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Breeding Ecology and Behavior of Kittlitz's Murrelet in Kodiak National Wildlife Refuge, Alaska: 2012 Progress Report

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USFWS, Kodiak Refuge

Kodiak National Wildlife Refuge
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Robin M. Corcoran[1], Heather L. Mackey[1], John F. Piatt[2], and William H. Pyle[1]

Abstract

The 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. Few studies have focused on this species and very little is known about its nesting ecology. For the fifth consecutive year, we studied the breeding ecology and behavior of Kittlitz's murrelets on southwest Kodiak Island, Alaska. We systematically searched nesting habitat for active nests, placed motion-sensitive cameras at nests to assess chick feeding rates and nest predation, and collected morphometric 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 21 active nests during 2012 and 14 of these nests produced chicks. Chick provisioning, nest depredation, and egg abandonment were recorded at 20 nests using remote cameras. We were able to determine fate on 20 of the nests, nine of which fledged for an apparent nest success of 45%, much higher success than in the previous four breeding seasons which averaged only 17%. Red fox was identified as the predator at three of the four depredated nests; the predator at the fourth nest was unknown due to camera failure. Four nests were abandoned; two of these nests were later determined to contain eggs that were infertile or unviable. Three chicks that died for unknown reasons in 2012, along with five chicks from 2011, were tested for saxitoxin, the neurotoxin associated with paralytic shellfish poisoning. Seven of the eight chicks tested positive and all at high enough levels to cause deathwhich implicates saxotoxin as a significant cause of chick mortality during this study.

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Introduction

The Kittlitz's murrelet (*Brachyramphus brevirostris*) is a rare seabird of the North Pacific and is 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 mortality 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 on 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 delivered to chicks by adults; 5) measure rate of chick growth; 6) measure hatching, fledging, and overall reproductive success; 7) collect blood, feathers, and egg-shell fragments for genetic analyses; and 8) characterize the seasonal activity patterns of adults by conducting regular early-morning surveys. Due to funding limitations the Agattu Island study ended in 2011. The Kodiak study continued with slightly modified objectives. Changes included collecting only feathers and egg-shell fragments for future genetic analysis (Objective 7) and suspending audio-visual surveys (Objective 8). We also put added emphasis on collecting un-hatched eggs and dead chicks for disease and contaminant analysis.

This report summarizes results from the fifth 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, and measures of nesting habitat characteristics during the summer of 2012 on southwest Kodiak Island, and compare selected results with those from previous years.

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 remaining area 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 broad classes of land cover dominate the island area, including shrub (42%), meadow (17%), dwarf shrub (14%), non-vegetated (12%), forest (10%), and wetland (4%).

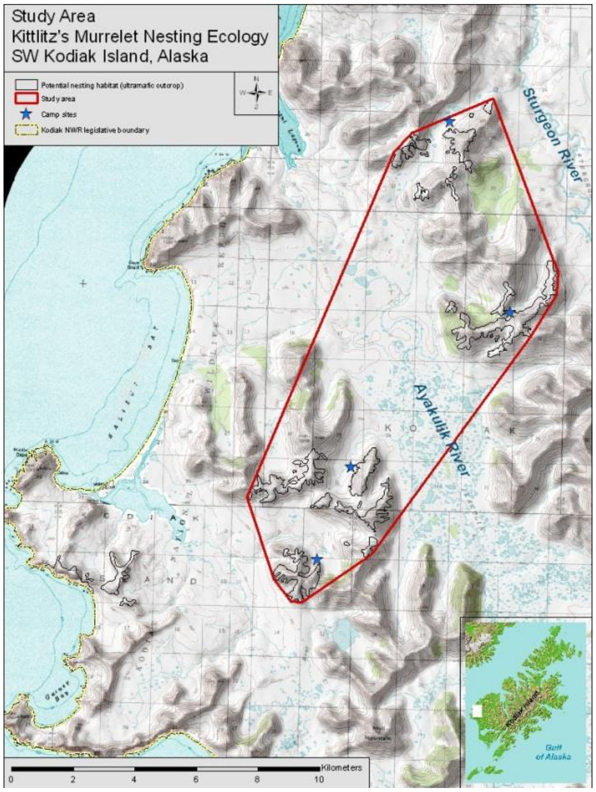

Figure 1. Map of study area, Kodiak Island, Alaska.

Two non-vegetated land cover classes, 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 on 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. To evaluate the possible role of weather conditions in nest survival, 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 2008-2012 (Western Regional Climate Center 2012; Appendix A). Data from this site indicate that the nesting season in 2012 was characterized by lower levels of precipitation and somewhat cooler temperatures than during 2008-2011 (Appendix A); however, the absence of temperature data for 13 days in early June 2008 compromises temperature comparisons between 2008 and additional years of the study.

Methods

Nest Searching and Monitoring

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. 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. Handheld GPS units (Garmin GPSMAP® 76cxs) 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 were 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. In cases of uncertainty, we used culmen morphology as a field mark to confirm identity based on observations made with spotting scope and evaluation of nest camera images where available. 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 may nest on the ground in habitats similar to those used by Kittlitz's murrelets (Nelson 1997, Nelson et al. 2010). During 2008-2012, 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 subsequently used 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 30-day incubation period (Day et al. 1999). Eggs were measured using dial calipers (± 0.1 mm), and mass obtained with a Pesola® 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). Cameras were deployed 0.9 - 1.5 meters from the nest scrape using an iron stake driven into the ground for support. This distance of cameras from nests was consistent with methods used in 2011 and was closer by approximately 0.5 meters than in 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 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, 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. Preserved sand lance specimens and adult wing chord and total head length measurements (approx. 125-140 mm, Day et al. 1999; 55 – 60 mm, pers. obs.) were used as benchmarks for measurements. Specimens of fish collected from the ground near nest sites were used to 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). The purpose of these nest-checks was to determine nest fate and to collect growth data from the chick. The first nest visit occurred when a chick was projected to be at least 4 to 6 days-old, another check occurred at day 9 to 12, and a final check at day 19 to 21. In 2012 the timing of nest checks was modified with the second visit occurring at 14 to 16 days, rather than 9 to 12 days old. The modification was recommended to improve documentation of the full progression of chick development throughout the hatch to fledge period (M.J. Lawonn, pers. comm.). During the first check the camera memory card was switched out with a blank card. The original memory card was viewed to determine the actual age of the chick and adjust the timing of subsequent checks if necessary.

During each visit chicks were weighed with Pesola spring scales (50 g, 100 g, 500 g) with the number of significant figures dependent on the scale (50= ±0.5 g). The length of the right wing was measured twice: from carpus to the tip of the longest primary with the wing held flat against a ruler, and from the carpus to the tip of the longest primary with the natural curve of the wing. Calipers were used to take linear measurements of total head, exposed culmen, tarsus, and tail length (the tail does not appear until 15 days post hatching).

Nest Characteristics

We collected data on nest site characteristics when nests were no longer occupied. Nest sites were surveyed at several spatial scales. The nest diameter, nest depth, and nest circumference were measured. The height, width, and length of key "nest rocks," features surrounding the nest that are large enough to act as a barrier against rock fall, buffer from the elements, or to provide cover from predators, were measured. Occasionally a large patch of moss was classified as a "nest rock" if it served any of these purposes. The area of the 25 and 50 meter plots were estimated based on geographic features. At the center of each plot the slope, aspect, nest aspect (compass direction nest was facing, in degrees), elevation, and ocean view (whether the ocean could be seen from the perspective of the searcher, from the nest) were recorded. On the 5 meter radius plot (centered on the nest site) percent coverage values were estimated for 13 types of ground cover. On the 25 meter and 50 meter plots percent cover values were estimated for 4 types of ground cover. The 50 m plot was added to the 5 and 25 m plots used in 2008 (Burkett et al. 2009) to better detect potential edge effects and determine the relative "patchiness" of non-vegetated terrain.

To compare habitat characteristics of nest sites with available 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. The minimum distance allowed between these two plots was 50 meters. In 2012 the restrictions on adjacent non-use plots were relaxed: plots were placed between 0 and 150 m from nest sites and there was no minimum distance requirement between the two non-use plots.

To facilitate comparison of nest sites with surrounding habitat, 50 points were selected within each of the 4 study sites, totaling 200 random points. In 2008- 2011 random points were required to be 50 meters apart, however, in 2012 this restriction was eliminated and there was no minimum distance between random points. Based on analysis of previous data this change will better examine the variation between utilized and unutilized habitat as well as capture edge effects. In each year of the study (2008-2012) the 50 meter restriction between random points was not applied to distances between random points and nest points or random points and adjacent non-use points.

Carcass and Egg Collection

Chicks found dead at nest sites were collected whole and kept cool until they could be placed in a propane freezer kept at the Duncan Lake study site. Feathers and eggshell fragments were collected from nest sites and stored in paper envelopes. Whole or damaged eggs were removed from abandoned nests and kept cool until they could be sent to Kodiak. Upon arrival in Kodiak, all specimens were stored in a -18 ˚C freezer for future analysis and archiving. Frozen chick specimens were sent to the USGS Wildlife Health Center (Madison, WI) for necropsy.

Predator Observations

Predators are a factor known to influence rates of nesting success of Kittlitz's murrelet (Kaler et al. 2008, Lawonn et al. 2011). Field workers have speculated that the magnitude of predator influence may be related to predator composition, abundance, and availability of alternative prey in the vicinity of areas used for nesting by Kittlitz's murrelet (Lawonn et al. 2012). To account for variation in predator composition and abundance, and their potential relationship to nesting success, predator data were systematically recorded in accordance with methods described by Sargaent et al. (1993). Field workers recorded the number of places where mammalian and avian predator taxa (e.g., red fox, eagle, etc.) were observed daily within each of four study sites. Convention for "place" was a 150-meter diameter circle and, for study site, a distance of 1 km or less from an ultramafic rock outcrop within and surrounding each of four discretely situated study sites. Location of mammalian predator observations, including apparent fox den sites, were recorded on a map of the study area. For analysis, we evaluated: (1) difference in observed and expected observation rates of commonly observed predator taxa within year and among study sites; (2) difference in observations rates between primary incubation and nestling periods; and (3) relationship between observation rates and murrelet nest success. If no differences are identified in observation rates among study sites, samples will be pooled to evaluate difference in observation rates among years.

Summary of Changes in Methods between 2008-11 and 2012

1) Audio-visual surveys were not conducted in 2012.
2) In previous field seasons growth data were collected from three different stages post-hatch: 4-6 days; 9-12 days; and 19-21 days. In 2012, the second nest visit was 14-16 days post hatch to get growth rate information for this stage.
3) Modifications were made to the manner in which nesting habitat was sampled. In 2012 the restrictions on selection of adjacent non-use plots were relaxed; plots were placed 0 and 150 m from nest sites and there was no minimum distance requirement between the two non-use plots.
4) A propane refrigerator-freezer located at the base camp permitted chicks found dead to be frozen instead of preserved in ethanol.
5) Blood samples were not collected from chicks, although we continued to collect intact abandoned eggs, egg shell fragments, and feathers for possible genetic and/or contaminants analysis should funding become available.
6) Consistent with a 2011 modification we attempted to place cameras at every active nest upon discovery to maximize the collection of data on chick provisioning.
7) Predator observations were recorded as the number of locations rather than actual number of each predator.
8) Operation of audio-visual surveys and songmeters was suspended.

Results and Discussion

Nest Searching and Monitoring

The initial nest searching effort extended from 2-18 June in which all potential nest habitat of ultramaphic rock with greater than 20° slope was systematically searched. From 19 June to 11 July the sites were re-searched with emphasis on habitat with high slope and large patch size.

We monitored a total of 21 active Kittlitz's murrelet nests. Twenty of these nests were discovered when the incubating adult flushed from the nest. The initial flush direction was down slope for each of these 20 adults. One nest found incidentally during a vegetation survey contained a chick whose age was estimated at 4-6 days.

One nest scrape used in 2012 was in the same location as a nest from 2011 although we found no evidence of past use such as egg shell fragments or a fecal ring. Reuse of nest scrapes occurred in four instances in 2011. The minimum distance between active nests in 2012 was 24.7 meters. Two nests were only 50.3 meters apart, and had activity periods that did not overlap. The first nest was abandoned immediately following discovery on 19 June and the second nest was initiated around 10 July. Based on the proximity of the nest sites and the respective dates of activity, the second nest could be a re-nesting attempt by the birds from the nearby location.

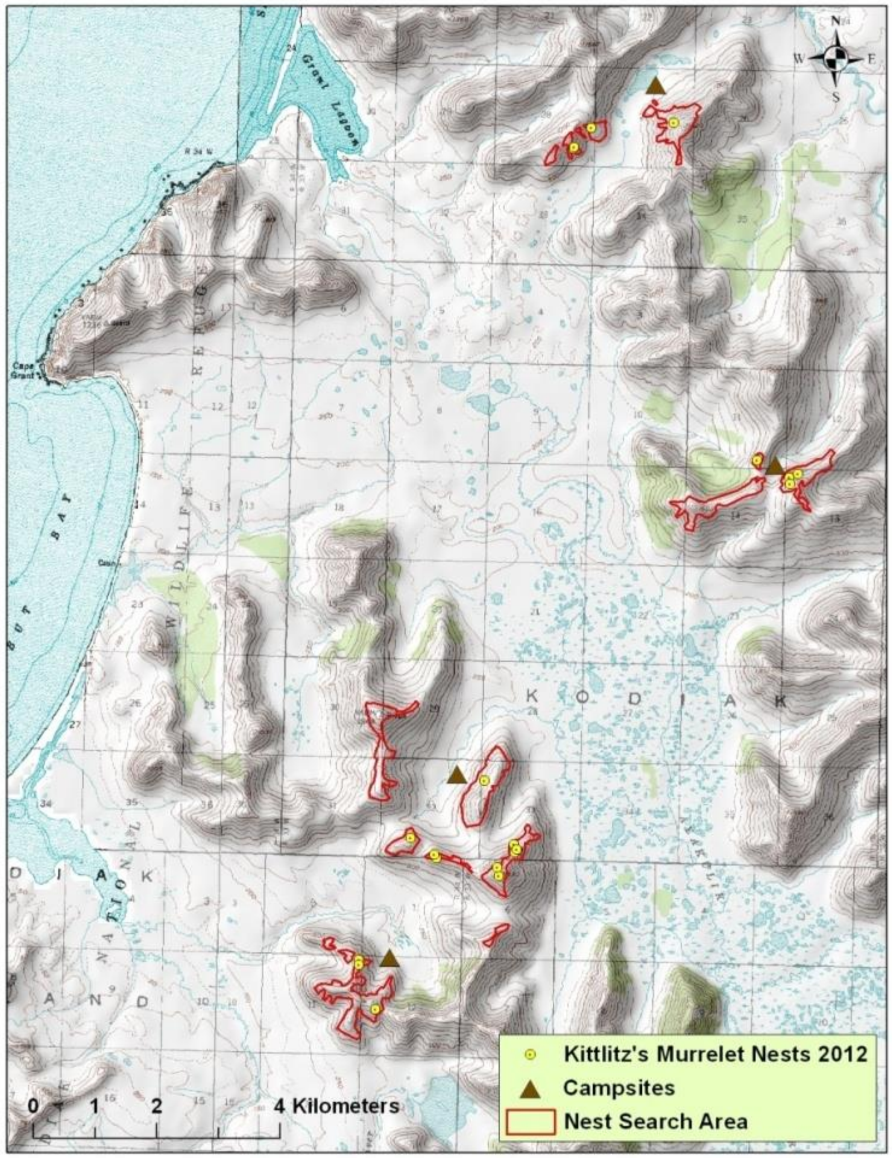

Figure 2. Active Kittlitz's murrelet nests found in 2012 on Kodiak Island, Alaska.

Adult return times were calculated for 16 nests with cameras. The average return time of an adult bird following flush was 590 min (Appendix B). In general, the variation observed in return times in 2012 was substantial and consistent with variation observed in previous years. If we exclude the one nest with an exceptionally long return time (2135 min) the average return time in 2012 was 487 min (range 17 to 776).

Based only on nests where hatch date was documented on camera, the average nest initiation date in 2012 was 14 June (range 25 May to 6 July). Nest initiation was later in 2012 than any of the previous years of the study except for 2008 (Median initiation date 2011 = 31 May; 2010 = 8 June; 2009 = 31 May; 2008 = 27 June). The outlying date, 6 July, likely represented a re-nesting attempt. In 2011, re-nesting also was observed. Tendency to re-nest following initial nest failure has been frequently reported for the congeneric marbled murrelet Nelson et al. 2010).

Nest Success

Apparent nest success was 45% (9 of 20 nests). Fledging was documented by cameras at seven of nine successful nests. At two nests, success was inferred by the amount of down shed just before fledge and the extensive fecal rings. The fate of the last nest located was unknown since it was still active when the camera was removed on 30 August, when the age of the chick was estimated at 20-22 days.

Seven of 21 nests failed during incubation. Four failures were attributed to egg abandonment; two were a result of red fox depredation; and one was a suspected depredation. In one case an egg was incubated at least 40 days before abandonment, which suggested that the egg was infertile or unviable. In a second case a parental adult removed the egg from the nest after at least 27 days incubation.

Four nests failed during the nestling stage. Although one nest with a chick was depredated by a red fox, cause of failure was not immediately apparent for the other three nests. Each nest was discovered with a dead chick estimated to be less than five days old. Cause of death did not appear to be related to low provisioning rates or poor weather conditions. The three chicks were frozen within two days of discovery and were later necropsied by pathologists with the USGS National Wildlife Health Center (Madison, WI, USA). Saxitoxin, produced by dinoflagellates and responsible for paralytic shellfish poisoning, was detected in the upper gastrointestinal contents of the chicks. Due to these initial results upper gastrointestinal content, liver, and/or kidney samples from the three 2012 chicks and five 2011 chicks that died under similar circumstances, were sent to the National Oceanic and Atmospheric Administration's Northwest Fisheries Science Center, Wildlife Algal-toxin and Response Network for additional analysis. High concentrations of saxitoxin were detected in the upper gastrointestinal contents and livers of the three chicks collected in 2012. Of the five chicks tested from 2011, four were positive for saxitoxin, but at levels lower than those found in the 2012 chicks (Shearn-Bochsler et al., manuscript submitted for publication). See Table 1 for a summary of nest fates in 2012.

Table 1. Summary of Kittlitz's murrelet nest fates on Kodiak Island, Alaska during the 2012 nesting season.

Nest Fate	Number of nests
Egg abandoned	4
Failed during incubation, red fox depredation	2
Failed during incubation, depredation by unknown predator	1
Failed during nestling stage, red fox depredation	1
Failed during nestling stage, dead chick found on nest scrape	3
Unknown	1
Fledged young	9
Total	21

The 2012 apparent nest success rate of 45% is considerably higher than overall nest success for the four previous seasons of 17%. The apparent nest success for the cumulative five year study (2008-2012) is 24% (18 of 74 active nests were successful, see Table 2).

The high rate of nesting success in 2012 compared to the previous four years of study might be attributed to a number of factors. Nest predation documented in 2012 was lower than previous years, and there were fewer unexplained chick deaths compared to 2011. Red fox remain the only species documented with cameras depredating nests. Consistent with previous years, we documented red fox as the principal nest predator in 2012. Over the course of the study 2008-2012, 13 of 15 documented depredation events have been attributed to red fox predation. Other frequently 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).

Table 2. Fate of active Kittlitz's murrelet nests found on Kodiak Island, Alaska during 2008-2012.

Nest Fate	2008	2009	2010	2011	2012	2008-2012	% for 2008-2012
Depredated/nest empty	2	8	6	9	4	29	39
Dead chick found in nest	0	1	2	8	3	14	19
Nest abandoned	1	2	3	1	4	11	15
Unknown fate	1	0	0	0	1	2	3
Chick fledged	0	1	4	4	9	18	24
Total	4	12	15	22	21	74	100

Nest Site Characteristics

Characteristics of active nest sites found in 2012 were generally consistent with those observed during the previous four years of study. Nest sites usually consisted of a shallow depression, or "scrape", covered with loose gravel-sized rock of 1-5 cm diameter and usually were situated just down slope of a large rock (commonly referred to as the nest rock).

Kittlitz's murrelet nests found in 2012 had a mean elevation of 302 m (SD = 69.3, n = 21). Nests were usually situated on relatively steep slopes, with all nests occurring at slopes equal to or greater than 20° (mean = 29°, SD = 3.6 , n = 21). The ocean was in view at 76.2% of the nest sites.

Meal Delivery and Chick Growth

A total of 732 meal deliveries were recorded at 12 nests while a live chick was present. There were a lower number of recorded meal deliveries in 2012 than 2011 because of camera failures in 2012. See Table 3 for information on prey delivery rates to chicks.

Composition of forage fish delivered to chicks was 72.4% sand lance, 15.7% capelin, salmonid spp. <1%, and unidentified 11.6% (Table 4). Sand lance was the dominant forage fish delivered to chicks in all years of study (Figure 3).

Growth rate data were collected from 12 chicks, nine of which eventually fledged. Five nests had cameras deployed on the hatching date, allowing accurate determination of hatch date, but only four cameras included complete data from hatch to fledge (Figure 4).

Table 3. Frequency of chick meals (single fish) delivered to Kittlitz's murrelet chicks on Kodiak Island, Alaska in 2012.

Nest ID	Mean meals/day	Range of meals/day	Total fish delivered	Total days monitored post-hatching	Nest fate
KODKIMU1201	2.75	0 – 4	11	4	Chick died 4 d post-hatch
KODKIMU1203	4.71	1 – 8	82	18	Fledged >18 d post-hatch
KODKIMU1205	4.36	2 – 7	96	21	Fledged 21 d post-hatch
KODKIMU1208	2.75	1 – 4	14	4	Chick died 4 d post-hatch
KODKIMU1209	4.44	3 – 8	43	9	Fledged 22 d post-hatch*
KODKIMU1211	4.30	2 – 6	46	10	Fledged unknown age**
KODKIMU1212	4.36	1 – 8	110	24	Fledged 24 d post-hatch
KODKIMU1214	4.44	2 – 7	84	18	Fledged unknown age
KODKIMU1216	3.92	1 – 7	93	24	Fledged 24 d post-hatch
KODKIMU1218	3.71	1 - 7	78	21	Fledged >21 d post-hatch***
KODKIMU1219	3.50	1 - 5	14	4	Chick depredated, 4 d post-hatch
KODKIMU1220	5.27	3 - 9	61	11	Fledged unknown age

* Missing images for 11.5 days
** Missing images for 3 days just prior to fledge
*** Missing images for last 3.5 days

Figure 3. Reconyx image of Kittlitz's murrelet adults delivering sand lance to a chick in the nest on Kodiak, Alaska.

Table 4. Composition of forage fish meals delivered to Kittlitz's murrelet chicks on Kodiak Island, Alaska during 2012.

Nest	Sand lance	Capelin	Herring	Salmonid spp.	Unknown spp.	Total fish
KODKIMU1201	8				3	11
KODKIMU1203	54	4			24	82
KODKIMU1205	79	7			10	96
KODKIMU1208	12	1			1	14
KODKIMU1209	28	3			12	43
KODKIMU1211	41	5				46
KODKIMU1212	70	31		2	7	110
KODKIMU1214	61	15			8	84
KODKIMU1216	63	17			13	93
KODKIMU1218	60	12			6	78
KODKIMU1219	12	2				14
KODKIMU1220	42	18			1	61
Total	530	115	0	2	85	732
% Total	72.4	15.7	0	0.3	11.6	100.0

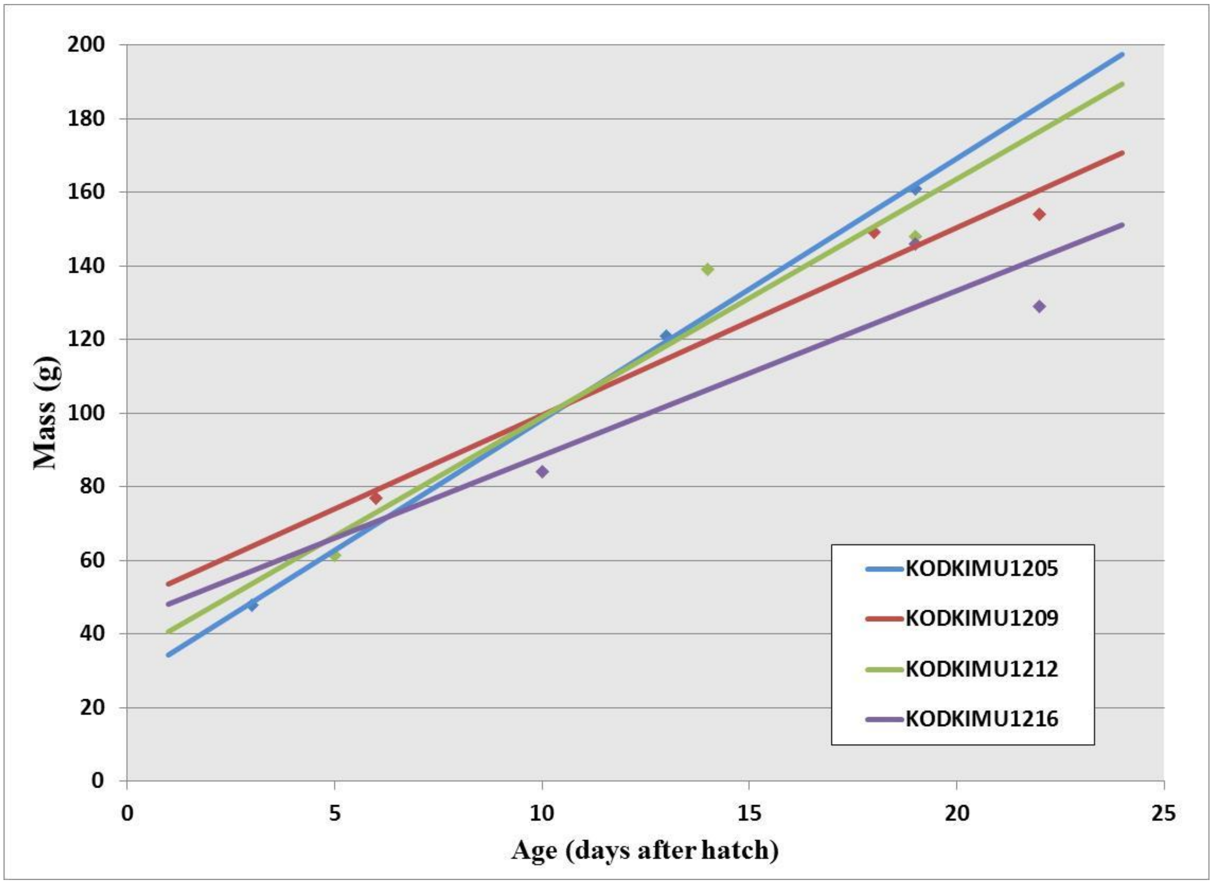

Figure 4. Growth in body mass of Kittlitz's murrelet chicks for known-age chicks on Kodiak Island, Alaska during 2012. Day 0 represents the day of hatch.

Incidental Kittlitz's Murrelet Nest

On 19 June a mountain goat research team photographed an incubating Kittlitz's murrelet in the Brosis Valley east of Uyak Bay. This nest was approximately 50 km east of the nesting ecology study area and was located on a steeper slope (60°) and at higher elevation (1,200 m) then is typical for our study. The team returned to the site on 25 July and found an egg that had been depredated near the nest scrape. This is additional documentation that Kittlitz's murrelets nest in a variety of locations and terrain on Kodiak Island (Figures 5 and 6).

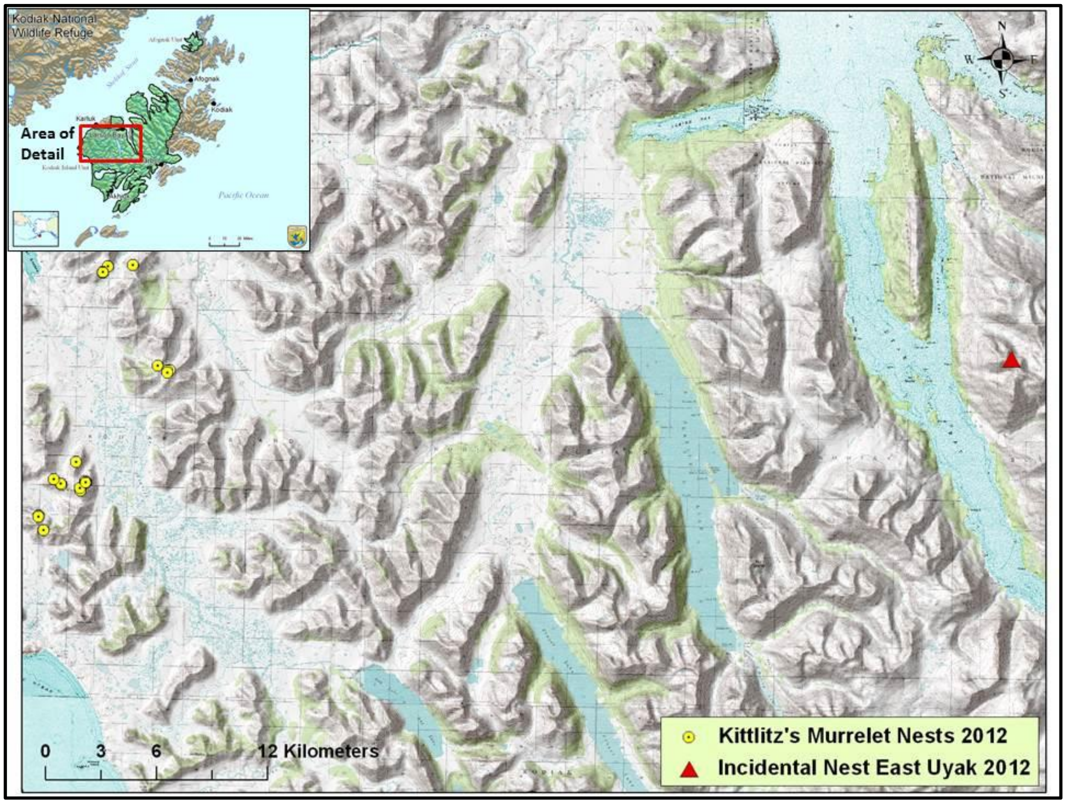

Figure 5. Location of an active Kittlitz's murrelet nest found on 19 June 2012 by the Refuge's mountain goat research crew in the Brosis Valley, east side Uyak Bay, Kodiak Island, Alaska.

Figure 6. Adult Kittlitz's murrelet photographed incubating a nest found on 19 June 2012 in the Brosis Valley, east side Uyak Bay, Kodiak Island, Alaska (photo: Aarin Sengsirirak/USFWS).

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APPENDIX A. Weather conditions, Kodiak Island, Alaska, 2008-2012.

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
2012	Booth Lake	1 Jun – 31 Aug	10.0	0.11

APPENDIX B. Adult return time after initial flush and egg measurements for Kittlitz's murrelet nests, Kodiak Island, Alaska, 2012.

Nest ID	Return time for adult (min)	Mass of egg (g)	Egg length (mm)	Egg width (mm)
KODKIMU1201	691	47	~	~
KODKIMU1202	510	49	58.5	39.5
KODKIMU1203	~	52	56.3	37.4
KODKIMU1204	535	50	60	38
KODKIMU1205	402	50	59	38.7
KODKIMU1206	~	44	56.9	38
KODKIMU1207	374	44	56.5	38.4
KODKIMU1208	735	38	55.5	38
KODKIMU1209	776	40	56.8	37.1
KODKIMU1210	2135	40	57	38
KODKIMU1211	~	45	59	40
KODKIMU1212	756	37.5	57	36.7
KODKIMU1213	160	42.5	60	38
KODKIMU1214	424	41	57	39
KODKIMU1215	491	47.5	57	38.3
KODKIMU1216	593	39	58	36.3
KODKIMU1217	~	37.5	60.7	36
KODKIMU1218	17	~	~	~
KODKIMU1219	76	44.5	58.5	38.5
KODKIMU1220	~	~	~	~
KODKIMU1221	763	39	56	37
mean	590	43.6	57.8	37.9
standard deviation	477	4.7	1.5	1.1

APPENDIX C. Chronology and fate of Kittlitz's murrelet nests in 2012, Kodiak Island, Alaska.

Nest ID	Date Discovered	Approximate Date Initiated*	Hatch Date	Last Date Nest Known to be Active	Fate
KODKIMU1201	02-Jun-12	31-May-12	30-Jun-12**	4-Jul-12	Chick died 4-July, 4 days post-hatch, no apparent cause
KODKIMU1202	02-Jun-12	01-Jun-12	~	12-Jul-12	Adult abandoned unviable egg, incubated at least 40 days
KODKIMU1203	02-Jun-12	01-Jun-12	02-Jul-12	24-Jul-12	Fledged but camera failed, minimum 19 days post-hatch
KODKIMU1204	04-Jun-12	30-May-12	~	29-Jun-12	Adult moved egg out of nest on 29-June
KODKIMU1205	08-Jun-12	5-Jun-12	05-Jul-12**	26-Jul-12	Fledged on 26-July at 11:06 p.m., 22 days post hatch
KODKIMU1206	12-Jun-12	4-Jun-12	04-Jul-12	29-Jun-12	Chick died on nest ~5 days post-hatch, camera failed after initial setup
KODKIMU1207	15-Jun-12	09-Jun-12	~	29-Jul-12	Egg depredated by red fox on 29-July, 29 days post-initiation
KODKIMU1208	17-Jun-12	25-May-12	24-Jun-12**	28-Jun-12	Chick died 28-June, 4 days post-hatch, no apparent cause
KODKIMU1209	17-Jun-12	10-Jun-12	10-Jul-12**	1-Aug-12	Fledged on 1-August at 10:57 p.m., 22 days post-hatch
KODKIMU1210	17-Jun-12	04-Jun-12	~	19-Jun-12	Adults returned to nest once after initial flush then abandoned egg
KODKIMU1211	17-Jun-12	25-May-12	24-Jun-12	22-Jul-12	Fledged on 22-July at 4:26 a.m., estimated 28 days post-hatch
KODKIMU1212	18-Jun-12	28-May-12	27-Jun-12**	21-Jul-12	Fledged on 21-July at 6:12 p.m., 24 days post-hatch
KODKIMU1213	24-Jun-12	19-Jun-12	~	3-Jul-12	Egg depredated by red fox on 3-July, 14 days post-initiation
KODKIMU1214	24-Jun-12	11-Jun-12	11-Jul-12	2-Aug-12	Fledged on 2-August at 10:52 p.m., estimated 22 days post-hatch
KODKIMU1215	27-Jun-12	18-Jun-12	~	8-Jul-12	Egg absent upon first nest check on 11 July, camera failed
KODKIMU1216	29-Jun-12	06-Jun-12	06-Jul-12**	30-Jul-12	Fledged on 30-July at 11:00 p.m., 24 days post-hatch
KODKIMU1217	29-Jun-12	24-Jun-12	~	29-Jun-12	Adults abandoned egg did not return after initial flush
KODKIMU1218	09-Jul-12	11-Jun-12	11-Jul-12**	5-Aug-12	Fledged but camera failed, estimated 23 days post-hatch
KODKIMU1219	11-Jul-12	6-Jul-12	5-Aug-12**	9-Aug-12	Chick depredated by red fox on 9-August, 4 days post-hatch
KODKIMU1220	26-Jul-12	21-Jun-12	18-Jul-12	9-Aug-12	Fledged on 9-August at 3:52 a.m., estimated 22 days post-hatch
KODKIMU1221	26-Jul-12	9-Jul-12	8-Aug-12	30-Aug-12	Unknown fate, last nest check 30-August, minimum 22 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 determined from camera images.

APPENDIX D. Details of Kittlitz's murrelet chick deaths, Kodiak Island, Alaska, 2012.

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 24hr period before chick death	Number of fish eaten by chick during 24hr period before death	Notes
KODKIMU1201	04-July-12	04-July-12	4	50	3.67	4	1	Chick died 4 days post-hatch, no apparent cause
KODKIMU1206	~ 29-June-12	11-July-12	~ 5	45				Chick died on nest ~5 days post-hatch, camera failed after initial setup
KODKIMU1208	28-June-12	30-June-12	4	~ 45	2.33	4	4	Chick died 4 days post-hatch, no apparent cause

APPENDIX E. Potential Kittlitz's murrelet predator species observed within one kim of study sites, Kodiak Island, Alaska, 2 June-31 July, 2012

Species		Date first observed	Date last observed	Total days observed	% field days observed	Observation rate (number of locations seen)
Common name	Scientific name					
Bald eagle	*Haliaeetus leucocephalus*	2-Jun-12	31-Jul-12	40	73	61
Sharp-shinned Hawk	*Accipiter striatus*	28-Jul-12	28-Jul-12	1	2	1
Parasitic Jaeger	*Stercorarius parasiticus*	10-Jun-12	31-Jul-12	7	13	7
Black-billed magpie	*Pica hudsonia*	2-Jun-12	31-Jul-12	35	64	51
Common raven	*Corvus corax*	5-Jun-12	28-Jul-12	12	22	14
Northwestern crow	*Corvus caurinus*	6-Jun-12	6-Jun-12	1	2	1
Red Fox	*Vulpes vulpes*	7-Jun-12	24-Jul-12	8	15	8