Breeding Ecology and Behavior of Kittlitz's Murrelet in Kodiak National Wildlife Refuge, Alaska: 2010 Progress Report

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Abstract

Kittlitz's murrelet (*Brachyramphus brevirostris*) is a rare seabird that nests in remote mountainous terrain in coastal areas of Alaska and the Russian Far East. It is one of the least-studied birds in North America and very little is known about its nesting ecology. For a third consecutive year, we studied the breeding biology and behavior of Kittlitz's murrelets on southwest Kodiak Island. We located nests by systematically searching nesting habitat, placed motion sensitive cameras on a subset of nests, and collected morphometric and genetic data on chicks after they hatched. We periodically monitored nests to determine the status of breeding birds. Following the end of breeding activities, we sampled ground cover at nest sites and random plots to characterize critical nesting habitat. During 2010, 16 nests were discovered. Ten of these nest produced chicks, of which four fledged. Chick provisioning, nest depredation and egg abandonment were recorded at eight nests using remote cameras. We also conducted 23 audio-visual surveys of birds flying to and from nesting areas, recording 238 total detections from four 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, declining seabird of the North Pacific and is one of the least-studied birds in North America. It is a non-colonial breeder that generally nests in unvegetated montane habitats, frequently near glacial ice fields (Day et al. 1983, Piatt et al. 1999, Burkett et al. 2009). The species nests primarily in Alaska, where long-term population monitoring has revealed declines of up to 80% in some local populations (Kuletz et al. 2003, Drew and Piatt 2008). Causes of these declines are poorly understood. Known sources of past mortality or loss of productivity include oil spills, gillnet by-catch, and disturbance from vessel activity (Wynne et al. 1992, Van Vliet and McAllister 1994, Agness 2006), but these factors cannot entirely explain recent declines. Other potential factors that may be contributing to population declines include fluctuations in marine food supplies (Piatt and Anderson 1996, Anderson and Piatt 1999), loss of foraging and/or nesting habitat due to glacial recession (Kuletz et al. 2003), effects of environmental contaminants (USFWS 2010), and changing patterns in avian predation (USFWS 2010).

Following the discovery that relatively large numbers of Kittlitz's murrelets were occupying inland habitat in western Kodiak Island in 2007 (Day and Barna 2007), and likely breeding there, we initiated a study of murrelet nesting ecology and behavior in 2008. In coordination with the Alaska Maritime National Wildlife Refuge, which began similar investigations of murrelets on Agattu Island in the western Aleutians (Kaler et al. 2008), and the FWS Endangered Species office, we adopted a five year plan for studies of Kittlitz's murrelet on Kodiak Island. The main goals of our program were to: 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; and, 8) Conduct audio-visual surveys for adult murrelets flying to and from nest sites.

This report summarizes results from the third year of our study of the nesting ecology and behavior of Kittlitz's murrelets in Kodiak National Wildlife Refuge, Alaska. Here we summarize results of systematic nest searches, observations of reproductive biology, measures of nesting habitat characteristics, and results of audio-visual surveys that were conducted during the summer of 2010 in southwest Kodiak Island. In addition, we present recommendations for research next year.

This work is being conducted in concert with a similar study on Agattu Island (Kaler et al. 2010), Alaska, managed by Alaska Maritime National Wildlife Refuge. Together, these two studies address fundamental gaps in our knowledge of Kittlitz's murrelet ecology and provide new information on the terrestrial nesting biology and behavior of this enigmatic species of seabird.

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 largely composed of large river valleys, upland tundra, meadows, and wetland complexes. Only the highest peaks on the island exceed elevations of 1,300 m. Vegetation on the island is variable, with northeast and east-central Kodiak Island dominated by Sitka spruce (*Picea sitchensis*) forests, while the southwest end of the island is generally unforested tundra, wetlands and meadows.

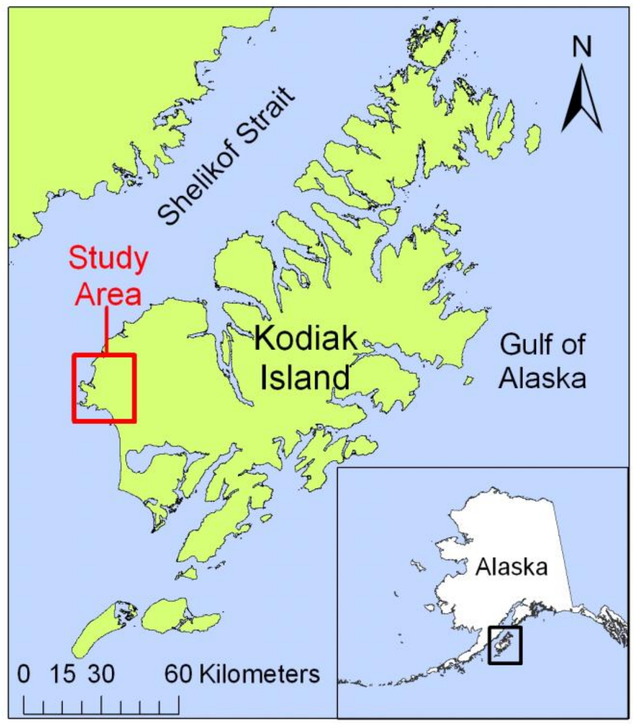

Figure 1. Map of study area.

Our study area included four discrete sites characterized by low to mid-elevation (up to 450 m) ridges and peaks that contain large continuous areas of scree and talus. The parent material of these sites is classified as ultramafic, a type of igneous rock containing high concentrations of heavy metals and scarce nutrients, the combination of which prevents the growth of most plants (Wilson et al. 2005). These expanses of ultramafic rock appear in stark contrast to surrounding slopes which are covered by lush plant growth. A relatively small area on western Kodiak Island contains these ultramafic materials, and so we were able to focus our field efforts on a few of these unvegetated sites within a large matrix of vegetated ground cover. No glacial ice or permanent snow lies within 30 km of the study area, and this distinguishes our site from glaciated sites with which Kittlitz's murrelet is more commonly associated (Day et al. 1983, Day et al. 1999). Terrain within the study area comprised ridges and peaks not exceeding 500 m, and could be negotiated without the need for technical climbing gear and expertise.

Weather data were collected at four main camps located adjacent to study sites (Figure 2). Average minimum and maximum daily temperatures from 27 May to 9 August were 7.2 °C (range -0.6 to 15.6°C) and 15.2 °C (range 8.7 to 23.0 °C). The mean daily precipitation was 0.33 cm, and total precipitation was 28.7 cm from 27 May to 21 August. Impacts of weather on Kittlitz'murrelet biology and behavior will be examined in the future, when we have data from more years for comparison.

Methods

Nest Searching and Monitoring

Dedicated searching for nests began on May 28 and continued through July 16. After July 16, nest-searching was conducted incidental to other activities. Nests were located by systematically searching poorly-vegetated or non-vegetated terrain (e.g., Burkett et al. 2009, Kaler et al. 2009). 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. 2008, J. Lawonn, pers. obs.). Search efforts were concentrated in areas dominated by scree and talus on ridges and peaks.

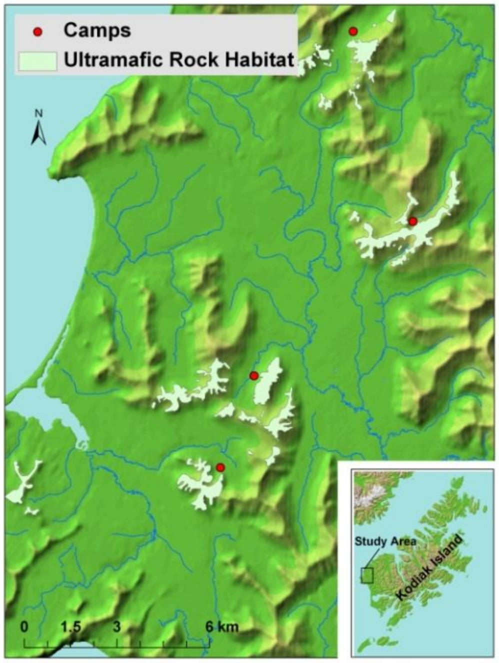

Figure 2. Location of camps and ultramafic rock areas.

We searched areas that were presumed to be optimal (large patches of scree or talus, high elevation, high slope) and marginal (small patches of scree or talus, low elevation, low slope) for adequate representation of potential breeding habitat. Areas within 30-200 m of a known active nest were not searched to avoid disturbance. Handheld GPS units were used to log search tracks to ensure that searches were conducted systematically.

Because the well-camouflaged adults are almost impossible to see on the ground even at close range, we discovered most nests after flushing an adult from the nest. One nest was discovered by visually sighting the adult on the nest, but the bird was inadvertently flushed several seconds after being located. Upon flush, we usually confirmed species identity using the presence of white outer rectrices to positively distinguish Kittlitz's murrelet from the very similar marbled murrelet (*Brachyramphus marmoratus*). In cases where we remained uncertain about identity, the nest was monitored at a distance (>30 m) with binoculars or spotting scope several days following discovery, and bill morphology and plumage characteristics of the attending adult were used to confirm species identity. Although no marbled murrelets had been detected within the study area in 2008 and 2009, they were detected on three mornings during audio-visual surveys in 2010, suggesting that marbled murrelets may also nest in the study area. Marbled murrelets are common breeders in other areas of Kodiak Island and occasionally nest on the ground in similar habitats used by Kittlitz's murrelets elsewhere (Nelson 1997).

Each egg and nest was photographed, as was the surrounding ground cover and terrain. These photographs were used to relocate nests after initial discovery and to help document habitat characteristics. To facilitate relocation of non-camera nests we placed a small mark near the nest scrape with a black permanent marker, or constructed a small rock cairn. Latex or nitrile gloves were worn by the crew when handling substrates near the nest to minimize the introduction of human scent.

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). Data collection at a newly discovered nest site typically required 10 minutes for nests that did not receive cameras, and 12 minutes for nests that did receive cameras. To encourage incubating adults to return to their nests quickly, we withdrew from the nest area when data collection was completed. We resumed our observations 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 and Reconyx PC900 HyperFire Professional High Output Covert Infrared). In one case, a camera was deployed after nest discovery late in the field season. The camera was installed as soon as possible following the brooding period; in this case, four days post-hatch.

Cameras were set from 1.5 to 2.0 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. Cameras were painted to blend in with the environment prior to deployment, 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 (PC90) or twelve (PC900) AA lithium batteries, depending upon model, and were outfitted with either 16 GB compact flash memory cards (PC90) or 16 GB HDHC memory cards (PC900). 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, unpubl. data). 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 for the PC90 and 60 days for the PC900; both types of 16 GB memory cards have a capacity of about 55-60 days with the same settings.

All photos taken by Reconyx cameras were viewed to detect depredation events and quantify adult attendance patterns. Camera images were also used to identify species of forage fish delivered to chicks. Sand lance (*Ammodytes hexapterus*) were readily identified in the adult'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. Images were assigned a status of "unknown" when image quality was not sufficient to categorize forage fish, when there was a lack of images, or when the fish itself was obscured by the adult. Some specimens of fish were collected from the ground near nest sites in both 2009 and 2010, and identified to species later. These opportunistic collections corroborated visual identifications.

Two types of nest-checks were performed. Formal nest-checks occurred after day four of the chick period. The purpose 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, in order to determine nest status. Only one opportunistic nest check was performed in 2010 from a distance of 30 m using a pair of 10 power binoculars.

The timing and number of formal nest checks was identical for both the camera group and the control group. Three 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. The first nest visit was scheduled when a chick was projected to be at least 4 to 6 days old. Another check occurred at day 10 to 12, and a final check was scheduled at day 20 or 21, just before fledging.

Nest Characteristics

We collected data on nest site characteristics after nests were no longer occupied. Nest sites 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. Occasionally a large patch of moss was classified as a "nest rock" if it served any of these purposes. At larger scales, three circular plots (5, 25, 50 m radius) surrounding each nest were sampled to assess nest site slope, aspect (compass direction nest was facing, in degrees), elevation, and ocean view (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 plot. We estimated percent coverage values for 13 types of ground cover on a 5 m radius plot centered on each nest site; and we estimated the percentage of non-vegetated ground cover on 25 and 50 m radius plots centered on each nest site. The 50 m plot was added to the 5 and 25 m plots used in 2008 (Burkett et al. 2009) in order to assess potential edge effects and determine the relative "patchiness" of non-vegetated terrain. 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 facilitate comparison of nest sites with surrounding habitat, more than 50 randomly selected vegetation plots were surveyed within the search coverage area at each of the four sites, for a total of 207 random points. Detailed analysis of habitat data will be conducted during fall-winter of 2011-2012.

Audio-visual Surveys

We documented Kittlitz's murrelet inland flight activity at four locations within the four main study sites. We recorded numbers of birds flying, flight directions, vocalizations, various behaviors, and noted a suite of environmental conditions (Burkett et al. 2009). Station locations were chosen by their proximity to known or suspected flyways and potential nesting habitat (e.g., extensive scree slope). Survey stations in 2010 were each located on the vegetated valley floor at base camp sites, adjacent to potential nesting habitat. We applied the same protocols as Burkett et al. (2009), but surveys began 90 (rather than 120) minutes before sunrise because very few vocalizations were detected prior to 90 minutes before sunrise during 2008. Surveys continued until one hour after sunrise, except when detections were made during the last half-hour of this period, in which case the survey was extended for 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 greater than 400 m.

Genetic and Fecal Sampling

We collected a small blood sample from chicks at 4 to 6 days of age by pricking the brachial vein with a 27 gauge needle. The sample was collected in triplicate in separate capillary tubes, each blown onto a piece of filter paper, and subsequently placed in a cryovial filled with 70% ethanol. Chicks found dead at the nest site were collected whole, placed in a Nasco Whirl-Pak specimen bag and covered with 70% ethanol. A one cm^3 piece of pectoral muscle was later removed from preserved chicks and stored in a cryovial containing 70% ethanol. Feathers and eggshell fragments were collected from nest sites and placed in a paper envelope. Whole and damaged eggs were removed from abandoned nests and contents were preserved in 70% ethanol if any embryonic material was present. The shells of whole eggs were preserved intact.

Fecal samples were collected from nest sites when available. Samples were placed in a Whirlpak or Cryovial and covered with 70% ethanol.

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 nesting habitat in the study area. During our second effort from late-June to mid-July we re-surveyed the same habitats searched in the first effort, but owing to time limitations did not re-survey some marginal habitats. In total, 15 active Kittlitz' murrelet nests were discovered within the four study areas (Figure 3). "Active" nests include nests containing a viable chick or egg. Additionally, one nest containing a dead Kittlitz's murrelet chick was discovered. Because of the lack of any discernable decomposition to the chick, this nest was classified as "recently failed" and was estimated to have failed 1 to 4 days before discovery.

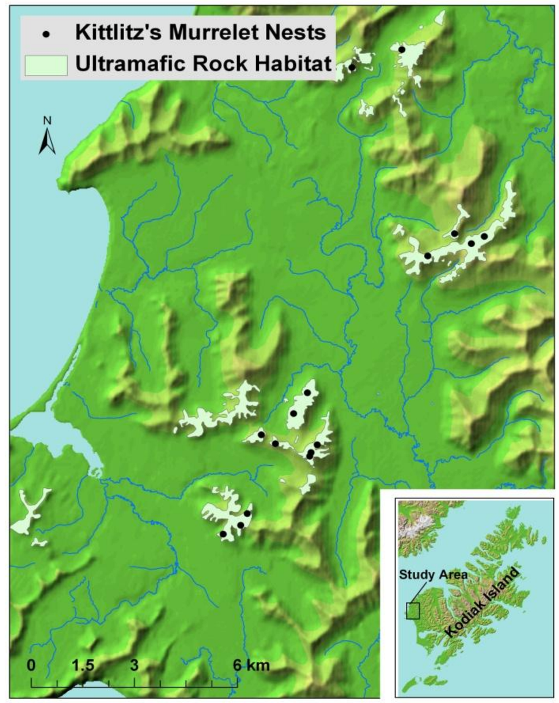

Figure 3. Active or recently failed Kittlitz's murrelet nests discovered in 2010.

In addition to active nests, four inactive nests were discovered. These nests appeared to have been used prior to 2010, and contained definitive evidence of prior occupancy, such as weathered shells, feathers, or feces. Seven potential murrelet nests were discovered as well. These nests exhibited the distinctive shape, size and composition of an active nest, but lacked any evidence of occupancy.

In all but one case, adults were flushed by searchers when they approached active nest sites. The average distance from a searcher an incubating bird flushed was 3.9 m (range = 1.5 - 9.0 m), consistent with flush distance observed during the previous two years of study. Initial flight direction following flush was always directly downslope.

The average return time for an adult bird to the nest was 156 minutes following departure of the field crew from the nest site (n = 6, Table 1). The range of return times was large, with four flushed adults returning in less than one hour, one at about 4 hours, and one bird at nearly 10 hours.

Table 1. Kittlitz's murrelet nest discovery and egg data, Kodiak Island, 2010.

Nest ID	Flush distance of adult (m)	Return time for adult (min)	Egg mass (g)	Egg length (mm)	Egg width (mm)
KODKIMU1001	2.5	26.0	39.0	53.8	36.9
KODKIMU1002	4.5	--	46.5	58.5	39.1
KODKIMU1003	4.0	41.0	40.5	56.1	37.3
KODKIMU1004	3.5	--	36.5	55.4	37.0
KODKIMU1005	2.0	17.0	46.0	58.2	39.2
KODKIMU1006	3.0	--	42.5	56.4	37.3
KODKIMU1007	8.5	583.0	47.5	59.7	38.8
KODKIMU1008	--	--	--	--	--
KODKIMU1009	3.5	253.0	39.5	57.7	37.5
KODKIMU1010	7.0	--	48.0	59.3	39.4
KODKIMU1011	3.0	16.0	43.5	57.4	38.9
KODKIMU1012	2.5	--	44.5	56.1	38.0
KODKIMU1013	3.5	--	--	--	--
KODKIMU1014	--	--	--	--	--
KODKIMU1015	3.5	--	--	--	--
KODKIMU1016	3.0	--	40.0	58.8	37.7
mean	3.9	156.0	42.8	57.3	38.1
standard deviation	1.8	228.4	3.7	1.8	0.9
standard error	0.5	93.2	1.1	0.5	0.3

Egg measurements and coloration fell within the usual range observed in Kittlitz's murrelets (Day et al. 1999). Egg coloration was generally a hazy light green, with scattered dark brown splotches concentrated near the larger end of the egg. The range of egg splotching was large: some eggs were marked across their entire surface while others showed almost no splotching.

Two nests discovered in 2010 were within five meters of at least one empty nest scrape. In one case, the nest was about five meters from another nest scrape created in a previous year, as evidenced by weathered shell fragments found in it. In the second case, we observed two empty nest scrapes about two meters from the active nest site, but neither contained shell fragments. To date, six of 34 active nest scrapes have exhibited such "satellite" nests on Kodiak Island. It is unclear whether these scrapes are evidence of nest area fidelity, represent breeding attempts by different birds, or, in the case of totally empty satellite nests, are scrapes that were abandoned before laying in favor of the active nest scrape.

Initiation of Kittlitz's murrelet nests in 2010 was later and more asynchronous than in 2009, though determination of inter-annual differences is complicated by error associated with estimation of the age of eggs or chicks upon nest discovery. This error was not accounted for in determination of initiation dates in 2009 and 2010. Median initiation date in 2010 was 5 June (range 19 May–15 July), compared with 30 May in 2009 (range 28 May–22 June). The peak of nest initiation in 2010 occurred between 31 May and 19 June. A group of three late-nesting birds initiated in July (Figure 4).

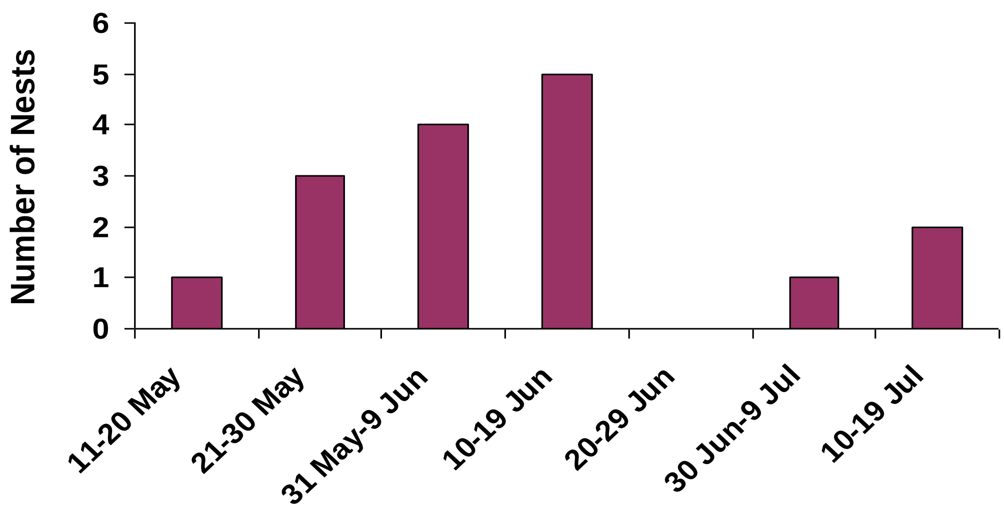

Figure 4. Kittlitz's murrelet nest initiation date, 2010.

Nest Success

Four of 16 nests contained a chick that successfully fledged; a simple index of breeding success would be 0.25 chicks/pair (Table 2, Appendix A). A more sophisticated analysis that combines estimated survival rates of individual eggs and chicks will be conducted at a later time. Two of four successful nests were monitored by Reconyx camera. Both of these nests appeared to fledge on day 23 of the chick stage, where day one represents date of hatch. One of these camera nests was discovered during hatch when a pipped hole in the egg's shell was approximately 1 cm in diameter. The hatch date for the other camera nest was determined as the day before the first meal delivery was made. One nest without a camera was estimated to have fledged between day 22 and 24, but the exact date of hatch was unknown and so the duration of the fledgling period cannot be determined with certainty. One nest was discovered when a startled chick flew from the nest as we approached. This chick's flight ended when it landed about 10 m downslope of the nest. The chick then walked back up the slope toward the nest site, before successfully flying from the slope about 3-5 minutes later.

During our first round of nest visits, timed to occur at about day six post-hatch, three of 16 nests were found with no apparent shell, feather, or fecal remnants, suggesting depredation during the egg stage. Three nests were abandoned during the egg stage, two of which contained apparently unviable eggs (i.e., addled egg with no detectable embryo), which were collected following their abandonment. The other presumed unviable egg was recorded by camera to have been depredated by a red fox (*Vulpes vulpes*) at least 42 days after it was laid, a minimum of twelve days past the mean incubation period of 30 days.

Table 2. Summary of Kittlitz's murrelet nest fates, Kodiak Island, 2010.

Nest Fate	Number of nests
Failed during incubation, nest empty	3
Unviable egg	3
Failed during chick stage, red fox predation	1
Failed during chick stage, nest empty	2
Failed during chick stage, dead chick present	3
Fledged	4
Total	16

Six of 16 nests failed during the early chick stage. Three of these were apparently depredated: one nest was depredated by an unknown predator on the day of hatch (documented by camera); one chick was depredated by a red fox on day three or four of development (documented by camera); and one nest was discovered with chick down and one fecal spot in the nest, indicating depredation before formation of a fecal ring; i.e., very soon after hatch. Dozens of scattered wing and contour feathers from an adult bird around the latter nest scrape indicated the adult may have been depredated as well, possibly while brooding.

Three nests contained dead chicks. One of these chicks was documented by camera to have been ejected from the nest scrape one day after hatch, seven days after its discovery. The sequence of events leading to the chick's ejection was unclear. At 12:12 a.m. an adult was present on the nest, brooding the chick. The next image taken at 12:15 showed the adult to be absent and the chick lying about 20 cm downslope of the nest. An adult returned again to the nest site 33 minutes later. Camera images show that this chick could not right itself from a supine position after leaving the nest, and died about 12 hours later, still about 20 cm downslope of the nest. The other two chicks died of unknown causes. The first was approximately five days old, and had three cm of the tail end of a 12 cm sand lance (*Ammodytes hexapterus*) protruding from its mouth, suggesting death by asphyxiation. The other was three to four days old, and may have died of exposure following an extended period of windy, wet weather. All dead chicks were collected for later genetic studies.

The survival rates of eggs and chicks were similar between "disturbed" nests with cameras and "control" nests without cameras, though the small sample size may preclude determination of statistical significance. During 2009 and 2010, 60% of successful nests (n = 5) had cameras placed on site, whereas 48% of failed nests (n = 21) had cameras placed on site. Three nests discovered in 2009 and 2010 are not included in this analysis. Two of these nests were discovered late in the season when cameras were not carried, and one nest that was to receive a camera had already been depredated upon discovery (egg shells and contents present in nest). Due to differences in camera protocols, we excluded data from a single nest outfitted with a camera in 2008.

Nest Site Characteristics

Nest site characteristics in 2010 were generally consistent with nests observed during the previous two years of study. Nest scrapes were usually composed of loose gravel-sized rock of diameters ranging from less than 1 cm to 5 cm. In a few cases the nest scrape was partially or totally comprised of dead or living moss. A large rock or clump of moss was present directly upslope of most nests in 2010, but one nest had no prominent nest rock. Ground cover within 5, 25, and 50 m nest plots was predominantly unvegetated (mean vegetated cover = 6.7, 6.2, and 6.9 %, respectively, Appendix B), and was composed primarily of scree and talus.

Kittlitz's murrelet nests found in 2010 had a mean elevation of 300 m (SE = 17.3, Appendix B). Nests were usually situated in relatively steep habitats, with all nests occurring at slopes equal to or greater than 20° (mean 28.4°, SE = 0.94, Appendix B). The ocean was in view at 90 percent of nest sites, a finding that may have biological significance for fledging juveniles who must fly to the ocean without any parental guidance. Other nest characteristics are presented in Appendix C.

Meal Delivery and Chick Growth

Parental attendance patterns and meal deliveries were documented by use of remote, automatic cameras (set to capture images at three-minute intervals and when activated by motion, see Methods). Adults delivered meals most frequently at dawn and dusk (Figure 5). The majority (64.8%) of all meals were delivered between 5:00 – 8:00 a.m. and 10:00 p.m. – 1:00 a.m.; similar to the 60.4% seen last year during the same time intervals. Very few deliveries were recorded between the hours of 1 and 5 a.m. during either 2009 or 2010.

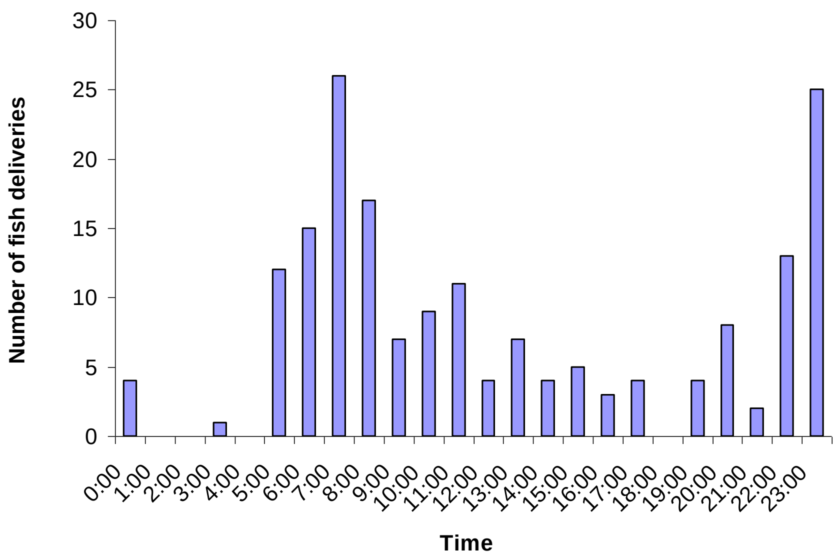

Figure 5. Daily pattern of meal deliveries to Kittlitz's murrelet chicks, Kodiak Island, 2010.

A total of 177 meal deliveries were recorded at five nests while a live chick was present (Table 3). On 5 occasions, adults delivered fish to an empty nest after fledging, chick death, or depredation had taken place. These latter data were not included in delivery rate analysis, but were included in analyses of forage species delivered to nests.

Table 3. Frequency of fish meal deliveries to Kittlitz's murrelet chicks, Kodiak Island, 2010.

Nest	Mean visits/day	SD	Range visits/day	Total fish delivered	Total days monitored	Nest outcome
KODKIMU1003	3.0	N/A	3	3	1	Depredated day 1
KODKIMU1005	4.0	2.45	1 - 6	16	4	Depredated day 4
KODKIMU1009	2.5	0.71	2 - 3	5	2	Chick died day 2
KODKIMU1011	3.6	1.74	1 - 7	79	22	Fledge
KODKIMU1013	3.9	1.52	0 - 6	74	19	Fledge

Sand lance was the most commonly delivered forage fish, comprising 59.3% of total fish observed (Table 4). Fusiform, "capelin-like" fish represented 7.7% of fish deliveries, while unknown fish comprised 33.0% of deliveries.

Table 4. Composition of forage fish meals delivered to Kittlitz's murrelet chicks, Kodiak Island, 2010.

Nest	Number of sand lance	Number of capelin-like fish	Number of unknown fish	Total Fish
KODKIMU1003	2	0	1	3
KODKIMU1005	13	0	3	16
KODKIMU1009	4	0	1	5
KODKIMU1011	40	8	31	79
KODKIMU1013	47	6	24	77
KODKIMU1014	2	0	0	2
Total fish	108	14	60	182
% Total	59.3	7.7	33.0	100

One noteworthy camera image showed three adult birds surrounding an active nest containing a chick on 29 July at 6:45 a.m.; none of the adults had a fish in its bill. The previous image taken at 6:42 a.m. showed only one adult in the frame, which was provisioning a fish meal to the chick at the nest. While it is not unusual to observe two adults visiting a nest simultaneously, this was the first time we saw three birds in attendance, and it is unclear why a non-pair adult was present at the nest site.

Growth data were collected from three chicks, all of which eventually fledged (Figure 6). Increase in chick mass was very high between days 6-7 and day 11, and appeared to slow substantially between day 11 and day 21. The masses of two chicks measured approximately 2 days before fledging were 138 and 132 grams, about 60% of the average adult mass of 224 g (Burkett et al. 2009, Kaler et.al. 2010).

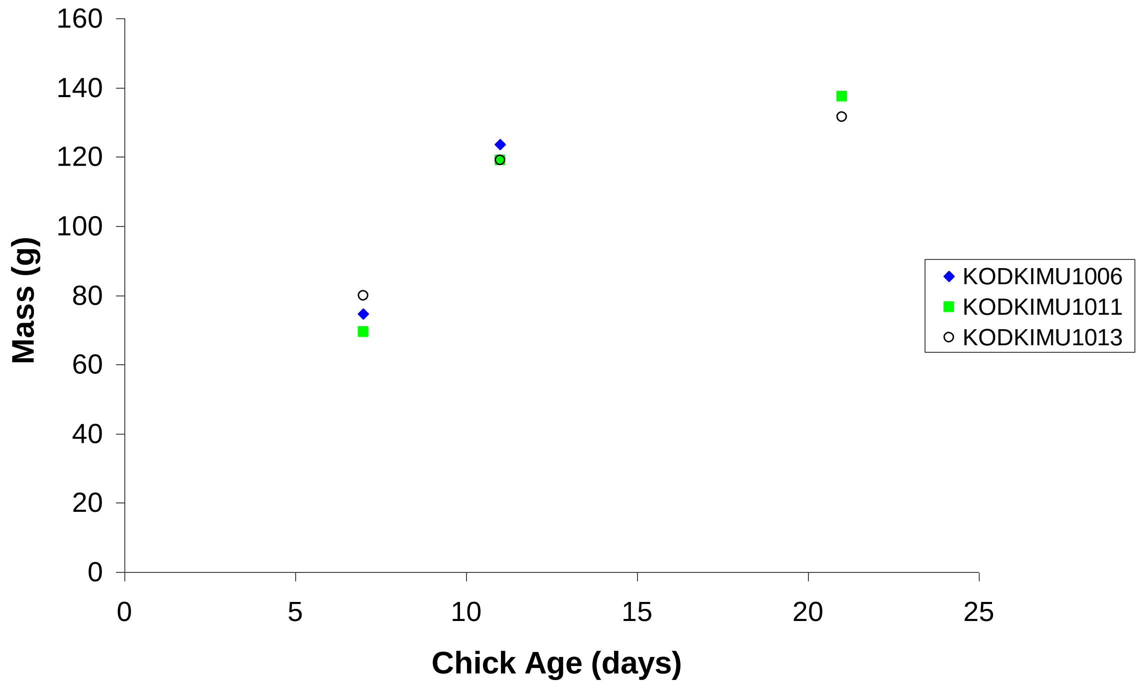

Figure 6. Kittlitz's murrelet chick mass and growth, Kodiak Island, 2010. Estimated age plotted for non-camera nest KODKIMU 1006. Chick age +/- 12 hours plotted for camera nests KODKIMU1011 and KODKIMU1013. Day 1 represents day of hatch.

Audio-visual Surveys

A total of 238 Kittlitz's murrelet detections were recorded during 23 audio-visual surveys (AV surveys) performed over a 12-week period at four survey stations. All birds were detected by sound, and no birds were detected visually during AV surveys in 2010. The mean number of detections per survey in 2010 was 9.3 (SE = 4.2, n = 23), substantially lower than detection rates in 2009 for the same locations visited at roughly the same times (mean = 20.9, SE = 6.6, n = 24). Causes for the difference in detection rates are unclear, but may relate to differences in weather conditions, breeding activity, or numbers of Kittlitz's murrelet present within the study area. Detections were most frequent from sunrise to one-half hour after sunrise (Figure 7), a figure consistent with findings in 2008 and 2009 (Burkett et al. 2009, Lawonn et al. 2009).

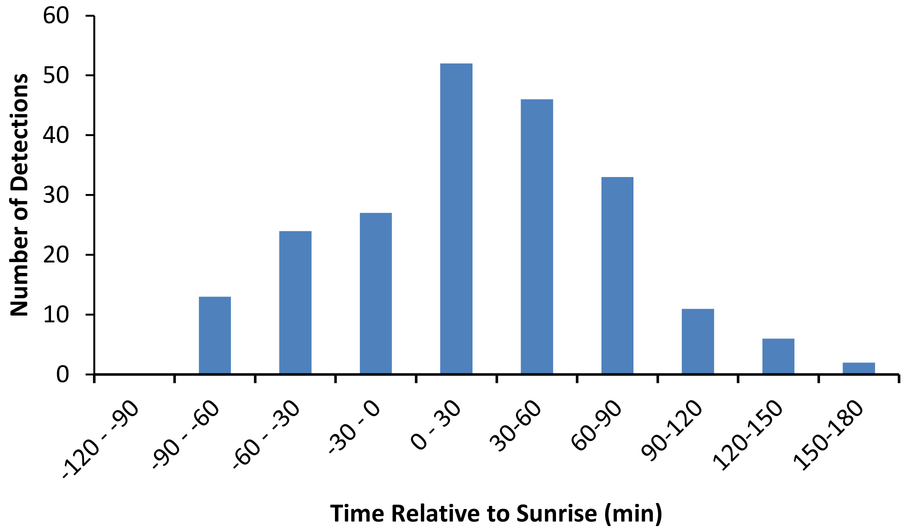

Figure 7. Timing of Kittlitz's murrelet detections relative to sunrise, Kodiak Island, May 28 - August 19, 2010. Sunrise equals 0.

Detection rates remained very low throughout June despite the success we had in finding nests that month. There was a marked increase in Kittlitz's murrelet activity during early to mid-July, and a decline in activity from late July into August (Figure 8). A similar high activity period extended through the month of July during both 2008 and 2009 (Burkett et al. 2009, Lawonn et al. 2009).

Marbled murrelets were detected within the study area during three different AV surveys, for a total of nine detections. No marbled murrelets had been detected during the 2008 and 2009 field seasons. The presence of marbled murrelets within the study area, albeit in apparently low numbers, highlights the importance of proper identification of murrelet species flushed from nests.

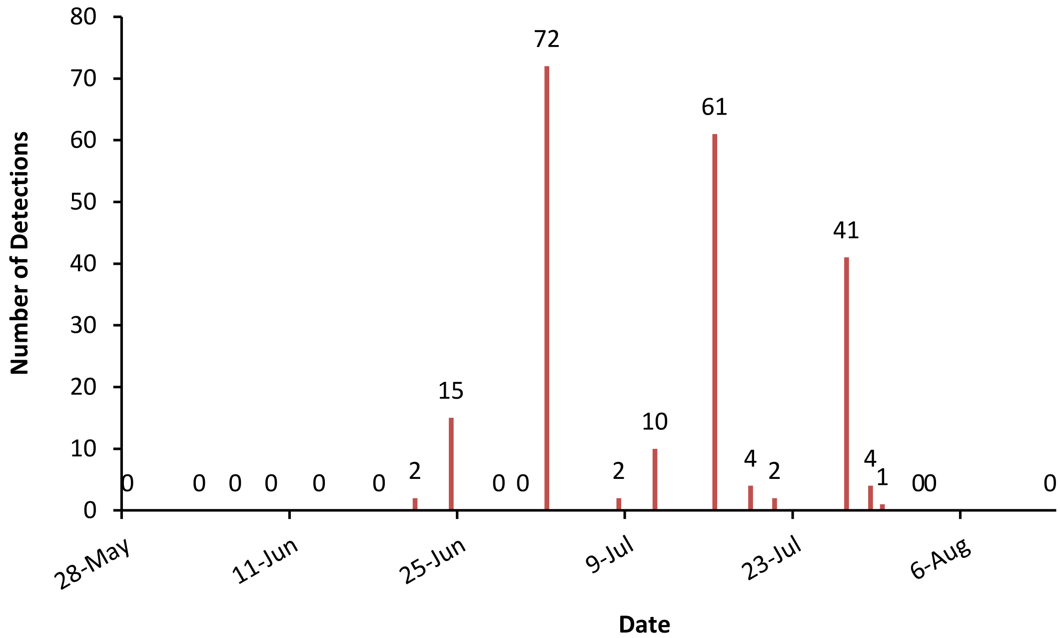

Figure 8. Number of Kittlitz's murrelet detections made during audio-visual surveys on Kodiak Island sites, May 28 - Aug 19, 2010.

Conclusions and Suggestions for 2011

The success rate of Kittlitz's murrelet nests was higher in 2010 compared to 2008 and 2009. Four of 16 nests fledged chicks in 2010, while only one fledged in 2009 and none fledged in 2008. Altogether, only 5 of 34 known breeding attempts on Kodiak Island from 2008 to 2010 yielded fledglings. It is unclear whether data collected in all years of this study are truly representative for Kittlitz's murrelets in Kodiak, or elsewhere in the Gulf of Alaska. Clearly, any estimate we could make for long-term breeding success of Kittlitz's murrelet within the study area would benefit from more years of research.

The low nesting success we observed could be attributed to a number of factors. Camera data revealed that predation was the most important limiting factor on camera nests over the last three years. If it is assumed that all egg and chick disappearances were caused by depredation, predation may have accounted for up to 56% of nest failure for all nests (Figure 9). Depredation rates were lower (38%, n=16) in 2010 than in the two previous field seasons (72%, n=18). Foxes were observed on 20.4% of field days (n=18, Appendix D), and were seen delivering food including pink salmon (*Oncorhynchus gorbuscha*) and unknown prey items to at least one presumed den site within 100 meters of potentially suitable nesting habitat. Additionally, game trails and fox scat were frequently observed on scree slopes near Kittlitz's murrelet nests, even on slopes of up to 30 degrees. Foxes accounted for 4 of 5 nest depredations documented by cameras from 2008 to 2010, while the remaining nest was depredated by an unknown predator. Other commonly observed potential predators within the study area include the common raven (*Corvus corax*), bald eagle (*Haliaeetus leucocephalus*), and black-billed magpie (*Pica hudsonia*) (Appendix D).

In our study area, differences in annual rates of breeding success may be related to variation in availability of alternate fox prey, such as tundra vole (*Microtus oeconomus*), willow and rock ptarmigan (*Lagopus* spp.) and pink salmon during the murrelet nesting period. Field observations and anecdotal reports (W. Pyle, unpubl.) suggested that vole populations irrupted in some lowland regions of Kodiak Island during summer of 2010, although high numbers of voles were not observed near the study sites. Additionally, high numbers of pink salmon were observed in 2010 in drainages within two km of potential murrelet nesting habitat, and high numbers relative to previous years of both rock and willow ptarmigan were seen within the study area.

Other factors that reduced breeding success included non-hatching eggs and chick mortality. Chick death secondary to malnourishment, or after exposure to inclement weather accounts for about 12% of total nest failures. Six eggs thought to be unviable have been observed from 2008-10, representing nearly 18% of total eggs laid. It is possible that our activities contributed to the loss of egg viability. The cooling of eggs following nest discovery could cause embryo mortality, especially when the incubating bird is absent for many hours following flush. In future work, we will continue all possible efforts to vacate nest areas quickly following discovery.

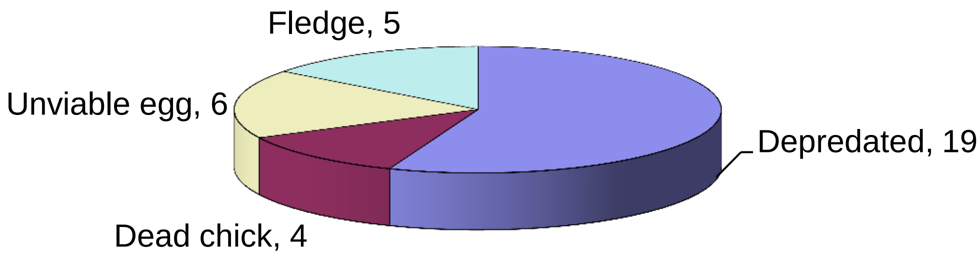

Figure 9. Fate of Kittlitz's murrelet nests (n=34) on Kodiak Island, 2008-2010.

Camera images from six different nests in 2010 suggest that sand lance are important forage fish for nesting Kittlitz's murrelets within the study area. Measurements from three chicks indicate that growth rates on Kodiak may be high compared with rates from Agattu Island (Kaler et al., 2008, Kaler et al. 2009). Though detailed analyses have yet to be performed, it seems possible that differences in quality of forage fish delivered to chicks may be at least partially responsible for the difference in growth rates among islands.

Camera placement and performance proved very effective in 2010, but some improvements can still be made. A relatively high percentage (33%) of fish delivered to nests in 2010 were unidentifiable, and it would probably facilitate fish identification if we moved cameras closer to nest sites after eggs have hatched. A camera distance of .75 to 1 m from nest sites might be ideal.

We will also consider placing cameras on every nest we find in subsequent years of this study, in order to increase information gathered on meal delivery rates, diet composition and fate of nests. Our approach so far has been to try and assess effects of investigator disturbance on nest sites by placing cameras on only half the nests discovered. However, it appears that the presence of cameras on nest sites had little influence on nest success so far, although sample sizes from 2009 and 2010 are small. Increasing the number of cameras used on our study site would also be desirable because it would provide more data for comparing chick growth rates and diet composition between our study area and Agattu Island, which appear quite different with respect to these parameters (Kaler et al. 2009, Kaler et al. 2010).

We discovered two cases where inactive satellite nests existed within five meters of an active or recently active nest in 2010, and observed four similar cases in 2008 and 2009. Such inactive nests located in close proximity to active nests have been observed in studies of marbled murrelets, and it is possible that these paired nests belonged to the same mating pair (Naslund 1995). They may represent repeated nesting attempts within one breeding season, reflect inter-annual nest area fidelity, or reflect selection for specific microhabitat characteristics by numerous pairs of birds over different years.

Nesting habitat characteristics were consistent among study years. All nests were found on predominantly non-vegetated terrain at altitudes greater than 215 meters on relatively steep slopes. These data will be analyzed in detail in the future. Audio-visual surveys demonstrated similar seasonal patterns in attendance compared to those documented in 2008-2009. Low numbers of detections were made early and late in the field season, with peak activity occurring in mid to late July. Total numbers observed in 2010, however, were lower than found in 2008-2009. Detailed analysis of audio-visual data will also occur in the future.

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Appendix A. Chronology and fate of Kittlitz's murrelet nests found on Kodiak Island, 2010

Nest ID	Date Discovered	Approximate Date Initiated	Hatch Date*	Last Date Nest Known to be Active	Group	Fate
KODKIMU1001	31-May-10	28-May-10	27-Jun-10	8-Jul-10	Camera	Unviable egg depredated by fox on day 42
KODKIMU1002	12-Jun-10	1-Jun-10	30-Jun-10	12-Jun-10	Control	Failed during chick stage
KODKIMU1003	15-Jun-10	30-May-10	29-Jun-10	30-Jun-10	Camera	Depredated by unknown predator on day 1 of chick stage
KODKIMU1004	15-Jun-10	23-May-10	22-Jun-10	23-May-10	Control	Failed during egg stage
KODKIMU1005	17-Jun-10	31-May-10	30-Jun-10	3-Jul-10	Camera	Depredated by fox on day 4 of chick stage
KODKIMU1006	17-Jun-10	13-Jun-10	13-Jul-10	4-Aug-10	Control	Fledged
KODKIMU1007	18-Jun-10	17-Jun-10	17-Jul-10	26-Jul-10	Camera	Adult abandoned unviable egg
KODKIMU1008	22-Jun-10	19-May-10	18-Jun-10	21-Jun-10	Control	Chick found dead upon discovery of nest
KODKIMU1009	23-Jun-10	29-May-10	29-Jun-10	30-Jun-10	Camera	Chick ejected from nest on day 2 of chick stage
KODKIMU1010	28-Jun-10	19-Jun-10	20-Jul-10	19-Jun-10	Control	Failed during egg stage
KODKIMU1011	1-Jul-10	17-Jun-10	16-Jul-10	7-Aug-10	Camera	Fledged 5:45 am, 7-Aug, 22 days post-hatch
KODKIMU1012	12-Jul-10	11-Jul-10	10-Aug-10	2-Aug-10	Control	Failed during egg stage
KODKIMU1013	16-Jul-10	17-Jun-10	16-Jul-10	7-Aug-10	Camera	Fledged 22:50 pm, 7-Aug, 22 days post-hatch
KODKIMU1014	28-Jul-10	4-Jun-10	4-Jul-10	28-Jul-10	Control	Chick fledged immediately upon discovery
KODKIMU1015	29-Jul-10	7-Jul-10	6-Aug-10	11-Aug-10	Camera	Chick found dead in nest
KODKIMU1016	4-Aug-10	15-Jul-10	14-Aug-10	4-Aug-10	Control	Adult abandoned unviable egg

*Hatch dates estimated by egg flotation in water (Rizzolo and Schmutz 2007, Kaler et al. 2008), and camera images

Appendix B. Selected characteristics of Kittlitz's murrelet nests, Kodiak Island, 2010

PLOT ID	Avail Nest Rock >20 cm	Ocean View?	Slope	Elevation (m)	5 m % Vegetated	25 m % Vegetated	50 m % Vegetated
KODKIMU1001	15	Y	35	384	3	5	5
KODKIMU1002	25	Y	21	230	7	5	5
KODKIMU1003	30	Y	30	346	10	12	14
KODKIMU1004	27	Y	30	404	33	9	8
KODKIMU1005	15	Y	27	220	3	3	3
KODKIMU1006	15	N	29	263	3	3	3
KODKIMU1007	20	Y	27	455	8	10	10
KODKIMU1008	50	Y	36	289	2	1	1
KODKIMU1009	6	Y	25	219	2	3	3
KODKIMU1010	20	Y	30	390	1	2	3
KODKIMU1011	13	Y	30	280	24	30	30
KODKIMU1012	12	N	22	235	3	3	2
KODKIMU1013	15	Y	28	233	6	5	6
KODKIMU1014	11	Y	30	320	2	3	4
KODKIMU1015	12	Y	22	378	1	1	3
KODKIMU1016	32	Y	24	279	9	7	7
KODOLDNST1002	15	Y	31	215	3	4	5
KODOLDNST1003	17	Y	34	183	6	6	8
KODOLDNST1004	12	Y	26	377	2	3	5
KODOLDNST1005	30	Y	30	303	6	9	12
Mean	19.6	0.9	28.35	300.15	6.7	6.2	6.85
Standard Error	2.28	0.07	0.94	17.35	1.80	1.43	1.43
Standard Deviation	10.17	0.31	4.18	77.58	8.05	6.38	6.41

Appendix C. Ground cover (%) and physical characteristics of Kittlitz's murrelet nest sites and random plots, Kodiak Island, 2008-2010

2010 Nest Statistics

	% Rock <1 cm	% Rock 1-5 cm	% Rock 5-10 cm	% Rock 10-30 cm	%Rock >30 cm	Avail Nest Rock >20 cm	% soil	% Lichen cover	% Orange crustose lichens	% Moss	% Grass	% Forb	% Shrub	5 m % Vegetated	Converted Ocean View	Slope	Elevation (m)	25 m % Vegetated	50 m % Vegetated
Mean	16.8	26.0	22.5	18.5	10.1	19.6	0.3	0.3	0.2	1.5	0.8	0.2	3.9	6.7	0.90	28.4	300.2	6.2	6.9
Standard Error	1.5	2.0	1.3	1.2	1.4	2.3	0.1	0.1	0.1	0.3	0.2	0.1	1.5	1.8	0.07	0.9	17.3	1.4	1.4
Standard Deviation	6.5	9.1	6.0	5.5	6.1	10.2	0.6	0.5	0.5	1.5	1.1	0.3	6.8	8.1	0.31	4.2	77.6	6.4	6.4
Count	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.00	20.0	20.0	20.0	20.0

2008-10 Nest Statistics

	% Rock <1 cm	% Rock 1-5 cm	% Rock 5-10 cm	% Rock 10-30 cm	%Rock >30 cm	Avail Nest Rock >20 cm	% soil	% Lichen cover	% Orange crustose lichens	% Moss	% Grass	% Forb	% Shrub	5 m % Vegetated	Converted Ocean View	Slope	Elevation (m)	25 m % Vegetated	50 m % Vegetated
Mean	14.3	23.9	22.7	22.1	10.1	21.2	0.3	0.8	0.1	1.9	0.9	0.3	4.2	7.0	0.89	28.9	331.4	6.8	7.7
Standard Error	1.4	1.6	1.0	1.8	1.1	2.0	0.1	0.2	0.1	0.3	0.2	0.1	1.0	1.3	0.05	0.7	12.2	1.0	1.1
Standard Deviation	8.4	10.0	6.1	11.0	6.8	12.2	0.7	1.3	0.4	2.0	1.0	0.5	6.3	7.8	0.31	4.3	75.1	6.1	6.7
Count	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.00	38.0	38.0	38.0	37.0

2010 Random Plot Statistics

	% Rock <1 cm	% Rock 1-5 cm	% Rock 5-10 cm	% Rock 10-30 cm	%Rock >30 cm	Avail Nest Rock >20 cm	% soil	% Lichen cover	% Orange crustose lichens	% Moss	% Grass	% Forb	% Shrub	5 m % Vegetated	Converted Ocean View	Slope	Elevation (m)	25 m % Vegetated	50 m % Vegetated
Mean	19.5	22.7	18.7	13.4	9.3	14.9	0.5	0.9	0.3	2.8	1.9	0.7	10.4	15.9	0.7	25.9	319.6	16.4	17.2
Standard Error	0.7	0.8	0.6	0.5	0.7	0.8	0.1	0.2	0.1	0.3	0.2	0.1	1.3	1.6	0.0	0.4	5.1	1.5	1.5
Standard Deviation	10.8	11.1	8.8	7.6	10.3	12.0	1.0	2.4	1.4	4.6	2.8	2.1	18.9	23.6	0.5	6.4	73.7	21.9	22.0
Count	208.0	208.0	208.0	208.0	208.0	208.0	208.0	208.0	208.0	208.0	208.0	208.0	208.0	208.0	208.0	208.0	208.0	208.0	208.0

Appendix D. 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-23 August, 2010.

Species		Date first	Date last	Total Days	Mean no.
Common name	Scientific name	observed	observed	Observed	observed/day
Bald Eagle	*Haliaeetus leucocephalus*	1-Jun-10	12-Aug-10	32	0.56
Golden Eagle	*Aquila chrysaetos*	26-May-10	15-Aug-10	21	0.32
Unidentified Eagle	–	6-Jun-10	22-Jul-10	3	0.03
Merlin	*Falco columbarius*	10-Jul-10	11-Aug-10	6	0.07
Peregrine Falcon	*Falco peregrinus*	22-Jun-10	22-Jun-10	1	0.01
Parasitic Jaeger	*Stercorarius parasiticus*	8-Jun-10	23-Jul-10	4	0.06
Black-billed Magpie	*Pica hudsonia*	26-May-10	18-Aug-10	46	0.89
Common Raven	*Corvus corax*	28-May-10	18-Aug-10	15	0.36
Northern Shrike	*Lanius excubitor*	15-Jul-10	17-Aug-10	4	0.09
Red Fox	*Vulpes vulpes*	30-May-10	12-Aug-10	22	0.32
Kodiak Brown Bear	*Ursus arctos middendorffi*	26-May-10	17-Aug-10	6	0.1