Breeding Ecology and Behavior of Kittlitz's Murrelet in Kodiak National Wildlife Refuge, Alaska: 2009 Progress Report

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Abstract

Kittlitz's murrelet (*Brachyramphus brevirostris*) is a rare seabird that nests in remote alpine terrain in coastal areas of Alaska and the Russian Far East. It is considered to be one of the least-studied birds in North America and very little is known about its nesting ecology. We studied Kittlitz's murrelet during the summer of 2009 in known and suspected nesting habitats on western Kodiak Island. This effort represented the second year of a five-year research project focusing on the breeding ecology of Kittlitz's murrelet in Kodiak National Wildlife Refuge. Thirteen nests were discovered and monitored over the 10-week study period. Five nests produced chicks, and one chick fledged. Images of nest depredation and egg abandonment were recorded by hidden camera, and detailed nest provisioning data were also obtained from images. We recorded nest characteristics and quantified characteristics of ground cover surrounding nest sites. Pre-dawn audio-visual surveys performed in 2008 were used successfully to locate nesting habitat in 2009. Audio-visual surveys were continued in 2009, and 32 surveys were conducted in several locations.

Key Words: Kittlitz's murrelet, *Brachyramphus brevirostris,* Kodiak National Wildlife Refuge, nesting biology, reproductive success, audio-visual survey, habitat use, provisioning rate, chick diet, predation.

Introduction

Kittlitz's murrelet (*Brachyramphus brevirostris*) is a rare and declining seabird of the North Pacific, and is one of the least-studied birds in North America. It is a non-colonial breeder that nests in relatively poorly-vegetated montane habitats, frequently near glaciated terrain (Day et al. 1983, Burkett et al. 2009, Kaler et al. 2009). The species nests primarily in Alaska, where long-term population monitoring has revealed declines of up to 80% in many local populations (Kuletz et al. 2003, Van Pelt and Piatt 2003, Drew and Piatt 2008). Causes of this decline are not completely understood. The literature identifies known sources of mortality including oil spills, gillnet by-catch and events related to vessel activity (Wynne et al. 1992, van Vliet and McAllister 1994, Agness 2006). Less definable changes, including fluctuations in marine food webs (Piatt and Anderson 1996, Anderson and Piatt 1999) and loss of foraging and/or nesting habitat due to glacial recession (Kuletz et al. 2003), may also be contributing to the bird's decline.

This report summarizes results from the second year of a planned five-year study of the breeding biology of Kittlitz's murrelet in Kodiak National Wildlife Refuge, Alaska. Here we summarize the results of systematic nest searches, observations of reproductive biology, characterization of nesting habitat, and results of audio-visual surveys during the summer of 2009. In addition, we present recommendations for research next year.

The entire five-year project encompasses the following goals:

1. Locate and study as many Kittlitz's murrelet nests as possible;
2. Characterize nesting habitat (e.g., altitude, rock type, vegetation, etc.);
3. Monitor incubation duty of adults at nests and delivery of meals to chicks;
4. Identify prey in chick meals;
5. Measure rate of chick growth;
6. Measure hatching, fledging and reproductive success;
7. Collect blood, feathers or egg-shell fragments for genetic study of populations;
8. Conduct audio-visual surveys for adult murrelets flying to and from nest sites.

This work is being conducted in concert with a similar study on Agattu Island, Alaska, which is managed by Alaska Maritime National Wildlife Refuge. In conjunction, these two studies are addressing fundamental gaps in our knowledge of Kittlitz's murrelet.

Study Area and Climate

Kodiak Island (57.396° N, 153.483° W) is located in the northern Gulf of Alaska, and is the largest island in the Kodiak Archipelago, with an area of 8,975 km^2 (Figure 1). Mountains cover most of Kodiak Island's interior, with the balance including large river valleys, meadows and wetland complexes. The highest peaks on the island exceed elevations of 1,300 m. Vegetation on the island is variable, with northeast Kodiak Island dominated by Sitka spruce (*Picea sitchensis*) forests, while the southwest end of the island is generally unforested tundra, wetlands and meadows.

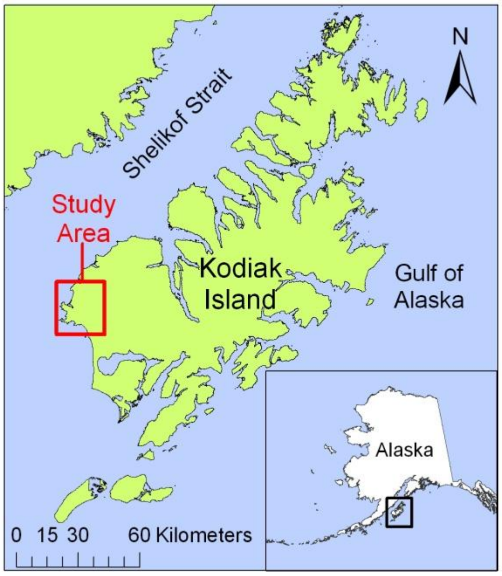

Figure 1. Map of study area.

Our study area included four discrete sites characterized by low to mid-elevation (up to 450 m) ridges and peaks which have large continuous areas of scree and talus. The parent material of these bare sites is known as ultramafic, a class of rock having a high metal content and scarce nutrients (e.g., Ca, K, P), the properties of which prevents the growth of most plants (Wilson et al. 2005). These expanses of bare rock are in stark contrast to the surrounding slopes which are covered by lush plant growth. Since a relatively small area on western Kodiak Island contains these ultramafic parent materials, we were able to focus our study on a few unvegetated sites within a large matrix of vegetated ground cover. No glacial ice or permanent snow lies within 30 km of the study area, a fact which distinguishes our site from the glaciated sites with which Kittlitz's murrelets are commonly associated (Day et al. 1983, Day et al. 1999). The terrain within the study area comprises ridges and peaks not exceeding 500 m, and is generally easy to negotiate without the need for technical climbing gear and expertise, making breeding habitats relatively accessible.

Daily weather data were collected at four main camps and one camp that was only briefly surveyed (Figure 2). Average maximum and minimum daily temperatures from 27 May to 4 August were 17.1 °C (range 26 to 6.7 °C) and 6.8 °C (range -2.9 to 13.5°C). The mean daily and total precipitation was 0.25 cm and 17.13 cm for the same period.

Methods

Nest Searching and Monitoring

Figure 3. Location of camps and ultramafic rock areas.

Dedicated searching for nests began on May 28 and continued through July 15. After July 15 nest searching was conducted incidental to other activities. Nests were located by ground-searching rocky, non-vegetated terrain (e.g., Burkett et al. 2009, Kaler et al. 2008). Searchers walked parallel to the fall line of slopes 5-10 m abreast of each other, a little more than the average flush distance of an incubating murrelet (Kaler et al. 2009, J. Lawonn, pers. obs.). Search efforts were concentrated in areas dominated by scree, talus, and bedrock on ridges and peaks. Efforts were made to search both optimum and marginal areas (i.e. areas lower in elevation, with low slope angle, or comprising small, patchy areas of scree or talus) for adequate representation of all available habitats. Areas within 30 m of a known active nest were not searched to avoid disturbance. Handheld GPS units were used to log the effort and ensure that searches were conducted systematically.

Because the cryptic adults are almost impossible to see on the ground even at close range, we discovered all nests after flushing an adult from the nest site. Upon flush, the presence of white outer rectrices was used to positively distinguish Kittlitz's murrelet from the very similar marbled murrelet. In cases where we remained uncertain about identity, the nest was monitored at a distance (>30 m) with a spotting scope 1-2 days following discovery, and bill morphology and plumage characteristics were used to confirm species identity. No marbled murrelets (*Brachyramphus marmoratus*) have been detected within the study area in 2008 and 2009, but they are common breeders on other areas of Kodiak Island and occasionally nest in similar habitats as Kittlitz's murrelets in other areas of their range (Nelson 1997).

Each egg and nest was photographed, as well as the surrounding ground cover and terrain. These photographs were used to relocate nests after initial discovery. Occasionally a black permanent marker was used to place a small mark on a rock one to three meters from the nest to facilitate relocation, if practical. Cairns were not constructed to facilitate relocation of the nest in order to prevent creating visual and scent cues to potential predators. Latex or nitrile gloves were worn by the crew when handling substrates near the nest to minimize the introduction of human scent near the nest.

The approximate date of nest initiation was determined by floating the egg in water (Westerskov 1950, Rizzolo and Schmutz 2007). Eggs were measured using dial calipers (±0.1mm), and mass obtained with a spring scale (±0.5 g). The process of data collection at a nest site typically took about 10 minutes for nests that did not receive cameras, and 15 minutes for nests that did receive cameras. To encourage incubating adults to return to their nests quickly, we withdrew from the nest area when finished with data collection and resumed our activities on a different face of the same ridge or peak, or moved completely to a different ridge.

Weather-resistant motion-triggered cameras were placed on every other nest upon discovery (Reconyx PC90 RapidFire Professional Covert Color IR), though timing and location sometimes required consecutively discovered nests receiving cameras. In any case, nests were divided in to a "control" group and a "camera" group so that we could assess the possible disturbance effects of camera placement. Cameras were set from 2 to 2.5 meters away from the nest scrape using an iron stake driven into the ground for support. Rocks were piled around the camera body to make it as inconspicuous as possible. To provide further camouflage, the cameras were painted to blend in with the environment, and were outfitted with visors to reduce glare from the reflective lens and flash surfaces (after Kaler et al. 2008). Cameras were powered by six AA lithium batteries fitted into C-cell adapters and were outfitted with 16 GB compact flash memory cards (Sandisk). The cameras were programmed to photograph all motion-triggered events as well as take one photo every three minutes, an interval assumed to be the approximate minimum time an adult Kittlitz's murrelet will remain at a nest while feeding a chick (J. Piatt, N. Naslund, pers. comm.). All photos were recorded with a time and date stamp. The battery life for these settings at the temperatures and light levels on our study sites was approximately 30 days; the 16 GB memory card has a capacity of about 55-60 days at the same settings.

Two types of nest-checks were performed. Formal nest-checks were assigned after day five of the chick period. The function of these checks was to determine nest fate and to collect growth and genetic data on the chick. The second type of nest-check was opportunistic, and only occurred from a distance using optics to determine nest status.

After initial discovery, nests were not revisited until a minimum of five days after the predicted hatch date, although nests were checked opportunistically when possible with binoculars from a distance of greater than 30 m when searches occurred in adjacent terrain. We did not deviate from our parallel search paths when performing such a check to avoid causing dead-end scent trails leading in the direction of the nest. Occasionally it was possible to view incubating adults from a distance of 80-300 m through the use of a spotting scope. Nests visible from such long range were monitored to determine nest status as time, terrain, and good judgment permitted.

The timing and number of visitations to the nest sites was identical for both the camera group and the control group. The first nest visitation was scheduled when a chick was projected to be at least five days old, or when the nest was known to have failed as determined by a remote check using a spotting scope or binoculars. Two visitations were scheduled for each chick after hatch, ideally more than one week apart as determined by our camp location, to collect growth data and genetic samples. Only one nest was still active when checked the first time (at day seven), and this same chick was checked once again on day 17 before it fledged on day 24 as revealed by camera images.

Nest Characteristics

We collected data on nest site characteristics after nests were no longer occupied. Nests were surveyed at several spatial levels. At the smallest scale, we measured nest diameter, nest depth, and nest circumference, and classified the type and composition of substrate in and immediately surrounding the nest scrape. We also identified and measured key "nest rocks", which are features surrounding the nest that are large enough to act as a barrier against rock fall, buffer from the elements, or to conceal the nest, egg, incubating adult, or chick from predators. Nest diameter and depth were measured, and the composition of the nest cup and its circumference were characterized. We also noted nest aspect (compass direction nest was facing, in degrees) and whether the ocean could be seen from the nest. Geographic and landscape data (geographic coordinates, elevation, slope, etc.) were recorded at the center of each nest plot. At a larger scale, three circular plots (5, 25, 50 m radius) surrounding the nest were also surveyed. The 50 m plot was added to the 5 and 25 m plots used in 2008 in order to capture potential edge effects and determine the relative "patchiness" of non-vegetated terrain. Using a 5 m radius plot centered on each nest site, we estimated percentage cover values to 13 types of ground cover. Using 25 and 50 m radius plots centered on each nest site, we estimated the percentage of non-vegetated ground cover. To compare habitat characteristics of nest sites with nearby habitat, two adjacent non-use plots were placed at a random bearing and random distance (between 50 and 150 m) from nest sites, and were surveyed in the same manner as nest plots.

To assess elevation-dependent factors that might influence nest site selection, including differences in vegetation and substrate composition, we randomly assigned intensive elevation-based habitat samples to five nest sites. These elevation plots were located along the fall line extending through the nest at 50 m intervals. At each 50 m interval, one center plot was located on the fall line, and one plot was located on either side of the center plot at a random distance between 50 and 150 m, at the same elevation as the center plot. These elevation plot tiers extended to the top of the ridge above the nest and down to the valley floor below. Finally, to facilitate comparison of nest sites with surrounding habitat, 138 randomly selected vegetation plots were surveyed within the search coverage area at 3 of the 4 sites. Detailed analysis of habitat data will occur at a later date.

Audio-visual Surveys

We recorded Kittlitz's murrelet activity at 10 locations among the four main study areas and in one outlying area. We recorded numbers of birds flying, flight directions, vocalizations, various behaviors, and noted a suite of environmental conditions (Evans-Mack et al. 2003, Burkett et al. 2009). Station locations were chosen by their proximity to known or suspected flyways and quality nesting habitat. Survey stations varied from the vegetated valley floor at most base camp sites, to sites along ridgelines that were generally surrounded by scree, talus, and bedrock. Station elevations ranged from 79 m to 443 m. We applied the same protocol as was as is explained in Burkett et al. (2009), but surveys were begun 90 minutes before sunrise rather than 120 minutes before sunrise because very few audio detections were made earlier than 90 minutes before sunrise during 2008. Surveys lasted until one hour after sunrise, except when detections were made during the last half hour of this period. In these cases the survey was extended until 30 minutes after the last detection. Surveys were not conducted if periodic wind gusts exceeded 15 miles per hour, or if the observer considered it impossible to hear calls from a distance of greater than 400 m.

Results and Discussion

Nest Searching and Monitoring

Our first search effort extended from late-May to late-June, and included most of the high-potential Kittlitz's murrelet habitat among the four study sites. During our second effort from late-June to mid-July we re-surveyed the same habitats as the first effort, but did not re-search some marginal habitats because of time limitations. In total, 12 active and one failed Kittlitz's murrelet nests were discovered among the four sites (Figure 3). The failed nest contained fresh shell fragments and conformed to the typical appearance of a Kittlitz's murrelet nest.

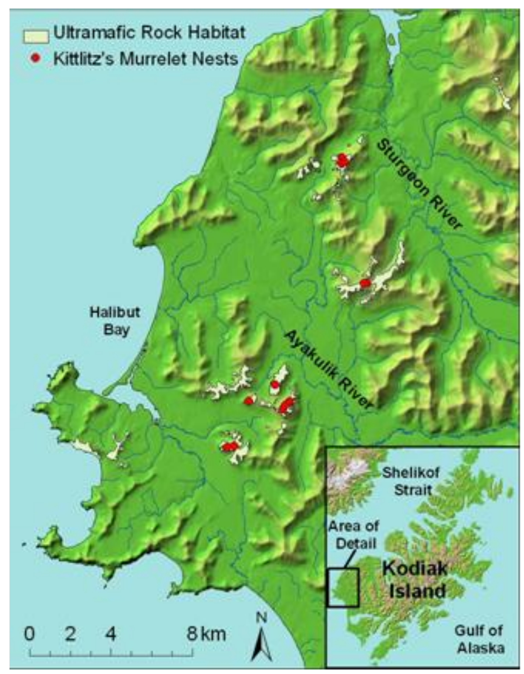

Figure 3. Kittlitz's murrelet nests discovered in 2009.

The average distance an incubating bird flushed from a searcher was 3.9 m, but birds flushed as close as 1.5 m and as far as 9 m away. Initial flight direction following flush was always directly downslope.

The average time for an adult bird to return to its nest after being flushed was 175 minutes following departure of the field crew from the nest site (SE = 77.7, n = 6, Table 1). This duration is a potential cause for concern because complete egg cooling could possibly affecting embryo survival. The spread for return times is large, with three nests experiencing adult return times of less than 45 minutes, while three nests experienced return times between two and seven hours (Table 1).

Egg measurements and coloration fell within the known range for Kittlitz's murrelet. Two empty nest scrapes were found within one meter of two different active nests. One of these satellite nests contained weathered shell fragments that were at least one year-old. Two presumed satellite nests were found in 2008, but neither of these contained shell fragments.

Table 1. Flush distance, adult return time, and egg measurements for Kittlitz's murrelet, Kodiak Island, 2009.

Nest ID	Flush distance of adult (m)	Return time for adult (min)	Mass of egg	Egg length	Egg width
KODKIMU0901	2.5	N/A	39	54.2	36.9
KODKIMU0902	4	127	51.5	60.2	40.8
KODKIMU0903	9	N/A	47.5	58.1	38.8
KODKIMU0904	7	455	42.5	55.3	37.8
KODKIMU0905	1.5	N/A	42.0	55.2	38.2
KODKIMU0906	2.5	15	44.5	57.4	40
KODKIMU0907	4	N/A	42.0	57.5	38.1
KODKIMU0908	2	N/A	44.0	56.9	38.9
KODKIMU0909	3	44	41.5	62.6	37.8
KODKIMU0910	3	37	40.5	58.9	37.6
KODKIMU0911	2	371	41.5	55.3	37
KODKIMU0912	6	N/A	33.0	59.0	39.2
KODKIMU0913[1]	N/A	N/A	N/A	N/A	N/A
Mean	3.9	174.8	42.5	57.6	38.4
standard deviation	2.3	190.2	4.5	2.4	1.2
standard error	0.6	77.7	1.2	0.7	0.3

[1]Nest found depredated; no data

Kittlitz's murrelet nest initiation on our study site was somewhat synchronous. Nests were initiated from 23-May to 22-June. Ten of twelve nests were initiated between 23-May and 9-June (Appendix A). The median initiation date for nests was May 31 (n = 12).

Nest Success

One nest out of 13 contained a chick that successfully fledged, while the remainder of nests failed, yielding a 0.077 success rate (Table 2). Eight of 13 nests failed at the egg stage as indicated by the absence of chick-derived fecal matter near the rim of the nest. Four of these failed nests were empty upon our first visit, and were presumably depredated. One of these four nests contained a few fresh shell fragments, but we could not determine whether the nest was active when the egg was destroyed. Two nests were documented by camera to have been depredated by red foxes (*Vulpes vulpes*) during the incubation stage. In the two cases where eggs were abandoned, the egg was found mostly intact within the nest scrape, though a hole was found in one, possibly an artifact of a predation or scavenging attempt. Both abandonments occurred more than 16 days after discovery.

Five nests survived to the chick stage. One of these was documented by camera to have been depredated by a red fox. Two nests were found empty, with fecal matter on the rim, indicating failure at the chick stage. One chick was found dead at the nest site at day one or two of development, with seven desiccated sand lance (*Ammodytes hexapterus*) found surrounding the nest.

Table 2. Summary of nest fates.

Nest Fate	Number of nests
Failed during incubation, nest empty	4
Failed during incubation, red fox predation	2
Abandoned during late incubation	2
Failed during chick stage, red fox predation	1
Failed during chick stage, nest empty	2
Failed during chick stage, dead chick present	1
Fledged	1
Total	13

Nest Characteristics

Nest scrapes were all composed of loose gravel-sized rock of diameters ranging mostly from less than 1 cm to 5 cm. A large rock or clump of moss was present directly upslope of all nests. Cover within the 5, 25, and 50 m nest plots was predominantly non-vegetated (mean 93.2, 92.7, and 91.5 percent, respectively), and was composed primarily of scree and talus (Appendix B). More detailed ground cover data were taken at nest plots, as well as non-use plots, elevation plots and random plots. Analysis of these data will occur at a later time with the objective of determining habitat characteristics involved in nest site selection.

Kittlitz's murrelets within the study area chose nesting habitats from 270 to 454 m in elevation (Table 3). Nests were usually situated near the tops of ridges, as indicated by the high value of the nest site elevation divided by the ridge elevation directly above the nest (0.908, SE = .024). Nests were usually situated in relatively steep habitats with all nests occurring at slopes equal to or greater than 20°. The ocean was visible from 85 percent of nest sites, and is a factor that may have significance in nest site selection given that fledging juveniles must navigate to the ocean without any parental guidance. The minimum flight distance to the ocean may also be significant factor in nest selection. Kittlitz's murrelets may favor sites closer to the ocean both to reduce energy costs during meal delivery to chicks and to ensure a successful fledging flight of a juvenile bird. Mean minimum flight distance for 2009 was 8.08 km (SE = 0.40).

Table 3. Landscape data at nest sites.

Nest ID	Elevation of Nest (m)	Ridge Elevation Above Nest (m)	Nest Elevation/Ridge Elevation (m)	Slope (degrees)	Aspect (degrees)	Ocean in View (Y = 1)	Flight Distance to Ocean (km)[1]
KODKIMU0901	415	422	0.983	26	90	N	10.4
KODKIMU0902	375	453	0.828	37	253	Y	7.4
KODKIMU0903	312	440	0.709	29	347	Y	7.6
KODKIMU0904	320	326	0.982	31	17	Y	10.5
KODKIMU0905	447	461	0.970	28	318	Y	8.5
KODKIMU0906	343	380	0.903	34	335	Y	8.4
KODKIMU0907	270	275	0.982	20	190	Y	6.6
KODKIMU0908	270	327	0.826	26	265	Y	7.8
KODKIMU0909	317	339	0.935	30	316	Y	6.5
KODKIMU0910	322	328	0.982	25	216	Y	6.3
KODKIMU0911	387	419	0.924	34	333	Y	10.1
KODKIMU0912	388	474	0.819	34	226	Y	7.4
KODKIMU0913	454	474	0.958	28	103	N	7.6
mean	355.4	393.7	0.908	29.4	--	0.85	8.08
standard deviation	60.9	67.8	0.087	4.6	--	--	1.44
standard error	16.9	18.8	0.024	1.3	--	--	0.40

[1]Estimate of shortest distance a fledging KIMU would fly to reach tidally influenced ocean water

Parental Attendance, Meal Delivery, and Chick Growth

Cameras were deployed on six nests and revealed attendance patterns, meal deliveries, and depredation events. The motion sensor on the cameras proved to be unreliable at detecting bird movement at the camera distance and settings used. However, the motion sensor did capture some feeding events that fell between the three-minute interval shots, and showed that feeding duration may occasionally be less than the three-minute interval assumed to represent the minimum. We consider that on some occasions, feeding events, switching of incubation duties and other activities may have been missed entirely by the camera.

Incubation duties were divided between the parent birds for all observed nests. Typically, one parent would incubate for 24 hours before being relieved by its mate during the pre-dawn hours. Incubation duties usually alternated every day, but there were times when it appeared that the same bird would incubate for 48 hours or longer. Capturing the moment when birds exchanged incubation duties at the nest site proved to be difficult for some pairs, possibly because they exchanged duties very quickly (i.e. less than the three minute interval time between camera shots).

Four significant lapses in incubation were observed for nest KODKIMU0906, the nest containing the chick that eventually fledged. On day 22 of embryonic development, the adult left the nest at 4:54 a.m., and the nest remained unincubated for 12 hours, 9 minutes, until an adult returned to incubate at 3:03 p.m. On day 23 the nest remained unincubated for 16 hours; on day 24 for nearly 17 hours; and on day 29 and 30 for nearly 17 hours. In total, the egg remained unincubated for 61 hours and 21 minutes during the last 8 days of its development.

Adult attendance was most frequent at dawn and dusk. The time intervals 5:00 – 8:00 a.m. and 10:00 p.m. – 1:00 a.m. represented 60.4% of all meal deliveries to nests KODKIMU0906 and KODKIMU0909, the only camera-documented nests that reached the chick stage (Figure 4). No deliveries were recorded between the hours of 1 and 3 a.m.

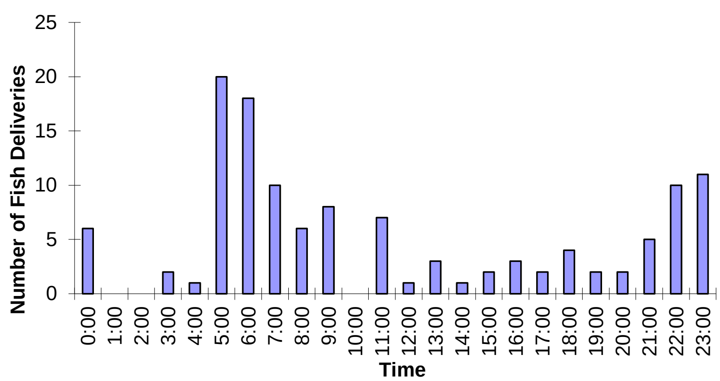

Figure 4. Hourly number of fish delivered to two Kittlitz’s murrelet nestlings on Kodiak Island, 2009.

A total of 85 meal deliveries were recorded being made to nest KODKIMU0906 before fledging, and 31 deliveries were made to nest KODKIMU0909 over the course of seven days (Table 4). Average delivery rates for nests KODKIMU0906 and KODKIMU0909 were 3.54 and 4.43 meals per day (SD = 1.69 and 4.43; Table 4). Visit durations ranged from approximately 1 to 24 minutes. Two abnormally long visitations to nest KODKIMU0909 were not included when calculating summary statistics. The first was a 5 hour 15 minute visit where the adult brooded the chick after feeding; the other was a 3 hour 9 minute visit where the adult arrived at the nest with a fish at 12:45 a.m. and did not feed the chick until 3:45 a.m. Nest KODKIMU0906 was monitored for the entire 24-day chick period and KODKIMU0909 was monitored for seven days before the nest was depredated by a red fox.

Table 4. Delivery rates for adult Kittlitz's murrelets from time-lapse and motion-triggered photos.

Nest	Average Visits Per Day	SD	Range of Visits/Day	Total Visits	Total Days Monitored
KODKIMU0906	3.54	1.69	1 – 7	85	24
KODKIMU0909	4.43	4.43	3 – 6	31	7

Camera images were used to identify species of forage fish delivered to nests. Sand lance (*Ammodytes hexapterus*) were readily identified in the adult bird's bill based on its distinctive needle-shaped body, uniquely tapered caudal peduncle and pointed rostrum. Camera resolution was insufficient to distinguish among fusiform-shaped fish such as capelin (*Mallotus villosus*), herring (*Clupea* spp.), and small salmonids such as juvenile pink salmon. These fish were all lumped within the "Capelin-like" category of fishes. No gadids including pollock or cod species were seen being fed to chicks. The distinctive body shape of these fishes would presumably be apparent in camera images. Images were assigned a status of "unknown" where light levels were not sufficient to categorize forage fish, where there was a lack of images, or where the fish itself was obscured by the adult.

Sand lance was the most commonly delivered forage fish, representing 51.8% and 77.4% of total deliveries to nests KODKIMU0906 and KODKIMU0909 (Table 5). Unknown fish comprised 41.2% of deliveries for KODKIMU0906 and 22.6% of deliveries to KODKIMU0909. Camera position and adult perch locations played a large part in whether fish identification at the nest was possible; thus " % unknown" does not necessarily represent a difference in fish species delivered, but might signify that one camera afforded a clearer view of fish than another. Fusiform, capelin-like fish comprised 7.1% of fish deliveries to KODKIMU0906 and none to KODKIMU0909.

Table 5. Percentage of different forage fish groups delivered to Kittlitz's murrelet nests.

Nest	% Sand lance	% Capelin-like	% Gadid-like	% Unknown	Total Fish
KODKIMU0906	51.8	7.1	0	41.2	85
KODKIMU0909	77.4	0	0	22.6	31

Growth data are only available for the chick that eventually fledged (Table 6). At day 7 the chick weighed 71 grams, and at day 17 it weighed 155.5 grams. The chick's mass at both nest visits was about twice the mass of similar-aged Kittlitz's murrelet chicks measured on Agattu Island (Kaler et al. 2008) and may reflect differences in growth rates between the two sites.

Table 6. Chick growth data for nest KODKIMU0906.

Date	Chick age[1] (days old)	Mass	Wing chord, flat (mm)	Total head (mm)
6-Jul-09	7	71	42	44.9
16-Jul-09	17	155.5	96	54.8

[1] Day 1 is date of hatch

Audio-visual Surveys

A total of 525 Kittlitz's murrelet detections were recorded during 32 audio-visual surveys performed over a ten-week period. Ten survey stations were sampled. Four stations located less than 50 m from base camp comprised the core of our effort, accounting for 18 of the 32 counts. When possible, two surveys were performed simultaneously at different locations, optimally in much different situations (e.g. valley bottom vs. mountain peak), in order to facilitate comparison of detection rates.

During audio-visual surveys, most birds were detected by ear and remained unseen. In 2009, 98.3% of detections were solely audio. Only eight visual detections were made of Kittlitz's murrelets during surveys. The average lateral distance of all detections was 417.2 m (SE = 9.11, range = 0 - 1,000 m, n = 480).

In 2008, ridgetop survey stations yielded a higher ratio of visual detections compared to 2009, probably because the observer was simply closer to birds flying over high altitude terrain. In 2009 we conducted comparatively few ridgetop surveys and thus had relatively few visual sightings. In general, Kittlitz's murrelets presented very difficult visual targets for the surveyor because of the poor light conditions in which they typically flew, along with their cryptic coloration and high-speed flight. Additionally, heavy fog and rain frequently reduced visibility to less than 200 meters, further restricting the possibility of visual detection.

Although the majority of detections were audio only, many sightings of Kittlitz's murrelets were made during formal surveys and at other times, providing insights into aspects of their biology and behavior. During an audiovisual survey conducted in conditions of very poor visibility on May 28, a single Kittlitz's murrelet was observed making slow progress upvalley, making wide erratic turns, zig-zagging, and flapping its wings in a manner so that the upstroke and downstroke appeared to pass through the maximum vertical range possible. This behavior was observed while the bird was flying within a very dense fog layer (visibility 50-100 m), slowly progressing toward a large scree field at the head of a valley. It circled our camp twice at an altitude of about five meters, and let out a high-pitched call, and continued upvalley, at an overall course speed no greater than about 40 km/hr. Probably this type of "bat-like" flight was necessary to stay aloft at the very low airspeed the bird maintained to navigate in the poor visibility conditions present that morning. Since these low visibility conditions are frequent on Kodiak Island throughout the morning hours, this type of flight might be common.

Several observations of Kittlitz's murrelets flying over potential nesting habitat were made outside of formal audio-visual surveys. On May 28, a lone Kittlitz's murrelet was seen at 4:15 p.m. flying at high speed about 1 m above ground level on a high ridgeline. On July 2 at 3:45 a.m., a lone Kittlitz's murrelet was seen 1-2 m from the ground flying at high speed toward a known active nest about 100 m away. On July 16 at 9:30 a.m. a lone bird passed the crew three times at a distance of 25-100 m at about 1-5 m above ground level at high to moderate speed. On July 29, a pair of birds was observed flying at high speed about 1 m from the ground through moderately dense fog toward a large scree field. These flights were all seen in areas dominated by scree and talus ground cover, at elevations over 250 m. This type of low, inconspicuous flight behavior is consistent with the general strategy of predator avoidance as suggested by the bird's cryptic coloration, nest site selection, and largely crepuscular activity patterns. Along with many similar observations made during 2008, these observations suggest that capture of Kittlitz's murrelets by mist net within the vicinity of a known nest site might be feasible, especially during the very early morning hours.

We did not make any visual detections of groups of murrelets interacting in flight during 2009. In both 2007 (Day and Barna 2007) and 2008 (Burkett et al. 2009) several groups of murrelets including three or more birds were observed exhibiting acrobatic flight, including several possible cases of agonistic or display behavior where birds or pairs of birds appeared to interact with, and even chase one another. It should be noted that so few visual detections were made in 2009 that even if such behavior were common, it would not have been represented in our surveys.

The mean number of detections per audio-visual survey was 20.91 (SE = 6.6, range = 0 – 140, n = 24 surveys). The mean number of vocalizations per survey was 113.46 (SE = 43.0, range 0 – 973, n = 24). The length of activity periods ranged from one minute during a morning when only one detection was made, up to seven hours on a morning with 140 detections. Detections were most frequent from one-half hour before sunrise to sunrise, and 73% of all detections were made within the time interval between 90 minutes before and 30 minutes after sunrise (Figure 5).

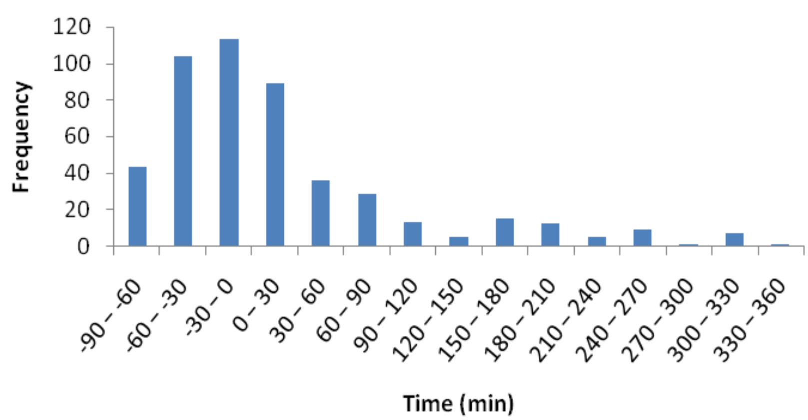

Figure 5. Kittlitz's murrelet detections relative to sunrise, Kodiak Island, May 28 – July 31 2009 (0 = sunrise).

The majority of detections included one or two birds that were heard vocalizing, although occasionally three birds were heard within the same group (Figure 6). It was impossible to determine the exact number of birds in a group without visual confirmation, since members of a potential group might not vocalize during an observation.

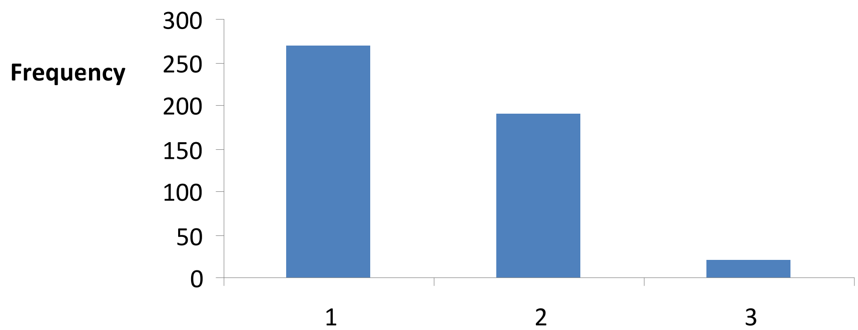

Figure 6. Number of Kittlitz's murrelets detected per group on Kodiak Island, May 28 – July 31, 2009.

Detection rates remained relatively low throughout June in spite of the success we had nest searching that month. There was a marked increase in Kittlitz's murrelet activity during late July that was noted at two survey stations (Figure 7). During 2008 a similar high activity period extended nearly four weeks through the month of July (Burkett et al. 2009).

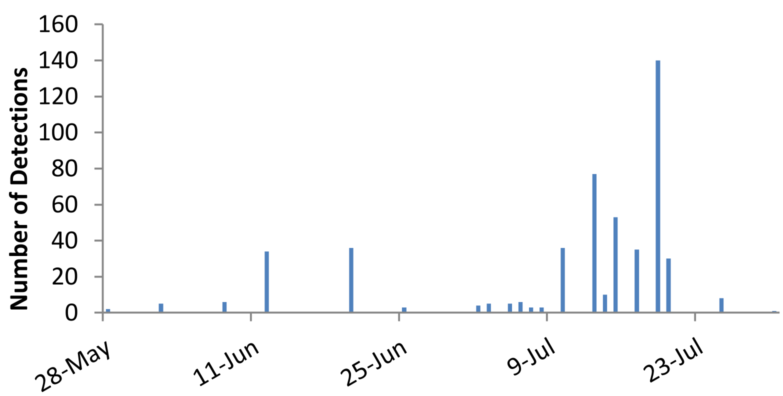

Figure 7. Number of Kittlitz's murrelet detections made during audiovisual surveys on Kodiak Island sites, May 28 – 30 July,

Audio-visual surveys were performed outside of the main study area at two previously unsurveyed sites on Kodiak Island during 2009. Both of these areas contain some non-vegetated habitats that could be used by Kittlitz's murrelets for nesting. Numbers of detections were made on both of these sites, and both could serve as potential areas for nest searching in the future (Pyle 2009).

Conclusions and Suggestions for 2010

Only one of 13 nests was successful in 2009, and was the only success among 18 nests found and monitored during 2008 and 2009. The low nesting success we observed could be attributed to a number of factors. Results of camera data showed that predation may have been a limiting factor over the last two years. Of seven nests that had cameras deployed over the last two years, four of these have been depredated by foxes well after discovery, two nests were abandoned late during the incubation stage, and one bird fledged.

Though it is possible we may have contributed to depredation of nests camera images do not provide any supporting data for this. All predation events occurred more than 72 hours after a visit by field staff, a sufficient time to make scent following unlikely in Kodiak Island's wet climate. Foxes were common at all elevations in the study areas and may have found nests serendipitously while en route to other locations, or as they pursued more common prey species. Foxes were observed on 25.7% of field days (n = 18, Appendix C), and were seen delivering food including snipe (*Gallinago gallinago*) and snowshoe hare (*Lepus americanus*) to presumed den sites within 100 meters of Kittlitz's murrelet habitat. Additionally, game trails and fox scat were frequently observed on ridgetops, possibly because they serve as important thoroughfares between river valleys and lowland habitats. Areas near these same ridgetops were preferred by Kittlitz's murrelets for nest sites, possibly because of a preference for higher elevation habitats.

Several other possible Kittlitz's murrelet predators were seen regularly throughout the summer, including Bald Eagle and Common Raven (Appendix C). We have no evidence yet that avian predation is significant on Kodiak, but it has been shown to be a factor in nest failures on Agattu Island (Kaler et al. 2008, Kaler et al. 2009). In addition to predation, poor nutrition or harsh weather might have caused nests to fail, with scavengers removing unincubated eggs or dead chicks and thus making an exact determination of nest fate impossible. Both avian predation and weather exposure are known to influence reproductive performance on Agattu Island, Alaska (Kaler et al. 2008). During 2008-2009 in Kodiak, three nests were abandoned during incubation, possibly because of egg damage secondary to a natural rock fall, extended parental absence from the nest site, poor fishing conditions that lead to poor adult health, or outright adult mortality. Camera images from two nests suggest that sand lance are an important forage fish for Kittlitz's murrelets on Kodiak Island. Measurements from one chick indicate that growth rates on Kodiak may be high compared with Agattu Island. More forage fish and chick growth rate data is expected to be collected in the future.

Nesting habitat characteristics were consistent between 2008 and 2009. All nests were found on predominantly non-vegetated, rocky terrain at altitudes greater than 260 meters on relatively steep scree slopes. Large areas of non-vegetated terrain that were searched at lower elevations yielded no nests. We discovered two cases where satellite nests existed within two meters of an active or recently active nest. One of these satellite nests found in 2009 contained shell fragments that were at least one year old. Nests located in close proximity to one another have been observed in the marbled murrelet (Naslund 1993), and it is possible that these paired nests belonged to the same mating couple. They may represent repeated nesting attempts within one breeding season, reflect inter-annual nest site fidelity, or reflect selection for specific microhabitat characteristics by numerous pairs of birds over different years.

Audio-visual surveys revealed similar patterns of attendance to those observed in 2008. Low numbers of detections were made early and late in the field season, with peak activity occurring in mid to late July. Detailed analysis of audio-visual data will occur in the future. Observations of inland flying behavior suggest that adult Kittlitz's murrelets regularly fly very close to the ground and use landmarks to navigate well-used routes to their nests during low light periods. These characteristics lend themselves very well to capture by mist net, which might be a relatively inexpensive capture option for the purpose of attaching satellite transmitters to Kittlitz's murrelet adults on Kodiak Island. One site near the Alitak Cannery that was surveyed on Kodiak Island during July 2009 might be a perfect location for such attempts because of an abundance of accessible nesting habitat and very close access to the ocean (Pyle 2009).

Thirteen Kittlitz's murrelet nests were found during the 2009 field season, a substantial increase from the five nests found in 2008. Our success in 2009 was largely a product of the expansion of our study area to include four separate sites. These sites were selected by locating areas that contained suitable habitat and then conducting audio-visual surveys to confirm the presence of Kittlitz's murrelets before initiating intensive nest searching efforts. This method for locating potential nesting areas may be a relatively inexpensive way to determine occupancy on presumed nesting habitat compared to the use of radar or "blind" searching. With a larger sample set and a more thorough understanding of Kittlitz's murrelet behavior, this technique might prove useful in identifying important breeding habitat throughout the bird's range. Much potential habitat exists within the interior of Kodiak Island at higher altitudes with which Kittlitz's murrelet nests are typically associated (Day et al. 1983). Performing focused audio-visual surveys in the high altitude interior of Kodiak Island is a potential next step in locating breeding strongholds in other areas of the Kittlitz's murrelet's range.

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Appendix A. Status of Kittlitz's murrelet nests found on Kodiak Island, 2009.

Nest ID	Date Discovered	Approximate Date Initiated	Projected Hatch Date*	Last Date Nest Known to be Active	Group	Fate
KODKIMU0901	2-Jun-09	28-May-09	27-Jun-09	2-Jun-09	Control	Failed during incubation
KODKIMU0902	8-Jun-09	29-May-09	28-Jun-09	24-Jun-09	Camera	Egg abandoned 24-Jun-09, 05:04 am
KODKIMU0903	9-Jun-09	6-Jun-09	6-Jul-09	29-Jun-09	Control	Failed during incubation
KODKIMU0904	11-Jun-09	9-Jun-09	9-Jul-09	15-Jun-09	Camera	Egg depredated by red fox 15-Jun-09, 01:00
KODKIMU0905	11-Jun-09	31-May-09	30-Jun-09	16-Jun-09	Control	Failed during chick stage
KODKIMU0906	12-Jun-09	31-May-09	30-Jun-09**	23-Jul-09	Camera	Fledged day 24
KODKIMU0907	12-Jun-09	27-May-09	26-Jun-09	28-Jun-09	Control	Failed during chick stage
KODKIMU0908	13-Jun-09	27-May-09	26-Jun-09	28-Jun-09	Control	Chick found dead at day 1 or 2 of development
KODKIMU0909	18-Jun-09	23-May-09	22-Jun-09**	30-Jun-09	Camera	Chick depredated by red fox 30-Jun-09, 01:51 am
KODKIMU0910	22-Jun-09	9-Jun-09	9-Jul-09	11-Jul-09	Camera	Egg abandoned 11-Jul-09, 06:37 am
KODKIMU0911	25-Jun-09	22-Jun-09	22-Jul-09	5-Jul-09	Camera	Egg depredated by red fox on 5-Jul-09, 03:35 am
KODKIMU0912	29-Jun-09	22-Jun-09	22-Jul-09	3-Jul-09	Control	Failed during incubation
KODKIMU0913	30-Jun-09				Control	Failed during incubation; fresh shell fragments found in empty nest

*Projected hatch dates based on float curves (Rizzolo and Schmutz 2007, Kaler et al. 2008)

**Actual hatch date indicated by camera images

Appendix B. Comparison of ground cover on 5, 25, and 50 meter nest plots.

Nest ID	5 m % Unvegetated	25 m % Unvegetated	50 m % Unvegetated	5 m % Vegetated	25 m % Vegetated	50 m % Vegetated
KODKIMU0901	96.0	95.0	97.0	4.0	5.0	3.0
KODKIMU0902	98.0	96.0	97.0	2.0	4.0	3.0
KODKIMU0903	68.1	78.0	77.0	32.0	22.0	23.0
KODKIMU0904	99.0	99.0	99.0	1.0	1.0	1.0
KODKIMU0905	89.0	93.0	92.0	11.0	7.0	8.0
KODKIMU0906	88.0	90.0	85.0	12.0	10.0	15.0
KODKIMU0907	95.0	97.0	94.0	5.0	3.0	6.0
KODKIMU0908	99.0	100.0	100.0	1.0	0.1	0.1
KODKIMU0909	96.1	93.0	91.0	4.0	7.0	9.0
KODKIMU0910	97.0	86.0	78.0	3.0	14.0	22.0
KODKIMU0911	94.0	85.0	87.0	5.0	15.0	13.0
KODKIMU0912	98.0	97.0	97.0	2.0	3.0	3.0
KODKIMU0913	94.0	96.0	96.0	6.0	4.0	4.0
mean	93.2	92.7	91.5	6.8	7.3	8.5
standard deviation	8.3	6.4	7.6	8.3	6.3	7.6
standard error	2.3	1.8	2.1	2.3	1.8	2.1

Appendix C: Potential predator species observed on Kodiak study sites.

Possible Kittlitz's Murrelet predator species observed within one km of Kodiak Island study areas, 26 May-3 August, 2009.

Species		Date first observed	Date last observed	No. days observed	Max no. observed/day
Common name	Scientific name				
Bald Eagle	*Haliaeetus leucocephalus*	26-May-09	3-Aug-09	42	3
Golden Eagle	*Aquila chrysaetos*	30-May-09	25-Jun-09	3	1
Unidentified Eagle	–	1-Jun-09	17-Jun-09	3	1
Rough-legged Hawk	*Buteo lagopus*	29-Jun-09	13-Jul-09	2	1
Merlin	*Falco columbarius*	24-Jul-09	24-Jul-09	1	1
Parasitic Jaeger	*Stercorarius parasiticus*	13-Jun-09	7-Jul-09	6	2
Black-billed Magpie	*Pica hudsonia*	29-May-09	3-Aug-09	47	8
Common Raven	*Corvus corax*	16-Jun-09	3-Aug-09	15	2
Northern Shrike	*Lanius excubitor*	6-Jun-09	18-Jul-09	4	2
Red Fox	*Vulpes vulpes*	27-May-09	3-Aug-09	18	3
Kodiak Brown Bear	*Ursus arctos middendorffi*	27-May-09	13-Jul-09	6	2