Ten Years of Investigating Auklet-Rat Interactions at Kiska Island, Alaska: Summary of Monitoring from 2001-2010

Research camp at Tangerine Cove, and the auklet colony on the 1960's lava dome, June 2010 © ALB

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Executive Summary

We quantified productivity and survival of Least and Crested Auklets, and indexed the relative abundance and distribution of Norway Rats, at Sirius Point, Kiska Island, Alaska from May-August 2010. Overall, Least Auklet productivity (0.66) was high, typical of rat-free colonies, and no different than productivity on nearby, rat-free Buldir Island (0.64). Crested Auklet productivity (0.61) was also similar to Buldir (0.69) in 2009. Survival of Least Auklets from 2008-2009 (the most recent estimate) was 0.81, an increase on the previous period. Rat abundance, based on our indexing method and general observations, was very low, similar to conditions observed in 2007. Continued monitoring of auklet demography at Kiska is necessary to further quantify natural variability at this large auklet colony and to further understand the effects of rats on Crested Auklets' breeding biology and demography. Under present conditions and in the absence of immigration from other colonies, the Least Auklet population at Sirius Point is expected to decline rapidly over the next two decades.

Introduction

The large auklet (*Aethia* spp.) colony at Sirius Point, Kiska Island, Aleutian Islands, Alaska (52°08'N, 177°37'E), has over a million Least (*Aethia pusilla*) and Crested Auklets (*A. cristatella*) and covers more than 1.8 km^2 in area (Jones *et al.* 2001; Byrd *et al.* 2005). Due to the enormous numbers present, and spatial extent of the colony, estimating, or even observing, population-level effects of introduced predators is a difficult proposition. Norway rats (*Rattus norvegicus*) were introduced to Kiska during the military occupations of 1942-1946 (Murie 1959), have extirpated several bird species from the island, and likely present a long-term threat to the remaining breeding seabirds on the island, including auklets (Major *et al.* 2006; Major *et al.* submitted). This was our tenth year of monitoring auklet demography, and our fifth year of monitoring rat abundance and distribution at Kiska. Our cumulative observations have shown that when rat abundance is high, auklet productivity is low (e.g., the years 2001-2002), but rat abundance has been, for some unknown reason, highly variable and unpredictable among years, and very low for the last few years. A quantitative method of indexing rat abundance was devised (Eggleston et al. in prep) and implemented at Sirius Point in 2006 (Eggleston and Jones 2006), refining our ability to correlate rat activity with auklet population parameters. Nevertheless, only long-term demographic monitoring and modelling will indicate whether auklets and rats are in stable coexistence at Kiska.

Sirius Point is a critical breeding site for auklets because it contains the largest patch of available auklet breeding habitat in the Aleutians in the form of a 45-year-old lava dome (Coats *et al.* 1961; Simkin *et al.* 1981). It is also home to about 5% of the global Least Auklet and Crested Auklet populations (Gaston and Jones 1998) and is perhaps the largest Least Auklet colony in the Aleutian Islands (Byrd et al. 2005). Understanding the population dynamics of auklets in relation to rats is therefore critical to their successful management and conservation in Alaska.

The objectives of our overall study were to:

1) Quantify Least and Crested Auklet productivity from representative areas of the Sirius Point colony for the 2010 breeding season,

2) Identify causes of auklet breeding failure (especially if involving rats),

3) Quantify Least Auklet annual adult survival at one representative study plot for 2001-2009 from resightings of previously colour-marked birds in 2010 (again assessing possible effects of rats), and

4) Redeploy a rat monitoring transect protocol to quantify inter-year variation in relative abundance of rats at Sirius Point.

In addition, we are also conducting detailed analysis of diet, moult and general biology of auklets as well as diet of rats, although these analyses are ongoing and will be presented elsewhere.

Methods

Auklet Productivity

Least and Crested Auklet productivity was measured at Sirius Point, Kiska Island using established methods (Fraser *et al.* 1999; Major *et al.* 2006; Bond *et al.* submitted) that have been employed consistently since 2001. In short, we visited breeding sites every 4-7 days, and determined their status (empty, egg, chick, adult, unknown). We considered sites active when we found an adult on two consecutive visits, or we saw an egg. We scored sites as successful in fledging a chick if the chick disappeared after 25 days (Least Auklets, Roby and Brink 1986) or 26 days (Crested Auklets, Fraser *et al.* 1999). We defined reproductive success as the proportion of active nests from which chicks fledged. We used apparent estimates of reproductive parameters (chicks fledged per pair) rather than a Mayfield-corrected estimate since we were interested in the relative measures of reproductive performance, not absolute estimates (Johnson 2007). We also assumed that any biases created by using apparent estimators were consistent across all years. Furthermore, Major *et al.* (2006) found that Mayfield estimates for Least Auklet productivity at Kiska Island from 2001-2003 did not differ from uncorrected estimates as presented here. We began searching for active nests within 3-4 days in any given year, and so effects of left truncation, or the inability to detect nests that failed prior to the first visit (Johnson 2007), would be uniform across the study. Similarly, a single criterion was used to infer successful fledging, meaning that differences in reproductive success reported here were not due to methodological differences.

Any failed crevice was examined closely to determine the cause of failure, including whether rat predation was responsible. These data were compared to similar data collected at the auklet colony at Main Talus, Buldir Island (52°23’N, 175°55’E) using the same protocol. Buldir has no rats, its colony is only about 100 km from the colony at Sirius Point, and thus provides a useful comparison to Sirius Point in determining the effect of rats on auklet productivity. Previously (2001-2007), our auklet productivity data were compared to those from Kasatochi Island (52°11’N, 175°31’W), but the volcanic eruption at Kasatochi in August 2008 ended auklet monitoring there (Smith *et al.* 2010; Williams *et al.* 2010). At Kiska, we used three plots to estimate productivity at Sirius Point (New Lava, Old Lava Low and Old Lava High), and these are believed to be representative of the auklet colony at present (Jones et al. 2001, Major et al. 2006). IN 2010, we also established a new plot on the old lava flow above camp to monitor Crested Auklet nests; these data have been included in the Old Lava High plot. We used a binomial generalized linear model with a logit link in SPSS 16 (SPSS Inc., Chicago, IL, USA) to examine differences among plots and between islands (Bond *et al.* submitted). Values were considered significant when $p < 0.05$.

Timing of Breeding

We estimated date of hatching for a sample of Least Auklet nests. We included only nests that we scored as an egg on one visit, and as a chick on the very next (4-7 days later), and we assumed hatching date to have occurred at the midpoint between the two visits. Again, these data were compared to both long-term data from Kiska and Buldir islands. Analysis of variance (ANOVA) was used to test for differences among plots on Kiska, and between Buldir and Kiska islands.

Auklet Survival

A population of marked Least and Crested Auklets of unknown age was established on a single plot on the 1964 lava dome in 2001 (Jones et al. 2001) A capture-mark-resighting protocol to measure annual survival on this study plot has been employed each year (2001-2010). Birds were captured on the 50 m^2 plot using noose carpets and adults and were marked with a uniquely-numbered metal band and combination of Darvik colour bands (Jones *et al.* 2002; Jones *et al.* 2004). We did not colour-band subadults (two-year-old individuals, identified using criteria in Bédard and Sealy (1984) as having worn, brown flight feathers and foreheads), and they were not included in the analysis. We resighted colour-marked auklets during their main activity periods (0900-1500 and 2200-0030 Hawaii-Aleutian Standard Time) from late May to early August each year, encompassing the entire breeding cycle. Using procedures described in Lebreton et al. (1992), annual probabilities of survival (ϕ) and resighting (*p*) were generated using Program MARK (White and Burnham 1999). Because our capture technique captures both breeding and non-breeding individuals, some individuals are never seen again after marking (Jones *et al.* 2002; Jones *et al.* 2007). These transient "prospectors" result in a lower estimate of survival on the first occasion after marking

(Pradel *et al.* 1997; Prévot-Julliard *et al.* 1998; Bertram *et al.* 2000; Jones *et al.* 2007). To account for this permanent emigration, we included a transient term that modelled survival estimates for the period following capture independently of estimates in subsequent years. This results in the first estimate of survival being the product of both survival and permanent emigration from the study plot (Pradel *et al.* 1997). To ensure a robust estimate of survival, individuals were only considered "alive" if seen at least twice during the summer (Bond and Jones 2007, 2008, 2009)

We tested the goodness-of-fit of the global model to the data using 100 parametric bootstraps (Jones *et al.* 2002; Jones *et al.* 2007). From these bootstraps, we obtained the mean model deviance and mean ĉ, a measure of overdispersion, or extra-binomial variation. This variation arises when assumptions of the model are not met, such as variation in the recapture rates of individuals (White and Burnham 1999; Burnham and Anderson 2002). The observed deviance and ĉ were divided by the mean values from the bootstraps and the higher of the two values was taken as an estimate of overall overdispersion, ĉ. We restricted our candidate models to the global model, plus a series of reduced parameter models. We did not construct every reduced parameter model, many of which would have poor fit, but rather we used the approach of Lebreton et al. (1992) by first modelling recapture rates to determine the best structure for recapture rates and then modelling survival rates.

Model selection was based on quasi-Akaike Information Criteria adjusted for small sample size and overdispersion ($QAIC_c$). Models with lower $QAIC_c$ values were considered the best compromise between a good fit to the data and overparameterization of the models (Burnham and Anderson 2002). We also calculated Akaike weights, which indicate how well a model fits the data when compared with other models (Burnham and Anderson 2002). Throughout, we used model notation from Lebreton et al. (1992) where we described the parameterization explicitly (y_1 = first year after capture, t = variation with time). We used year classes rather than age classes as the marked individuals were of unknown age.

Norway Rat Abundance and Distribution

Because a census method for rats using snap-traps is not feasible at Sirius Point because of the large auklet population, detection using chew marks at stations set across the auklet colony was recommended and an indexing protocol (Eggleston and Jones 2006). Following this protocol, wax blocks were set at the same stations and along the same transect lines used from 2006-2009. Eighty stations (8 transects of 10 stations with stations approximately 25m apart) covered representative habitat types of the Sirius Point auklet colony. Two replicate six-day monitoring trials were carried out, with one during 12-17 June and another during 12-17 July. Differences among plots, between months and among years were tested, controlling for elevation, using a generalized linear model, and multiple comparisons were made using 95% confidence intervals of estimated marginal means. Differences were considered significant when confidence intervals did not overlap.

Additional Observations

A list of bird species identified from 25 May – 06 August is presented in Appendix I, and a summary of Norway rat sign observations is in Appendix II. Throughout the season, attempts were made to document all bird species that may be breeding at Sirius Point, either by finding a nest or fledged young.

Results

Least Auklet Productivity & Phenology

There was no difference among plots in hatching success ($\chi^2 = 1.95$, $p = 0.38$) or overall reproductive success ($\chi^2 = 0.029$, $p = 0.97$), so data from all plots were pooled. Hatching success was 0.82, essentially unchanged over recent years, and not significantly different from Buldir in 2010 ($\chi^2 = 0.07$, $p = 0.80$). Reproductive success was the highest ever recorded at Kiska at 0.66 chicks fledged per pair. Overall reproductive success was not significantly different on Kiska compared to Buldir in 2010 ($\chi^2 = 0.01$, $p < 0.96$). See Table 1 for complete productivity details.

There was no significant difference among plots in Least Auklet breeding phenology as assessed by hatching date ($F_{2, 48} = 1.29$, $p = 0.29$), so data were pooled. Overall, the mean hatching date was 29 June ± 5.31 days (n = 51 nests). From 2002-2008, the mean annual hatching date ranged from 28 June to 05 July. Least Auklet phenology was not significantly different on Kiska than Buldir in 2010 (mean hatching date on Buldir: 28 June; $F_{1, 66} = 1.00$, $p = 0.32$).

Crested Auklet Productivity & Phenology

There was no difference among plots in hatching success ($\chi^2 = 1.91$, $p = 0.39$) or overall reproductive success ($\chi^2 = 2.12$, $p = 0.35$), so data from all plots were pooled. Hatching success was 0.78, also similar to previous years, and not significantly different from Buldir in 2010 ($\chi^2 = 0.16$, $p = 0.69$). Reproductive success was typical of Crested Auklets on Kiska, with 0.61 chicks fledged per pair. Overall reproductive success was not significantly different on Kiska than on Buldir in 2010 ($\chi^2 = 0.39$, $p < 0.53$). See Table 3 for complete productivity details.

Sample sizes were not large enough to compare Crested Auklet phenology among plots, so data were pooled. The mean hatching date was 05 July ± 5.88 days (n = 13), however we do not have sufficient data to make comparisons with other years at Kiska. Crested Auklets hatched significantly later than Least Auklets on Kiska in 2010 ($F_{1, 62} = 13.84$, $p < 0.001$), and also significantly later than Crested Auklets on Buldir ($F_{1, 35} = 4.15$, $p = 0.049$).

Least Auklet Survival

The top-ranked model included survival varying with year and three groups of recapture rates (Table 6). Survival from 2008-2009 (the latest that can be estimated) was 0.810. This follows a low survival rate of 0.684 in 2007-2008. Full details, including annual estimates of survival and estimates of recapture rate are presented in Table 7.

Crested Auklet Survival

We again estimated Crested Auklet apparent annual survival at Sirius Point. We urge caution in drawing conclusions from this analysis, as our sample of marked birds was small (Table 5b), although estimates in the most recent (2007-2008 and 2008-2009) years are relatively robust because of increased effort to mark individuals. The top-ranked model included a transient effect, where survival for the period immediately following banding was lower than other occasions (Table 8). Crested Auklet survival has been declining steadily, and in 2008-2009 was 0.744. Full details are provided in Table 9.

Norway Rat Abundance and Distribution

There were significant effects of year ($p = 0.004$) and month ($p < 0.001$), and no interactions were significant. Transect location was not a significant predictor of rat detection ($p = 0.08$). Similarly, elevation had no effect on rat detection ($p = 0.85$). Overall, there were more rat detections in 2006 than any other year, followed by 2008 and 2009, with very few rat detections in 2007 and 2010. There were generally more detections in June than in July ($p < 0.001$).

There was no significant relationship between rat abundance and hatching, fledging or overall reproductive success in either Least (all $p > 0.06$) or Crested Auklets (all $p > 0.08$) from 2006-2010. Apart from Least Auklet hatching success ($p = 0.08$), all other relationships were insignificant (all $p > 0.14$).

Discussion

Least Auklet Productivity & Phenology

Least Auklet productivity on Kiska in 2010 was at a level typical of most Aleutian colonies (Bond *et al.* submitted), and was not significantly different from rat-free Buldir in 2010. This fits well with the low number of detections on rat transects in both June and July this year, and the scarcity of rat droppings observed in areas near camp that we check visually every year. It appears as though productivity responds to bimodal rat abundances – in other words, there is a critical threshold of rat abundance that seems to cause auklet reproductive failure (2001, 2002), below which auklets are able to buffer the effects of rats on reproductive success. Rats have never been as abundant, qualitatively, as 2001 and 2002. We note, however, that while productivity may be the most visible indication of rat effects on demography, seabirds' population trajectories are most sensitive to changes in adult survival (see below).

At Buldir nearly all of the auklet crevices monitored annually are the same ones checked from one year to the next (ILJ). In contrast, at Kiska, an additional 10-30 new crevices need to be located and marked each year to maintain an adequate sample of nests for productivity analysis. At present, there are over 450 marked crevices, of which only 192 were occupied (i.e., a high proportion of suitable breeding sites are unoccupied). As Least Auklets have typically high nest-site fidelity (Roby and Brink 1986; Jones and Montgomerie 1991), this suggests that some combination of factors may be at play. These could include: 1) that disturbance caused by rats has differentially reduced fidelity at Sirius Point; 2) that disturbance caused by investigators (us) has reduced site fidelity at Sirius Point; 3) that there are more high quality breeding sites at Kiska than pairs of auklets; or 4) that the auklet population is declining (Major et al. submitted), resulting in more unoccupied nest sites. We can probably eliminate possibility 2), as the identical monitoring procedures/protocol are followed at Buldir and Kiska – one or more of the other options seems likely.

We found no significant difference in the timing of breeding of Least Auklets between Kiska and Buldir in 2010. We note, however, that phenological data were only available for 17 nests on Buldir, and so the power to detect small but significant differences was lowered.

Crested Auklet Productivity

Crested Auklet productivity appears to have been relatively (to Least Auklets) unaffected by rats and has remained consistently between 0.4-0.6 chicks fledged/pair, except for higher success in 2004 and 2006. In 2010, there was no difference between Crested Auklet productivity on Kiska and Buldir. Locating Crested Auklet crevices to monitor on Kiska is more challenging because the Sirius Point colony contains 80% Least Auklets and only 20% Crested Auklets (Day *et al.* 1979; Byrd *et al.* 2005; Jones and Hart 2006), so Crested Auklet nest crevices were inherently less likely to be sampled. Secondly, Crested Auklets tend to nest much deeper in talus slopes and lava formations than Least Auklets (Bédard 1969), making active nests much harder to find and monitor. Finally, the initial sample of crevices monitored (on three plots, Jones *et al.* 2001; Major *et al.* 2006) was in areas of the colony with low densities of Crested Auklets. These points may suggest that greater efforts to monitor Crested Auklets should be made at Kiska in future years.

Nevertheless, we believe the survival of Least Auklet eggs and chicks in crevices at Sirius Point is likely to be an appropriate proxy for the survival of Crested Auklet eggs and chicks because nether species defends their nests actively, and chicks of both species are helpless, unaccompanied by an attending adult for the majority of the nestling period (Jones 1993b, a), and thus would appear to be equally vulnerable to attack by rats.

Very few Crested Auklet nests have been monitored on New Lava (total for all 2001-2010 = 48), but in five of these years, no chicks fledged. In total, only nine Crested

Auklet chicks fledged in monitored crevices on this plot from 2001-2010. This evidence, although limited, leads us to believe that rat predation or disturbance in this area could be a significant cause of Crested Auklet reproductive failure.

As with Least Auklets, Crested Auklets tended to breed later this year on Kiska than on Buldir, although the sample size of nests from Kiska for which we had hatching date was small (n = 13). Future years should focus on Crested Auklet breeding biology at Kiska, and its relationship to rats.

Least Auklet Survival

After a sharp decline in 2007-2008, apparent survival of Least Auklets at Kiska rose in 2008-2009 to 0.810, very near the long-term average at Kiska of 0.827, and the 1992-2007 average at Buldir (0.849) and the 1998-2006 average at Kasatochi (0.839; Jones et al. unpubl. data). Population modelling from Kiska indicates that the Least Auklet population is expected to decline rapidly in the next 20 years (Major *et al.* submitted). Changes in seabird populations are most sensitive to variation in adult survival (Hamer *et al.* 2002), and so we are concerned that such low survival rates, combined with the potential for negative effects of rats on productivity, will hasten this decline.

Crested Auklet Survival

We examined Crested Auklet survival again this year. Although birds have been marked since 2001, only 30 individuals were marked from 2001-2006 (Table 5b). We marked larger numbers of individuals in 2007-2010, and therefore attempted an analysis. The estimate for 2008-2009 continues the declining pattern from 2002 (that, coincidentally or not, matches a longer term trend at Buldir for Crested Auklets). Our estimates included two years of 100% survival and six of the eight estimates are based on data from only 30 individuals, and so should be interpreted with caution. Additional years with larger banding efforts (> 30 individuals marked) are required to fully resolve patterns in survival of Crested Auklets at Sirius Point. The mean estimate from Kiska (0.862) is higher than the means recorded from 1992-2007 at Buldir (0.795) or from 1998-2006 at Kasatochi (0.775; Jones et al. unpubl. data), but when only robust estimates from 2007-2009 at Kiska are used, the mean survival estimate drops to 0.738, lower than either other island, and almost certainly contributing to a declining population (Hamer *et al.* 2002).

Despite the lowest survival estimate for both Least and Crested Auklets occurring in 2007-2008, survival estimates were not correlated between the two species ($r^2 = 0.038$, $p = 0.64$), suggesting that they may be responding differently to both oceanography and rats.

Norway Rat Abundance and Distribution

Rats were not as abundant in 2010 as in 2008 or 2009, and the low number of detections overall, although higher in June (3) than July (0) for the first time, are likely not biologically different. In each year, high numbers of detections have been found in Glen Curly, including the only detection in 2007 and the majority of detections in 2008 and 2009. This area borders the 1964 lava dome on the east and an area not occupied by auklets on the west. Why rats are more abundant here than nearby Glen Larry or on the Old Lava Low transects is, at present, unknown. Rats undoubtedly make use of the intertidal zone at Steam Beach and Tangerine Cove during the winter and spring (Witmer *et al.* 2006; Kurle *et al.* 2008), and so the gullies could represent similar refugia, especially early in the season when snow cover at higher elevations may limit the rats' distribution (ALB, ILJ pers. obs.). Alternatively or in addition, due to its geological funnel-like structure, Glen Curly could be a route for rat dispersal inland from the beach areas through spring and summer.

Rat abundance was not correlated significantly with any reproductive parameter in either Least or Crested Auklets during 2006-2010. This is, however, based on only five years' rat abundance data from the indexing protocol (Eggleston et al. in prep), and in none of these years were rats as qualitatively abundant as 2001 or 2002. Additional years' data are urgently needed to understand the exact relationship between rat abundance and auklet productivity quantitatively. It may take ten or more years to detect the relationship statistically (less if Kiska experiences plague-levels of rat abundance as experienced in 2001-2002).

Additional Observations

There were several Glaucous-winged Gull (*Larus glaucescens*) nests near camp this year. One nest above camp fledged three chicks, and numerous fledged young were observed in late July and early August. The number of gulls present at the end of the season was often 20-30 individuals of all age classes – a drastic increase since 2001.

Song Sparrows (*Melospizia melodia*) did not breed at Sirius Point in 2009, but one singing male was present when we arrived in 25 May, and up to five individuals were seen together in late July / early August, indicating possible post-breeding dispersal from Little Kiska. In addition, single individuals were seen at intervals of 2-3 weeks throughout the summer, whereas no sparrows were encountered in 2008 until the end of July. In contrast, no sparrows were observed over wide areas of Kiska south of the volcano that were explored by the authors in 2010.

For the third year in a row, a large number of fledgling Least Auklets and smaller numbers of Crested Auklets were found dead in Glen Larry in what we believe to be a toxic gas vent. This is the area of the birds presumed killed by wind in 2007 (Bond and Jones 2007). We performed a quantitative analysis of atmospheric gases at this site this year. Preliminary analysis suggests that slightly elevated concentrations of CO_2 may be one of several factors contributing to post-fledgling auklet mortality.

Conclusions and Recommendations

1. Additional years of simultaneous monitoring of auklet population parameters with monitoring rat abundance and distribution using a quantitative method, especially during years of high rat abundance such as 2001 and 2002, are required to measure the effects of rats on auklet demography accurately.
2. The current status of Crested Auklets at Kiska, where they represent over 35% of the Aleutian Islands population, is poorly understood. A larger number of marked individuals for survival analysis, and of breeding crevices to monitor productivity are required to assess the effects of rats on this species' demography.
3. An assessment of immigration among auklet colonies in the Aleutian Islands and Bering Sea would be useful for predicting population changes at Sirius Point, where the Least Auklet population is predicted to decline significantly over the next two decades in the absence of immigration. This, combined with predicted declines at other colonies in the Aleutians due to vegetative succession, and the loss of Kasatochi as a breeding site in the short term, is cause for concern about the status of auklets in the Aleutian chain.

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Tables

Table 1. Least Auklet productivity and known causes of breeding failure as measured from three plots at Sirius Point, Kiska Island, Alaska in 2010.

	Lava Dome	Old Lava 'Low'	Old Lava 'High'*	Kiska Total
Crevices monitored, n (a)	70	31	44	146
Number hatched (b)	59	23	36	118
Egg abandoned	1	3	2	6
Egg disappeared	8	5	6	19
Egg broken	0	0	1	1
Egg predated	2	0	0	2
Egg displaced	0	0	0	0
Crevice collapse	0	0	0	0
Dead adult in crevice	0	0	0	0
Number fledged (c)	45	20	31	96
Small dead chick	5	2	0	7
Chick disappeared	9	1	5	15
Chick predated	0	0	0	0
Large dead chick	0	0	0	0
Hatching success (b/a)	0.84	0.74	0.82	0.81
Fledging success (c/b)	0.76	0.87	0.86	0.81
Reproductive success (c/a)	0.64	0.64	0.70	0.66

*Includes the new Crested Auklet plot on the old lava flow above camp

Table 2. Least Auklet productivity from plots on Kiska and Buldir islands in 2010.

	Lava Dome	Old Lava 'Low'	Old Lava 'High'	Kiska Total	Buldir[1]
n (a)	70	31	44	146	76
Number hatched (b)	59	23	36	119	63
Number fledged (c)	45	20	31	96	49
Hatching success (b/a)	0.84	0.74	0.82	0.81	0.83
Fledging success (c/b)	0.76	0.87	0.86	0.81	0.78
Reproductive success (c/a)	0.64	0.64	0.70	0.66	0.64

[1]AMNWR unpublished data.

Table 3. Crested Auklet productivity and known causes of breeding failure as measured from three plots at Sirius Point, Kiska Island, Alaska in 2010.

	Lava Dome	Old Lava 'Low'	Old Lava 'High'*	Kiska Total
Crevices monitored, n (a)	6	8	32	46
Number hatched (b)	3	8	25	36
Egg abandoned	1	0	1	2
Egg disappeared	2	0	5	7
Egg broken	0	0	1	1
Egg predated	0	0	0	0
Egg displaced	0	0	0	0
Crevice collapse	0	0	0	0
Dead adult in crevice	0	0	0	0
Number fledged (c)	3	7	18	28
Small dead chick	0	0	1	1
Chick disappeared	0	1	6	7
Chick predated	0	0	0	0
Large dead chick	0	0	0	0
Crevice collapse	0	0	0	0
Hatching success (b/a)	0.50	1.00	0.78	0.78
Fledging success (c/b)	1.00	0.88	0.72	0.78
Reproductive success (c/a)	0.50	0.88	0.56	0.61

*Includes the new Crested Auklet plot on the old lava flow above camp

Table 4. Crested Auklet productivity from plots on Kiska and Buldir islands in 2010.

	Lava Dome	Old Lava 'Low'	Old Lava 'High'	Kiska Total	Buldir[1]
n (a)	6	8	32	46	129
Number hatched (b)	3	8	25	36	109
Number fledged (c)	3	7	18	28	89
Hatching success (b/a)	0.50	1.00	0.78	0.78	0.84
Fledging success (c/b)	1.00	0.88	0.72	0.78	0.82
Reproductive success (c/a)	0.50	0.88	0.56	0.61	0.69

[1]AMNWR unpublished data.

Table 5a. Number of Least Auklets banded at Sirius Point, Kiska Island, Alaska from 2001-2010.

Year	Newly banded adults	Newly banded subadults	Within-year recaptures	Between-year recaptures	Total Captures
2001	198	36	36	-	270
2002	20	1	0	5	26
2003	12	0	0	14	26
2007	114	12	22	20	168
2008	125	56	12	33	226
2009	53	51	4	31	139
2010	46	25	3	4	78
Total	**568**	**181**	**78**	**107**	**833**

Table 5b. Number of Crested Auklets banded at Sirius Point, Kiska Island, Alaska from 2001-2010.

Year	Newly banded adults	Newly banded subadults	Within-year recaptures	Between-year recaptures	Total Captures
2001	23	4	2	-	29
2002	1	0	0	0	1
2003	6	0	0	0	6
2007	23	2	1	1	27
2008	41	9	4	6	60
2009	26	4	0	5	35
2010	7	0	0	0	7
Total	**127**	**19**	**7**	**12**	**165**

Table 6. Comparison of CMR models from program MARK for Least Auklets at Sirius Point, Kiska Island, Alaska from 2001-2009, where ϕ is survival, p is the encounter probability and t is time. Adjusted for $\hat{c}$ = 2.585.

Model	$QAIC_c$	$\Delta QAIC_c$	QAIC Weight	Model Likelihood	No. Parameters	Deviance
A {$\phi_{(t)}$ $p_{(grouped)}$}	952.747	0.00	0.980	1.000	12	144.701
B {$\phi_{(t)}$ $p_{(t)}$}	960.896	8.15	0.017	0.017	17	142.649
C {$\phi_{(Year1+t)}$ $p_{(t)}$}	964.744	12.00	0.002	0.003	17	146.497
D {$\phi_{(.)}$ $p_{(t)}$}	967.935	15.19	< 0.001	< 0.001	10	163.950
E {$\phi_{(t)}$ $p_{(.)}$}	984.570	31.82	< 0.001	< 0.001	10	180.586
F {$\phi_{(.)}$ $p_{(.)}$}	1011.176	58.43	< 0.001	< 0.001	2	223.330

Table 7. Least Auklet survival at Sirius Point, Kiska Island, Alaska - estimates (ϕ) and encounter probabilities (p) for 2001-2009 as determined by model A from program MARK with confidence intervals adjusted for $\hat{c}$ = 2.197. Resight probability groups are A: 2002, 2003, 2004, 2008; B: 2005; C: 2006, 2007, 2009.

			95% Confidence Interval	
Parameter	Estimate	Standard Error	Lower	Upper
$\phi_{2001\text{-}2002}$	0.897	0.036	0.804	0.949
$\phi_{2002\text{-}2003}$	0.952	0.031	0.841	0.987
$\phi_{2003\text{-}2004}$	0.830	0.049	0.712	0.906
$\phi_{2004\text{-}2005}$	0.783	0.093	0.552	0.914
$\phi_{2005\text{-}2006}$	0.740	0.097	0.514	0.885
$\phi_{2006\text{-}2007}$	0.922	0.070	0.635	0.988
$\phi_{2007\text{-}2008}$	0.684	0.057	0.563	0.784
$\phi_{2008\text{-}2009}$	0.810	0.057	0.675	0.898
p_A	0.902	0.021	0.853	0.936
p_B	0.457	0.083	0.305	0.618
p_C	0.784	0.042	0.691	0.854

Table 8. Comparison of CMR models from program MARK for Crested Auklets at Sirius Point, Kiska Island, Alaska from 2001-2009, where ϕ is survival, p is the encounter probability and t is time. Adjusted for $\hat{c}$ = 1.146.

Model	$QAIC_c$	$\Delta QAIC_c$	QAIC Weight	Model Likelihood	No. Parameters	Deviance
A {$\phi_{(Year1+t)}$ $p_{(grouped)}$}	340.595	0.00	0.965	1.000	9	51.132
B {$\phi_{(Year1+t)}$ $p_{(t)}$}	347.261	6.67	0.034	0.036	13	49.137
C {$\phi_{(.)}$ $p_{(t)}$}	360.592	20.00	< 0.001	< 0.001	10	68.987
D {$\phi_{(t)}$ $p_{(t)}$}	360.770	20.17	< 0.001	< 0.001	17	53.734
E {$\phi_{(t)}$ $p_{(.)}$}	382.016	41.42	< 0.001	< 0.001	10	90.411
F {$\phi_{(.)}$ $p_{(.)}$}	384.689	44.09	< 0.001	< 0.001	2	109.814

Table 9. Crested Auklet survival at Sirius Point, Kiska Island, Alaska - estimates (ϕ) and encounter probabilities (p) for 2001-2009 as determined by model A from program MARK with confidence intervals adjusted for $\hat{c}$ = 1.137. Resight probability groups are A: 2002, 2003, 2009; B: 2004, 2006, 2007, 2008; C: 2005.

			95% Confidence Interval	
Parameter	Estimate	Standard Error	Lower	Upper
$\phi_{Initial}$	0.746	0.045	0.648	0.824
$\phi_{2002-2003}$	1.000	0.001	0.999	1.000
$\phi_{2003-2004}$	1.000	0.001	0.999	1.000
$\phi_{2004-2005}$	0.969	0.102	0.034	1.000
$\phi_{2005-2006}$	0.908	0.115	0.366	0.993
$\phi_{2006-2007}$	0.794	0.109	0.511	0.934
$\phi_{2007-2008}$	0.731	0.131	0.425	0.909
$\phi_{2008-2009}$	0.744	0.089	0.538	0.878
p_A	1.000	0.001	0.999	1.000
p_B	0.907	0.037	0.807	0.959
p_C	0.421	0.121	0.215	0.658

Table 10. Summary of Norway rat activity at eight wax block transect stations from 2006-2010 at Sirius Point, Kiska Island.

	June			July			June	July	Grand
Year	Day 1	Day 2	Day 3	Day 1	Day 2	Day 3	Total	Total	Total
2006	7	6	6	21	27	27	19	75	94
2007	0	0	0	0	1	0	0	1	1
2008	2	3	7	5	6	14	12	25	37
2009	1	0	4	6	7	12	5	25	30
2010	1	1	1	0	0	0	3	0	3

Figures

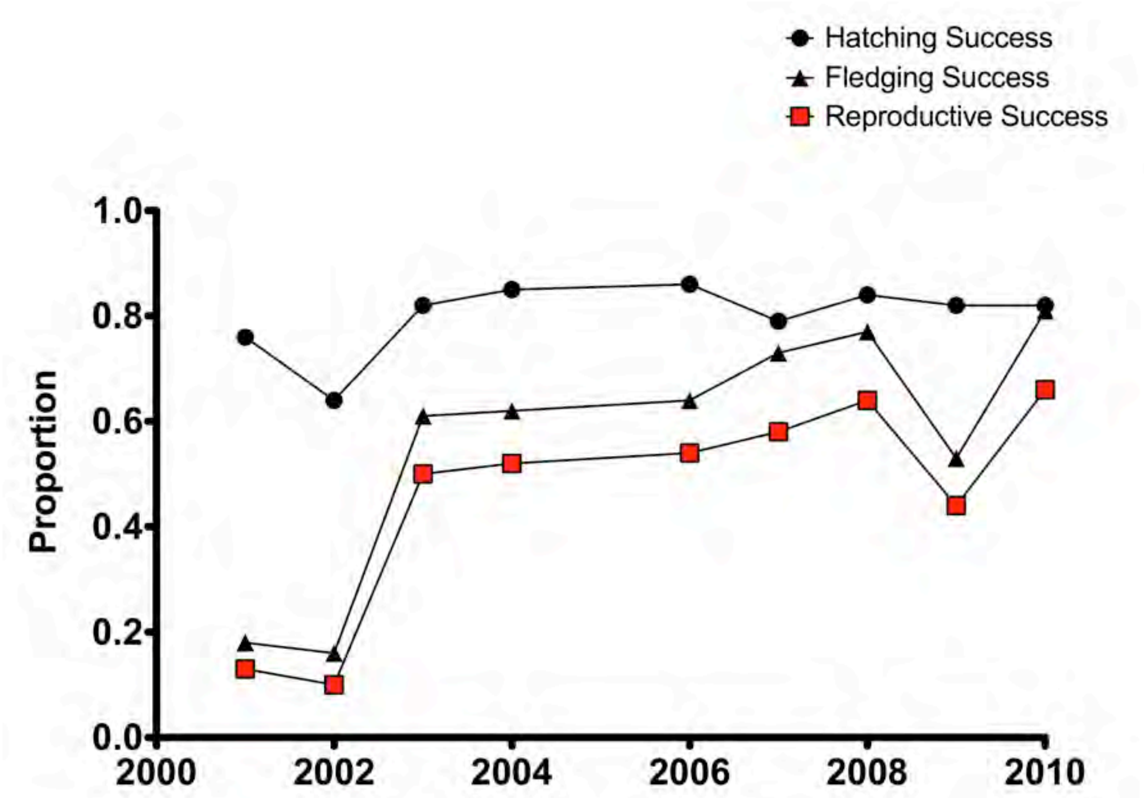

Figure 1. Hatching, fledging and overall reproductive success of Least Auklets at Sirius Point, Kiska Island, Alaska, from 2001-2010.

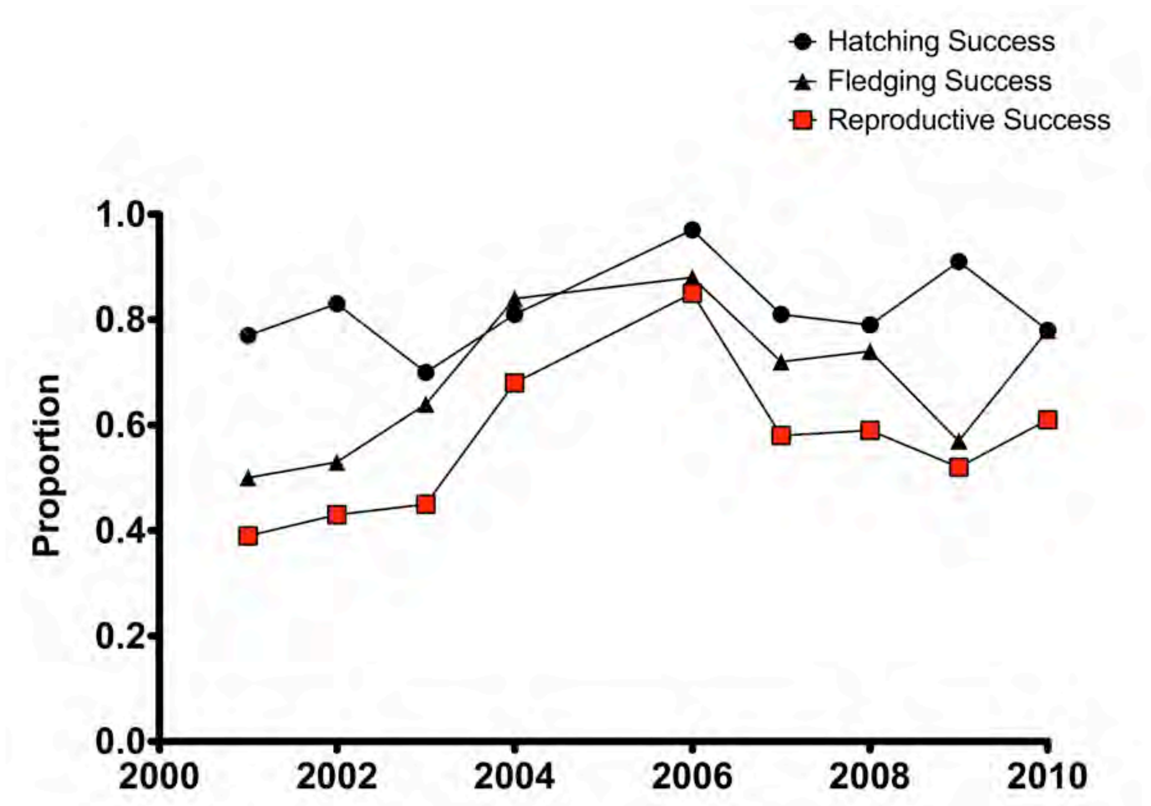

Figure 2. Hatching, fledging and overall reproductive success of Crested Auklets at Sirius Point, Kiska Island, Alaska, from 2001-2010.

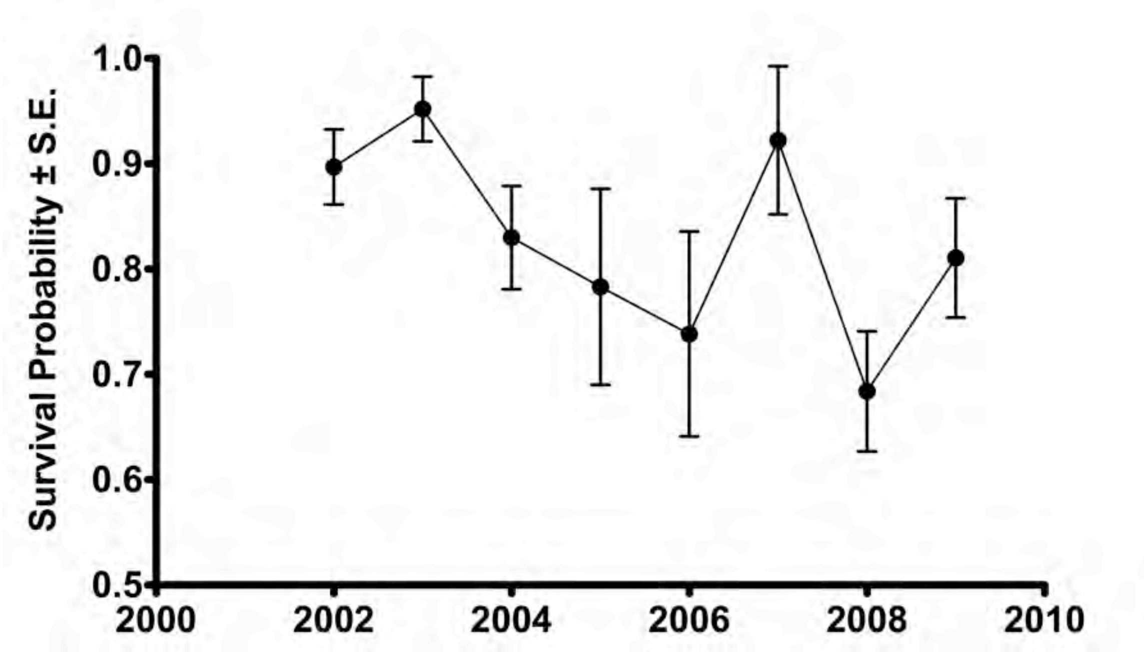

Figure 3. Apparent interannual survival estimates (± standard error) for Least Auklets at Sirius Point, Kiska Island, Alaska. Estimates are presented for the year following marking (i.e., 2002 represents survival from 2001-2002) and were derived from the top-ranked model using Program MARK.

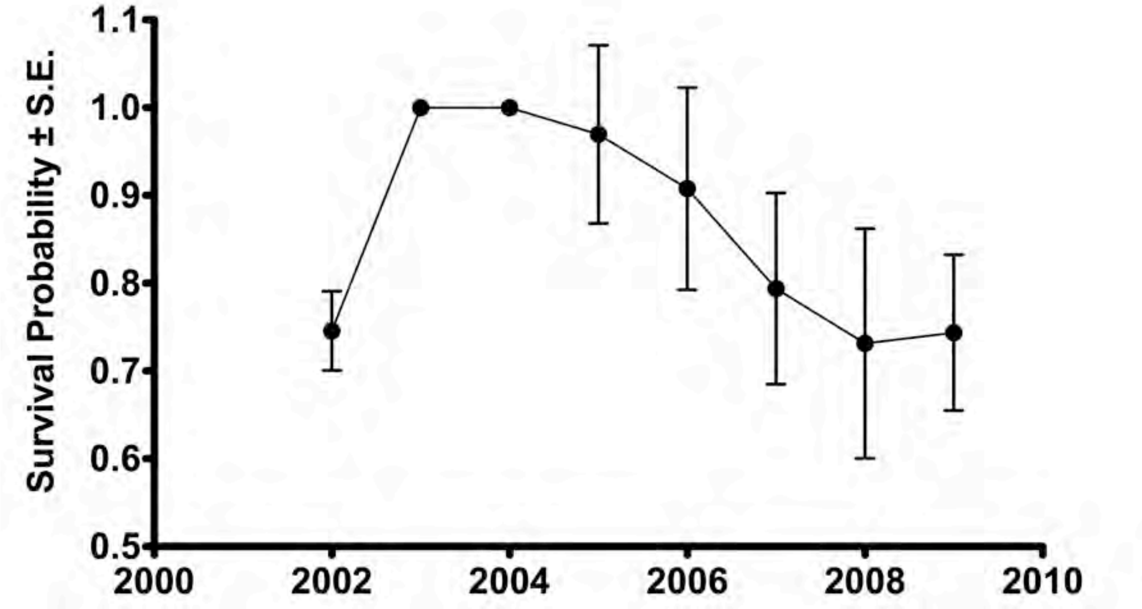

Figure 4. Apparent interannual survival estimates (± standard error) for Crested Auklets at Sirius Point, Kiska Island, Alaska. Estimates are presented for the year following marking (i.e., 2002 represents survival from 2001-2002) and were derived from the top-ranked model using Program MARK.

Appendices

Appendix I

List of birds recorded at Sirius Point from 25 May – 06 August 2010. Confirmed or suspected breeding species are indicated with an asterisk.

***Tundra Swan** *Cygnus columbianus* – A pair of adults with a large cygnet were observed at Middle Kiska Lake on July 27 – the second confirmed breeding on Kiska Island.

***Aleutian Cackling Goose** *Branta hutchinsii leucopariea* – Large flocks frequently observed over Sirius Point and roosting on the south side of Kiska Volcano (nests on southern part of Kiska).

***Common Eider** *Somateria mollissima v-nigrum* – Both males and females present at Sirius Point on numerous occasions through the summer, and ducklings present at the end of the season after 04 July.

Harlequin Duck *Histrionicus histrionicus* – male and female pair on 01 June and 05 June off Sirius Point.

White-winged Scoter *Melanitta fusca* – male and female pair off Sirius Point on 21 July.

Black Scoter *Melanitta americana* – one second-year male seen off Steam Beach on 27 May.

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

***Greater Scaup** *Aythya marila* – Common at Christine Lake.

***Common Merganser** *Mergus merganser* – A few were observed at Christine Lake.

***Red-breasted Merganser** *Mergus serrator* – Uncommon at Christine Lake; one male and one female observed at Sirius Point in early June.

Common Loon *Gavia immer* – One individual at Christine Lake in late July.

Laysan Albatross *Phoebastria immutabilis* – Uncommon off Sirius Point.

Short-tailed Shearwater *Puffinus teniurostris* – Uncommon off Sirius Point.

Northern Fulmar *Fulmaris glacialis* – Uncommon off Sirius Point.

***Leach's Storm-petrel** *Oceanodroma leucorhoa* – Uncommon at Sirius Point, heard at camp during one night in June and at Christine Lake. Suspected breeder?

***Fork-tailed Storm-petrel** *Oceanodroma furcata* – Uncommon at Sirius Point, heard occasionally at night from camp. Suspected breeder; breeds on Little Kiska?

***Pelagic Cormorant** *Phalacrocorax pelagicus* – Common, breeds locally.

***Red-faced Cormorant** *Phalacrocorax urile* – Uncommon, breeds locally.

***Bald Eagle** *Haliaeetus leucocephalus* – Uncommon breeder.

***Peregrine Falcon** *Falco peregrinus* – Uncommon local breeder. One nest above Ican Beach fledged two chicks. The usual nest site above camp was not occupied.

***Rock Ptarmigan** *Lagopus mutus* – Uncommon on volcano slopes and around Witchcraft Point, especially in June and early July.

Black Oystercatcher *Haematopus bachmani* – seen and heard frequently in June around camp at near Hector's Valley.

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

***Parasitic Jaeger** *Stercorarius parasiticus* – Uncommon breeder in the Lake District

***Glaucous-winged Gull** *Larus glaucescens* – Common, breeds locally. Many more loafing, probably non-breeding birds present this year than in 2007 -2009; over 50 counted on several occasions. One nest above camp fledged three chicks, and others above Ican Beach were likely successful.

Common Murre *Uria aalge* – Uncommon off Sirius Point, breeds locally.

Thick-billed Murre *Uria lomvia* – Both species breed locally (Pillar Rock).

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

***Parakeet Auklet** *Aethia psittacula* – Uncommon breeder at Sirius Point.

***Least Auklet** *Aethia pusilla* – Abundant breeder at Sirius Point.

***Crested Auklet** *Aethia cristatella* – Abundant breeder at Sirius Point.

Whiskered Auklet *Aethia pygmaea* – Heard above camp on 05 June.

Horned Puffin *Fratercula corniculata* – Rare off Sirius Point.

***Tufted Puffin** *Fratercula cirrhata* – Uncommon off Sirius Point, breeds locally (Wolf Point and Little Kiska).

Common Raven *Corvus corax* – Two birds occasionally at Sirius Point, and almost daily from late July until the end of the season.

***Pacific Wren** *Troglodytes pacificus* – (formerly Winter Wren) Common breeder.

Middendorff's Grasshopper-Warbler *Locustella ochotensis* – a single bird was heard singing from the tall grass near the tents at Witchcraft Point, early in the morning of July 20 by Ian. This occurrence recalls that from Buldir Island, of a bird heard singing in tall grass near camp by Ian (later mist-netted) on July 27, 1990.

***Song Sparrow** *Melospizia melodia aleutica* – Single individuals seen on several occasions throughout the summer, and up to five seen in late July and early August; possible post-breeding dispersal from Little Kiska. One singing male was present on our arrival at camp on 25 May.

***Lapland Longspur** *Calcarius lapponicus* – Common in alpine meadows, at Christine Lake, and on the old lava flow.

***Snow Bunting** *Plectophenax nivealis* – Uncommon breeder.

Common Rosefinch *Carpodacus erythrinus* – One female was in the house pits at Raynard Cove on June 30 and July 1. This is the second year in a row that this species has been recorded on Kiska during summer (one was seen near South Head, June 26, 2009).

***Gray-crowned Rosy-finch** *Leucosticte tephrocotis* – Common breeder.

Appendix II

Summary of Norway rat signs observed at Sirius Point in 2010 (LeAu: Least Auklet; CrAu: Crested Auklet).

Date	Location	Comments
May 25	Camp	Numerous tracks around camp, and droppings in the cabin
May 27	Glen Larry	2 depredated LeAu eggs and 1 LeAu adult
May 29	Camp Beach	1 depredated LeAu egg
May 31	Glen Larry	1 depredated LeAu adult
June 2	Old Lava, above camp	Cache 1: 29 LeAu eggs, 3 CrAu eggs
June 2	Above camp	2 depredated LeAu eggs, 1 CrAu egg
June 5	New Lava	2 depredated LeAu eggs near crevice C336
June 7	Old Lava (Crested Plot)	2 depredated LeAu eggs, 1 CrAu egg
June 7	Storage cave above camp	Cache 2: 2 LeAu egg, 3 CrAu eggs, 4 LeAu adults
June 11	New Lava	2 depredated LeAu adults (near L326 and X52)
June 11	New Lava	Cache 3: 2 LeAu eggs, 3 CrAu eggs
June 11	New Lava	Productivity crevice L301, 1 depredated LeAu egg
June 13	Old Lava Low	1 depredated LeAu adult
June 13	Above camp	1 depredated LeAu egg, 1 CrAu egg
June 18	Old Lava Low	1 depredated LeAu adult
June 28	Camp	Rat caught in snap trap
July 3	Above camp	2 depredated LeAu eggs
July 14	Glen Larry	2 depredated LeAu eggs
July 21	Glen Larry	1 depredated LeAu fledgling
August 4	Camp	Rat seen on camp beach