Breeding Ecology and Behavior of Kittlitz's Murrelet in Kodiak National Wildlife Refuge, Alaska: 2011 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 most poorly-known birds in North America and very little is known about its nesting ecology. For the fourth consecutive year, we studied the breeding biology and behavior of Kittlitz's murrelets on southwest Kodiak Island, Alaska. We systematically searched nesting habitat for active nests, placed motion-sensitive cameras on a subset of nests to assess chick feeding rates and nest predation, and collected morphometric and genetic data on chicks. We periodically visited nests to determine their status and to measure chick growth rates. Following the end of breeding activities, we sampled ground cover at nest sites and random plots to characterize nesting habitat. We discovered 22 active nests during 2011; 14 of these nests produced chicks, of which four fledged. Chick provisioning, nest depredation, and egg abandonment were recorded at 19 nests using remote cameras. We also conducted 16 audio-visual surveys of Kittlitz's murrelets in the vicinity of documented nesting habitat and recorded 372 total detections at five survey sites.

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

Introduction

Kittlitz's murrelet (*Brachyramphus brevirostris*) is a rare seabird of the North Pacific and one of the more poorly-known birds in North America (Day et al. 1999). It is a non-colonial breeder that generally nests in un-vegetated montane habitats, frequently near glacial ice fields (Day et al. 1983, 1999; Piatt et al. 1999; Burkett et al. 2009). The species nests primarily in Alaska, where long-term population monitoring suggests significant declines in some local populations (Kuletz et al. 2011a, 2011b; Piatt et al. 2011). Causes of these apparent 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 et al. 2008), but these factors cannot entirely explain recent population declines. Other potential contributing factors may 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 2011); and changing patterns in avian predation (USFWS 2011).

We initiated a study of Kittlitz's murrelet nesting ecology and behavior in 2008, following the discovery of murrelet flight activity over inland habitat in western Kodiak Island during July 2007 (Day and Barna 2007). In coordination with the Alaska Maritime National Wildlife Refuge, which began a similar investigation of Kittlitz's murrelets on Agattu Island in the western Aleutians (Kaler and Kenney 2008), and the Region 7 USFWS Office of Ecological Services, we adopted a five-year plan for studies of Kittlitz's murrelet on Kodiak and Agattu islands. Specific objectives were to: 1) locate and study as many Kittlitz's murrelet nests as possible; 2) characterize nesting habitat (e.g., altitude, substrate type, vegetation, etc.); 3) monitor incubation shifts of adults at nests and rate of meal delivery to chicks; 4) identify prey in chick meals; 5) measure rate of chick growth; 6) measure hatching, fledging, and overall reproductive success; 7) collect blood, feathers, and egg-shell fragments for future genetic analyses; and 8) characterize the seasonal activity patterns of adults by conducting regular early-morning surveys.

This report summarizes results from the fourth year of our study of the nesting ecology and behavior of Kittlitz's murrelets in Kodiak National Wildlife Refuge, Alaska. 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 2011 in southwest Kodiak Island, and compare selected results with those from previous years. In addition, we present recommendations for further research on Kittlitz's murrelets in Kodiak Island habitats.

Our research, along with a concurrent study on Agattu Island, addresses fundamental gaps in our knowledge of Kittlitz's murrelet breeding ecology and provides new information on the terrestrial nesting biology and behavior of this enigmatic species of seabird. To further these research ends, the USGS - Oregon Cooperative Fish and Wildlife Research Unit at Oregon State University was added as a cooperator on the study, and the senior author is pursuing a graduate degree, with thesis research addressing several of the project objectives referenced above.

Study Area and Climate

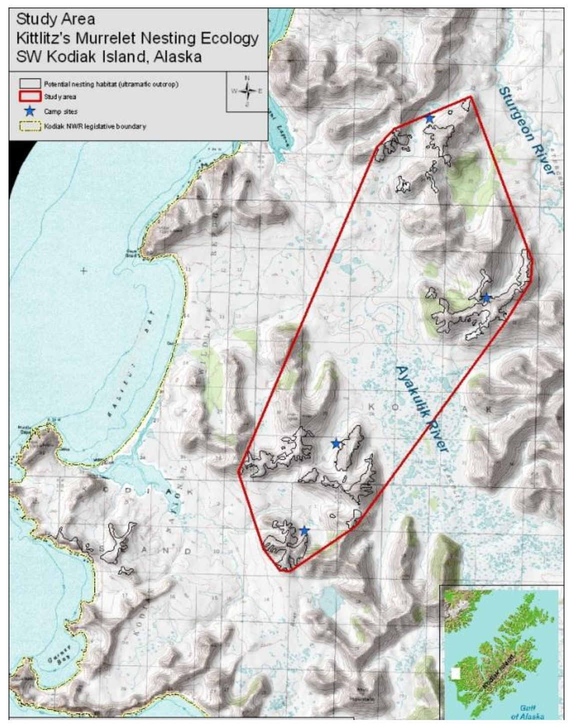

Figure 1. Map of study area.

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. Mountains cover most of the interior of Kodiak Island, with the balance largely composed of non-mountainous uplands, small and large river valleys, and tidal flats. Only the highest peaks on the island exceed elevations of 1,300 m. Relatively few types of vegetative communities dominate land cover on the island, including shrub (42%), meadow (17%), dwarf shrub (14%), non-vegetated (12%), forest (10%), and wetland (4%).

Two non-vegetated land cover types, bedrock and talus, were regarded as potentially suitable habitats for nesting Kittlitz's murrelets. Together these types comprise 46,800 ha (5%) of land cover on Kodiak Island, and are distributed primarily within alpine areas exceeding 600 m elevation. Our study area was characterized by low to mid-elevation (up to 460 m) ridges and peaks that included large continuous areas of scree and talus. The parent material at these sites is classified as ultramafic, a type of igneous rock containing high concentrations of heavy metals and low concentrations of nutrients; this combination prevents the growth of most vascular plants (Alexander et al. 2006). Expanses of exposed ultramafic rock produce scree and talus habitats at relatively low elevations within our study area on Kodiak Island, and appear in stark contrast to surrounding slopes of similar elevation, which are covered with lush plant growth. Exposed ultramafic rock is uncommon in the Kodiak Archipelago, but relatively abundant within the study area (Wilson et al. 2005). Collectively, the ultramafic exposures in the study area comprise 78% (720 of 921 ha) of the exposed bedrock in southwestern Kodiak Island. Our study was conducted at four discrete sites, each characterized by one or more contiguous ultramafic outcrops exceeding 100 ha in size, up to a maximum size of 448 ha (Figure 1).

The absence of glaciers distinguishes the study area from others on mainland Alaska where concentrations of Kittlitz's murrelets are known or presumed to nest (Day et al. 1983, 1999). The few glaciers that do exist on Kodiak Island are small in area, restricted to the highest peaks, and collectively encompass an estimated total area of 2,500 ha. No glacial ice or permanent snow exists within 30 km of our study area. Historically, the study area was surrounded by extensive glaciers and ice sheets during the last glaciation 25,000-10,000 Y.B.P. (Mann and Peteet 1994). Mountains within the study area, however, including those currently used by nesting Kittliz's murrelets, were apparently ice-free during this period.

Climatically, the study area is located within one of the driest regions of Kodiak Island (Karlstrom and Ball 1969). Total annual precipitation at sea level ranges between 76 cm and 102 cm, the range reported at the community of Larsen Bay, which is approximately half the range reported for the city of Kodiak. We collected weather data at camp locations adjacent to each of the four study sites, but were only able to collect these data during periods when the camps were occupied. Hence, our weather records are a composite of data collected at four different locations, which probably differed somewhat in weather conditions. Average minimum and maximum daily temperatures from 27 May to 26 August 2011 were 7.4 °C (range -0.4 to 12.2 °C) and 16.6 °C (range 7.3 to 21.6 °C), respectively. Mean daily rainfall was 0.40 cm, and total precipitation during the study period was 35.12 cm (Appendix A). To enable inter-annual comparisons unbiased by potential differences in weather conditions among camps, we compiled data from the Booth Lake Remote Automated Weather Station, located approximately 14 km southwest from the center of the study area (57.2678° N 154.565° W) for June – August during 2008-2011 (Western Regional Climate Center 2012; Appendix A). Data from this site indicate that the nesting season in 2011 was characterized by higher levels of precipitation and somewhat cooler temperatures than during 2008-2010 (Appendix A); however, the absence of temperature data for 13 days in early June 2008 compromises temperature comparisons between 2008 and 2011.

Methods

Nest Searching and Monitoring

Dedicated searches for nests began on May 30 and continued through July 18, 2011. After July 18, nest-searching was conducted incidental to other data collection activities. Nests were located by systematically searching sparsely-vegetated or un-vegetated terrain (Burkett et al. 2009, Kaler et al. 2009). Searchers walked abreast of each other, separated by 5-10 m, a little more than the average flush distance of an incubating murrelet (Lawonn et al. 2009, 2011), and parallel to the contour line of slopes. Search efforts were concentrated in large patches of scree and talus. These were searched contiguously so as to thoroughly search large blocks of suitable nesting habitat. We searched areas that were presumed to be highly suitable (large patches of scree or talus, high elevation, steep slope) and less suitable (small patches of scree or talus, low elevation, low slope) for nesting, in order to sample a full range of potential breeding habitats. Areas within 30-50 m of a known active nest were not searched to avoid disturbing active nests. Handheld GPS units were used to log search tracks and to ensure that searches were conducted systematically.

We discovered most active Kittlitz's murrelet nests after flushing an incubating adult because the well-camouflaged adults are almost impossible to see on the ground, even at close range. The only exception was one nest that was discovered when an unattended chick was visually detected on its nest. We used the presence of white outer rectrices as a definitive field mark for identification of flushed adult Kittlitz's murrelets. We used optics or nest camera images to confirm our initial identification in cases of uncertainty, using culmen morphology as a field mark. Although no individuals of the morphologically-similar marbled murrelet (*B. marmoratus*) were detected within the study area in 2008 and 2009, they were detected during three different morning audio-visual surveys in 2010 and during two non-survey mornings during 2011. Marbled murrelets are common breeders in other areas of Kodiak Island and occasionally nest on the ground in habitats similar those used by Kittlitz's murrelets (Nelson 1997, Nelson et al. 2010). During 2008-2011, no marbled murrelet nests were discovered within the study area.

Each murrelet egg and nest was photographed, as was the surrounding ground cover and terrain. Photographs were used subsequently to facilitate nest relocation and to document habitat characteristics. To facilitate relocation of nests where a remote camera was not deployed, we placed a small mark on a prominent rock near the nest scrape using a black permanent marking pen, 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.

We estimated the date of nest initiation by floating the egg in water (Westerskov 1950, Rizzolo and Schmutz 2007), scaling egg buoyancy benchmarks against an assumed a 30-day incubation period (Day et al. 1999). Eggs were measured using dial calipers (± 0.1 mm), and mass obtained with a spring scale (± 0.5 g). Data collection at a newly discovered nest site typically required 10 minutes for nests where no camera was deployed, and 12 minutes for nests where a camera was deployed. To encourage incubating adults to return to their nests quickly, we withdrew from the nest area immediately once data collection was completed. We resumed our observations on a different face of the same ridge or peak, or moved to a completely different ridge.

Weather-resistant, motion-triggered cameras were placed on every active nest upon discovery (Reconyx PC90 RapidFire Professional Covert Color IR and Reconyx PC900 HyperFire Professional High Output Covert Infrared). In two cases, a camera was deployed several days after nest discovery because no cameras were available. In three cases nests had failed before we were able to place cameras near them.

Cameras were deployed 0.9 - 1.5 meters from the nest scrape using an iron stake driven into the ground for support. The distance of cameras from nests was reduced by an average of about 0.5 m in 2011 compared with previous study years in order to facilitate identification of fish species delivered to chicks and to increase the likelihood of activity near the nest triggering the camera's motion sensor. Previous nest/camera distances ranged from 1.5 m to 2 m. Rocks were placed around the camera body, when necessary, to provide concealment and camera stability. Cameras were camouflaged with paint prior to deployment, and were outfitted with visors to reduce glare from the reflective lens and flash surfaces (after Kaler and Kenney 2008). Cameras were powered by six (PC90) or 12 (PC900) AA lithium batteries, depending upon the model, and were outfitted with either 16 GB compact flash image storage cards (PC90) or 16 GB HDHC image storage 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 will remain at a nest while feeding a chick (J. Piatt and 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 image storage cards have a capacity of about 55 - 60 days with the same camera settings.

All photos taken during the period from two days before hatch to the end of nesting activity were viewed to: 1) detect depredation events, 2) quantify adult attendance, and 3) quantify the number, size, and species of fish delivered to chicks by parents. Pacific sand lance (*Ammodytes hexapterus*) were readily identifiable in the adult's bill based on its distinctive needle-shaped body, tapered caudal peduncle, and pointed rostrum. Owing to closer camera placement in 2011, resolution was generally sufficient to distinguish the identity of fusiform-shaped fish, such as capelin (*Mallotus villosus*) and small salmonids. Images were assigned a status of "unknown" when image quality was not sufficient to identify fish, when there was a lack of images, or when the fish itself was obscured by the adult. We assigned each fish to one of the following four size classes: < 8 cm, 8-12 cm, 12-16 cm, and >16 cm fork length, when possible. We used preserved specimens of sand lance and the wing chord of fish-bearing adult murrelets (ca. 125-140 mm; Day et al. 1999) to calibrate estimates of fish size observed in digital images. Specimens of discarded fish were collected from the ground near nest sites in 2009, 2010, and 2011, and identified to species later. These opportunistic collections helped corroborate visual identification and size estimates.

Three nest-checks occurred at each active nest after day 4 of the nestling period (estimated by floating eggs in water), although errors in age estimation occasionally resulted in earlier visits to the nest. The purpose of these nest-checks was to determine nest fate and to collect growth and genetic data from the chick. The timing and number of nest-checks was identical for both the group where cameras were deployed and the control group. Nest visits were scheduled when a chick was estimated to be 4 - 6 days post-hatch, 9 - 13 days post-hatch, and 19 - 21 days post-hatch.

Nest Characteristics

We collected data on nest site characteristics when nests were no longer occupied. Nest site characteristics were assessed at several spatial levels. At the smallest scale, we measured the diameter, depth, and circumference of nest scrapes, 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 were large enough to serve as a barrier to rock fall, a wind-break, 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 was similarly situated immediately up-slope of a nest. At larger scales, three circular plots (5-, 25-, and 50-m radius) centered on 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 cover values for 13 types of ground cover on a 5-m radius plot centered on each nest site, and we estimated the percent un-vegetated ground in each 25- and 50-m radius plot centered on the nest site. To compare characteristics of nest sites with nearby habitat, two adjacent non-use plots were placed at a random bearing and a random distance (between 50 and 150 m) from nest sites, and were characterized in the same manner as nest plots.

To facilitate comparison of nest sites with surrounding habitat, 227 randomly-selected vegetation plots were surveyed within the search coverage area among the four sites. Detailed analysis of habitat data will be reported in the senior author's Master's Thesis, the Final Report for the cooperative project, and subsequent peer-reviewed publications.

Audio-visual Surveys

We documented Kittlitz's murrelet inland flight activity at five locations within the four main study sites. Consistent with protocol devised by Burkett et al. (2009), we recorded numbers of murrelets flying, flight directions, vocalizations, other behaviors, and weather. The locations of flight activity survey sites were chosen for their proximity to known or suspected flyways and potential nesting habitat (i.e., extensive scree slopes). Four flight survey sites in 2011 were located on the vegetated valley floor at base camps, adjacent to potential nesting habitat. One additional flight survey site that was located on a scree-talus covered slope was surveyed only once. Surveys were initiated 90 minutes before sunrise and continued until one hour after sunrise, except when murrelets were detected 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 wind gusts exceeded 15 miles per hour, or if conditions otherwise made it impossible for the observer to hear murrelet calls that were more than 400 m distant.

Genetic and Fecal Sampling

We collected a small blood sample from each chick between 4 and 15 days post-hatch by pricking the brachial vein with a 27-gauge needle. Samples were collected in triplicate in separate capillary tubes, blown onto filter paper, and stored in cryovials filled with 70% ethanol. Chicks found dead at the nest site were collected whole, placed in a Nasco Whirl-Pak specimen bag, and immersed in 70% ethanol. A 1-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 stored in paper envelopes. Whole or damaged eggs were removed from abandoned nests and egg contents were preserved in 70% ethanol, if any embryonic material was present. Fecal samples were collected from nest sites when available. Upon arrival in Kodiak, all specimens were stored in a -18 ˚C freezer before being sent to the USGS Alaska Science Center (Anchorage, AK) for analysis and archiving. Dead chick specimens were sent to the USGS Wildlife Health Center (Madison, WI) for necropsy.

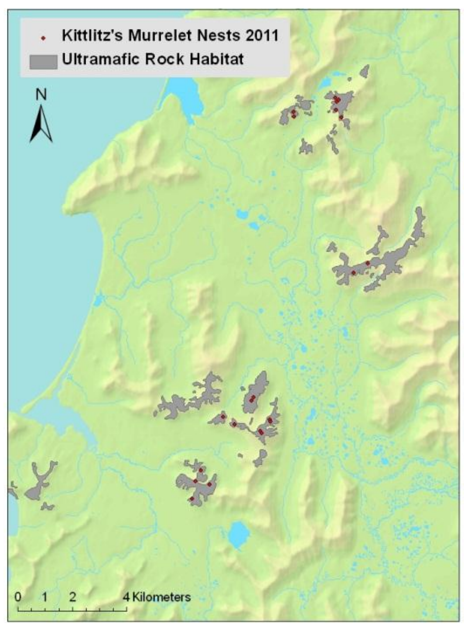

Figure 2. Active Kittlitz’s murrelet nests discovered in 2011

Results and Discussion

Nest Searching and Monitoring

Our first nest search effort extended from 30 May to 25 June, and included most of the highly suitable Kittlitz's murrelet nesting habitat in the study area. During our second nest search effort from late-June to mid-July, we re-surveyed the same habitats searched during the first effort, but owing to time limitations, we did not re-survey some areas of apparent low suitability. In total, 22 active Kittlitz' murrelet nests were discovered in the four study sites (Figure 2); 17 nests were discovered during our first nest search, three on the second, and two were discovered incidental to other activities following the end of nest searching.

In addition to active nests, seven "inactive" Kittlitz's murrelet nest scrapes were discovered: one during the first search effort and six during the second. These nest scrapes exhibited the distinctive shape, size, and substrate composition of an active nest, and contained evidence of prior occupancy, such as weathered shell fragments, feathers, or feces. Based on the degraded appearance of eggshell fragments, three nest scrapes were considered to have been active prior to 2011, including one nest containing a nearly complete UV-degraded egg; we were unable to determine the year of activity for three inactive nest scrapes. Only one inactive nest scrape had clearly been active early during the 2011 nesting season. This nest scrape, found on 21 July, contained a very large, fresh fecal ring and a large amount of fresh down was present within and near the nest scrape. We presume that this nest scrape contained a chick that either fledged or was depredated at a very advanced stage of development. While it is possible that at least some of these inactive nest scrapes may have been used by the closely-related marbled murrelet, we consider this unlikely because no active marbled murrelet nests were found during extensive nest searching over the four years of the study.

Fourteen "potential" Kittlitz's murrelet nest scrapes were discovered in 2011. These nest scrapes had the characteristic appearance of active nest scrapes, but lacked any clear evidence of previous occupancy. Notably, one active nest was discovered when we checked the status of a "potential nest scrape" found 43 days earlier during the first nest search effort. A chick estimated to be approximately six days post-hatch was present on the nest scrape, indicating that the egg was laid approximately seven days after discovery of the empty potential nest scrape. It was unclear whether the unoccupied nest scrape had been recently constructed when first discovered, or had been initiated in a previous year. In either case, discovery of this chick in a "potential" nest scrape suggests that at least some of the other potential nest scrapes discovered during the 2008-2011 study were made by Kittlitz's murrelets, though it is unclear whether these nests were abandoned before laying, were depredated, or were used later in the season after we had discontinued nest searching. Eventual use of a potential nest scrape had not been observed during the 2008-2010 field seasons.

For the other 21 active nests found in 2011, incubating adults were flushed by searchers when they approached active nest sites. Flush distance averaged 4.3 m (range = 1.0 – 9.0 m, Appendix B), consistent with flush distance observed during the previous three years of the study. Initial flight direction following the flush from the nest was invariably directly downslope in 2011, consistent with nests found in previous study years.

For active nests where a camera was deployed, the average time for re-occupancy by an adult bird was 370 min after the field crew departed the nest site (n = 16, Appendix B). The range of re-occupancy times was large, with seven re-occupancies in less than an hour, while the remaining nine nests were re-occupied between 5 and 23 hours after the field crew departed the nest site (Appendix B).

Egg measurements and coloration were, with the exception of one egg, within the previously observed ranges for Kittlitz's murrelet eggs (n = 21 eggs; Day et al. 1999). Egg coloration was generally a hazy light green background, with scattered dark brown splotches concentrated near the larger end of the egg. One anomalous egg exhibited a pale brown background with scattered dark brown splotches. No other eggs with this background color had been found during the previous years of this study. The extent of egg splotching varied widely among eggs; some eggs were marked across their entire surface, while others showed almost no splotching.

Four nest scrapes used in 2011 were also active in previous years. Two of these formerly active nest scrapes were active in 2010, one was active in 2009, and one was active in 2008. Reuse of nest scrapes had not been observed during the previous years of the study, although efforts were made in 2009 and 2010 to check previously occupied nest scrapes.

Six active nests discovered in 2011 were within 20 m of at least one empty "satellite" nest scrape (either an "inactive" or "potential" nest site). Ten of 49 active nests found during 2008-2011 occurred near one or more inactive satellite nest scrapes. It is unclear whether the presence of these satellite nest scrapes was a result of fidelity by a pair to a nesting area, represented breeding attempts by different birds or, in the case of satellite nests that did not contain shell fragments, was the result of abandonment of an initial nest scrape before egg-laying.

Estimated egg-laying dates averaged earlier in 2011 than in 2010 and 2008, but was similar to average egg-laying in 2009 (Figure 3). Median estimated egg-laying date in 2011 was 31 May (range 18 May – 12 July, n = 22), compared with a median egg-laying date of 8 June in 2010 (n = 16), 31 May in 2009 (n = 12), and 27 June in 2008 (n = 4). The peak of egg-laying in 2011 occurred between 21 May and 9 June, when 14 of 22 eggs were estimated to have been laid. Three late-nesting birds laid eggs in late June and July (Figure 3), potentially indicating re-nesting attempts, which have been observed for the congeneric marbled murrelet (Nelson et al. 2010). A similar pulse of late-nesting Kittlitz's murrelets was observed in both 2009 and 2010. To assess possible error in estimation of egg-laying date related to the egg flotation method, we performed a Student's one-sample t-test on the difference between the estimated hatch date and the actual hatch date for 18 nests where cameras were deployed and found a discrepancy of 1.78 days (95% CI = 0.04, 3.51). We therefore adjusted our estimates of egg-laying date by adding 2 days for nests where hatch was not documented by camera.

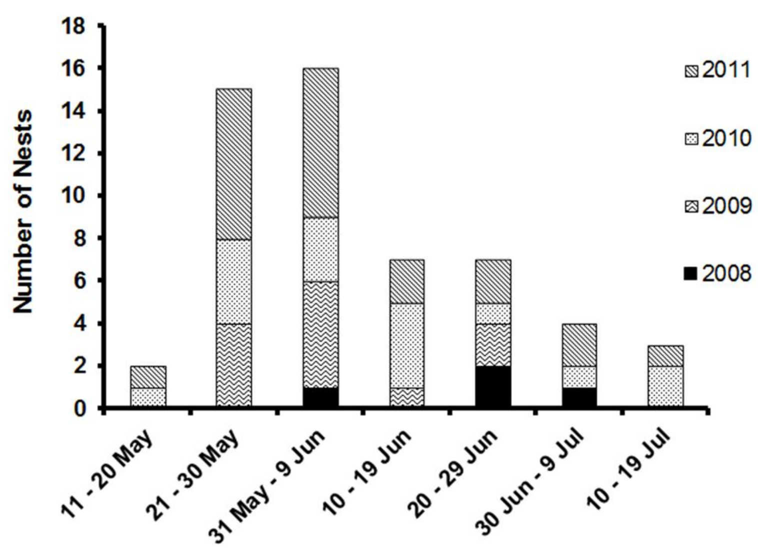

Figure 3. Kittlitz's murrelet egg-laying dates on Kodiak Island, Alaska during 2008-2011.

Nest Success

Four of 22 active nests found in 2011 fledged young, yielding an apparent nest success rate of 0.18 chicks/breeding pair (Table 1, Appendix C). A comprehensive analysis of nest survival will be presented in subsequent reports. Two successful nests were monitored by camera from early incubation until the chick fledged; cameras were deployed at the other two nests an estimated 3 days and 10 days post-hatch. Chicks at the two nests where hatch date was known fledged 26 and 28 days post-hatch; these nestling periods were several days longer than those of nests monitored from hatching to fledging in 2010 (22 days post-hatch, n = 2) and 2009 (24 days post-hatch, n = 1).

For three nests where cameras were not deployed, two were found empty at the first nest check, and contained no fecal ring or other sign of a chick, suggesting nest depredation during the incubation stage. The remaining nest contained a dead chick estimated to have been 3 days post-hatch at time of death.

Table 1. Summary of Kittlitz's murrelet nest fates on Kodiak Island, Alaska during the 2011 nesting season.

Nest Fate	Number of nests
Failed during incubation, nest empty	2
Egg abandoned	1
Failed during incubation, red fox depredation	5
Failed during nestling stage, red fox depredation	1
Failed during nestling stage, depredation by unknown predator	1
Failed during nestling stage, dead chick found on nest scrape	8
Fledged young	4
Total	22

Of 19 active nests where cameras were deployed, five (26%) were depredated by red foxes (*Vulpes vulpes*) during the incubation stage (Table 1, Appendix C). Two nests where cameras were deployed were depredated during the nestling stage, one of which was by a red fox. Camera images for the other nest reveal the disappearance of the chick from its nest at seven days post-hatch and disturbance of rocks in the nest area, but did not capture an image of the predator.

Eight of 14 chicks that were known to have hatched (57%) died on the nest during the nestling stage at from 3 days to 25 days post-hatch. This extent of chick mortality apparently unrelated to predation had not been observed during previous years of the study, although relatively high depredation rates in prior years may have precluded detecting this magnitude of chick mortality from other causes. Although camera images captured events leading up to the chick's death at seven of the eight nests where chicks died, the cause of death was not apparent, but did not appear to be related to starvation, as evidenced by low food provisioning rates by parents, or to exposure, as evidenced by poor weather conditions (Appendix D).

Six chicks found dead on the nest were preserved in 70% ethanol and subsequently necropsied at the USGS National Wildlife Health Center (Madison, WI, USA) following the field season. The necropsy report indicated that the general body condition of all chicks was fair to good, suggesting adequate nutrition. Five of the six necropsied chicks had significant lesions associated with infection by nematode-like endoparasites that were unidentifiable because of the generally decomposed condition of the chick specimens. Parasites or evidence of parasites were located in the proventriculus, gizzard, large intestine, and bursa, as well as in the lungs and arteries. Red focal areas were found on the heart muscle of two chicks, which may also have been caused by endoparasites. These endoparasites had caused significant lesions and, for at least one of the six dead chicks, was clearly the cause of death. Visceral gout was also present in at least one dead chick, resulting in dehydration (USGS National Wildlife Health Center 2012).

Nest Site Characteristics

Characteristics of active nest sites found in 2011 were generally consistent with those observed during the previous two years of study. Nest sites usually consisted of a shallow depression, or "scrape", covered with loose gravel-sized rock of 1-5 cm diameter. In a few cases the nest scrape consisted partly or totally of dead or living moss. For most active nests found during 2011, the nest scrape was situated just downslope of a large rock or a large clump of moss, consistent with nests found in previous years.

Kittlitz's murrelet nests found in 2011 had a mean elevation of 311 m (SD = 72.8, n = 22). Nests were usually situated on relatively steep slopes, with all nests occurring at slopes equal to or greater than 20° (mean = 28.9°, SD = 3.2, n = 22). The ocean was in view at 18 (83%) of the nest sites, which may have biological significance for fledging juveniles who must fly to the ocean without any guidance from parents. Results from a comprehensive analysis of nest site characteristics and nest site selection will be presented in the final project report, as well as the senior author's M.S. thesis and a subsequent peer-reviewed publication.

Meal Delivery Rates and Chick Growth

Patterns of parental nest attendance and meal delivery rates were documented using cameras deployed near the nest site. A total of 945 chick meal deliveries were recorded at 13 nests while a live chick was present (Table 2), a substantial increase over the sample size of approximately 300 chick meal deliveries that were recorded at seven nests during 2008-2010.

Table 2. Frequency of chick meals (single fish) delivered to Kittlitz's murrelet chicks on Kodiak Island, Alaska in 2011.

Nest ID	Mean meals/day	Range of meals/day	Total fish delivered	Total days monitored post-hatching	Nest fate
KODKIMU1101	3.30	1 - 5	33	10	Chick died 10 d post-hatch
KODKIMU1106	4.30	1 - 7	116	27	Chick depredated, 27 d post hatch
KODKIMU1107	3.00	1 - 6	21	7	Chick died 7 d post-hatch
KODKIMU1108	4.64	1 - 9	116	25	Fledged 26 d post-hatch
KODKIMU1109	4.67	1 - 8	84	18	Chick died 18 d post hatch
KODKIMU1110	4.71	3 - 6	33	7	Chick died 7 d post-hatch
KODKIMU1111	4.38	2 - 7	105	24	Chick died 24 d post hatch
KODKIMU1112	2.67	1 - 5	8	3	Chick died 3 d post-hatch
KODKIMU1114	4.91	2 - 7	54	11	Chick died 11 d post-hatch
KODKIMU1115	5.50	1 - 12	154	28	Fledged 28 d post-hatch
KODKIMU1116*	4.08	1 - 8	102	25	Fledged ca.26 d post-hatch
KODKIMU1118	2.86	1 - 6	20	7	Chick depredated, 7 d post-hatch
KODKIMU1122**	5.82	2 - 11	99	17	Fledged ca. 27 d post-hatch

* Camera deployed at nest approximately 3 days post-hatch
** Camera deployed at nest approximately 10 days post-hatch

Pacific sand lance was the most commonly delivered forage fish to chicks, comprising 73.9% of all fish delivered. Capelin represented 6.2% of chick diet (by food item), while Pacific herring (*Clupea pallasi*) and salmonids each represented < 0.5% of food items, and unidentifiable fish comprised 19.3% of food items (Table 3). Unidentifiable fish were almost exclusively a product of poor image quality resulting from low light, precipitation, or because the fish was obscured by the adult or the surrounding substrate. Assuming that provisioned fish composition under these conditions was the same as occurred under good viewing conditions, Pacific sand lance comprised 91%, and capelin 8%, of provisioned food items. Results from a detailed analysis of all chick meal delivery data will be presented in the final project report, M.S. thesis, and related publications.

Table 3. Composition of forage fish meals delivered to Kittlitz's murrelet chicks on Kodiak Island, Alaska during 2011.

Nest	Sand lance	Capelin	Herring	Salmonid spp.	Unknown spp.	Total fish
KODKIMU1101	23	2	0	1	7	33
KODKIMU1106	73	6	0	1	36	116
KODKIMU1107	18	2	0	0	1	21
KODKIMU1108	92	9	0	0	15	116
KODKIMU1109	46	7	0	0	31	84
KODKIMU1110	33	0	0	0	0	33
KODKIMU1111	91	8	0	0	6	105
KODKIMU1112	5	0	0	0	3	8
KODKIMU1114	50	1	0	0	3	54
KODKIMU1115	107	11	1	0	35	154
KODKIMU1116	76	1	1	0	24	102
KODKIMU1118	15	1	0	0	4	20
KODKIMU1122	69	11	2	0	17	99
Total	698	59	4	2	182	945
% Total	73.9	6.2	0.4	0.2	19.3	100.0

Growth rate data were collected from 11 chicks, four of which eventually fledged. Nine nests had cameras deployed at the hatching date, allowing accurate determination of hatch date. The rate of increase in chick body mass appeared to be high between day 6-7 post-hatch and day 11 post-hatch; after day 11 post-hatch chick growth rate appeared to slow (Figure 4). We did not collect data of chick growth < 48 hours before the chicks fledged because our estimates of the length of the nestling period were too short, reflecting the shorter nestling periods observed in previous years compared to nestling periods observed in 2011.

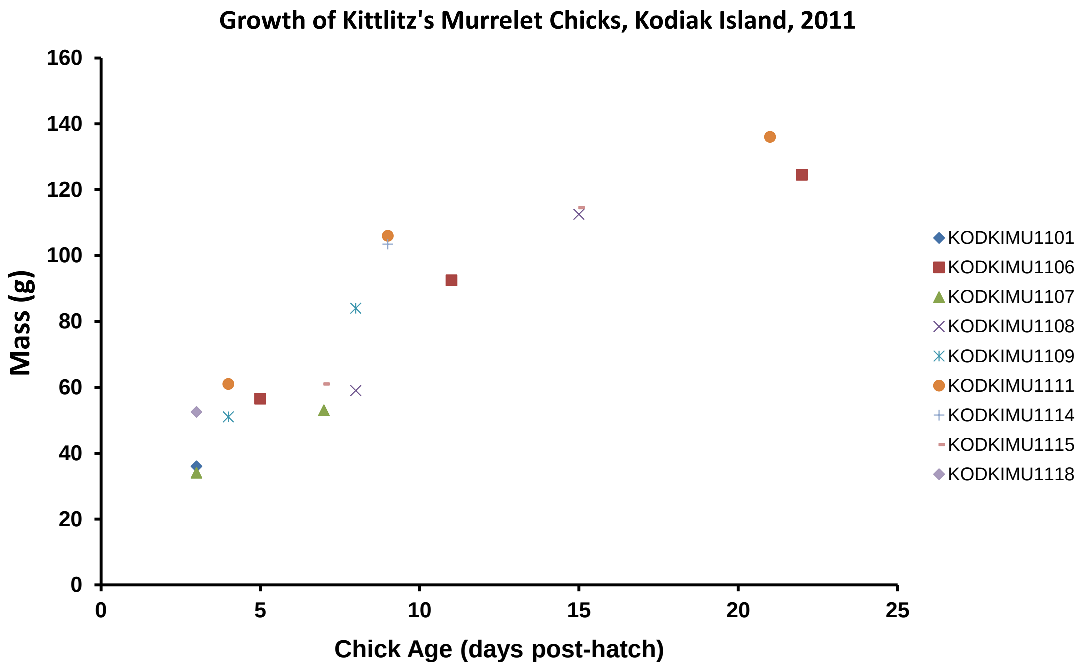

Figure 4. Growth in body mass of Kittlitz's murrelet chicks for known-age chicks on Kodiak Island, Alaska during 2011. Day 0 represents the day of hatch.

Audio-visual Surveys

A total of 373 detections of flying Kittlitz's murrelets were recorded during 16 audio-visual surveys conducted over a 12-week period at five different survey sites. The mean number of detections per survey in 2011 was 23.3 (SE = 6.3, n = 16), compared with 9.3 detections in 2010 (SE = 4.2, n = 23), and 20.9 detections in 2009 (SE = 6.6, n = 24). Sources of inter-annual variation in detection rates are unclear, but may relate to differences in weather conditions, breeding activity, or numbers of Kittlitz's murrelets present within the study area. In 2011, detections were most frequent during the half-hour before sunrise (Figure 5), whereas during 2008-2010 detections were most frequent in the half-hour after sunrise (Burkett et al. 2009; Lawonn et al. 2009, 2011).

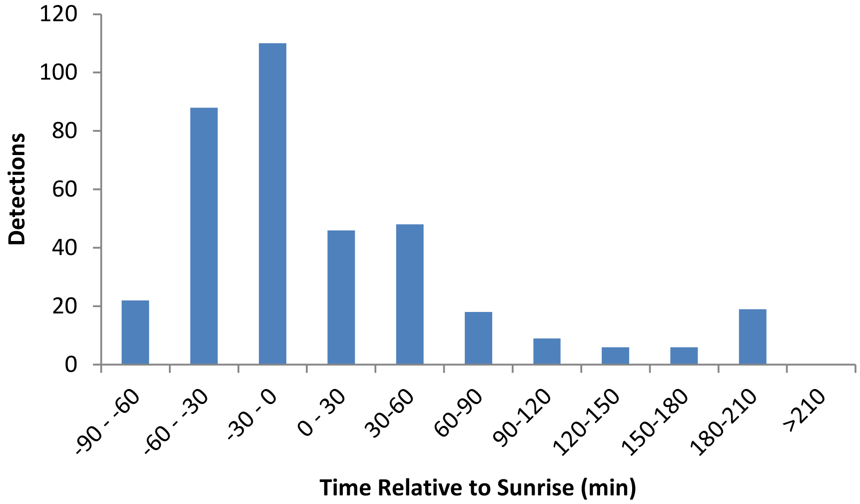

Figure 5. Timing of detections of flying Kittlitz's murrelets relative to sunrise on Kodiak Island, Alaska during May 31-July 31, 2010. Sunrise equals 0.

Detection rates were generally low throughout June, despite success in finding active nests during that month. There appeared to be a marked increase in Kittlitz's murrelet activity during early to mid-July, and a decline in activity from late July into August (Figure 6). Similar seasonal patterns were observed during 2008-2010, with the highest detection rates during early to mid-July (Burkett et al. 2009, Lawonn et al. 2009, 2011). No marbled murrelets were detected during audio-visual surveys in 2011.

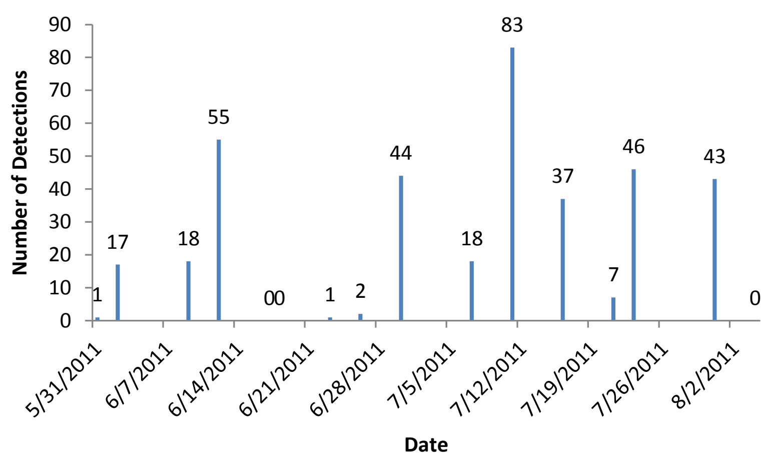

Figure 6. Number of detections of flying Kittlitz's murrelets during audio-visual surveys at five survey sites on Kodiak Island, Alaska during May 31-August 4, 2011.

Conclusions and Recommendations

Four of 22 active Kittlitz's murrelet nests found in 2011 eventually fledged young, yielding a fledging rate of 18%. Combining data from all four years of the study, 9 of 53 active nests (17%), and 9 of 56 known breeding attempts (16%; includes non-active nests that contained an addled egg or fresh egg remains when discovered), fledged young during 2008-2011. These fledging rates are biased high, however, because they do not include most nests that failed before they were discovered. It is unclear whether nest success rates measured during the four years of this study are representative of Kittlitz's murrelet nesting success elsewhere on Kodiak Island, or Alaska in general. Estimation of long-term breeding success within the study area would benefit from additional years of nest monitoring, especially given the presumed longevity of adults of the species (Day et al. 1999).

Table 4. Fate of active Kittlitz's murrelet nests found on Kodiak Island, Alaska during 2008-2011.

Nest Fate	2008	2009	2010	2011	2008-2011	% for 2008-2011
Depredated/nest empty	2	8	6	9	25	47
Dead chick found in nest	0	1	2	8	11	21
Nest abandoned	1	2	3	1	7	13
Unknown fate	1	0	0	0	1	2
Chick fledged	0	1	4	4	9	17
Total	4	12	15	22	53	100

The low nesting success that was observed during 2008-2011 could be attributed to a number of factors. Camera data revealed that predation was the most important single factor limiting nesting success at nests where cameras were deployed during our study. If we assume that all eggs and chicks that disappeared were removed by predators, nest depredation may have accounted for up to 47% of nest fates, and 58% of nest failures (Table 4). The depredation rate in 2011 (41%, n = 22) was somewhat lower than in 2008 and 2009 (63%, n = 16), but similar to the depredation rate in 2010 (40%, n = 15). Red foxes accounted for 10 of 12 depredation events that were documented on camera, suggesting that foxes were the principal nest predator within the study area during 2008-2011. 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 E).

Because of the presumed importance of nest depredation by red foxes in our study area, it is possible that inter-annual differences in Kittlitz's murrelet breeding success may be related to variation in availability of alternative prey for foxes during the nesting season, such as tundra voles (*Microtus oeconomus*), willow and rock ptarmigan (*Lagopus* spp.), and pink salmon (*Oncorhynchus gorbuscha*). Population fluctuations of red foxes may also be important predictors of Kittlitz's murrelet nest success on Kodiak Island. We observed marked differences in fox numbers in the study area, both among sites and among years. Foxes were only observed on 12% of days in the field during 2011, the lowest percentage over the three years when the study encompassed the entire study area. Foxes were seen on 25% of days in 2010, and 26.5% of days in 2009.

Other factors that limited the breeding success of Kittlitz's murrelets in the study area included eggs that failed to hatch and chick mortality that could not be attributed to predation. Six eggs that were apparently either infertile or addled were recorded during 2008-2010, representing about 11% of eggs discovered. No infertile or addled eggs were observed in active nests discovered in 2011, although one apparently fertile egg (determined by dissection) was abandoned late in the breeding season. In addition, a nearly intact addled egg was discovered in June 2011 that appeared to have been laid in 2010. Chicks that were found dead in the nest accounted for 21% of all nest fates, and 26% of all nests that failed. Of 11 nests where dead chicks were found in the nest, eight were from 2011. It is unclear whether the significant pathology associated with endoparasites found in some Kittlitz's murrelet chicks that were found dead in the nest during 2011 represent an ongoing phenomenon, or indicate a potentially emerging or irregularly occurring disease among Kittlitz's murrelets on Kodiak Island. It is also unclear whether conditions during 2011 could have made chicks more susceptible to endoparasites compared to previous years, or whether high predation rates in previous years may have precluded detection of chick mortality caused by endoparasites on the scale observed in 2011. The high chick mortality rates associated with high endoparasite burdens in our study, along with available data suggesting low reproductive success for Kittlitz's murrelets in other areas of its breeding range (Kuletz et al. 2003, Day and Nigro 2004, Kaler and Kenney 2008, Kaler et al. 2009, 2010, 2011, Lawonn et al. 2009, 2011), indicates the need for investigation of parasitic disease as a potential limiting factor for productivity in Kittlitz's murrelets.

Camera images from 13 different nests in 2011 corroborated findings from 2009 and 2010 that Pacific sand lance is an important forage fish for nesting Kittlitz's murrelets within the study area. Among the 1,232 forage fish delivered to nests where cameras were deployed during 2009-2011, 915 (74%) were sand lance, and among identifiable fish, 91% were sand lance. Although the nestling period was several days longer in 2011 compared with 2009 and 2010, it appeared that average chick growth rates on Kodiak Island for all study years were substantially higher than chick growth rates observed at Agattu Island during 2007 - 2010 (Kaler et al. 2009, Kaler et al. 2010, Kaler et al. 2011). Although detailed analyses have yet to be performed, it is likely that differences in species composition, and rate and condition of forage fish delivered to chicks may have accounted for the differences in chick growth rates between the two islands.

Although annual sample sizes were small and preliminary analysis is complicated by inter-annual differences, it appears that camera deployment near active Kittlitz's murrelet nests had no negative impact on fledging success. Across the four study years when cameras were deployed near nests, cameras were deployed at 33 active nests and 20 nests served as controls. During 2008 we only deployed one camera near a nest during late incubation, 12 days after discovery. During 2009 and 2010, we deployed cameras near roughly every other nest immediately upon discovery. During 2011, we attempted to deploy cameras near every nest immediately following discovery to maximize the collection of data on chick provisioning. Across all study years, nests where cameras were deployed appeared to have lower depredation rates than control nests, while nests where cameras were deployed had somewhat higher rates of fledging, abandonment, and dead chicks.

Table 5. Nest fates for Kittlitz's murrelet nests where cameras were deployed compared to control nests on Kodiak Island, Alaska during 2008-2011

Nest Fate	Control (number)	Control (%)	Camera (number)	Camera (%)
Chick Fledged	2	10	7	21
Nest Depredated	13	65	12	36
Egg Abandoned	2	10	5	15
Dead Chick Found	3	15	8	24
Unknown Fate	0	0	1	3
Total	20	100	33	100

The apparent difference between treatment groups (camera present vs. control) is reduced if data collected in 2008 and 2011 are removed; protocols for deploying cameras near nests were different in those two years and thus may have biased the results. The bias may be especially large in 2011, when cameras were deployed at nearly all nests. However, regardless of which data are included in the preliminary analysis, depredation rates were apparently no higher, and may have been lower, at nests where cameras were deployed compared with controls (Table 6).

Table 6. Fates for Kittlitz's murrelet nests where cameras were deployed compared to control nests on Kodiak Island, Alaska during 2009-2010

Nest Fate	Control (number)	Control (%)	Camera (number)	Camera (%)
Chick Fledged	2	15	3	21
Nest Depredated	9	69	5	36
Egg Abandoned	1	8	4	29
Chick Found Dead	1	8	2	14
Total	13	100	14	100

Camera placement and performance proved more effective in 2011, when cameras were placed about 1 meter from the nest, compared to 2009 and 2010, when the distance of the camera from the nest ranged from 1.5 to 2 meters. A camera-to-nest distance of 1 meter, about the minimum focal length of the cameras, produced images of sufficiently high resolution to enable identification of most forage fish species, as well as capturing a much higher proportion of motion-triggered events than a longer camera placement distance. Because we did not observe any obvious negative effects on nesting success from shorter camera-to-nest distances in 2011, and because the research value of camera-generated data is so high, we recommend that, in future studies, cameras be deployed 1-1.5 meters from each nest as soon as the nest is discovered. This recommended protocol can be adjusted if negative effects on survival of monitored Kittlitz's murrelet nests become apparent.

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Appendix A. Weather conditions, Kodiak Island, 2008-2011

Year	Sites	Dates	Mean high (˚C)	Mean low (˚C)	Total rainfall (cm)	Average daily rainfall (cm)
2008	Sturgeon	6 Jun - 13 Aug	13.3	5.6	16.01	0.27
2009	Sturgeon, Duncan, Kahuna, Anvil	27 May - 4 Aug	17.1	6.8	17.13	0.25
2010	Sturgeon, Duncan, Kahuna, Anvil	27 May - 21 Aug	15.2	7.2	28.72	0.33
2011	Sturgeon, Duncan, Kahuna, Anvil	27 May - 26 Aug	16.6	7.4	35.13	0.40

Year	Site	Dates	Mean temperature (˚C)	Average daily rainfall (cm)
2008	Booth Lake	14 Jun – 31 Aug	10.8	0.14
2009	Booth Lake	1 Jun – 31 Aug	10.4	0.20
2010	Booth Lake	1 Jun – 31 Aug	10.5	0.25
2011	Booth Lake	1 Jun – 31 Aug	10.2	0.29

Appendix B. Flush, adult return time, and egg measurements for Kittlitz's murrelet nests, Kodiak Island, 2011

Nest ID	Flush distance of adult (m)	Return time for adult (min)	Mass of egg (g)	Egg length (mm)	Egg width (mm)
KODKIMU1101	4	717	40	56	37.8
KODKIMU1102	2	387	48.5	60.8	38.8
KODKIMU1103	1	666	40.5	58.6	38
KODKIMU1104	4	~	44.5	59.1	37.5
KODKIMU1105	1.75	18	51	59.2	40.4
KODKIMU1106	6.5	11	42.5	56.9	38.3
KODKIMU1107	2	336	~	~	~
KODKIMU1108	3	1329	39.5	54.3	36.3
KODKIMU1109	2.5	42	45	58.4	38.7
KODKIMU1110	2.5	16	45	60.6	38.3
KODKIMU1111	7.5	522	47.5	59.8	40.2
KODKIMU1112	3	26	38	56.5	36.8
KODKIMU1113	~	~	39.5	56.1	37.7
KODKIMU1114	4	435	44.5	62.7	37.9
KODKIMU1115	9	26	40	~	~
KODKIMU1116	6	~	41.5	56.9	38.2
KODKIMU1117	8	~	~	~	~
KODKIMU1118	7	642	~	59.2	40
KODKIMU1119	4	14	41.5	~	~
KODKIMU1120	4	726	46	58.3	38.4
KODKIMU1121	4	~	44	~	~
KODKIMU1122	~	~	~	~	~
mean	4.3	369.6	43.3	58.3	38.3
standard deviation	2.3	383.5	3.5	2.1	1.1

Appendix C. Chronology and fate of Kittlitz's murrelet nests found on Kodiak Island, 2011

Nest ID	Date Discovered	Approximate Date Initiated*	Hatch Date**	Last Date Nest Known to be Active	Group	Fate
KODKIMU1101	07-Jun-11	01-Jun-11	01-Jul-11	11-Jul-11	Camera	Chick died on 11-July, 10 days post-hatch
KODKIMU1102	07-Jun-11	01-Jun-11	~	22-Jun-11	Camera	Egg depredated by red fox on 22-June, approx. 21 days post-initiation
KODKIMU1103	09-Jun-11	20-May-11	~	10-Jun-11	Camera	Egg depredated by red fox on 10-June, approx. 21 days post-initiation
KODKIMU1104	09-Jun-11	28-May-11	~	9-Jun-11	Control	Egg absent upon first nest check
KODKIMU1105	11-Jun-11	31-May-11	~	26-Jun-11	Camera	Egg depredated by red fox on 26-June, approx. 26 days post-initiation
KODKIMU1106	15-Jun-11	29-May-11	28-Jun-11	25-Jul-11	Camera	Chick depredated by red fox on 25-July, 27 days post-hatch
KODKIMU1107	16-Jun-11	18-May-11	17-Jun-11	24-Jun-11	Camera	Chick died on 24-June, 7 days post-hatch
KODKIMU1108	16-Jun-11	13-Jun-11	13-Jul-11	7-Aug-11	Camera	Fledged on 7-August at 10:57 p.m., 26 days post-hatch
KODKIMU1109	17-Jun-11	30-May-11	29-Jun-11	17-Jul-11	Camera	Chick died on 17-July, 18 days post-hatch
KODKIMU1110	17-Jun-11	24-May-11	23-Jun-11	30-Jun-11	Camera	Chick died on 30-June, 7 days post-hatch
KODKIMU1111	18-Jun-11	30-May-11	29-Jun-11	23-Jul-11	Camera	Chick died on 23-July, 24 days post-hatch
KODKIMU1112	20-Jun-11	28-May-11	27-Jun-11	30-Jun-11	Camera	Chick died on 30-June, 3 days post-hatch
KODKIMU1113	21-Jun-11	01-Jun-11	01-Jul-11	1-Jul-11	Control	Dead chick found in nest, estimated 3 days post-hatch
KODKIMU1114	23-Jun-11	31-May-11	30-Jun-11	11-Jul-11	Camera	Chick died on 11-July, 11 days post-hatch
KODKIMU1115	24-Jun-11	23-Jun-11	23-Jul-11	20-Aug-11	Camera	Fledged on 20 August at 6:24 a.m., 28 days post-hatch
KODKIMU1116	23-Jun-11	31-May-11	30-Jun-11	25-Jul-11	Camera	Fledged on 25-July at 10:48 p.m., estimated 26 days post-hatch
KODKIMU1117	25-Jun-11	27-May-11	~	25-Jun-11	Control	Egg absent upon first nest check
KODKIMU1118	30-Jun-11	15-Jun-11	15-Jul-11	22-Jul-11	Camera	Chick depredated by unknown predator on 22-July, 7 days post-hatch
KODKIMU1119	10-Jul-11	18-Jun-11	~	13-Jul-11	Camera	Egg depredated by red fox on 13-July, 25 days post-initiation
KODKIMU1120	15-Jul-11	2-Jul-11	~	27-Jul-11	Camera	Egg depredated by red fox on 27-July, 25 days post-initiation
KODKIMU1121	20-Jul-11	10-Jul-11	~	11-Aug-11	Camera	Egg abandoned; feathered embryo ~ 25-30 d.o. collected from egg on 8/22
KODKIMU1122	11-Aug-11	7-Jul-11	~	1-Sep-11	Camera	Fledged on 1 September at 3:48 a.m., estimated 27 days post-hatch

*Estimates based a presumed 30-day incubation period (Kaler et al. 2008). Egg age estimated by egg floatation in water (Rizzolo and Schmutz 2007, Kaler et al. 2008), and backdated from hatch from camera nests, when possible.

**Hatch date indicated by camera images.

Appendix D. Details of Kittlitz's murrelet chick deaths, Kodiak Island, 2011

Failed nest*	Date of chick death	Date chick collected	Chick age at death (days post-hatch)	Chick carcass mass (g)	Failed chick feeding rate (fish/day)	Number of fish deliveries during 24 hr period before chick death	Number of fish eaten by chick during 24 hr period before death	Notes
KODKIMU1101	7/11/2011	7/12/2011	10	88.0	3.2	6	6	Chick died between 5:48 and 11:51 a.m. during an intense three-day rain storm period; chick behavior not visible in camera images; carcass weight appeared normal when collected.
KODKIMU1107	6/24/2011	6/26/2011	7	53.0	3.5	4	5	Chick died about 5:44 a.m. Chick had difficulty consuming fish throughout its life; up to three stockpiled fish accumulated at nest at times; chick died one hour after ingesting a dessicated fish delivered at least 36 hours previously, one cm of fish's tail projected from bill at time of death; chick's down partially wetted from morning rain at time of death; chick appeared underweight.
KODKIMU1109	7/17/2011	Carcass not present; feathers collected 7/20/2011	18	N/A	4.6	7	3	Chick died about 11:45 a.m. during mild weather (17° C, little wind); chick ate 3 large sand lance between 6:21 and 7:17 a.m., then refused food four times during the six hours before death, did not lift head in begging position for last two provisioning attempts; appeared well-fed and otherwise healthy beforehand; scavenged by raven after death.
KODKIMU1110	6/30/2011	7/3/2011	7	80.5	4.7	5	5	Chick died about 1:24 p.m. during relatively mild weather; very large chick; regurgitated fish present on nest rim, near head of carcass. Chick appeared well-fed and otherwise healthy before death.
KODKIMU1111	7/23/2011	7/26/2011	24	127	4.6	7	3	Chick died about 2:18 a.m. following a day of very mild, dry weather (high for previous day about 20◦ C). Chick leapt 20 cm downslope of nest scrape 3 minutes before death as adult was flying in the background; refused fish on 28 occasions from 9 days post-hatch until death, though carcass weight appeared normal. Chick fully feathered, appeared close to fledging; 50% down remaining over plumage; wing chord comparable to chicks measured 1 day before fledge in 2010.
KODKIMU1112	6/30/2011	7/3/2011	3	34.0	3.0	6	5	Small chick died about 9:24 a.m during relatively mild weather; two fish eaten within 5 hrs of death; chick appeared to reject a provisioned sand lance approximately 3 hours prior to death, and ate nothing thereafter.
KODKIMU1113	Approx. 7/4/2011	7/9/2011	Approx. 2-3	N/A	N/A	N/A	N/A	Nest did not receive camera; time and circumstances of chick death unknown. Chick carcass badly decomposed upon revisit; appeared to have been 2-3 days old at time of death.
KODKIMU1114	7/11/2011	7/13/2011	11	123.0	4.9	8	8	Very large chick died during the late evening on July 10 or early morning July 11 during extended rainstorm; chick appeared well-fed and otherwise healthy during adult provisioning visits before death.

*2011 nests for which feeding information is available from hatch to fledge; feeding rates calculated up to the developmental period corresponding to the age at chick death for failed nests.

Appendix E. Potential Kittlitz's murrelet predator species observed within one km of Kodiak Island study areas, 27 May-26 August, 2011

Species		Date first observed	Date last observed	Total Days Observed	% Field Days Observed
Common name	Scientific name				
Bald Eagle	*Haliaeetus leucocephalus*	28-May-11	23-Aug-11	60	65.2
Golden Eagle	*Aquila chrysaetos*	30-Jun-11	23-Aug-11	3	3.3
Unidentified Eagle	–	20-Jun-11	23-Jun-11	2	2.2
Merlin	*Falco columbarius*	15-Jun-11	17-Aug-11	6	6.5
Unidentified Falcon spp.	*Falco spp.*	1-Jun-11	22-Aug-11	3	3.3
Parasitic Jaeger	*Stercorarius parasiticus*	29-May-11	27-Jul-11	10	10.9
Black-billed Magpie	*Pica hudsonia*	29-May-11	23-Aug-11	63	68.5
Common Raven	*Corvus corax*	24-Jun-11	23-Aug-11	18	19.6
Northern Shrike	*Lanius excubitor*	13-Jun-11	22-Aug-11	11	12
Red Fox	*Vulpes vulpes*	8-Jun-11	11-Aug-11	11	12
Short-tailed weasel	*Mustela erminea*	17-Jun-11	21-Aug-11	2	2.2
Kodiak Brown Bear	*Ursus arctos middendorffi*	17-Jun-11	9-Aug-11	3	3.3