


Figure 3. Home ranges for 4 female rats at Sirius Point, Kiska Island during June – July 2006 (95% kernel estimates).

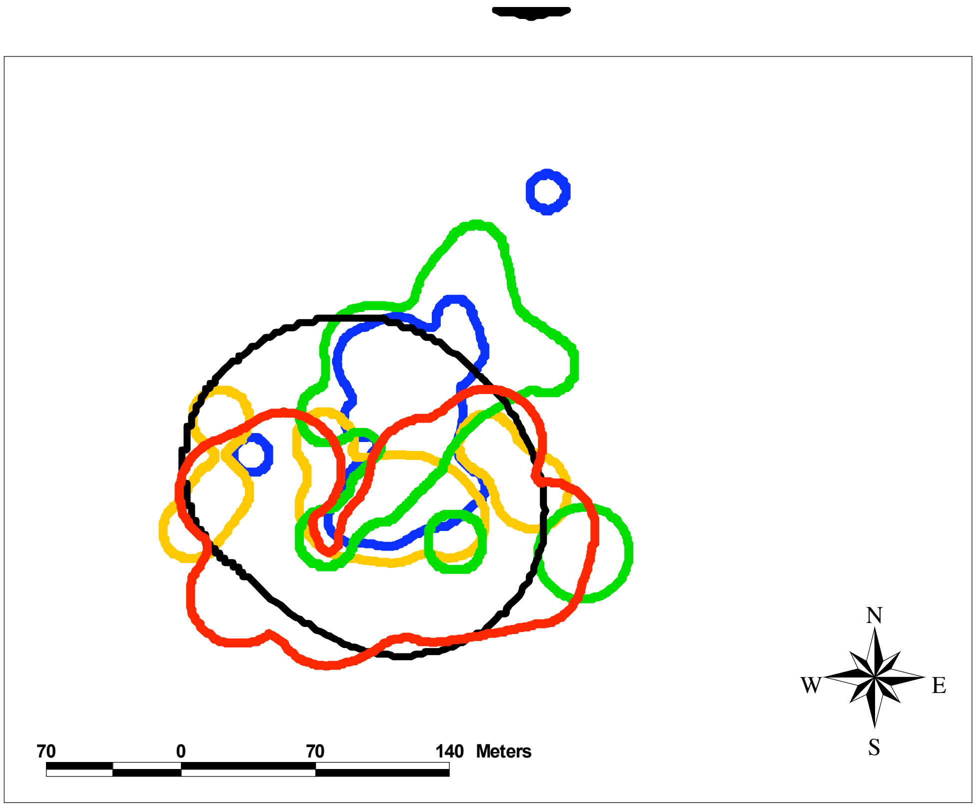


Figure 4. Home ranges of five male rats at Sirius Point, Kiska Island during June-July 2006 (95% kernel estimates).

Appendix I. UTM coordinates and elevation for activity index stations set-up in 2006

| Indexing Station ID | Location | UTM coordinates | | elevation |
|---|---|---|---|---|
| 1 | New | 540846 | 5775881 | 116 |
| 1.5 | New | 540799 | 5775888 | 131 |
| 2 | New | 540745 | 5775890 | 152 |
| 2.5 | New | 540698 | 5775892 | 176 |
| 3 | New | 540654 | 5775899 | 186 |
| 3.5 | New | 540822 | 5775883 | 147 |
| 4 | New | 540776 | 5775887 | 175 |
| 4.5 | New | 540729 | 5775890 | 195 |
| 5 | New | 540679 | 5775894 | 199 |
| 5.5 | New | 540628 | 5775898 | 193 |
| 71 | New | 540815 | 5775780 | 175 |
| 72 | New | 540792 | 5775776 | 175 |
| 73 | New | 540765 | 5775773 | 181 |
| 74 | New | 540737 | 5775769 | 191 |
| 75 | New | 540711 | 5775783 | 183 |
| 76 | New | 540685 | 5775775 | 188 |
| 77 | New | 540665 | 5775779 | 213 |
| 78 | New | 540642 | 5775780 | 207 |
| 79 | New | 540620 | 5775785 | 216 |
| 80 | New | 540592 | 5775778 | 205 |
| 21 | Gully | 540838 | 5775772 | 107 |
| 22 | Gully | 540833 | 5775756 | 117 |
| 23 | Gully | 540810 | 5775733 | 86 |
| 24 | Gully | 540805 | 5775711 | 102 |
| 25 | Gully | 540792 | 5775691 | 128 |
| 26 | Gully | 540773 | 5775678 | 167 |
| 27 | Gully | 540756 | 5775653 | 177 |
| 28 | Gully | 540756 | 5775637 | 158 |
| 29 | Gully | 540738 | 5775623 | 164 |
| 30 | Gully | 540714 | 5775617 | 181 |
| 61 | Gully | 540519 | 5775515 | 129 |
| 62 | Gully | 540497 | 5775527 | 145 |
| 63 | Gully | 540480 | 5775543 | 160 |
| 64 | Gully | 540464 | 5775561 | 165 |
| 65 | Gully | 540456 | 5775584 | 163 |
| 66 | Gully | 540439 | 5775601 | 164 |
| 67 | Gully | 540418 | 5775614 | 164 |
| 68 | Gully | 540394 | 5775615 | 141 |
| 69 | Gully | 540369 | 5775612 | 131 |
| 70 | Gully | 540343 | 5775614 | 135 |
| 11 | Low | 540655 | 5775521 | 249 |
| 12 | Low | 540672 | 5775507 | 261 |

| | | | | |
|---|---|---|---|---|
| 13 | Low | 540690 | 5775492 | 263 |
| 14 | Low | 540704 | 5775468 | 281 |
| 15 | Low | 540721 | 5775449 | 283 |
| 16 | Low | 540736 | 5775428 | 290 |
| 17 | Low | 540750 | 5775408 | 296 |
| 18 | Low | 540764 | 5775388 | 309 |
| 19 | Low | 540779 | 5775369 | 336 |
| 20 | Low | 540784 | 5775343 | 357 |
| 41 | Low | 540736 | 5775580 | 220 |
| 42 | Low | 540754 | 5775559 | 224 |
| 43 | Low | 540769 | 5775540 | 234 |
| 44 | Low | 540784 | 5775519 | 248 |
| 45 | Low | 540802 | 5775505 | 268 |
| 46 | Low | 540814 | 5775485 | 295 |
| 47 | Low | 540830 | 5775466 | 322 |
| 48 | Low | 540842 | 5775451 | 340 |
| 49 | Low | 540861 | 5775431 | 358 |
| 50 | Low | 540878 | 5775411 | 369 |
| 31 | High | 540850 | 5775250 | 399 |
| 32 | High | 540872 | 5775264 | 396 |
| 33 | High | 540894 | 5775277 | 403 |
| 34 | High | 540912 | 5775292 | 406 |
| 35 | High | 540935 | 5775304 | 408 |
| 36 | High | 540954 | 5775320 | 405 |
| 37 | High | 540983 | 5775337 | 406 |
| 38 | High | 540995 | 5775349 | 399 |
| 39 | High | 541019 | 5775362 | 397 |
| 40 | High | 541033 | 5775377 | 373 |
| 51 | High | 540947 | 5775151 | 482 |
| 52 | High | 540964 | 5775168 | 486 |
| 53 | High | 540979 | 5775183 | 487 |
| 54 | High | 541003 | 5775203 | 495 |
| 55 | High | 541017 | 5775219 | 469 |
| 56 | High | 541033 | 5775232 | 455 |
| 57 | High | 541053 | 5775247 | 421 |
| 58 | High | 541074 | 5775260 | 406 |
| 59 | High | 541092 | 5775272 | 396 |
| 60 | High | 541109 | 5775292 | 403 |

Appendix II. Rat presence recorded (w=wax blocks, c=chew sticks and t= tracking tunnel) within the eight transect lines for the index of rat activity in 2006

| | June | | | | | | | | | | July | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 13 | | | 14 | | | 15 | | | Total | 13 | | | 14 | | | 15 | | | Total |
| Treatment | w | c | t | w | c | t | w | c | t | | w | c | t | w | c | t | w | c | t | |
| New 1 | 1 | 1 | 0 | 3 | 0 | 0 | 2 | 0 | 0 | 7 | 2 | 2 | 0 | 5 | 3 | 0 | 5 | 2 | 0 | 19 |
| New 2 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 0 | 1 | 5 |
| Gully 1 | 3 | 0 | 0 | 2 | 0 | 1 | 2 | 0 | 1 | 9 | 7 | 1 | 6 | 7 | 4 | 7 | 8 | 7 | 9 | 56 |
| Gully 2 | 3 | 2 | 0 | 1 | 0 | 0 | 2 | 0 | 0 | 8 | 8 | 1 | 0 | 9 | 1 | 3 | 7 | 1 | 6 | 36 |
| Low 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 2 | 1 | 0 | 1 | 7 |
| Low 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 2 | 3 | 3 | 1 | 3 | 3 | 1 | 4 | 24 |
| High 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| High 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Appendix III. Birds seen during Sirius Point Study, May 23-August 12, 2006. (breeding species in bold face)

Common Loon *Gavia immer* Heard and seen at Christine Lake.

Laysan Albatross *Diomedea immutabilis* Common off Sirius Point.

Black-footed Albatross *Diomedea nigripes* Uncommon off Sirius Point.

Northern Fulmar *Fulmarus glacialis* Common off Sirius Point.

Short-tailed Shearwater *Puffinus tenuirostris* Uncommon off Sirius Point.

Leach's Storm-Petrel *Oceanodroma leucorhoa* Rare off Sirius Point. Heard at night at camp and at Christine Lake.

Fork-tailed Storm Petrel *Oceanodroma furcata* Rare off Sirius Point. Frequently heard at night at camp in June.

**Pelagic Cormorant** ***Phalacrocorax pelagicus*** Uncommon, breeds locally.

**Red-faced Cormorant** ***Phalacrocorax urile*** Common, breeds locally.

Canada Goose *Branta canadensis* Flocks flying by Sirius Point regularly

**Green-winged Teal** ***Anas crecca*** Common at Christine Lake.

**Greater Scaup** ***Aythia marila*** Lots at Christine Lake.

Common Merganser *Mergus mergansor* Uncommon at Christine Lake.

Red-breasted Merganser *Mergus serrator* Common at Christine Lake.

**Bald Eagle** ***Haliaeetus leucocephalus*** Common breeder.

**Peregrine Falcon** ***Falco peregrinus*** Common breeder.

**Rock Ptarmigan** ***Lagopus mutus*** Common on slopes of volcano.

Wood Sandpiper *Tringa glareola* Christine Lake.

**Parasitic Jaeger** ***Stercorarius parasiticus*** Uncommon off Sirius Point, probably breeds at Christine Lake.

**Glaucous-winged Gull** ***Larus glaucescens*** Common at auklet colony, one chick fledged from Sirius Point.

**Black-legged Kittiwake** ***Rissa tridactyla*** Common, breeds locally

**Thick-billed Murre** ***Uria lomvia*** Uncommon off Sirius Point, breeds locally (Pillar Rock).

Common Murre *Uria aalge* . Uncommon off Sirius Point, breeds locally (Pillar Rock).

**Pigeon Guillemot** ***Cepphus columba*** Rare off Sirius Point (breeds locally?)

**Parakeet Auklet** ***Cyclorhynchus psittacula*** Uncommon breeder, Sirius Point.

**Crested Auklet** ***Aethia cristatella*** Abundant breeder, Sirius Point.

**Least Auklet** ***Aethia pusilla*** Abundant breeder, Sirius Point.

**Whiskered Auklet** ***Aethia pygmaea*** Rare breeder, Sirius Point, heard at night near camp.

Horned Puffin *Fratercula corniculata* Uncommon off Sirius Point.

**Tufted Puffin** ***Fratercula cirrhata*** Uncommon off Sirius Point (breeding near Wolf Point).

Northern Raven *Corvus corax* Two birds frequented Sirius Point area throughout the summer.

**Winter Wren** ***Troglodytes troglodytes*** Uncommon at Sirius Point, rare along shore of Christine Lake.

**Lapland Longspur** ***Calcarius lapponicus*** Common in meadows.

**Snow Bunting** ***Plectrophenax nivalis*** Common in stony habitat.

**Gray-crowned Rosy Finch** ***Leucosticte arctoa*** Uncommon at auklet colony.

Song Sparrow *Melospiza melodia* One adult and one juvenile seen in August at auklet colony.

Whooper Swan *Cygnus cygnus* Rare, 5 seen flying over Christine Lake on 8 June 2006.

Appendix IV. Summary of Norway rat sign found in 2006.

| *Date* | *Location* | *Comments* |
|---|---|---|
| May 22, 2006 | Sirius Point auklet colony (cabin) | Cabin destroyed by winter weather: rat's ate all food stored at cabin over the winter, rat droppings scattered all over cabin and gear. |
| Late May – early June | Sirius Point Auklet Colony | Around camp there is quite a bit of fresh rat sign. |
| June 14, 2006 | Sirius Point Auklet Colony (Gully between new and old lava flow) | Cache 1: Rat cache with 1 adult Least Auklet and 23 Least Auklet eggs. |
| June 16, 2006 | Sirius Point Auklet Colony (above Squid cave) | Cache 2: Rat cache with 1 Storm petrel, 25 Least Auklet eggs and 4 Crested Auklet eggs. |
| June 16, 2006 | Sirius Point Auklet Colony (10 m from Cache #2) | Cache 3: Rat cache with 1 adult Least Auklet and 4 auklet eggs |
| June 20, 2006 | Sirius Point Auklet Colony (Gully between new and old lava flow) | Cache 4: Rat cache with at least 16 Least Auklet eggs. |
| June 28, 2006 | Sirius Point Auklet Colony (Steam Beach fumorle) | Cache 5: Rat cache with 1 adult Least Auklet and 2 Least Auklet eggs with dead chicks. |
| July 2006 | Christine Lake | Footprints and droppings found in the sand along the lake's shore |
| June - August 2006 | Sirius Point Auklet Colony (Gullies) | High rat activity at indexing stations. In August we found lots of predated fledgers |
| July 2006 | Sirius Point Auklet Colony (cabin) | Adult and juvenile rat's frequently seen in cabin and eating holes in trash. |
| June – August 2006 | Old Lava Dome | Rat's radio tracked in old lava dome above camp. Sign not abundant and hard to find |
| August 2006 | Old Lava Dome (high) | Rat's finally ate wax blocks |
| June – August 2006 | New Lava Dome | Rats were radio tracked moving around in the new lava dome. |
| Late July – Early August 2006 | Bob's Plateau | Lots of predated auklet fledglings |