Summary report – 2010 summer field activity

Evaluating the feasibility of Crested Auklet enhancement via habitat restoration at Gareloi Island, Aleutian Islands

For

Keesal, Young & Logan
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Polaris Applied Sciences

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Executive Summary

Research to evaluate the feasibility of enhancing Crested Auklet populations on Gareloi Island by removing vegetation, to increase access to subterranean nest cavities at an established colony, continued during the summer of 2010. Research activity focused on two objectives: 1) to continue an experiment involving observations on four pairs of 100 m^2 plots established in 2009 (referred to as “old plots”) in which vegetation was removed from one plot in each pair (referred to as “manipulated”) at the end of the 2009 breeding season; and 2) to delineate and conduct observations on 30 new pairs of 100 m^2 plots (referred to as “new plots”). After Crested Auklet observations were completed at the end of the 2010 breeding season, vegetation was removed from one of the plots in each of the 30 new plot pairs. Measures of Crested Auklet numbers, surface activity and visible nests were completed on the four original plot pairs and 30 new plot pairs, with the number of breeding pairs also estimated on each of the old plots.

The results of two independent census techniques, imagery obtained by time-lapse cameras and estimation of total individuals using capture-mark-recapture (CMR), indicated a substantial increase in Crested Auklet numbers on the old plots in 2010 compared to 2009. The percentage increase was 359% based on time-lapse imagery and 476% utilizing CMR. Overall, both techniques suggested a larger increase on the unmanipulated (control) plots. Estimated number of breeding pairs on the 8 old plots increased by approximately 75%. The substantial increase in numbers occurred despite the old plots being inadvertently established in areas with pre-existing very high densities of Crested Auklets.

While overall there was an increase in the number of breeding pairs per plot, calculated by CMR data, the results were mixed for evidence of an effect due to vegetation removal. Two of four old plot pairs showed an increase in the estimated number of breeders on the manipulated half, and three of four on the control half. The CMR derived estimates (of numbers of birds on the surface and breeding pairs) had

very large confidence limits due in part to the high bird numbers in both years relative to the our sample size of marked individuals. While this decreases the value of these measurements in assessing the effects of the habitat manipulation, the uniform increase in surface birds for all plots indicates a consistent result, and one supported by the independent time-lapse imagery.

The number of occupied Crested Auklet nest crevices visible from the surface showed a decrease on both control and manipulated plots between 2009 and 2010, while Least Auklet (*Aethia pusilla*) nests remained unchanged on control plots and increased by 40 percent on manipulated plots. Interpretation of changes in auklet nests visible from the surface is complicated as the majority of nests are located in inaccessible subterranean cavities not visible from the surface. Thus, the decrease in Crested Auklet nests observed could be due to pairs moving to deeper less accessible nests while the increase in Least Auklets, which occupy more shallow cavities than Least, could be the result of the vegetation removal and decreased competition from Crested Auklets. These differences may also have been affected by differences in searcher efficiency, since the individuals comprising the field crew in 2010 differed from those comprising the field crew in 2009.

Breeding success of visible Crested Auklet nests did not differ between control and manipulated plots in 2010, suggesting that the removal of vegetation or peat had no deleterious (via e.g., disturbance) effect on auklets breeding near the colony's surface.

The 30 new plot pairs delineated and monitored in 2010 supported lower numbers of Crested Auklets than the old plots (before manipulation in 2009) based on time lapse imagery (mean maximum counts of 9 vs 15 per plot), and crevice nest counts (mean counts of 14 vs 80 per plot) and thus have high potential for manipulation-driven increases due to their dense cover of vegetation and peat.

The results from 2010 are noteworthy for demonstrating a large increase in numbers of Crested Auklets occupying plots compared to 2009, but confounded by increases on both manipulated and unmanipulated plots, precluding confirmation of vegetation removal as the cause of the increase. The increase in numbers might relate to interannual differences in colony attendance or prospecting birds, but given the direct juxtaposition of the “manipulated” and “unmanipulated” plots in a plot pair it may be that unmanipulated plots experienced an increase due to their proximity to vegetation removal that attracted birds to a general area and that removal of surface vegetation provided access to underground cavities and tunnels far larger than the area where vegetation was removed. Fieldwork in 2011 should help to sort out the importance of vegetation removal versus interannual population factors in the observed increase as it will provide a second year of post-manipulation observations from the four old pairs of plots and the initial post-manipulation observations from the 30 pairs of new ones. Enhanced measurement of Crested Auklet movement into the new plots, recruitment and local breeding and quantification of the number of additional birds resulting from vegetation modification will be the focus of new activity in 2011.

Introduction

Counting Crested and Least Auklet numbers and assessing population changes at their breeding colonies is difficult. Most auklet breeding sites (nests) are located in inaccessible rock crevices that can neither be observed nor counted although at most sites at least some nests are visible (Jones 1993a,b). Birds are visible standing on the surface of the colony site during daily activity periods during the breeding season (Jones 1993a,b), with some individuals in a local population present daily and others rarely or never visible on the surface. Many individuals taking part in 'surface activity' are non-breeding birds and transients (Jones 1992). Surface counts vary greatly and unpredictably from day to day, within the season, and between years, with the relationship to the local breeding population weak and difficult to define (Jones 1992, Gall 2002, Sheffield et al. 2006, Renner et al. 2010). Although surface counts provide a measure of auklet activity at a site, they are not a proxy for local population numbers or for numbers breeding (Jones 1992, Gall 2002, Sheffield et al. 2006, Renner et al. 2010). Two studies have argued that capture-mark-recapture approach should be the best means of quantifying numbers (Jones 1992, Sheffield et al. 2006), but this has never been tried on a large scale at multiple sites or experimentally. Capture-mark-recapture uses a known number of marked individual birds and the ratio of marked to unmarked birds observed later to estimate numbers within an area a breeding colony. Our 2009 study at Gareloi included multiple methods of assessing Crested Auklet numbers, including counts of visible nests and surface counts, in addition to capture-mark-recapture estimates of numbers of individuals frequenting and breeding on study plots.

In 2009, a before-after controlled impact (BACI) experiment was initiated at Gareloi Island to test whether removal of vegetation overgrowth and peat from parts of an auklet colony site would increase nesting opportunities for Crested Auklets (Conners and Jones 2009). Auklets (*Aethia* spp.) nest in rock crevices produced by coastal erosion (talus slopes and beaches) and in blocky and porous lava flows (http://www.mun.ca/serg/AAHab.html). In the Aleutian Islands, where most of Alaska's Crested Auklets nest, colony sites occur inland on recent lava flows and talus. Re-vegetation of exposed rock (plant succession -

http://www.mun.ca/serg/succession1.html) occurs within decades of a lava flow or rockslide produced by a seismic event, covering and eventually rendering sites unsuitable for auklet nesting activity by blocking access to crevices (Jones and Hart 2006). Auklet breeding is therefore limited by access to suitable naturally occurring crevices as they are unable to dig their own breeding sites. This is especially true in the Aleutians that are at the southern limit of auklet breeding and that have a mild wet climate that facilitates plant growth and limits exposed rock. Kiska Island (site of a major lava dome eruption during 1966-1968) has the largest patch of fresh lava of any auklet colony in the Aleutians, but has introduced Norway rats (*Rattus norvegicus*) that depredate Least and Crested Auklets, sometimes severely. Rat-free Gareloi Island (with many auklets nesting in lava from a 1938 eruption) has the next largest amount of suitable habitat, mostly covered with advancing vegetation (Jones and Hart 2006).

To evaluate the effectiveness of direct enhancement of breeding habitat structure at an active auklet colony, Crested Auklet activity was measured on eight representative 100 m^2 plots delineated at Gareloi in 2009. Plots were set up in pairs with each 100 m^2 plot directly abutting its partner, to allow for comparable manipulated and control sections in our experiment. A total of 614 Crested Auklets were colour banded, and surface counts measuring the ratios of banded to unbanded birds and breeding to non-breeding birds were completed prior to vegetation and peat removal from one plot in each plot pair (randomly selected) at the end of the 2009 auklet breeding season (Conners and Jones 2009).

This report describes year two of a habitat modification project at Gareloi Island's auklet colony. This project was undertaken with the assumption that breeding habitat is limited at Gareloi due to encroaching vegetation, preventing some Crested Auklets from nesting (Jones and Hart 2006). Our research here aimed to test the hypothesis that the removal of encroaching vegetation, exposing new suitable breeding habitat at the colony site, will increase the number of breeding pairs and produce extra Crested Auklets.

In 2010, Crested Auklet fieldwork at Gareloi Island occurred during May 28 - August 6th and aimed to 1) re-measure auklet surface activity on the modified and control plots of each plot pair established in 2009; 2) re-measure numbers attending and breeding density of Crested Auklets at the same eight study plots by capture-mark-recapture (colour band re-sights, using the c.150 birds marked on each plot in 2009); 3) re-measure the comparative nesting density estimator by counting breeding sites visible using direct observation; and 4) establish 30 new plots on low density areas of the Gareloi southeast colony for an enlarged experiment, with pre-manipulation measurements of bird activity and visible nest numbers.

1.0 Methods

1.1 Assessment at 2009 study plots A, B, C and D

1.1.1. Capture-mark-recapture: population estimates

The eight plots set up in 2009 were named as follows – each pair of adjacent plots were given the same letter, the manipulated (vegetation-removed) side was identified by the subscript ‘m’ and the control (undisturbed) side was identified by the subscript ‘u’. For example, in the A plot pair, 10 m x 10 m plot Am was adjacent to 10 m x 10 m plot Au. To estimate the number of Crested Auklets frequenting each plot, we measured the ratio of banded to unbanded birds seen on the surface of each plot. As the number of individually marked birds present was also determined by observation, this ratio provides an estimate of the number of individual birds using each plot (subject to some simplifying assumptions). We conducted counts on four of the eight plots each day during June 8th – August 1st, except during high winds and rain, to obtain a mean value of the ratio that best reflected the true proportion of previously marked Crested Auklets on each plot. Counts of banded to unbanded individuals were taken every 10 minutes for four hours during the morning activity period (1100h - 1500h) from June 8th - August 1st and during 1.5 hours in the evening activity period (2100h - 0000h) from July 2nd - 13th. The number of Crested Auklet individuals using the surface of each plot ($N_{surface}$) was then estimated using the maximum count from each day as:

$N_{surface}$ = number marked and resighted at least once x (1/(mean decimal proportion observed marked during resighting activity))

1.1.2. Capture-mark-recapture: breeding population estimates

To estimate the number of breeding individuals using each plot, we also measured the ratio of banded to unbanded individuals. 'Breeders' were identified as Crested Auklets arriving at each study plot with a chick meal as indicated by the presence of a distended throat pouch. This method gives an indication of the number of individuals that successfully reached the chick rearing stage. Any marked individual seen delivering food at least once was identified as a 'breeder', and the total number of marked breeding individuals was determined for each plot by noting the presence of a chick meal being carried by a marked individual. Cumulative counts were performed continuously during four 30-minute intervals during the morning activity periods (1130h - 1200h, 1230h - 1300h, 1330h - 1400h, 1430h - 1500h) beginning July 2nd and ending August 1st.

The number of Crested Auklet individuals that reached the chick rearing stage ($N_{breeders}$) on each plot was estimated using the maximum count from each day as:

$N_{breeders}$ = number of marked birds seen delivering food at least once x 1/(mean decimal proportion of marked to unmarked birds delivering a chick meal)

For each plot, the number of active breeding sites (i.e., breeding pairs) that reached the chick rearing stage was thus estimated as half the number of individuals delivering chick meals.

Watches to look for birds delivering chick meals took place at somewhat different times in 2009 and 2010. In 2009, counts were performed during both morning and evening hours, while in 2010 counts focused on the daily peak of activity (1130-1500h). The discrepancy in time periods was inadvertent and unlikely to affect comparability of the measurements.

1.1.3. Capture-mark-recapture: resighting band combinations

In 2009, 614 Crested Auklets were banded with unique combinations of three color Darvik (PVC) leg bands on the eight study plots. In order to estimate the number of Crested Auklets using each plot we recorded all band combinations observed during the Crested Auklet activity period between 1100-1500h HADST, during June 8th - August 1st 2010, except during days of heavy rain and wind. For each marked bird we noted which half of the plot it was sighted within and whether it was carrying a chick meal.

1.1.4. Movement of marked Crested Auklets

We conducted an analysis of Crested Auklet inter-annual movement at the southeast colony site by determining the plots frequented by color-marked individual birds in 2009 and again in 2010. Only birds with a clear plot preference in a plot-pair (seen on only one plot in 2009) were used in the movement analysis, although we did record birds that frequented the border of adjacent plots. We tallied birds that returned to the same plot side (e.g., Am to Am), the same plot pair but and different side plot (e.g., Am to Au), and those that switched to an entirely different plot-pair between years (e.g., Am to Cu).

1.1.5. Crested Auklet nesting crevice counts and breeding success

Searchers attempted to locate visible Crested and Least Auklet active breeding sites (indicated by the presence of an incubating adult, or an egg in an appropriate location) were located within plot boundaries. Active sites that were located were marked on hand drawn maps following the 2009 procedures (see Conners and Jones 2009) on June 9th (Plot pair A), June 10th (Plot pair C), June 16th (Plot pair D), and June 17th (Plot pair B). These accessible, active breeding sites were rechecked once to evaluate hatching success on each half of the four study plots on July 11th (Plot pair A), July 13th (Plot pair B), July 10th (Plot pair C), and July 12th (Plot pair D). Crested Auklet hatching success was measured by the proportion of nests (with an egg or incubating adult) found that produced a nestling (as indicated by the presence of a living or dead nestling or hatched eggshells).

1.1.6. Crested Auklet surface counts at study plots (Reconyx cameras)

Four Reconyx time-lapse cameras were placed adjacent to plot pairs A, B, C, and D on June 5th in the same locations and with the same fields of view as in 2009 (Conners and Jones 2009). Cameras were programmed to make a digital image every five minutes between 0900-1500h HADST every day until July 25th. By viewing images, maximum auklet counts were recorded for each plot for each day of camera monitoring. Auklet surface counts are indicative of the amount of time birds were spending on the surface (Jones 1992) and the intensity of surface activity, but provide at best a weak indicator of the breeding population size. We scrolled through each day of photographs, choosing time periods with the highest number of birds present, counting the number of auklets. When the maximum number of birds was identified, the number for each species (Least and Crested) was noted. To compare between plot types (control versus manipulated) and years (2009 versus 2010) we used Generalized Linear Models with negative binomial distributions.

1.2 New plots delineated in 2010

1.2.1 Plot Selection

Low elevation portions of the Southeast colony were explored during the first week of June 2010 to identify and stake out 60 new 10m x 10m plots (i.e., 30 plot pairs with dimensions 10 m by 20 m). These plots were selected based on criteria that included: 1) little or no auklet activity, 2) high amounts of vegetation, and 3) presence of underlying lava or talus, as well as proximity to the previously surveyed southeast colony site (Jones and Hart 2006). We conducted observations at suitable locations during peak auklet activity (1100-1500h) to verify low surface activity on all potential plots prior to choosing them for delineation and study. Once locations were found to be suitable, each plot was delineated by marking the corner of each 10m by 10m plot with a painted wooden stake. Position fixes were taken using a handheld GPS instrument at the upper right hand corner of each 10m by 10m plot.

1.2.2. Crested Auklet surface counts at study plots (Reconyx cameras)

Eight new Reconyx time-lapse cameras, programmed to make a digital image every five minutes between 0900-1500h HADST, were rotated approximately every four days (weather dependant) among the 30 newly established plot pairs so the mean image date was the same for all plots. Cameras were placed on a tripod at a distance far enough to capture both control and manipulated plots (approximately 20 meters from the center of each 20m x 10m plot pair). All camera positions and orientations were fixed using a handheld GPS instrument, compass bearing, and tripod height (Table 1). At the end of the season, a stake with each respective plot and camera number was placed at the center of each tripod location. Each plot was photographed for approximately four days in June and four days in July (Table 2) and both Crested and Least Auklets were counted in each image. We distinguished Crested from Least Auklets based on size (Crested Auklets are much larger) and coloration (Least Auklets have white on the breast). Images from periods when fog or rain reduced visibility were discarded. We calculated the daily average and the maximum count of surface activity for each species on each plot.

1.2.3. Crested Auklet nesting crevice survey, new plots

To estimate the number of auklets breeding on each of the 30 new plot pairs delineated in 2010 we searched for visible Crested and Least Auklet active breeding sites (indicated by the presence of an incubating adult, or an egg in an appropriate location) were located within plot boundaries and marked their locations on hand drawn maps following 2009 procedures (see Conners and Jones 2009) during June 14th-21st.

1.2.4. Vegetation Analysis

To quantify extent of vegetation cover and suitable auklet habitat on each new plot, we estimated the approximate percent cover of all major plant groups or bare soil and rock during July 19th-21st. Most plants were identified to species and all unidentified species were photographed.

2. Results

2.1. Assessment of plots A, B, C, and D from 2009

2.1.1. Capture-Mark-Recapture: estimating number of individuals

During June 8th - August 1st 2010 we made 4058 counts of marked and unmarked Crested Auklet numbers, approximately 506 counts on each of the eight plots. Overall, there was an average of 0.13 marked birds and 10.58 unmarked birds present on the surface during each ten minute count. Within each plot, the mean proportion of marked birds standing on the surface was as follows: Am: 0.012, Au: 0.011, Bm: 0.031, Bu: 0.007, Cm: 0.021, Cu: 0.014, Dm: 0.007 and Du: 0.017 (Table 3). Thus, the mean number of individuals ± 95% confidence intervals using each plot ($N_{surface}$) were estimated (Table 3, Fig. 2). CMR estimates of the number of individuals present on each plot increased between 2009 and 2010 on all plots (averaging 226% on manipulated plots, 726% on control plots, Fig. 2), with very broad confidence limits on all estimates.

2.1.2. Capture-Mark-Recapture: estimating number of breeders

During July 2nd - August 1st, 2010 four half-hour continuous counts of all individuals landing on each plot were performed, resulting in 296 half-hour counts, approximately 37 half-hour counts on each plot. To obtain an estimate of the Crested Auklet pairs raising chicks, we made counts separating marked and unmarked individuals with and without chick meals. Overall there was an average of 2 marked and 49 unmarked birds arriving at the plots with chick meals during each half-hour count. Within each plot half the mean proportion of marked Crested Auklets arriving with a chick meal was: Am: 0.029, Au: 0.054, Bm: 0.094, Bu: 0.010, Cm: 0.069, Cu: 0.061, Dm: 0.058, and Du: 0.042 (Table 3). Thus, the mean number of individuals ± 95% confidence intervals that successfully hatched chicks ($N_{breeders}$) was estimated (Table 3). CMR estimates of $N_{breeders}$ increased on some plots and decreased on others (averaging a 9% increase on manipulated plots and a 351% increase on undisturbed plots, Fig. 3), with broad confidence limits on all estimates. The large increase on the undisturbed plots was influenced by a massive increase (1400%, possibly anomalous) on plot Du. If we assume a productivity level of 0.5 (chicks fledged per nest per breeding season, Major et al. 2006), Crested Auklet chick production at the four study plots would be Am: 140, Au: 87, Bm: 131, Bu: 205, Cm: 72, Cu: 61, Dm: 113, and Du: 129 (based on CMR derived estimates of breeding pairs), or an average of 117 chicks fledged per 100 m^2 of colony surface area, or 114 and 120 chicks fledged per 100 m^2 of colony surface on the modified and unmodified sides of a plot pair.

2.1.3. Capture-Mark-Recapture: Resighting and movement of marked birds

In 2009 a total of 614 adult Crested Auklets were trapped and marked with unique combinations of three colored leg bands. During June 8th-August 1st 2010 we resighted a total of 267 (43%) band combinations more than one time (Appendix 1), of these resighted individuals a total of 157 (59%) were seen carrying a chick meal (Table 3). Most color-marked Crested Auklets seen in both 2009 and 2010 were seen on the same plot on which they were originally marked, but some moved (Table 4). On average, 83% of birds on unmanipulated plots stayed on the same plot, and 85% of birds on manipulated plots stayed. A total of 7 birds (5% of birds seen in both years) moved to a completely different plot pair between years (3 to unmanipulated sub-plots and 4 to manipulated sub-plot sides). A total of 11 birds (8% of bird seen in both years) moved within plot pairs, 9 from the unmanipulated side to the manipulated side and 2 from the manipulated side to the unmanipulated side. A total of 24 of the 309 birds located in 2009 (8%) occurred on both sides of a plot pair (e.g. Am and Au).

2.1.4. Crested Auklet nesting crevice counts and hatching success

Following procedures outlined in Conners and Jones (2009), we searched for visible active breeding crevices within each of the eight plots and recorded the contents of each. To compare the densities of breeding birds we present our data in comparison with those breeding crevices found in 2009. Overall we found between 34-100 active breeding crevices on each of the plots, with the majority of those crevices being occupied by Crested Auklets (Table 5). To control for searching effort between years and among plots we calculated the proportion of Crested Auklet nesting crevices within each plot and compared that proportion between the control and manipulated plots

(Table 6). In general, the ratios between the control and manipulated plots were not highly different, but the ratios suggest that Crested Auklet nesting density was highest in the manipulated plots, except in the case of plot C; but did not change between 2009 and 2010. Hatching success was calculated for each of the eight plots. Overall, hatching success ranged between 0.55 - 0.78 and did not differ between manipulated and control plots (mean: 0.64 manipulated, 0.69 control; Tables 7-8).

2.1.5. Crested Auklet surface counts at study plots (Reconyx cameras)

In 2010, we recorded maximum surface counts using four cameras placed in the same locations as 2009. On average, in 2010 there were more Crested Auklets observed on plots Au, Bu, Cm, and Du than in 2009, with mean seasonal counts of 22.9 ± 9.8, 36.8 ± 18.3, 23.3 ± 14.6, and 19.3 ± 9.8 (Table 9, Fig. 3). For plot pair A, in 2009, surface activity was greater on the manipulated plot, whereas in 2010 activity was greater on the unmanipulated plot (Table 9). For plot pair C, in 2009 surface activity was greater on the unmanipulated plot, whereas in 2009 activity was greater on the experimental plot. There was a significant difference in maximum surface count on unmanipulated and manipulated plots in 2010 ($G = 36.4$, $df = 1$, $p < 0.001$), with more birds observed on unmanipulated plots (25.5 ± 0.41 versus 22.2 ± 0.36 on manipulated plots). However, there was also a significant interaction between plot type (unmanipulated versus manipulated) and the plot pair (A, B, C, D) therefore this observed effect was different for each plot. There was also a significant increase in the number of birds observed in 2010 versus 2009 ($G = 68.6$, $df = 1$, $p < 0.001$, 19.9 ± 1.8 in 2010 versus 6.6 ± 0.63 in 2009). However there was no significant interaction between plot type (unmanipulated and manipulated) and year, therefore there was no clear trend dependent on plot type.

2.2 New plots

2.2.1. New plot selection

We established and monitored 30 new plot pairs prior to vegetation removal from half of these plots at the end of the 2010 breeding season. We selected 20 plot pairs along the southern limits of the north-eastern portion of the colony, called “Plots 1-20N”. The southern limits of this portion of the colony had very low surface activity, but surround a central portion with high activity. Plot pairs were in groups of five, with alternating orange and red stakes for each adjacent plot pair. We selected six plot pairs around a northern mid-elevation volcanic crater, called “Plots 1-6U”. The edge of the crater had very low surface activity, while activity within the crater was very high. Finally, we selected 4 plot pairs close to 2009 plot pairs A, B, C, and D within the southern portion of the colony, called “Plots 1-4S”. These plot pairs had relatively low surface activity compared to the denser colony directly west. Plot locations are shown on a topographical map (Fig. 1) and on hand-drawn diagrams (Appendix C).

2.2.2. Surface counts

Each new plot pair at the northeastern portion of the colony was photographed for four days in June and four days in July. New plot pairs at the northern crater and around 2009 plot pairs were photographed for eight days in June and eight days in July (Table 2). Plot pairs with the highest level of Crested Auklet surface activity include 11 N, 2U, and 13N with a average count of 4.87 ± 7.29, 4.68 ± 7.05, and 3.75 ± 5.74 Crested Auklets per five minutes and maximum count of 45, 87, and 45 respectively (Table 10).

2.2.3. Crested Auklet nests

Following procedures outlined in Conners and Jones (2009) we located and mapped all accessible, active breeding crevices on each of the 60 new plots delineated in 2010. Overall, there were relatively few active crevices located within these plots. The largest number of Crested Auklet crevices were located within plots at the south colony (mean=10, range=0-28), slightly smaller numbers were observed at the north colony (mean=7, range=0-34), while the fewest active crevices were found at the upper colony sites (mean=4, range=0-11; Table 11).

2.2.4. Vegetation analysis

Within each of the 60 new plots delineated in 2010 we examined both adjacent 10m x 10m meter plots in a plot pair for percent cover of all plant species, and exposed rock or soil. We found very low levels of exposed rock or soil, with a maximum of 15% cover of each. All plots were covered, for the majority, by the grass *Calamagrostis* sp. and other species of grasses and ferns. Grass was present over underlying volcanic rock usually in tussocks, between each grass tussock moss and lichen were present along with intermittent soil and herbs such as *Stellaria* sp. and *Claytonia sibirica* (Appendix 2).

3. Discussion

During year two of the habitat modification study at Gareloi Island's southeast auklet colony the field crew successfully collected the first results assessing the response of Crested Auklets to experimental removal of surface vegetation and peat from four plot pairs on a high auklet density area. Because previous studies (Jones 1992, Gall 2002, Sheffield et al. 2006, Renner et al. 2010) have identified capture-mark-recapture as a useful method for assessing auklet numbers, fieldwork in 2009 and 2010 emphasized this approach, but surface counts and visible nest counts were also employed. Observations were made on eight plots delineated, surveyed and monitored (surface counts, nest counts, and vegetation cover) in 2009. Four of these (randomly selected) underwent removal of surface vegetation and peat after the 2009 auklet breeding season (Conners and Jones 2009). In 2010 we also successfully delineated, monitored and surveyed 30 new plot pairs located at three locations along the edges of the auklet nesting colony. Each of the new plot pairs had one plot devegetated in August 2010, after the auklet breeding season activity had ceased.

Here we assess the cumulative implications of our experiments and observations based on the 2009 and 2010 results. Briefly:

- It is apparent that the usefulness of our capture-mark-recapture approach was limited by the low (averaging 5%) proportion of marked Crested Auklets at the four very high density plot pairs selected in 2009, leading to broad confidence limits on estimates of numbers.
- The apparent increases in both breeding and nonbreeding Crested Auklets on all plots (Figs. 2-3) are consistent with the nesting habitat exposed by vegetation

removal attracting birds, although other explanations are possible.

- Increases in bird numbers (Figs. 2-3) on both the manipulated and undisturbed plots indicates either that the area affected by vegetation removal is larger than anticipated in our experimental design, or that there was a general increase in numbers at the colony site between years unrelated to our experiment.
- Substantial increases in numbers were observed in 2010 even though the experimental plots were established in areas of the colony with pre-existing high densities of Crested Auklets.
- The observed changes in the number of accessible (visible from the plot's surface) auklet nests on both manipulated and undisturbed plots indicates vegetation removal may allow Crested Auklets to move to deeper cavities with a resulting increase in surface Least Auklet nests due to decreased nest-site competition.
- Reproductive success was high on the disturbed (vegetation-removed) sites, indicating no deleterious effect of our habitat manipulation.
- Fieldwork in 2011 will help determine if the increase in numbers observed in 2010 was due to the vegetation removal, and not an unrelated interannual variation in colony numbers or attendance, by providing one more year of observations from the eight old plots and the first year of post-manipulation monitoring for the 60 new plots.

3.1. Number of individuals and breeders present on plots

There was a substantial increase in the number of Crested Auklets occupying and breeding on the experimental plot pairs in 2010 compared to 2009 (Table 3, Figs. 2-3). The capture-mark-recapture data indicated that the number of individuals visible and standing on the surface on all plots increased by an average of 476% while the number of breeding pairs increased by an average of 180%. Unfortunately, due to the low (averaging c. 5%) proportion and variance in the observed proportions of marked birds standing and delivering food used in the capture-mark-recapture calculations, the confidence limits on our estimates are very large and the differences between years are likely not statistically significant. A more precise and consistent measure of auklet numbers would have been achieved had the proportion of banded birds been between 25% and 50% of the birds present, a proportion anticipated with 650 birds marked on 8 low density 10 m by 10 m plots. Unfortunately the marks were deployed at 8 extremely high density plots. However, an overall increase in the number of birds occupying the plots is supported by the independent data obtained with time-lapse cameras that indicated an increase of 360% in surface counts on the same plots. These latter direct counts of standing individuals are not vulnerable to the same computational drawbacks of the capture-mark-recapture estimates, although surface activity has a less direct relationship to absolute numbers (Jones 1992, Gall 2002, Sheffield et al. 2006, Renner et al. 2010). Taken together, these results suggest that a larger number of Crested Auklets occurred on all plots in 2010 than in 2009, while the capture-mark-recapture suggests an increase in number of breeders on five of the eight plots.

Both manipulated and unmanipulated plots experienced increases in individuals, with neither the capture-mark-recapture estimates nor the time-lapse images showing a difference in response by plot treatment (vegetation-removed versus undisturbed 'control' plots, Table 3). Nevertheless, the uniform response at both manipulated and undisturbed plots (e.g., Fig. 2) is consistent with a positive effect of the vegetation removal experiment if the manipulations attracted birds to both manipulated plot as well as adjacent areas. Our 2009 experimental design used pairs of abutting 10 m by 10 m plots, one destined to be manipulated and the other as an undisturbed control, to ensure the comparability of pairs of plots at a colony site with highly variable substrate characteristics across the terrain. The weakness of this design, apparent in 2010, is that auklets attracted to manipulated plots could spill over onto adjacent control plots, making the experimental results less clear. While some plot pairs displayed a differential response in numbers for the two plots there was no consistent pattern. A slightly higher level of Crested Auklet activity increase between 2009 and 2010 was observed on control plots Au and Bu, while on plot C, the activity increase was 3.5x greater on the manipulated (vegetation-removed plot half). Taken altogether, the results are consistent with vegetation removal causing greater overall activity (if the increase spills across adjacent plots), but the full BACI comparison is equivocal on this point. The results are also consistent with a colony wide increase in numbers between 2009 and 2010 resulting from natural processes unrelated to our experiment.

A possible “large area” attraction versus a “plot specific” attraction exposed a flaw in the experimental design of the Gareloi BACI experimental design (Conners and Jones 2009) that aimed to examine the relative change in surface attendance between adjacent control and manipulated plots and assumed a more spatially limited response. The experiment also failed to anticipate the potential changes in surface activity when access is provided to a large volume of subterranean nesting cavities, more than just the cavities immediately below a manipulated plot, through elimination of obstructing vegetation on a relatively small area. Nevertheless, the abutting plot pair design did benefit from the similarity of physical substrate (extruded lava) on plots in a pair. If non-abutting plots had not been used, their comparability in the experimental manipulation of surface vegetation and peat would have been limited.

It is important to note that the observed increases occurred (Table 3, Figs. 2-3) despite the fact that the study plots already supported high densities of Crested Auklets. Our original aim in 2009 was to select study plots with moderate to low numbers of Crested Auklets – areas that would maximally benefit from habitat manipulation. Instead, we inadvertently selected very high density plots – swamping our cohort of 651 marked birds and limiting the precision of the capture-mark-recapture estimates of numbers. If the observed increase in Crested Auklet numbers between 2009 and 2010 was related to our vegetation manipulation, then the results suggest that even high density sites can benefit. The 30 new plots delineated in 2010 will demonstrate the response of auklets to vegetation removal in lower density areas compared to the 2009 plots.

3.2. Active breeding site counts

While the observations of adult birds suggested a considerable increase in Crested Auklets at our study plots from 2009 to 2010 (Table 3, 9, Figs. 2-3), the number of Crested Auklet active-occupied nest crevices accessible and visible from surface counts declined while the number of Least Auklet nest crevices increased (Table 5). On the unmanipulated (no vegetation change) plots visible Crested Auklets decreased and

Least Auklets remained unchanged. On the manipulated (vegetation removed) plots Crested Auklet visible nests declined while Least Auklet nests increased by 40%. While this decrease in visible nests appears at odds with the increases in surface activity, it could be due to the Crested Auklet pairs abandoning surface nests for more optimal subterranean nests. At most auklet colonies, such as the colony at Sirius Point, Kiska Island, Crested Auklets prefer subterranean nests to surface nests while Least Auklets prefer shallower more visible (to human searchers) breeding sites (Jones 1993a,b). If our 2009 removal of vegetation exposed openings to more desirable subterranean nests, Crested Auklets that had been using shallower crevices near the overlying vegetation may have abandoned their near-surface nests, allowing Least Auklets to move in (Table 5).

3.3. Breeding success

Productivity did not differ between control and manipulated plots in 2010 (Table 7), suggesting that the removal of vegetation or peat had no deleterious (via e.g., disturbance) or enhancing (not expected) effects on the ability of Crested or Least Auklets to incubate eggs to hatching. This is very good news in relation to the applicability of vegetation removal to auklet population enhancement.

3.4. Movement

The data on movement of marked birds indicates that individuals seen in both 2009 and 2010 tend to remain on the same plot with little movement to adjacent plots (Table 4). However, a high proportion (56% overall) of birds marked in 2009 were not seen again, a higher proportion that recorded at other Aleutian auklet colonies where color-marking projects are underway (Buldir and Kiska, ILJ). The best explanation for this is that surface standing birds at our plots at Gareloi (i.e., those likely to be caught in noose carpets) included a high proportion of non-breeding, transient, prospecting birds. This is consistent with Jones and Hart's (2006) suggestion that breeding sites at Gareloi are limiting – leading to a higher proportion of 'homeless' birds that show up in the color-marking study as transients. Alternatively or in addition, the deep subterranean structure of the lava flow and high breeding density at our 2009 Gareloi study plots could have made marked individuals difficult to resight. Although frustrating in that the phenomenon reduced our effect sample of marked individuals on plots, the result does indicate the presence of an abundance of birds looking for breeding sites – that would likely benefit from our habitat enhancement scheme.

3.5. New plots

The 2011 monitoring of the sixty new plots delineated in 2010 should provide a better test of the effects of vegetation removal on nesting densities because of their lower pre-manipulation numbers and also because they provide a larger and more diverse sample of plots than the four 2009 plot pairs. Unfortunately, capture-mark-recapture is not a viable method at such a large number of separate plots. Instead, we propose to make inferences about responses to vegetation removal from surface counts and visible nest counts, despite the limitations of these techniques.

4. Conclusions

The first year of post-manipulation observations on Gareloi, experimentally testing the utility of increasing Crested Auklet nesting pairs through removal of vegetation obstructing nesting habitat, are equivocal. Although there was considerable evidence for substantial increases in auklet numbers, no consistently greater increase in bird numbers occurred on manipulated sites compared to the undisturbed control sites in the experiment. However, the possibility of a ‘spill-over’ effect from manipulated areas to undisturbed control areas on the paired plots suggested that removal of vegetation might significantly increase numbers of Crested Auklets in the vicinity of the area manipulated and that numbers of breeding pairs may also increase. The area extent of the region of a colony that is affected by the removal of vegetation may have been much larger than originally anticipated and as a result we were unable to monitor changes from 2009 to 2010 on a truly “undisturbed” plot, due to the direct juxtaposition of “manipulated” and “unmanipulated” plots. Adjustments to the 2011 protocol will include Reconyx camera measurement of activity on areas immediately adjacent to devegetated areas, to detect such a ‘halo’ effect if it indeed is occurring.

The surface population estimates from 2009 and 2010 suggest that both the numbers and proportion of non-breeders increased from 50% to 80% between the two years. If this increase is a measure of birds prospecting the newly exposed nesting habitat then there should be a substantial increase in the number of breeding birds on old plots in 2011 and would indicate that the increased productivity expected from the restoration technique begins in the second summer after vegetation removal.

The data obtained in 2011, providing a second year of post-manipulation data for the old plots and the first year of post-manipulation data for the 60 new plots, will be essential for interpreting increases observed in 2010 and for determining the feasibility of vegetation removal as a restoration option. Data obtained in 2010 underlined the difficulties inherent in counting auklets and demonstrated the problems with quantifying the effects of a surface manipulation of known size that provides access to a volume of nesting crevices of unknown size. While vegetation removal appears to result in an increase in the number of birds breeding in an area, there is a need to quantify the results of the habitat manipulation in order to provide an estimate of the area of habitat that will need to be manipulated to restore the birds lost in the spill.

The ultimate questions being addressed in this study, are: 1) can vegetation modification in and near the auklet colony site at Gareloi Island provide extra breeding opportunities for Crested Auklets (i.e., provide breeding sites for pairs otherwise unable to breed)?, and if yes, 2) what area of vegetation might need to be modified to produce a required number of extra breeding sites? Our results thus far suggest that the answer to question 1 is quite likely yes (based on 2009-2010 increases in different independent measures of Crested Auklet numbers on and near devegetated areas), although more years of monitoring are required to measure a lasting impact of our experimental treatment. Assuming the answer to 1) does turn out to be yes, calculating how much area needs to be devegetated to make breeding opportunities for an additional 1000 pairs can be estimated, with the usual caveats that apply to any attempt to measure auklet numbers. Jones and Hart's (2006) survey estimated the proportion of 10 m by 10 m plots of different density present at the Southeast Colony at Gareloi Island. Among plots classified as occupied, 85 plots in the Southeast Colony were scored as high density (>100 occupied breeding sites), 41 as medium density (10-100 occupied breeding sites) and 171 as low density (1-10 occupied breeding sites; Jones and Hart 2006). Our capture-mark-recapture fieldwork in 2009 and 2010 at the 2009 plot-pairs A-D (similar to high density plots in the 2006 survey) suggested that the density of pairs per 100 m^2 averaged 286 in the year after devegetation (Table 3). Assuming that devegetation an unoccupied or low occupancy area of the Southeast Colony site makes breeding opportunities for only an additional 143 pairs per 100 m^2 (conservatively, half the density of high density site like plot-pairs A-D), seven 100 m^2 plots would have to be devegetated for each 1000 additional pairs. This latter estimate is based on the following assumptions: 1) the areas selected for devegetation have underlying substrate similar to high density areas of the auklet colony, 2) previously non-breeding pairs that would otherwise not breed move into the new sites and begin breeding with a few years, and 3) movement of previously breeding pairs into the new habitat is minimal. If these assumptions were met, this line of thinking suggests that devegetating 70 carefully selected 100 m^2 plots could provide for an additional 10^5 breeding pairs or about 50,000 additional Crested Auklet chicks (assuming productivity of 0.5).

Recommendations for 2011

- Collect Reconyx memory cards at least every two weeks and analyze continuously throughout the season.
- Each plot pair should have two Reconyx cameras; one focused on the control the other the manipulated plot.
- Additional Reconyx cameras should be placed to cover areas adjacent to the 30 new plots devegetated in 2010, to measure any 'halo' or spill-over effect onto areas beside devegetated areas.
- To accurately estimate reproductive success for comparison between the control and manipulated plots of each plot pair, a subset of crevices should be marked and monitored for both hatching and fledging success following the protocol presented by Major et al. (2006).
- For comparison, a set of marked crevices outside the manipulated plots should be monitored for reproductive success (perhaps a plot in a high density and one in a low density area).
- Bright blue paint pens work best, yellow and red tend to fade and blend with guano and spilled food loads late in the season
- Cameras on 2009 plots are redundant with the 10 minute counts completely during resighting (could these cameras be moved to monitor some of the 30 new plots manipulated in 2010?)
- New desiccant is required for 2011, perhaps reusable, desiccant should be changed at least once a week

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Table 1 Location of new, low density Crested Auklet plot pairs established in 2010 and the location and orientation of Reconyx cameras, at Gareloi Island, Alaska.

	Plot pair				**Reconyx Camera**			
	Latitude	**Longitude**	**Elevation (ft)**	**Accuracy (ft)**	**Latitude**	**Longitude**	**Height (")**	**Bearing (˚)**
1U	51°45.543	178°45.845	168	6	51°45.542	178°45.828	41	320
2U	51°45.558	178°45.830	173	6	51°45.478	178°45.936	33	310
3U	51°45.562	178°45.822	161	6	51°45.482	178°45.922	41	310
4U	51°45.563	178°45.800	145	6	51°45.470	178°45.900	42	40
5U	51°45.517	178°45.784	148	6	51°45.461	178°45.899	37.5	182
6U	51°45.540	178°45.892	174	6	51°45.544	178°45.878	39.5	226
1S	51°45.321	178°45.336	30	2	51°45.256	178°45.551	n/a	n/a
2S	51°45.316	178°45.354	31	4	51°45.242	178°45.452	n/a	n/a
3S	51°45.318	178°45.395	31	3	51°45.334	178°45.403	n/a	n/a
4S	51°45.337	178°45.464	29	4	51°45.331	178°45.431	n/a	n/a
1N	51°45.718	178°45.523	90	8	51°45.670	178°45.684	44.5	308
2N	51°45.722	178°45.536	91	8	51°45.685	178°45.669	35	208
3N	51°45.731	178°45.550	90	3	51°45.678	178°45.657	18	209
4N	51°45.736	178°45.561	87	3	51°45.672	178°45.646	37.5	215
5N	51°45.739	178°45.576	87	4	51°45.666	178°45.634	39	206
6N	51°45.696	178°45.490	84	3	51°45.644	178°45.593	45	219
7N	51°45.672	178°45.492	89	5	51°45.602	178°45.578	43	296
8N	51°45.664	178°45.501	83	4	51°45.591	178°45.582	49	279
9N	51°45.654	178°45.504	83	5	51°45.580	178°45.590	33.63	300
10N	51°45.645	178°45.508	85	6	51°45.571	178°45.592	41	304
11N	51°45.604	178°45.555	83	8	51°45.522	178°45.638	45	317
12N	51°45.601	178°45.556	97	3	51°45.519	178°45.649	42.5	322
13N	51°45.592	178°45.571	110	4	51°45.509	178°45.664	45	344
14N	51°45.585	178°45.592	108	3	51°45.513	178°45.661	36.25	336
15N	51°45.581	178°45.604	105	3	51°45.497	178°45.705	34	340
16N	51°45.572	178°45.662	122	4	51°45.483	178°45.767	35.5	352
17N	51°45.570	178°45.680	119	3	51°45.482	178°45.783	33	349
18N	51°45.570	178°45.697	126	4	51°45.481	178°45.795	36	344
19N	51°45.569	178°45.714	123	5	51°45.482	178°45.816	41.5	344
20N	51°45.571	178°45.723	128	6	51°45.689	178°45.703	37	350

Table 2: Start and end recording dates for each camera placed at each of 30 new plot pairs in 2010, at Gareloi Island, Alaska

Plot pair	Camera	Round 1				Round 2			
		Start	End	Start	End	Start	End	Start	End
1U	H	Jun-07	Jun-15	Jun-22	Jun-26	-	-	Jul-19	Jul-22
2U	G	Jun-15	Jun-18	-	-	Jul-11	Jul-14	-	-
3U	H	Jun-15	Jun-18	-	-	Jul-11	Jul-14	-	-
4U	G	Jun-19	Jun-22	-	-	Jul-01	Jul-05	Jul-15	Jul-18
5U	H	Jun-19	Jun-22	-	-	Jul-01	Jul-05	Jul-15	Jul-18
6U	G	Jun-06	Jun-14	-	-	Jul-06	Jul-10	Jul-19	Jul-22
1S	E	Jun-15	Jun-18	Jun-26	Jun-30	Jul-06	Jul-09	Jul-14	Jul-18
2S	F	Jun-15	Jun-18	Jun-26	Jun-30	-	-	Jul-14	Jul-18
3S	E	Jun-06	Jun-14	Jun-18	Jun-26	Jun-20	Jul-05	Jul-09	Jul-13
4S	F	Jun-07	Jun-13	Jun-18	Jun-25	Jun-30	Jul-05	Jul-09	Jul-13
1N	A	Jun-06	Jun-14	-	-	Jul-01	Jul-05	-	-
2N	A	Jun-14	Jun-18	-	-	Jul-19	Jul-22	-	-
3N	A	Jun-19	Jun-22	-	-	Jul-15	Jul-18	-	-
4N	A	Jun-22	Jun-26	-	-	Jul-11	Jul-14	-	-
5N	A	Jun-27	Jun-30	-	-	Jul-07	Jul-10	-	-
6N	B	Jun-06	Jun-14	-	-	Jul-01	Jul-05	-	-
7N	B	Jun-14	Jun-18	-	-	Jul-06	Jul-09	-	-
8N	B	Jun-19	Jun-22	-	-	Jul-10	Jul-14	-	-
9N	B	Jun-22	Jun-26	-	-	Jul-15	Jul-18	-	-
10N	B	Jun-27	Jun-30	-	-	Jul-19	Jul-22	-	-
11N	C	Jun-06	Jun-14	-	-	Jul-01	Jul-05	-	-
12N	C	Jun-14	Jun-18	-	-	Jul-06	Jul-10	-	-
13N	C	Jun-19	Jun-22	-	-	Jul-11	Jul-14	-	-
14N	C	Jun-22	Jun-26	-	-	Jul-15	Jul-18	-	-
15N	C	Jun-27	Jun-30	-	-	Jul-19	Jul-22	-	-
16N	D	Jun-06	Jun-14	-	-	Jul-01	Jul-05	-	-
17N	D	Jun-14	Jun-18	-	-	Jul-06	Jul-10	-	-
18N	D	Jun-19	Jun-22	-	-	Jul-11	Jul-14	-	-
19N	D	Jun-22	Jun-26	-	-	Jul-15	Jul-18	-	-
20N	D	Jun-27	Jun-30	-	-	Jul-19	Jul-22	-	-

Table 3. BACI experiment population parameters for plot pairs A-D at Gareloi Island Alaska in 2009 and 2010, based on Capture-Mark-Recapture (CMR) methods.

	BEFORE						AFTER					
Plot	2009 marked CrAus resighted ≥1 time[1]	Observed proportion standing that were banded	2009 $N_{surface}$	2009 marked CrAus sighted with food ≥1 time	Observed proportion with food that were banded	2009 $N_{breeders}$	2010 marked CrAus resighted ≥1 time	2010 Observed proportion standing that were banded	2010 $N_{surface}$ (% change)	2010 marked CrAus sighted with food ≥1 time	2010 Observed proportion with food that were banded	2010 $N_{breeders}$ (% change)
Am	53	0.0117	2615 ± 1161	37	0.0412	954±268	33	0.0115	4440±3454 (+70)	21	0.0286	560±242 (-41)
Au	41	0.0707	1779 ± 1613	22	0.0708	339±109	33	0.0112	6568±4923 (+269)	16	0.0541	346±318 (+2)
Bm	34	0.0331	690 ± 450	21	0.0547	441±187	44	0.0312	2715±2674 (+293)	33	0.0944	523±523 (+19)
Bu	24	0.1818[2]	242[2]	13	0.0253	727±365	20	0.0066	4269±5597 (+1664)	11	0.0103	821±390 (+13)
Cm	37	0.0548	892 ± 780	16	0.0304	513±230	36	0.0214	3445±5518 (+286)	14	0.0689	286±171 (-44)
Cu	28	0.1171	567 ± 464	21	0.0866	268±86	28	0.0143	3093±3755 (+446)	16	0.0605	242±162 (-10)
Dm	22	0.0239[2]	1422[2]	4	0.023	225±216	34	0.0074	5025±3460 (+253)	20	0.0584	452±246 (+101)
Du	63	0.0919	1132 ± 1042	14	0.0556	90±59	64	0.0170	7063±7391 (+524)	30	0.0423	1351±2024 (+1401)

[1]Some marked birds were seen and counted on both members of a plot pair, these birds are counted only once in the total band combinations seen within each of the four study plot pairs.
[2]Based on a limited proportion estimate – reliability is low.

Table 4: Movement during 2009-2010 of Crested Auklets individually color-marked in 2009 at Gareloi Island, Alaska.

plot	birds seen 2009	seen both years	stayed on plot 2009-2010	%	moved to a different plot 2009-2010	%	moved to a different subplot 2009-2010	%
Am	44	18	14	78	4	22	0	0
Au	34	21	19	90	0	0	2	10
Bm	33	20	20	100	0	0	0	0
Bu	24	11	8	73	0	0	2	18
Cm	35	16	15	94	1	6	0	0
Cu	25	16	12	75	2	13	2	13
Dm	13	6	4	67	0	0	2	33
Du	55	39	36	92	0	0	3	8

Table 5. Comparison of Crested and Least Auklet active breeding site (nest) counts at plot pairs A,B,C and D between 2009 and 2010, at Gareloi Island, Alaska

	2009				2010					
Plot	**CrAu**	**LeAu**	**Unknown sp.**	**Total**	**CrAu**	**LeAu**	**Unknown sp.**	**Total**	**CrAu % change**	**LeAu % change**
Am	75	31	13	119	34	10	0	44	-55	-68
Au	63	21	8	92	24	9	1	34	-62	-57
Bm	55	10	7	72	53	26	21	100	-4	+160
Bu	42	12	12	66	37	28	0	65	-12	+133
Cm	50	30	2	82	26	16	3	45	-48	-47
Cu	34	10	2	46	36	4	9	49	+6	-60
Dm	108	13	13	134	68	28	2	98	-37	+115
Du	108	27	8	143	43	23	15	81	-60	-15

	CrAu % change	LeAu % change
overall mean	-34	+20
mean for control	-32	0
mean for manipulated	-36	+40

Table 6. Comparison of the ratio of Crested Auklet nests between 2009 and 2010 and among the eight plot halves, at Gareloi Island, Alaska.

Plot	**2009**		**2010**	
	CrAu	**LeAu**	**CrAu**	**LeAu**
Am:Au	1.06:1.00	0.85:1.00	1.06:1.00	0.83:1.00
Bm:Bu	0.92:1.00	1.44:1.00	1.18:1.00	0.76:1.00
Cm:Cu	0.81:1.00	1.65:1.00	0.69:1.00	3.81:1.00
Dm:Du	1.12:1.00	0.54:1.00	1.09:1.00	0.84:1.00

Table 7. Summary of Crested Auklet hatching success among plot pairs A, B, C and D in 2010, at Gareloi Island, Alaska.

Plot	Hatched	Failed	Egg Disappeared	Fate Unknown	Hatching Success
Am	12	3	3	16	0.67
Au	27	3	7	4	0.73
Bm	24	9	11	9	0.55
Bu	24	4	6	3	0.71
Cm	22	14	2	2	0.58
Cu	6	1	4	25	0.55
Dm	51	15	2	0	0.75
Du	21	0	6	16	0.78

Table 8 Summary of statistical differences between hatching success on control and manipulated (vegetation removed) plots, at Gareloi Island, Alaska.

Plot	Chi-square	df	p-value
Am:Au	0.233	1	0.629
Bm:Bu	1.820	1	0.177
Cm:Cb	0.039	1	0.843
Da:Db	0.103	1	0.748
Overall (Manipulated:Control)	1.344	1	0.246

Table 9: Maximum daily counts from cameras placed at manipulated and control plots at the south-east colony Gareloi Island, Alaska in 2010.

	Am		Au		Bm		Bu		Cm		Cu		Dm		Du	
Date	CRAU	LEAU	CRAU	LEAU	CRAU	LEAU	CRAU	LEAU	CRAU	LEAU	CRAU	LEAU	CRAU	LEAU	CRAU	LEAU
06/06/2010	29	0	37	8	35	2	97	0								
07/06/2010	17	4	13	7	22	2	48	4	36	10	17	8	6	33	16	6
08/06/2010	38	5	17	12	32	0	62	3	57	5	7	2	5	24	5	7
09/06/2010	26	2	10	8	40	0	27	2	30	6	8	6	8	6	13	6
10/06/2010	40	4	41	9	34	0	65	2	62	10	14	10	11	4	15	10
11/06/2010	29	0	34	2	48	1	52	2	34	10	14	2	13	3	26	2
12/06/2010	16	0	24	0	20	0	50	0	11	3	23	2	17	0	28	0
13/06/2010	20	0	49	5	39	2	73	1	25	7	24	3	24	5	41	0
14/06/2010	35	9	42	2	20	1	57	3	23	8	17	1	12	13	17	8
15/06/2010	16	3	21	0	26	2	53	1	34	4	14	1	13	5	25	0
16/06/2010	19	3	22	1	51	0	53	3	38	5	17	4	18	5	12	5
17/06/2010	18	5	26	2	29	2	45	1	25	10	8	8	12	0	13	15
18/06/2010	16	4	14	7	37	1	23	3	n/a	n/a	n/a	n/a	4	7	11	5
19/06/2010	11	0	21	0	9	0	27	0	n/a	n/a	n/a	n/a	17	1	38	1
20/06/2010	13	7	15	6	15	1	34	0	n/a	n/a	n/a	n/a	16	6	22	2
21/06/2010	18	5	25	1	25	0	55	0	n/a	n/a	n/a	n/a	17	2	33	0
22/06/2010	15	1	3	8	20	0	55	11	n/a	n/a	n/a	n/a	4	2	7	15
23/06/2010	12	0	6	4	26	0	30	15	n/a	n/a	n/a	n/a	2	0	14	8
24/06/2010	13	1	14	8	31	1	22	7	n/a	n/a	n/a	n/a	10	2	20	0
25/06/2010	13	2	25	5	20	3	40	2	n/a	n/a	n/a	n/a	19	0	17	18
26/06/2010	17	5	11	8	22	4	27	2	20	5	15	2	12	0	13	2
27/06/2010	15	3	25	0	26	1	53	0	17	0	15	2	n/a	n/a	n/a	n/a
28/06/2010	14	4	26	6	21	4	44	1	33	5	13	0	n/a	n/a	n/a	n/a
29/06/2010	23	4	30	5	22	5	36	3	25	3	20	1	n/a	n/a	n/a	n/a
30/06/2010	33	2	28	2	19	4	44	1	20	4	29	0	n/a	n/a	n/a	n/a
01/07/2010	22	1	37	0	17	1	48	2	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
02/07/2010	9	5	31	0	33	4	41	4	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
03/07/2010	20	0	27	0	21	0	52	3	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
04/07/2010	21	0	23	6	26	0	56	0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
05/07/2010	22	4	26	4	51	3	20	2	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
06/07/2010	19	2	24	3	37	3	31	5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
07/07/2010	19	6	23	4	46	2	23	1	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
08/07/2010	11	1	11	3	46	2	26	2	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

09/07/2010	12	0	11	8	36	0	21	0	n/a	n/a	n/a	n/a	23	5	n/a	n/a
10/07/2010	19	3	30	1	35	0	20	1	0	0	16	0	31	2	n/a	n/a
11/07/2010	21	5	22	1	45	0	22	2	32	3	18	2	24	3	n/a	n/a
12/07/2010	19	3	31	6	9	0	5	0	35	3	16	3	17	6	n/a	n/a
13/07/2010	23	1	31	2	n/a	n/a	n/a	n/a	37	2	22	4	23	1	n/a	n/a
14/07/2010	17	3	30	2	33	2	23	4	19	5	19	3	10	1	n/a	n/a
15/07/2010	9	0	11	0	27	0	26	2	2	0	5	2	7	0	n/a	n/a
16/07/2010	16	2	24	1	44	3	22	2	21	0	23	1	28	1	n/a	n/a
17/07/2010	10	0	14	1	43	5	23	2	8	0	15	2	13	0	n/a	n/a
18/07/2010	20	5	28	2	38	3	22	4	18	0	17	0	19	2	n/a	n/a
19/07/2010	23	2	34	5	15	0	7	1	29	0	23	0	21	0	n/a	n/a
20/07/2010	20	0	21	1	53	3	26	0	3	0	14	0	12	0	n/a	n/a
21/07/2010	18	0	13	1	26	0	12	2	11	0	15	0	11	1	n/a	n/a
22/07/2010	9	0	12	0	62	4	40	0	5	0	12	0	8	0	n/a	n/a
23/07/2010	7	0	13	0	46	3	27	1	10	0	13	0	10	0	n/a	n/a
24/07/2010	12	1	24	0	25	0	19	0	11	0	14	0	11	0	n/a	n/a
25/07/2010	11	1	16	0	33	0	20	2	15	0	11	0	8	0	n/a	n/a
Grand Total	**925**	118	**1146**	167	**1536**	74	**1804**	109	**746**	108	**508**	69	**240**	118	**386**	110
Mean	**18.5**	2.4	**22.9**	3.3	**31.3**	1.5	**36.8**	2.2	**23.3**	3.4	**15.9**	2.2	**13.9**	3.8	**19.3**	5.5
SD	**7.4**	2.2	**9.8**	3.2	**12.1**	1.6	**18.3**	2.7	**14.6**	3.5	**5.3**	2.6	**7.0**	6.7	**9.8**	5.5

Table 10: Average and Maximum counts of Crested and Least Auklets on 60 new plots in 2010 at Gareloi Island, Alaska.

Plot		Ave CRAU	Std Dev	Ave LEAU	Std Dev	Max CRAU	Max LEAU
Upper Colony Plots							
1U	Control	0.59	1.76	0.14	0.50	19	4
	Manipulated	0.71	2.05	0.09	0.38	20	3
	Total	**1.29**	**3.82**	**0.23**	**0.89**	**39**	**7**
2U	Control	2.66	4.04	0.71	2.10	34	21
	Manipulated	2.02	3.01	1.28	3.13	51	10
	Total	**4.68**	**7.05**	**2.00**	**5.24**	**85**	**31**
3U	Control	0.19	0.54	0.04	0.38	12	7
	Manipulated	2.06	3.48	1.44	4.96	29	48
	Total	**2.25**	**4.03**	**1.48**	**5.34**	**41**	**55**
4U	Control	0.28	0.58	0.09	0.61	9	8
	Manipulated	1.41	1.24	0.29	1.06	22	8
	Total	**1.69**	**1.82**	**0.38**	**1.67**	**31**	**16**
5U	Control	0.50	0.53	0.05	0.22	8	1
	Manipulated	0.49	0.51	0.21	0.55	5	3
	Total	**0.99**	**1.04**	**0.26**	**0.77**	**13**	**4**
6U	Control	0.64	2.01	0.18	0.87	22	9
	Manipulated	1.45	3.18	0.52	1.69	29	16
	Total	**2.09**	**5.18**	**0.70**	**2.56**	**51**	**25**
South Colony Plots							
1S	Control	0.24	0.71	0.01	0.13	6	2
	Manipulated	0.56	1.11	0.07	0.32	7	3
	Total	**0.80**	**1.82**	**0.08**	**0.45**	**13**	**5**
2S	Control	0.07	0.42	0.004	0.07	6	1
	Manipulated	0.24	0.68	0.02	0.21	5	3
	Total	**0.31**	**1.09**	**0.03**	**0.28**	**11**	**4**
3S	Control	0.61	1.10	0.14	0.49	14	5
	Manipulated	0.43	0.76	0.10	0.35	8	3
	Total	**1.04**	**1.87**	**0.23**	**0.84**	**22**	**8**
4S	Control	0.78	0.91	0.06	0.30	6	4
	Manipulated	0.01	0.07	0.00	0.00	3	0
	Total	**0.79**	**0.98**	**0.06**	**0.30**	**9**	**4**
North Colony Plots							
1N	Control	0.29	0.81	0.09	0.48	6	6
	Manipulated	0.03	0.19	0	0.00	3	0
	Total	**0.31**	**1.00**	**0.09**	**0.48**	**9**	**6**
2N	Control	0.02	0.12	0	0.00	2	0
	Manipulated	0.01	0.16	0	0.00	2	0
	Total	**0.03**	**0.28**	**0.00**	**0.00**	**4**	**0**
3N	Control	0.01	0.16	0.004	0.06	3	1

	Manipulated	0.02	0.17	0.01	0.09	2	1
	Total	**0.03**	**0.33**	**0.01**	**0.15**	**5**	**2**
4N	Control	0.04	0.25	0.01	0.13	3	3
	Manipulated	1.10	2.44	0.09	0.37	20	4
	Total	**1.13**	**2.69**	**0.09**	**0.50**	**23**	**7**
5N	Control	0.15	0.50	0.05	0.28	3	3
	Manipulated	0.03	0.20	0.01	0.08	2	1
	Total	**0.18**	**0.69**	**0.06**	**0.36**	**5**	**4**
6N	Control	0.28	0.83	0.04	0.22	7	2
	Manipulated	2.09	3.36	0.33	0.82	19	8
	Total	**2.37**	**4.19**	**0.37**	**1.04**	**26**	**10**
7N	Control	0.18	0.81	0.04	0.34	8	7
	Manipulated	0.13	0.48	0.02	0.15	4	2
	Total	**0.32**	**1.29**	**0.06**	**0.50**	**12**	**9**
8N	Control	0.06	0.41	0.01	0.07	6	1
	Manipulated	0.04	0.24	0.01	0.13	2	3
	Total	**0.10**	**0.65**	**0.01**	**0.21**	**8**	**4**
9N	Control	1.14	3.21	0.23	0.84	27	7
	Manipulated	0.49	1.26	0.11	0.43	10	4
	Total	**1.63**	**4.47**	**0.33**	**1.27**	**37**	**11**
10N	Control	0.13	0.42	0.06	0.26	4	2
	Manipulated	0.17	0.67	0.03	0.20	5	2
	Total	**0.30**	**1.10**	**0.09**	**0.46**	**9**	**4**
11N	Control	1.56	2.92	0.28	0.79	21	10
	Manipulated	3.31	4.37	0.37	0.99	24	9
	Total	**4.87**	**7.29**	**0.64**	**1.78**	**45**	**19**
12N	Control	0.06	0.25	0.01	0.12	2	1
	Manipulated	0.85	1.64	0.10	0.48	10	6
	Total	**0.91**	**1.89**	**0.11**	**0.59**	**12**	**7**
13N	Control	3.53	5.17	0.12	0.54	40	8
	Manipulated	0.22	0.57	0.04	0.23	5	2
	Total	**3.75**	**5.74**	**0.17**	**0.77**	**45**	**10**
14N	Control	0.04	0.22	0.01	0.11	2	1
	Manipulated	0.01	0.09	0.002	0.05	1	1
	Total	**0.05**	**0.32**	**0.01**	**0.15**	**3**	**2**
15N	Control	1.27	1.83	0.24	0.68	11	8
	Manipulated	0.01	0.11	0	0.00	2	0
	Total	**1.28**	**1.94**	**0.24**	**0.68**	**13**	**8**
16N	Control	0.18	0.81	0.16	0.95	12	14
	Manipulated	0.23	0.80	0.11	0.48	8	6
	Total	**0.41**	**1.62**	**0.27**	**1.43**	**20**	**20**
17N	Control	0.18	0.59	0.12	0.46	6	4
	Manipulated	0.18	0.61	0.13	0.56	6	6
	Total	**0.36**	**1.19**	**0.24**	**1.02**	**12**	**10**
18N	Control	1.32	2.09	0.53	1.21	14	9

	Manipulated	0.45	0.91	0.08	0.34	4	3
	Total	**1.77**	**3.00**	**0.61**	**1.55**	**18**	**12**
19N	Control	0.03	0.19	0.02	0.18	2	3
	Manipulated	0.79	1.61	0.50	1.03	12	7
	Total	**0.82**	**1.80**	**0.52**	**1.20**	**14**	**10**
20N	Control	0.03	0.18	0.00	0.04	2	1
	Manipulated	0.08	0.38	0.02	0.18	4	2
	Total	**0.10**	**0.57**	**0.02**	**0.22**	**6**	**3**

Table 11 Crested and Least Auklet nest counts on the 60 new plots delineated in 2010 at Gareloi Island, Alaska.

Plot	CrAu	LeAu	Unknown	Total
Upper Colony Plots				
14	2	4	1	7
1U (west)	6	5	2	13
2U (north)	5	4	0	9
2U (south)	11	1	3	15
3U (north)	6	1	6	13
3U (south)	6	1	0	7
4U (north)	4	2	3	9
4U (south)	2	4	1	7
5U (east)	3	0	2	5
5U (west)	2	4	1	7
6U (east)	1	3	0	4
6U (west)	0	1	1	2
North Colony Plots				
1N (north)	2	2	2	6
1N (south)	1	3	0	4
2N (north)	5	1	3	9
2N (south)	4	4	0	8
3N (north)	5	2	10	17
3N (south)	17	6	0	23
4N (north)	11	8	6	25
4N (south)	12	5	0	17
5N (east)	5	2	1	8
5N (west)	17	13	0	30
6N (east)	11	7	4	22
6N (west)	11	5	0	16
7N (east)	2	3	1	6
7N (west)	10	3	0	13
8N (east)	8	0	3	11
8N (west)	6	1	1	8
9N (east)	4	0	1	5
9N(west)	34	12	1	47
10N (east)	3	3	0	6
10N (west)	7	2	3	12
11N (south)	6	3	0	9
11N (north)	4	0	1	5
12N (south)	5	2	0	7
12N (north)	15	9	1	25
13N (south)	5	2	5	12
13N (north)	14	3	6	23
14N (south)	14	5	1	20
14N (north)	7	4	1	12
15N (south)	3	2	0	5
15N (north)	0	0	0	0
16N (south)	3	2	0	5
16N (north)	0	1	1	2
17N (south)	0	0	0	0
17N (north)	0	0	0	0
18N (south)	2	0	0	2

18N (north)	16	1	0	17
19N (south)	2	1	4	7
19N (north)	2	1	0	3
20N (south)	0	0	0	0
20N (north)	0	2	0	2
South Colony Plots				
1S (east)	16	4	2	22
1S (west)	14	1	16	31
2S (north)	28	13	2	43
2S (south)	18	8	2	28
3S (north)	2	6	2	10
3S (south)	5	4	1	10
4S (east)	0	0	0	0
4S (west)	0	0	0	0

Figure 1: Location of 60 new plots selected in 2010 at Gareloi Island, Alaska: 5 Groups of 5 plot pairs were selected to the north-east (plots 1-20 “N”), 1 group of 6 plot pairss were selected near the northern crater (plots 1-6 “U”), and 1 group of 4 plot pairs were selected near the 2009 plot pairs to the south-east.

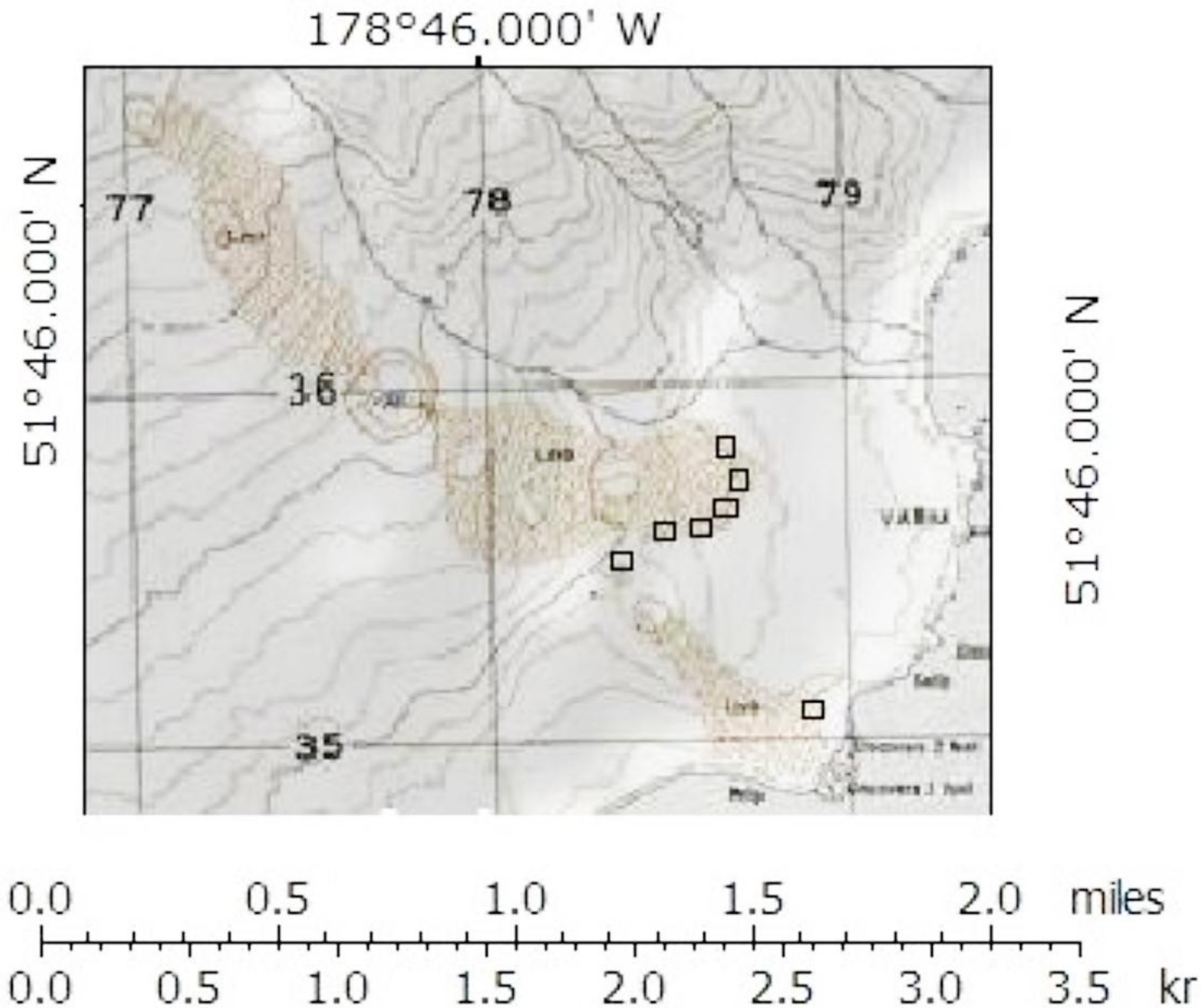


Figure 2 Capture-mark-recapture estimates of the number of Crested Auklets frequenting the vegetation manipulated plots Am, Bm, Cm, and Dm (left) and the undisturbed (Control) plots Au, Bu, Cu, and Du in 2009 and 2010 at Gareloi Island, Alaska

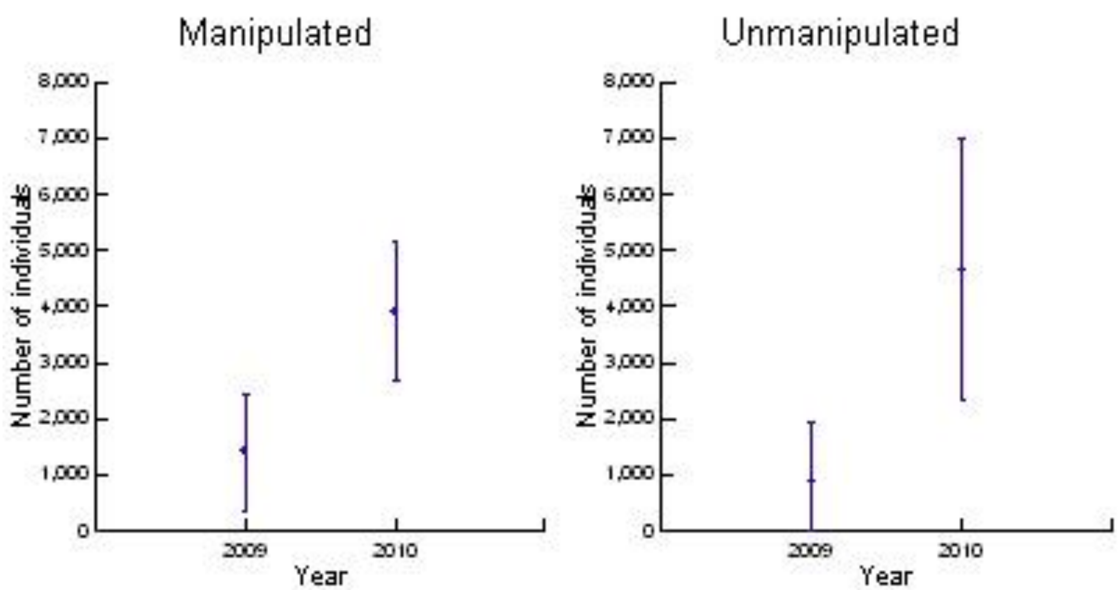


Figure 3 Capture-mark-recapture estimates of the number of Crested Auklets that reached the chick-rearing stage in 2009 and 2010 on study plots Am, Au, Bm, Bu, Cm, Cu, Dm and Du at Gareloi Island, Alaska

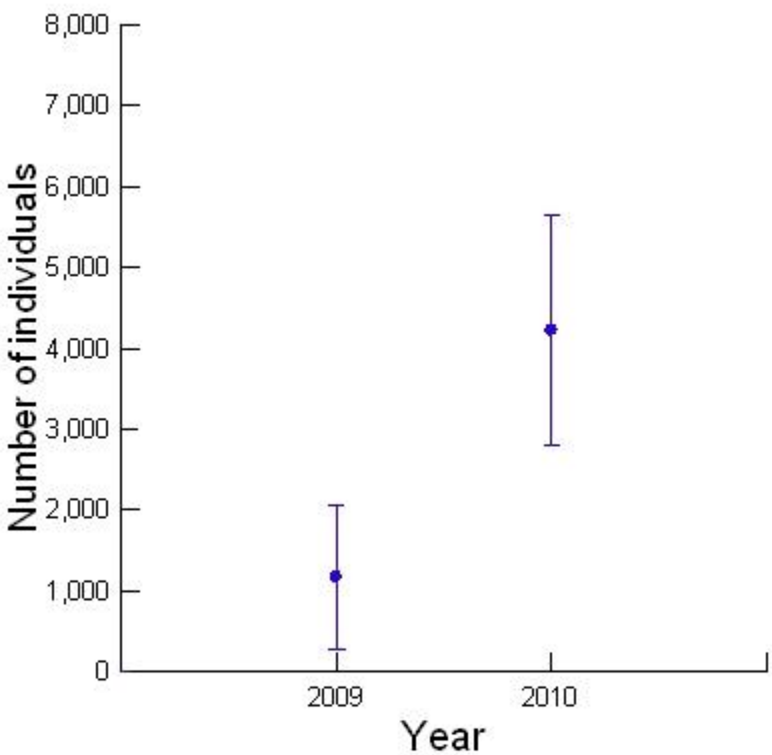
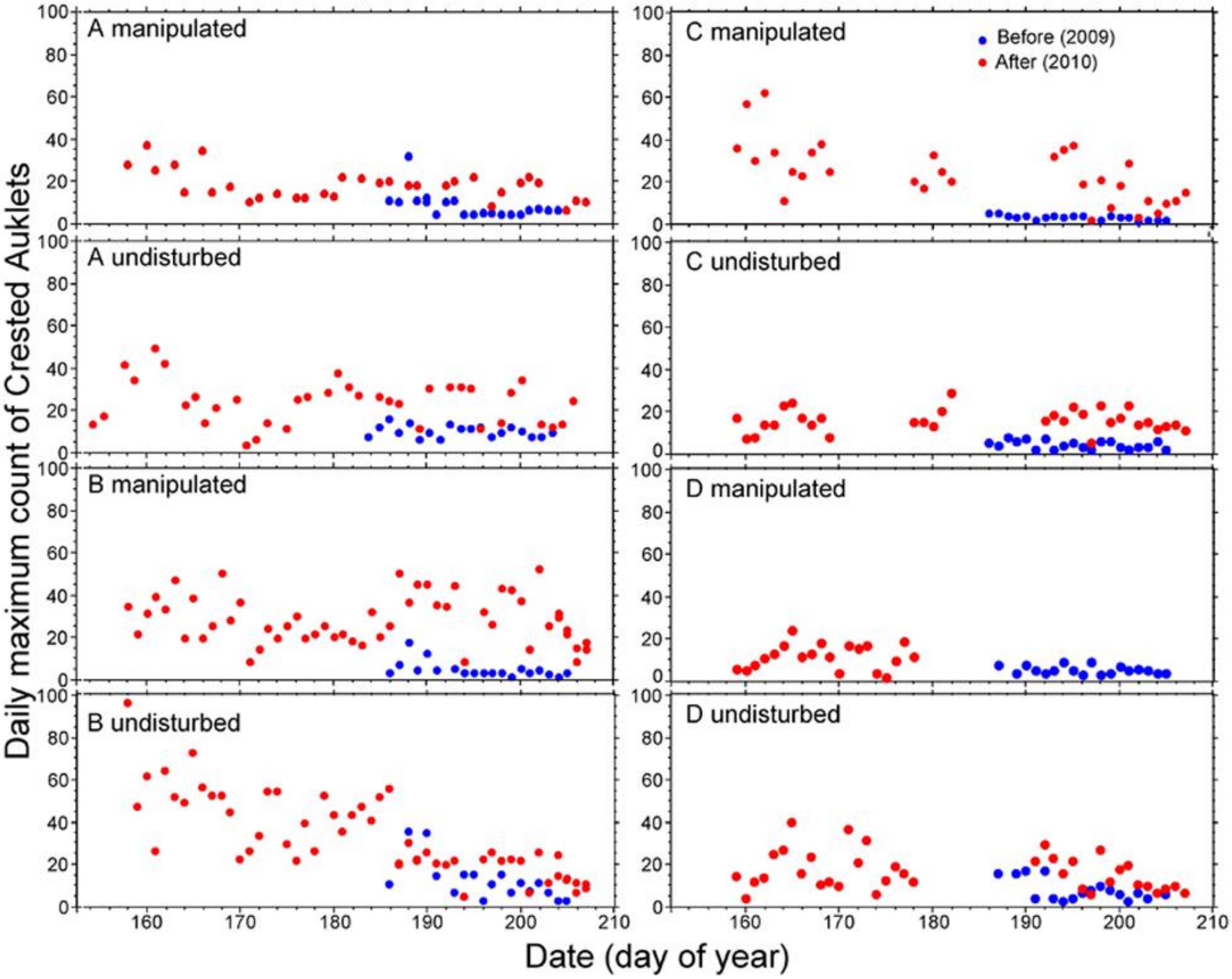


Fig. 3 Daily maximum counts in Reconyx images of Crested Auklets at plots Am, Au, Bm, Bu, Cm, Cu, Dm, Du during 2009 (blue) and 2010 (red) at the Southeast Colony, Gareloi Island, Alaska



Appendix 1 Marked Crested Auklets resighted at moderate density plots A, B, C, D at Gareloi Island in 2010.

Am	Au	Bm	Bu	Cm	Cu	Dm	Du
BK/DGY	BK/DGY	**BK/DGR**	BK/LGBK	BK/DGO	BK/DBY	**BK/DBDB**	BK/BKDG
BK/RDG	BK/RDG	**DB/DBDB**	**BK/OBK**	**BK/GYR**	**BK/DGLG**	BK/DBW	BK/DBW
DB/DGDB	BK/YY	DB/DBO	BK/WBK	DB/DBO	BK/GYBK	BK/OW	**BK/LGLG**
DB/DGW	**DB/DBY**	**DB/DGDG**	**DG/DGDG**	DB/OR	**BK/RY**	**BK/OY**	BK/OR
DG/DGY	DB/LGW	**DB/OY**	**LG/LGLG**	DG/LGR	BK/WLG	BK/RDB	**BK/OY**
DG/LGLG	DB/OW	**DB/RDB**	O/DBLG	DG/OO	**BK/YDB**	**BK/RGY**	BK/RGY
DG/OGY	**DB/WO**	**DB/WDB**	**O/DBY**	DG/OY	**DB/DBLG**	**BK/WO**	BK/RW
DG/WY	DB/YW	**DB/YLG**	**O/ODB**	DG/RY	DB/LGBK	**DB/DBGY**	DB/BKW
GY/BKO	**DG/DGR**	**DG/DBDB**	**O/RBK**	DG/WO	**DB/ODG**	DB/DBR	DB/DGO
GY/OBK	**DG/DGY**	**DG/GYLG**	R/DBLG	**DG/WW**	**DB/YDB**	**DB/DGR**	DB/LGDG
GY/YY	**DG/LGDB**	**DG/GYW**	**R/DBW**	GY/GYDB	**DG/GYDG**	DB/WDG	DB/OGY
LG/DGY	DG/WR	**DG/RW**	R/DGDB	LG/GYR	**DG/RY**	**DB/YR**	**DB/OO**
LG/LGW	DG/YDB	**DG/WDG**	**R/OR**	LG/RLG	**GY/GYBK**	DG/DBGY	DB/OY
LG/OO	GY/BKW	**GY/RW**	**W/DBY**	**O/DGW**	GY/GYO	**LG/DGDG**	**DB/RO**
LG/WDB	LG/DBW	**LG/WR**	**W/GYBK**	O/GYO	**LG/BKLG**	**LG/OY**	**DB/YBK**
O/BKDB	LG/WW	**O/LGDG**	**W/RDG**	O/GYR	**LG/DBY**	**LG/WBK**	**DB/YO**
O/OBK	**O/BKR**	**O/OW**	W/YBK	O/GYW	LG/GYBK	**O/BKY**	**DB/YR**
O/WDB	O/DGY	**O/OY**	Y/RLG	**O/LGR**	LG/LGO	O/YDB	DG/BKR
R/BKW	**O/YR**	O/RDG	Y/WBK	O/RW	LG/WGY	R/BKBK	DG/DBGY
R/ODG	**R/DBDB**	O/WR	Y/WGY	R/GYR	O/LGBK	**R/DBGY**	DG/DGO
R/RDB	**R/DGBK**	O/YGY		**R/GYW**	O/WGY	**R/DBY**	DG/LGDG
R/RW	**R/LGLG**	O/YO		**R/OW**	**O/YDG**	R/DGO	**DG/ODB**
R/WY	**R/RDB**	**R/DBO**		**R/WLG**	**W/DBGY**	R/OY	DG/YW
W/BKW	R/WY	R/DGY		W/BKLG	**W/GYO**	**R/RLG**	**LG/DGDB**
W/ODG	R/YLG	**R/LGDB**		W/GYO	W/GYY	R/WDB	O/BKW
W/RY	**W/BKDG**	**R/OBK**		**W/LGO**	Y/GYBK	**R/YDB**	O/BKY
W/WDG	W/DGLG	R/OLG		**Y/BKDB**	Y/OW	**W/BKO**	**O/DBGY**
W/YDB	W/RY	**R/RY**		**Y/BKO**	**Y/YW**	**W/DBDB**	O/DGLG
W/YW	**W/WDG**	R/YGY		Y/GYBK		**W/DGDG**	O/LGLG
Y/BKY	Y/LGLG	**R/YW**		**Y/GYLG**		**W/DGR**	**O/LGO**
Y/LGLG	**Y/ODG**	W/BKBK		**Y/GYW**		W/RO	O/ODG
Y/RW	Y/RW	**W/DBW**		Y/OO		W/WDB	**O/WDG**
Y/YBK	**Y/YY**	**W/DGGY**		Y/RDG		W/YLG	O/WO
		W/DGY		Y/RGY		**Y/YLG**	**O/YBK**
		W/RLG		Y/WDB			O/YY
		W/WLG		**Y/YO**			R/BKBK
		Y/DBLG					R/DGO
		Y/DGR					R/DGR
		Y/RBK					R/LGW
		Y/RLG					**R/OO**
		Y/RR					**R/RBK**
		Y/YDB					**R/RLG**
		Y/YGY					**R/WDG**
		Y/YR					R/WO
							R/WW
							W/BKY
							W/DBLG
							W/DGBK

							W/DGDG **W/OW** **W/RO** **W/WGY** **W/YLG** W/YR Y/BKR Y/DBDB **Y/DGGY** **Y/DGW** **Y/LGR** **Y/LGY** Y/ODB Y/RO Y/WLG Y/WW

* Individuals observed carrying a chick meal are noted in bold font

Appendix 2. Percent cover of each plant species on new plots in 2010 ('m' represents manipulated, 'u' represents undisturbed plots, 'T' represents trace or <1%).

Species	1Su	1Sm	2Sm	2Sm	3Su	3Sm	4Su	4Sm
Gymnocarpium sp.	12	10	5	7	2	5	1	1
Angelica sp.	15	15	5	5	3	5	4	3
Hemlock Parsley - *Conioselinum chinense*	-	-	-	-	-	-	-	-
Lupine - *Lupinus nootkatensis*	-	-	-	-	-	-	1	1
Rock	8	5	3	1	3	-	1	1
Moss	-	T	3	3	1	3	4	3
Dirt/Mud	-	10	10	15	8	5	-	10
Siberian Spring Beauty - *Claytonia sibirica*	-	-	-	T	-	1	1	1
Chickweed - *Stellaria sp.*	-	1	3	3	2	1.5	T	3
Narcissus-Flowered Anemone - *Anemone narcissiflora*	-	-	-	-	-	-	-	-
Willow - *Salix sp.*	-	-	-	-	-	-	-	-
Bog Orchid - *Plantanthera sp.*	-	-	-	-	-	-	-	-
Boreal Yarrow - *Achillea borealis*	-	-	-	-	-	-	T	-
Arctic Starflower - *Trientalis europaea*	-	-	-	-	-	-	-	-
Fireweed - *Epilobium behringianum*	-	-	-	-	1	T	-	-
Twayblade - *Listera cordata*	-	-	-	-	-	-	-	-
Lousewort - *Pedicularis chamissonis*	-	-	-	-	-	-	-	-
Bract Saxifrage - *Saxifraga bracteata*	-	-	T	-	-	-	-	-
Ranunculus sp.	-	-	T	T	-	1.5	T	-
Crowberry - *Empetrum nigrum*	-	-	-	-	-	-	-	-
Pearly Everlasting - *Anaphalis margaritacea*	-	-	-	-	-	-	-	-
Putchki - *Heraclium lanatum*	-	-	-	-	-	-	-	-
Pacific Reedgrass - *Calamagrostis nutkaensis*	42	55	57	63	73	55	78	69
Carex sp.	2	-	-	2	2	20	9	8
Sand Ryegrass - *Leymus arenarius*	15	-	-	T	1		T	0
Puccinellia langeana	6	4	14	1	4	3	1	-

Species	1Uu	1Um	2Uu	2Um	3Uu	3Um	4Uu	4Um	5Uu	5Um	6Uu	6Um
Gymnocarpium sp.	1	1		1	1	1	5	3	2	3	1	2
Angelica sp.	5	5	1	2	5	3	7	7	15	10	12	3
Hemlock Parsley - *Conioselinum chinense*	-	-	-	-	-	-	-	-	-	-	-	-
Lupine - *Lupinus nootkatensis*					-	-	-	-	-	-	-	-
Rock	3	3	3	3	1	T	T	-	-	1	-	3
Moss	5	3	3	2	2	2	3	5	7	3	-	3
Dirt/Mud	10	10	10	7	10	7	2	2	2	5	1	6
Siberian Spring Beauty - *Claytonia sibirica*		3		2	T	T	1	1	-	-	1	1
Chickweed - *Stellaria sp.*	3	3	1	5	2	2	2	5	5	3	-	1
Narcissus-Flowered Anemone - *Anemone narcissiflora*	-	-	-	-	-	-	-	-	-	-	-	-
Willow - *Salix sp.*	-	-	-	-	-	-	-	-	-	-	-	-
Bog Orchid - *Plantanthera sp.*	-	-	-	-	-	-	-	-	-	-	-	-
Boreal Yarrow - *Achillea borealis*	-	-	-	-	-	-	-	-	-	-	-	-
Arctic Starflower - *Trientalis europaea*	-	-	-	-	-	-	-	-	-	-	-	-
Fireweed - *Epilobium behringianum*	-	-	-	-	T	T	T	T	-	-	-	1
Twayblade - *Listera cordata*	-	-	-	-	-	-	-	-	-	-	-	-
Lousewort - *Pedicularis chamissonis*		-	-	-	-	-	-	-	-	-	-	-
Bract Saxifrage - *Saxifraga bracteata*	T	-	-	-	-	-	-	-	-	-	-	-
Ranunculus sp.	-	-	-	-	-	-	T	T	T	T	-	1
Crowberry - *Empetrum nigrum*	-	-	-	-	-	-	-	-	-	-	-	-
Pearly Everlasting - *Anaphalis margaritacea*	-	-	-	-	-	-	T	T	-	-	-	-
Putchki - *Heraclium lanatum*	-	-	-	-	-	-	-	1	-	-	-	-
Pacific Reedgrass - *Calamagrostis nutkaensis*	37	29	37	54	43	25	70	74	66	60	55	39
Carex sp.	7	7	4	8	4	13	2	2	2	4	5	4
Sand Ryegrass - *Leymus arenarius*	-	36	-	8	0	4	0	0	0	0	17	4
Puccinellia langeana	29	-	41	8	32	43	8	0	1	11	8	32

	1N	1N	2N	2N	3N	3N	4N	4N	5N	5N	6N	6N	7N	7N	8N	8N
Species	u	m	u	m	u	m	u	m	u	m	u	m	u	m	u	m
Gymnocarpium sp.	1	1	7	5	2	2		2	2	1	3	1		2	7	1
Angelica sp.	2	2	8	5	2	2	9	2	3	2	1	3	5	5	4	1
Hemlock Parsley - *Conioselinum chinense*	1	-	-	-	-	1	-	-	-	-	-	-	-	-	-	3
Lupine - *Lupinus nootkatensis*	12	10	6	5	5	-	-		-	-	-	-	-	-	-	-
Rock	1	1	4	-	5	2	5	3	5	2	9	2	5	2	-	2
Moss	3	1	2	-	-	3	3	2	2.5	3	1	-	1	2	-	3
Dirt/Mud	-	-	-	-	-	-	-	1	-	-	-	4	-	2	-	-
Siberian Spring Beauty - *Claytonia sibirica*	T	1	-	0.25	T	-	-	-	-	-	-	-	-	-	-	-
Chickweed - *Stellaria sp.*	T	-	-	0.5	-	1	-	-	2.5	1	-	T	-	1	-	-
Narcissus-Flowered Anemone - *Anemone narcissiflora*	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Willow - *Salix sp.*	-	-	1	0.5	-	-	-	-	-	-	-	-	-	-	-	-
Bog Orchid - *Plantanthera sp.*	1	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Boreal Yarrow - *Achillea borealis*	1	1	-	-	T	-	-	-	-	-	-	-	-	-	-	-
Arctic Starflower - *Trientalis europaea*	-	T	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fireweed - *Epilobium behringianum*	-	-	-	0.25	T	-	-	-	-	-	-	-	-	-	T	-
Twayblade - *Listera cordata*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lousewort - *Pedicularis chamissonis*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bract Saxifrage - *Saxifraga bracteata*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ranunculus sp.	T	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Crowberry - *Empetrum nigrum*	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Pearly Everlasting - *Anaphalis margaritacea*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Putchki - *Heraclium lanatum*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pacific Reedgrass - *Calamagrostis nutkaensis*	69	73	50	70	83	50	66	80	68	81	55	80	44	81	37	44
Carex sp.	8	8	2	1.5	2	-	5	-	9	5	5	-	5	1	3	-
Sand Ryegrass - *Leymus arenarius*	-	-	20	9	-	39	12	-	4	5	26	-	36	-	44	44
Puccinellia langeana	1	-	-	-	1	-	-	10	4	-	-	10	4	4	5	2

Species	9N u	9N m	10N u	10N m	11N u	11N m	12N u	12N m	13N u	13N m	14N u	14N m	15N u	15N m
Gymnocarpium sp.	4	10	4	2	3	-	3	1	10	10	4	20	6	
Angelica sp.	9	7	4	3	9	25	8	2	7	15	7	20	4	2
Hemlock Parsley - *Conioselinum chinense*	-	2	-	-	-	-	1	-	-	-	-	-	-	-
Lupine - *Lupinus nootkatensis*	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Rock	6	4	10	2	3	2	1	10	1	10	-	1	4	1
Moss	-	-	1	-	-	-	-	-	-	-	-	-	-	-
Dirt/Mud	-	-	-	1		5	1	2	-	10	-	3	-	2
Siberian Spring Beauty - *Claytonia sibirica*	-	1	-	1	-	-	-	-	-	-	-	-	-	-
Chickweed - *Stellaria sp.*	-	0.7	-	1	-	4	-	-	-	-	-	-	-	-
Narcissus-Flowered Anemone - *Anemone narcissiflora*	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Willow - *Salix sp.*	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bog Orchid - *Plantanthera sp.*	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Boreal Yarrow - *Achillea borealis*	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Arctic Starflower - *Trientalis europaea*	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fireweed - *Epilobium behringianum*	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Twayblade - *Listera cordata*	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lousewort - *Pedicularis chamissonis*	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bract Saxifrage - *Saxifraga bracteata*	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ranunculus sp.	-	0.3	-	-	-	1	-	-	-	-	-	-	-	-
Crowberry - *Empetrum nigrum*	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pearly Everlasting - *Anaphalis margaritacea*	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Putchki - *Heraclium lanatum*	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pacific Reedgrass - *Calamagrostis nutkaensis*	23	35	68	68	40	30	9	70	33	30	41	30	31	75
Carex sp.	2	-	1	2	1	-	-	-	2	-	2	1	-	-
Sand Ryegrass - *Leymus arenarius*	40	30	12	10	38	28	68	10	41	23	46	25	44	20
Puccinellia langeana	16	10	-	10	6	5	9	5	6	2	-	-	10	-

Species	16N u	16N m	17N u	17N m	18N u	18N m	19N u	19N m	20N u	20N m
Gymnocarpium sp.	1	5	5	5	7	5	1	1	1	T
Angelica sp.	5	15	3	5	10	7	2	7	5	10
Hemlock Parsley - *Conioselinum chinense*	-	-	-	-	-	-	-	-	-	-
Lupine - *Lupinus nootkatensis*	-	-	-	-	-	-	-	-	2	-
Rock	-	1	1	T	2	1	1	15	5	7
Moss	-		2	1	5	2	2	3	2	-
Dirt/Mud	-	1	10	3	7	10	5	12	-	1
Siberian Spring Beauty - *Claytonia sibirica*	-	-	-	2	2	1	-	1	-	2
Chickweed - *Stellaria sp.*	-	-	1	1	3	1	1	2	-	1
Narcissus-Flowered Anemone - *Anemone narcissiflora*	-	-	-	-	-	-	-	-	-	-
Willow - *Salix sp.*	-	-	-	-	-	-	-	-	-	-
Bog Orchid - *Plantanthera sp.*	-	-	-	-	-	-	-	-	1	T
Boreal Yarrow - *Achillea borealis*	-	-	-	T	-	-	-	-	2	2
Arctic Starflower - *Trientalis europaea*	-	-	-	-	-	-	-	-	-	-
Fireweed - *Epilobium behringianum*	-	-	1	-	1	1	-	-	-	1
Twayblade - *Listera cordata*	-	-	-	-	-	-	-	-	T	T
Lousewort - *Pedicularis chamissonis*	-	-	-	-	-	-	-	-	T	T
Bract Saxifrage - *Saxifraga bracteata*	-	-	-	-		-	-	-	-	-
Ranunculus sp.	-	1	-	T	T	T	-	-	-	T
Crowberry - *Empetrum nigrum*	-	-	-	-	-	-	-	-	-	3
Pearly Everlasting - *Anaphalis margaritacea*	-	-	-	1		-	-	-	1	T
Putchki - *Heraclium lanatum*	-	-	-	-	-	-	-	-	-	-
Pacific Reedgrass - *Calamagrostis nutkaensis*	68	42	54	66	25	37	44	30	75	2
Carex sp.	3	5	8	4	6	7	9	5	4	2
Sand Ryegrass - *Leymus arenarius*	23	30	-	8	19	14	35	1	2	62
Puccinellia langeana	-	-	15	4	13	14	-	23	-	7