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Breeding Ecology and Behavior of Kittlitz's Murrelet in Kodiak National Wildlife Refuge, Alaska: 2015 Progress Report

Timothy W. Knudson, Robin M. Corcoran, James R. Lovvorn, John F. Piatt, and William H. Pyle

USFWS, Kodiak Refuge

Kodiak National Wildlife Refuge
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Breeding Ecology and Behavior of Kittlitz's Murrelet in Kodiak National Wildlife Refuge, Alaska: 2015 Progress Report

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Abstract

The Kittlitz's murrelet (*Brachyramphus brevirostris*) is a rare seabird inhabiting coastal areas in Alaska and Eastern Russia. Very little is known about the species nesting ecology, winter range, and juvenile recruitment. This cryptically colored Alcid lays a single egg in rocky mountainous terrain at a wide range of elevations. The 2015 field season marked the eighth consecutive year researching this species breeding ecology and behavior in a remote area on southwest Kodiak Island, Alaska. Mountain slopes with sizeable areas of scree and talus were systematically searched for nests between late May and mid-July. We placed digital game cameras at nest sites to monitor nest fate, incubation shifts, chick feeding rates, and predation events. To obtain growth measurements we visited nests at regular intervals throughout chick development. When nests were no longer active we measured habitat characteristics at and near nest sites. We discovered 16 active nests. Three of 16 nests produced chicks but none fledged young. We obtained growth measurements from one individual and feeding rates from three chicks capturing 18 prey deliveries over 10 days monitored. Identified deliveries were composed of 76% Pacific sand lance (*Ammodytes hexapterus*), the main forage fish species recorded during the study, and 24% capelin (*Mallotus villosus*). Eight nests were depredated, six by red fox (*Vulpes vulpes*) and two by unidentified predators. Two chicks under six days old died at the nest site. To determine foraging areas and seasonal movements we trapped three adults at the nest during incubation using an 18 m mist-net, and placed 5 g solar-powered ARGOS satellite transmitters on the back of each murrelet using a four-suture attachment technique. All birds with transmitters left the nesting habitat and were located at-sea near the southwestern end of the Kodiak Archipelago in the vicinity of Geese Channel, Alitak Bay, Tugidak Island, and Sitkinak Island. Unfortunately, birds with transmitters abandoned nests and transmitters failed at approximately 10 days post-capture. Apparent nest success was 0% in 2015, the lowest nest success observed during this study since 2008. In 2012 and 2013, nest success was high (45%) compared to 2008-2011 and 2014, when only 17% of nests were successful. Over the eight year study 129 active nests have been found with 30 (23%) successfully fledging a chick.

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Introduction

The Kittlitz's murrelet (KIMU, *Brachyramphus brevirostris*) is a rare seabird of the North Pacific. The KIMU is one of the least studied birds in North America; its winter range and habits are largely unknown (Day et al. 1999) and its breeding ecology poorly understood (Kaler et al. 2009). Until recently knowledge of the species nesting ecology was limited to the 25 nests recorded prior to the 2000s (Day et al. 1999). KIMU are a relatively long-lived (15 years) Alcid with an estimated global population of at least 33,600 (Federal Register 2013), of which about 70% nest in coastal Alaska and 30% in eastern Russia. KIMU became a species of conservation concern when at-sea surveys suggested drastic declines in the population. The Department of the Interior recently concluded the population declined 30% annually beginning in 1989 but then stabilized about the year 2000 (Federal Register 2013). Factors such as vessel traffic, gill-net bycatch, and oil pollution may have contributed to KIMU declines in the past. These population trends, however, occurred among many species geographically separated by continents and oceans, so local influences do not seem adequate in themselves to explain recent declines. Large scale stressors that may have contributed to KIMU declines include changes in marine forage fish communities, loss of foraging and/or nesting habitat due to glacial recession, effects of environmental contaminants, and changing patterns in avian predation (van Vliet and McAllister 1994, Piatt and Anderson 1996, Kuletz et al. 2003). It is now well recognized that seabird populations can serve as indicators of regime shifts in marine environments that provide insights into effects of climate change and overfishing (Gill 2007, Zador et al. 2013).

Concern for this species arose due to its small population, patchy distribution, appearance of decline throughout all or part of range, and observed low reproductive success in the most important breeding areas (Day et al. 1999, Day and Barna 2007). The Kodiak National Wildlife Refuge (KNWR) has been researching the breeding biology of KIMU continuously since 2008. Following the opportunistic discovery of the first nest on Kodiak in 2006, researchers documented murrelet flight activity in the Kodiak Glacial Refugium at the southwest end of Kodiak Island (Day and Barna 2007). Research began in coordination with Alaska Maritime National Wildlife Refuge, U.S. Geological Survey Alaska Science Center, and Region 7 U.S. Fish and Wildlife Service Office of Ecological Services. Cooperative project objectives on Kodiak and Agattu islands included: 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 since 2012. Changes included collecting only feathers and egg-shell fragments for future genetic analysis (Objective 7) and suspending audio-visual surveys (Objective 8). We also increased efforts to collect un-hatched eggs and dead chicks for disease and contaminant analysis (Corcoran et al. 2014). Additionally starting in 2014, temperature data loggers were placed near the nest to measure the microclimate at each nest to better understand the thermoregulatory costs experienced by individual chicks. In 2015 adult KIMUs where trapped at the nest site during incubation and fitted with satellite transmitters to determine

foraging location and seasonal movements. In 2013 Southern Illinois University Carbondale joined the project as a cooperator. Funding for the 2012-2015 field seasons provided by the National Fish and Wildlife Foundation allowed research on Kodiak to continue.

This report summarizes the eighth year of nesting ecology research of KIMU in KNWR, Alaska. We summarize results from our systematic nest searches, nest monitoring, and measurement of nesting habitat characteristics collected during the summer of 2015 on southwest Kodiak Island, and compare selected results with those from previous years.

Study Area

Kodiak Island (57.396° N, 153.483° W, land area 8,975 km²) is located in the northern Gulf of Alaska about 150 km southwest of the Kenai Peninsula. The Shelikof Strait, which is only 40-50 km wide, separates Kodiak Island from the Alaska Peninsula mainland to the north. Two non-vegetated land cover types, bedrock and talus, were regarded as potentially suitable KIMU nest habitat, and made up 5% of the total area (46,700 ha) of Kodiak Island, reaching elevations up to 1,200 m (mostly >600 m). The study area is on the southwest side of the island, one of the driest regions, and encompasses 700 ha of exposed bedrock and talus slopes. Areas searched for KIMU nests were between 5 and 11 km from the ocean. These rocky areas are at elevations from 80 to 471 m, making them accessible to researchers, unlike many areas where birds presumably nest at high elevation alpine sites that require helicopters and technical climbing gear to access. Exposed rocky slopes in the study area are derived from ultramafic rock, an igneous parent material high in heavy metals and low in nutrients which supports very limited plant growth (Alexander et al. 2006).

Within the study area (Fig. 1), four base camps provided staging points for nest searching and monitoring. Field camps were located close to large areas of ultramafic rock that could be easily accessed with little travel time to the slopes. All camps were accessible by helicopter but only one could be reached by float plane; otherwise the area was limited to foot travel. Throughout the field season researchers traveled between study sites to conduct systematic searching and nest monitoring.

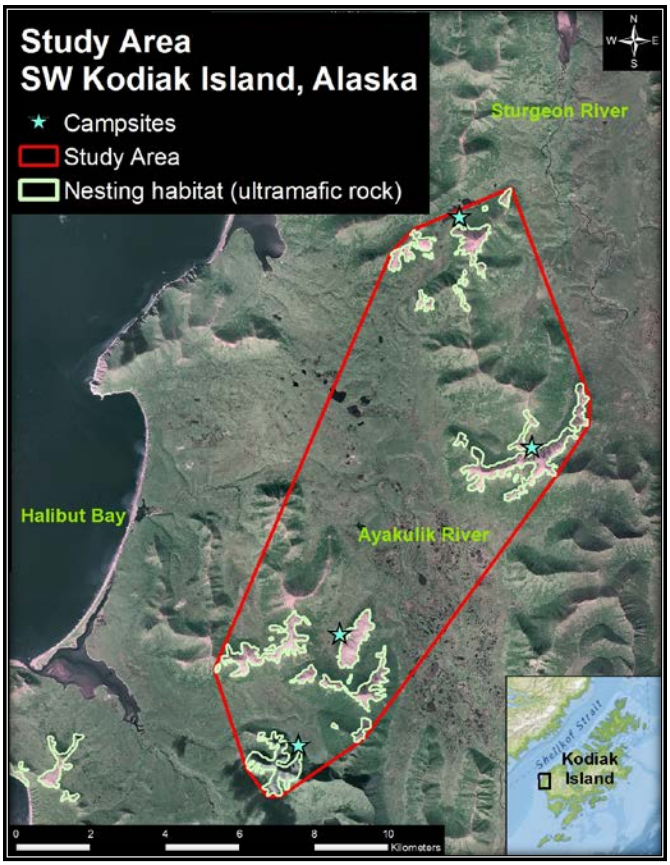

Figure 1. Map of study area on the west side of Kodiak Island, AK.

Methods

Systematic Nest Searching

The nesting habitat in ultramafic rock closest to each campsite was searched to the fullest extent possible within the available time, focusing first on high priority sites (where nests have been found repeatedly), second on medium priority sites (where nests have been found in lower densities), and finally on low priority sites (where nesting habitat exists but the area was not searched previously or, if searched, no nests had been found). On the first round of searching four to eight days were spent at each camp covering as much area as possible. Nest searching continued until late July when efforts shifted to collecting data on nest site characteristics.

At the start of each day the research team hiked to the lowest elevation of nesting habitat to be searched that day. They positioned themselves vertically up the slope with a gap of 5–10 m between each person. The person at the highest elevation led the systematic search. With pin-flags and a GPS unit (Garmin GPSMAP® 76cxs) in hand, this lead person walked at a constant elevation, stepping up 2–3 m to drop a flag as reference for the return line. The rest of the search team followed a horizontal distance of 2–3 m behind the lead searcher (to avoid falling rocks and spot flushing birds) and kept a vertical distance of 5–10 m between each searcher (Fig. 2 (A)). On a single line the distance between searchers would vary between 5-10 m as the slope of the mountain changed. The bottom searcher stayed about 2 m above the flags that were dropped on the preceding transect, walking down to collect each flag before returning to the current line. When the end of a transect was reached, the team moved up and reversed course, systematically searching the entire area to the ridge top. All transects were logged using two GPS units.

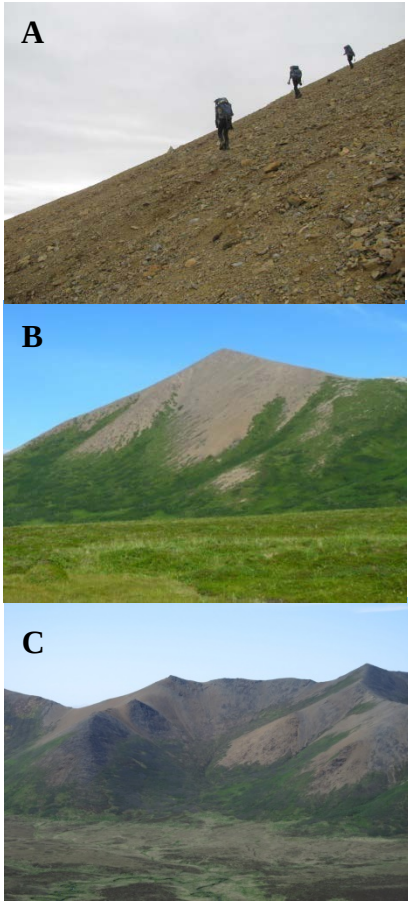

Figure 2. Image A shows researchers conducting systematic nest searching, and B & C show nesting habitat of Kittlitz's murrelet on Kodiak Island, AK.

Flushing an adult from the nest was by far the most common method of discovery. Occasionally lone chicks were found while searching and adults were spotted on the ground prior to flushing. Adults tended to flush and fly directly downslope, hugging the slope of the mountain. Flushing adults were identified as KIMU based on the outer white rectrices characteristic of this species. Once the flushing adult had flown out of sight, researchers focused on finding the single egg camouflaged among the rocks.

Procedures at the Nest

Once a nest was discovered, each person put on nitrile gloves to minimize scent around the nest and proceeded with an assigned task. One person photographed the area and recorded data, another person set up a Reconyx® camera painted to blend in with the surrounding rocks, and the third person floated and measured the single egg. Each camera was mounted on a stake

embedded in the rocks ideally about 1 to 1.2 m away from the nest, camouflaged with rocks, and aimed at the nest to record incubation shifts and feedings. Camera placement depended on the terrain around the nest. The egg was weighed to the nearest 0.5 g with a 100 g spring scale, measured with digital calipers to the nearest 0.1 mm (length and width), and floated to determine stage of incubation (Fig. 3). Stage of incubation was determined based on an assumed 30-day incubation period (Day et al. 1999) and egg floating benchmarks described by Rizzolo and Schmutz (2007).

Figure 3. Floating a Kittlitz's murrelet egg to determine stage of incubation.

In addition to recording measurements from the egg handler, the data recorder classified the nest by a nest identification number (KOD for Kodiak, species code KIMU, last two digits of the year, and number of nest found, e.g. KODKIMU1501 for first nest discovered in 2015). The date, UTM coordinates, time a nest was discovered, time the nest was left, observers, predators observed, confirmation of species, elevation, and the direction the adult flushed were also recorded. Prior to leaving the nest vicinity, researchers deployed a temperature data logger (Thermochron® iButtons, Embedded Data Systems DS1922L-F5#) in a makeshift nest bowl similar to the active nest (i.e. similar nest bowl composition, aspect, and nest rock) constructed within a six meter radius of the active nest. iButtons were programmed to log temperature every 10 minutes in 0.5°C increments and stored 8192 8-bit temperature readings. Each button logged new temperature events for just under 57 days. The iButton was deployed to measure the microclimate at each nest site to better understand the differing thermoregulatory costs of each chick. To encourage the adult to return quickly we attempted to keep time at the nest less than 10 min and moved to a different face of the ridge/peak or to a different ridge post discovery. Aside from scheduled nest visits we remained at least 50 m from all active KIMU nests during subsequent search efforts and activities in the area.

Using estimates of hatch date based on floating eggs, nest sites were visited at three intervals throughout development to obtain growth measurements. At each visit, observers noted whether the nest was active or inactive, checked camera function, looked for prey remains, recorded the weather, and collected morphological measurements of the chick. If a chick was present it was taken >30 m from the nest site to be processed to avoid disturbance at the nest. Morphological measurements taken included: head length, culmen, tarsus, wing chord from the wrist joint to tip of longest primary without depressing the wing, wing chord with the wing held flat against the ruler, and longest rectrix. Mass was measured with a spring scale to the nearest 0.5 g for chicks weighing <100 g, and to the nearest 2.5 g for chicks heavier than 100 g. Additional chick attributes recorded included percent coverage of down and presence or absence of an egg tooth. Fecal samples were collected at each visit and archived for potential future research. With an average fledging period on Kodiak of 24.8 days, nest checks were made at 4 to 6 days, 14 to 16 days, and 18 to 21 days to get an adequate representation of growth throughout development. The second observation period was changed in 2012 from 9–13 days to 14–16 days to obtain growth information for the later period (Corcoran et al. 2014).

Trapping Incubating Adults

Three adult Kittlitz's murrelets were trapped during incubation in an effort to determine foraging areas and seasonal movements along with testing trapping methods. We prepared to trap using

two potential methods: mist-netting and bow trapping. Mist-netting was the preferred option with a bow trap as a secondary method if mist-nets proved unsuccessful. To mist-net we approached each nest with a standard nylon mist-net (2.1-18 m, 110 denier, Avinet, Inc.) supported on aluminum poles stretched between two people, starting approximately 40 m down-slope from the nest site. Keeping the net outstretched the two individuals walked slowly upslope towards the nest until the net could be laid over the incubating adult or the adult flushed into the net. A third researcher was available to quickly secure the bird once it had been captured. The adult was removed from the net and taken over 40 m from the nest and fitted with a U.S. Fish and Wildlife stainless steel band and a 5 g solar-powered ARGOS satellite transmitter (Microwave Telemetry, Inc.). Transmitters were attached using non-absorbable sutures. First, several feathers on the central, dorsal surface between the scapulae were lifted and one strip (0.5 ×2.0 cm) of waterproof tape (No. 4651, Beiersdorf AG, Hamburg, Germany) was inserted adhesive side up and wrapped over on itself forming a secure tab. Second, a small amount (~1 drop) of Loctite 422®, 1-min cyanoacrilate adhesive was applied to the base of the transmitter which was then affixed to the top of the feathers and tape tab. Third, four sterile, surgical sutures (synthetic, non-absorbable 3-0 polypropylene monofilament, Ethicon™) were used to attach the transmitter to the skin via a sterile 21-gauge × 1.5 inch hypodermic needle (Newman et al. 1999). Specifically, for each suture, the skin below the transmitter suture channel was pinched using the thumb and forefinger, the needle was inserted through the pinched skin, and the suture was threaded through the needle. When the needle was removed the suture was retained under a 5-10 mm wide section of skin. The four sutures were then threaded back through the channels at the base of the transmitter and secured snuggly to the skin and feathers with four surgical square knots. Care was taken to ensure that the suture was snug and posed no risk for entanglement. This method of attachment had successfully been used previously to attach both VHF and satellite tags to KIMU in other regions of Alaska (Kissling et al. 2016, John Piatt pers. comm., May 2015). The adult was released at the nest site.

Nest Cameras and Estimation of Fish Length

A camera, Reconyx PC900, was placed at each nest discovered. In 2009 and 2010, Lawonn et al. (2012) investigated the effects of cameras on nest predation by randomly placing cameras at every other active nest discovered. He found no correlation between nest cameras and depredation (n=27); in fact, nests with a camera had a higher rate of fledging (0.21 with cameras vs. 0.10 without cameras). Starting in 2011, a camera was placed at every nest, and in subsequent years (2012-2013) there was a substantial increase in nest success (17% to 46%). Prior to the field season each camera was painted to blend in with the surrounding environment, fitted with a visor to reduce glare and rain on the lens, and tested for operation. Nest cameras were set to trigger on motion and at an interval of 3 min to provide images from discovery to fledging. When the motion sensor was triggered the camera snapped three photographs at 1-s intervals. During 2011, three cameras were set to 1-min intervals, and out of 199 meal deliveries recorded, only one visit was shorter than the 3-min interval, indicating a 3-min interval was adequate to film >99% of visits of parents to the nest (Lawonn et al. 2012).

Camera images from discovery until 24 hours after fledging or nest failure were reviewed at the end of the field season. Incubation shifts, hatching, adult brooding, meal deliveries, depredations, fledging, nest fate, and any other events at the nest were recorded. For each meal delivery, the date, time, prey species, and whether the prey was consumed were inferred to the maximum capability of the images. To the extent possible, the length of each fish was estimated as a ratio

to the number of adult head lengths. An adult head length of 57.3 mm (from adult captured on Kodiak in 2015) was multiplied by each measured ratio to obtain an estimated fish length.

During nest checks, the cameras were inspected for battery life, memory space, and performance. Nest fate was determined from camera images and physical evidence present during the final nest check when the camera was retrieved. Predation events were described with date, time, species, and written comments. A nest was considered abandoned if an adult left an unattended egg and never returned. In case of camera failure, physical evidence at the nest site helped to infer nest fate. A large fecal ring at the back of the nest accompanied by down, shed by the chick just prior to fledge, was accepted as evidence of a successful nest. If there was no chick present on the first nest check, hatch was determined by the presence of fecal and egg fragments and a depredation event was assumed.

Nest Site Characteristics

Dedicated nest searching ended in mid-July and the remainder of the field season was spent visiting nests to gather growth rate data, and measuring physical characteristics at each nest site, along with randomly selected sites near nest site locations. Nest site measurements included slope, aspect, elevation, and whether the ocean was in view. Areal extent of cover type was estimated within a 5 m radius, with less detailed estimates within radii of 25 and 50 m. Within the 5 m plot, percent coverage was estimated for bare soil, rock <10 cm diameter, rock 10–30 cm diameter, rock >30 cm diameter (including exposed bedrock), available nest rock (>20 cm diameter), and six categories of vegetation (lichen, orange crustose lichen, moss, grass, forb, and shrub). In the 25 and 50 m plots, the percentage of the area that was vegetated and unvegetated was estimated (Lawonn et al. 2012).

In our study area, KIMU laid a single egg in a shallow depression scraped in the rocky substrate, often having a ‘nest rock’ above the scrape that offered some shelter from the elements and helped to hide the incubating adult and later the growing chick. While at the nest site, researchers identified up to three nest rocks and measured the dimensions of the rocks (length × width × height). These rocks were usually directly above the nest scrape but can be off to the side of the nest bowl. The depth and diameter of the nest bowl were measured with a steel ruler to the nearest millimeter. Two plots near the nest site were randomly selected in the field and the same measurements made at nest sites were taken at the random sites for the 5, 25, and 50 m plots, except that the physical data measured at the nest bowl (nest rock dimensions, nest bowl dimensions) were not collected. Prior to leaving each nest, four pictures of the habitat were taken from the two sides of the nest, upslope, and downslope.

We had a solitary Lehman’s propane freezer at the Duncan Lake study site for biological samples. Samples were collected during each nest visit from the fecal ring located at the back of the nest, and buried at campsites to keep cool. Upon returning to town these samples were stored in a freezer at the KNWR headquarters. Any prey fish left around the nest site were collected when present. These specimens were buried at camp, frozen at the first chance, and were also placed in a freezer at the KNWR headquarters office upon return to town. Egg shell fragments and adult contour feathers were collected opportunistically, stored in envelopes, and archived for future research at the KNWR headquarters. Abandoned eggs and dead chicks were collected in Ziploc bags, buried at camp, and frozen as soon as possible.

Predators Observations

Predation has had a large impact on KIMU nest success throughout the study. Using protocol described by Sargeant et al. (1993) the number of predators observed during the field season and the number of places a predator species was seen each day were recorded. All recorded observations were within 1 km of ultramafic rock nesting habitat at the four sites.

Results and Discussion

Nest Searching and Monitoring

On 23 May a research team of four was flown into Duncan Lake on the west side of Kodiak Island. The team spent the summer hiking between four basecamps (Fig. 4) that served as staging points to systematically search for KIMU nests, monitor nests once discovered, and conduct habitat surveys at the end of the field season. After 80 days in the study area the crew was flown out of the field and back to the city of Kodiak on 10 Aug. Dedicated nest searching began on the 26 May and concluded on the 21 July. With the arrival of more volunteers from the 3 July to 15 July two teams of three to five searched independently at two study sites. Typically, nest searching is completed at each of the four sites before a second round of searching begins. However, due to nest trapping commitments in 2015, the Duncan site was searched twice before the Anvil site had been searched once. We systematically searched potential ultramafic rock nesting habitat with slopes greater than 20°, focusing the search effort on steeper slopes and larger patches of ultramafic rock. Three of the four sites were searched completely on the second round but due to time and logistic constraints we only completed a partial second search at the fourth site, Anvil. During late June, time was dedicated to nest monitoring and travel between sites was often dictated by the schedule of nest checks.

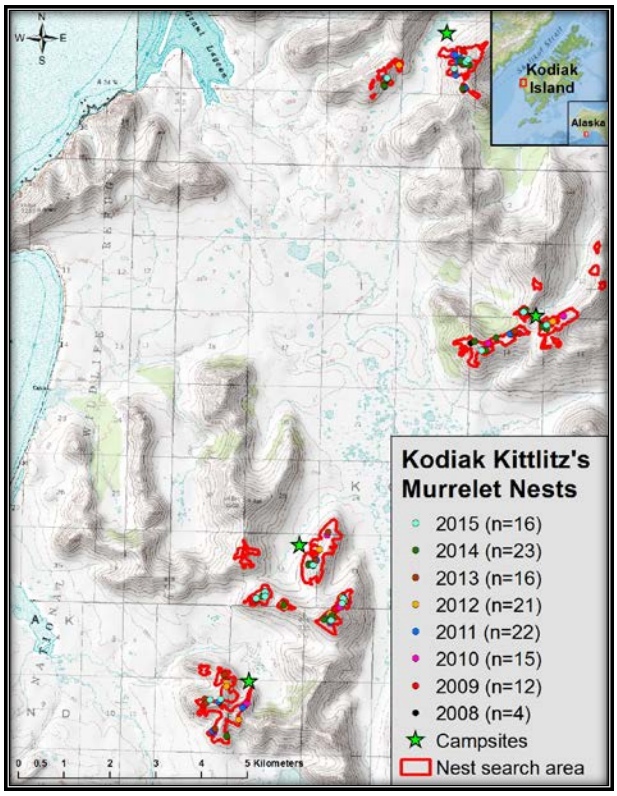

Figure 4. Kittlitz's murrelet nest locations from 2008-2015 on Kodiak Island, AK.

Nest searching concluded on the 21 July yielding 16 active KIMU nests and one nest discovered with a depredated egg in the nest bowl. Fifteen of the 16 nests were located after flushing an incubating adult, and one was discovered during systematic searching when an adult was spotted incubating among the rocks. The average distance at which an adult KIMU flushed from the nest in response to searchers was 2.8 meters in 2015. The range of flush distance was similar to previous years of the study, and ranged from 0.5 m to 7 m in 2015. While taking nest habitat measurements at an inactive nest we discovered a skeleton and down of a murrelet chick from a previous years nesting attempt in the clump of dirt and moss on the edge of the nest bowl.

Additionally in 2015, 11 nests were discovered within 20 m of nest sites found in previous years of the study, and two of these were in the same nest bowl. The only two nests active simultaneously within 100 m of each other were 64 m apart. We have documented reuse of the same nest bowl in different years on 11 occasions. A total of 39 nests have been located within 20 m of a nest used in a preceding year.

Table 1. Summary of Kittlitz's murrelet adult return times after initial flush of incubating adult on Kodiak Island, AK during the 2009-2015 nesting seasons.

Year	Mean Return Time	Minimum Return Time	Maximum Return Time
2009	174	15	455
2010	156	17	583
2011	370	14	1329
2012	487	17	776
2013	210	23	540
2014	359	15	1025
2015	334	20	753
Mean	299	17	780

*The outliers of 2135 min in 2012 and the 3404 min in 2015 were removed from the analysis.

As in previous years there was a wide range of return times for adults after initial flush (20-753 min) (Appendix B). The mean return time for 2015 was 334 min, which is in the upper range for the eight year study (Table 1). Average time from initial flush to when researchers left the nest was 12 minutes in 2015, slightly higher than the 10 minute goal. On one occasion we spotted a returning murrelet fly by the nesting area as we left the nest indicating KIMU will return to the nest within 10-12 minutes of initial flush.

Table 2. Kittlitz's murrelet nest initiation dates on Kodiak Island, AK from 2008-2015. Average initiation dates include known and estimated hatch back calculated based on a 30-day incubation period.

Year	Average Initiation Estimates
2008	22 June
2009	3 June
2010	11 June
2011	6 June
2012	14 June
2013	15 June
2014	4 June
2015	11 June

Based on estimated and known hatch dates the average initiation date was 11 June (range 22 May to 14 July). Renesting was likely observed in multiple seasons (2011, 2013, 2014, and 2015) represented by birds initiating nests far beyond mean initiation dates recorded for this species on Kodiak Island. Tendency to re-nest following initial nest failure has been frequently reported for the congeneric marbled murrelet (*Brachyramphus marmoratus*) (Nelson et al. 2010).

Trapping Incubating Adults

Trapping began on 22 June and ended 24 June. We captured three adults on the first attempt using the mist-netting method. On two occasions we were able to lay the 18 m mist-net directly on top of the incubating adult. In both cases the bird did not flush when the net was laid upon them, but flushed after a researcher approached to within three meters. In the third case the incubating adult flushed directly downslope when the net was five meters away, and was captured in the bottom half of the net.

Unfortunately, at the first nest trapped (KODKIMU1501) the egg was damaged when a small rock, dislodged while the net was being taken off the adult bird, slid from above the nest and hit the egg, breaking it open. A marbled murrelet dummy egg that was used to practice trapping methods was placed in the nest to determine if the adult would return to incubate. However,

camera images revealed that only the untrapped adult returned and incubated sporadically from the trapping day of 22 June to the 25 June when the dummy egg was removed. After reviewing camera images from all three nests it was determined that none of the trapped adults returned to the nest site. At nest KODKIMU1509 the untrapped adult incubated sporadically from the trapping day of 24 June to the 7 July. At nest KODKIMU1502, the single untrapped adult incubated sporadically for seven days and the egg hatched on 30 June. Three prey deliveries were made to the chick from 1 to 3 July. However, the chick died between 2 and 3 July and was collected on the first nest visit after trapping on 3 July. The camera was left at the nest site until 10 Jul, but no adult murrelet activity was seen after 3 July. Information on trapped adults can be found in Appendix J.

Figure 5. Kittlitz's murrelet in breeding plumage with satellite transmitter attached.

Data acquired from satellite transmitters indicated that the trapped adults (Fig.5) did not return to the nesting area. Although the transmitters on the nesting adult KIMU recorded locations for only about ten days, the birds all used the nearshore marine waters near the southern end of Kodiak Island and the Trinity Islands. This region was also used in the late summer by a KIMU satellite tagged by USGS researchers in Icy Bay in 2010, which migrated to Kodiak in late August and spent almost a month foraging in the Geese Channel north of the Trinity Islands on Kodiak. The recent satellite telemetry result may enable researchers to design a survey to generate the first population estimates for KIMU in the Kodiak Archipelago.

Nest Success

Apparent nest success was 0% (0 of 13, the three trapped nests were not included in the analysis since the adults abandoned due to the trapping event). This is the lowest nest success observed since the first year of the study in 2008. However, 2008 was a pilot study and only one of the four study sites was searched and four active nests monitored (Fig. 6). Predation (n=8) was the leading cause of nest failure, followed by egg (n=4) and chick (n=1) abandonment. Of the 13

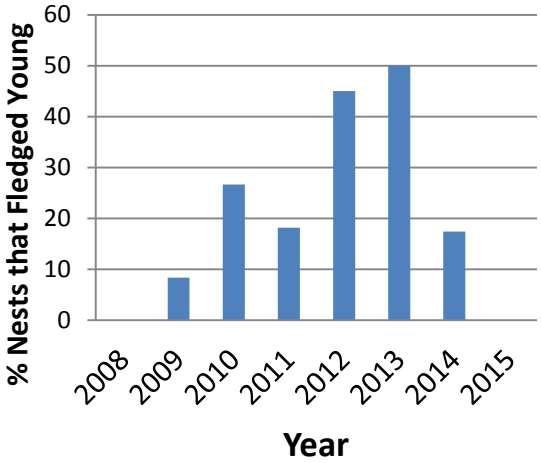

Figure 6. Annual percentage of Kittlitz's murrelet nests that fledged on Kodiak Island, AK from 2008-2015.

Table 3. Summary of Kittlitz's murrelet nest fates on Kodiak Island, AK during the 2015 nesting season.

Nest Fate	Number of nests
Egg abandoned	4
Failed during incubation, red fox depredation	4
Failed during incubation, depredation by unknown predator	2
Failed during nestling stage, red fox depredation	2
Failed during nestling stage, dead chick found on nest scrape	1
Trapped during incubation (nest failure)	3
Fledged young	0
Total	16

untrapped nests, six nests were depredated by red fox (five at egg stage and one at chick stage), two by an unknown predator, one chick appeared to be abandoned by adults and died at the nest three days after hatch, and four eggs were abandoned (Table 3). The predator at two nests could not be identified due to camera motion missing the predation event. Nest fate had to be determined by a combination of physical evidence at the nest and existing camera images. Detailed nest fates for 2015 can be found in Appendix C and a summary of nest fates from 2008-2015 can be found in Appendix G, Table 4, and Figure 7.

The predator responsible for nest depredation was recorded by camera at 30 of the 55 nests that failed due to predation. Of those 30 identified predators, 28 were red fox (Fig. 8). The majority (41) of depredation events occurred during incubation and only a few (14) during chick rearing. Prior to 2014 the red fox was the only species documented depredating KIMU nests on Kodiak Island. During the 2014 season camera images revealed two instances where a black-billed magpie (*Pica hudsonia*) depredated a nest in egg stage.

Apparent nest success in 2012-2013, 45% and 50% respectively, was higher than the 17% average nest success observed during the other years (2008-2011 & 2014) of the study (Fig. 6). While chick death has been a frequent cause of nest failure (17%) (Appendix D), in 2013 far fewer chicks died on the nest for unknown reasons. In 2012-2013, nest predation was lower than all previous years of the study. Predation rates dropped from 49% in 2008-2011 to 26% in

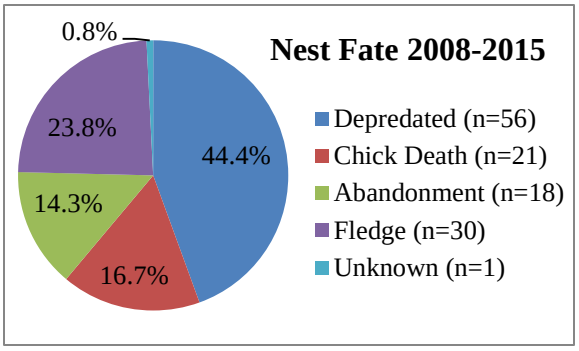

Figure 7. Compiled Kittlitz's murrelet nest fate from 2008-2015 on Kodiak Island, AK.

Table 4. Fate of Kittlitz's murrelet nests found on Kodiak Island, AK during 2008-2015.

Nest Fate	2008	2009	2010	2011	2012	2013	2014	2015	2008-2015
Depredated	2	8	7	9	4	6	12	8	56
Dead chick	0	1	2	8	3	1	5	1	21
Abandoned	2	2	2	1	4	1	2	4	18
Fledge	0	1	4	4	9	8	4	0	30
Unknown	0	0	0	0	1	0	0	0	1
Trapped	0	0	0	0	0	0	0	3	3
Total	4	12	15	22	21	16	23	16	129

2012-2013, and coincided with an increase in nest success during the same time period. In 2014 and 2015 predation rates increased to 52% and 62% respectively, the second and third highest recorded on Kodiak. Red fox were observed on 13% of observation days in 2012, 6% in 2013, 24% in 2014, and 21% in 2015 (Appendix E). The decline in predation rates during the 2012-2013 nesting season could have resulted from fewer fox in the nesting habitat due to the abundance of alternative prey such as ptarmigan and tundra voles available in more vegetated habitats at lower elevations. We have speculated that the magnitude of predator influence may be related to predator composition, abundance, and availability of alternative prey in habitats used for nesting by KIMU (Lawonn et al. 2012). However, additional resources beyond the scope of this current research would be necessary to determine what influences these factors have on predation rates.

Predator Observations

The collection of predator observations recorded throughout the field season was standardized beginning in 2012 by using protocol described by Sargaent et al. (1993). The number of places a species of predator was seen each day was recorded. All observations were within 1 km of ultramafic rock nesting habitat at the four sites. Observations made of predators outside the 1 km range of nesting habitat were not included in the totals. The length of time spent in the field was 64 days in 2012, 62 days in 2013, 77 days in 2014, and 80 days in 2015. When the crew was split up in multiple groups in different locations predator observations were recorded separately increasing the number of observation days. The total number of observation days when crews recorded predators was 61 in 2012, 65 in 2013, 81 in 2014, and 96 in 2015.

Figure 8. Red foxes captured depredating Kittlitz's murrelet nests during the 2015 field season.

The black-billed magpie and bald eagle (*Haliaeetus leucocephalus*) have been the most frequently observed predators within our study sites in recent years. While only red foxes and black-billed magpies have been documented depredating KIMU nests on Kodiak Island, there were additional potential predator species that were frequently observed including common raven (*Corvus corax*) and golden eagle (*Aquila chrysaetos*). For more information on predator observations refer to Appendix E.

Nest Site Characteristics

Characteristics of KIMU nests located during 2015 were consistent with the observations collected during the previous seven years of research. All nests where located in ultramafic rock habitat with less than 35% vegetation coverage within a 5 m radius. Nests consisted of a shallow nest bowl made in loose rock 1-5 cm in diameter below a large rock (commonly known as a nest rock).

The average percent of vegetation coverage within a 5 m, 25 m, and 50 m radius of nests discovered in 2015 was 4%, 5%, and 5% respectively. These fall within 4% of the eight year averages of 6%, 8%, and 9% respectively. Nests have been found at a range of elevations from 162 m to 455 m. The 2015 mean nesting elevation (330 m) was higher than the average across all eight years (318 m). Nests in 2015 were found on steeper slopes (mean 35°, range 20-47°) than average (mean 32°; range 20-49°). Additional information on nest site characteristics can be found in Appendix F.

In 2015 we estimated ground coverage at 200 random and 30 near nest habitat plots. Data have been collected on about 1200 random plots within the search area from 2008-2015. Analysis of nest site habitat characteristics from 2008-2011 indicated that KIMU selected sites with lower vegetation cover, more rocks 5–30 cm, fewer rocks >30 cm, and steeper slopes than random sites. However, there was no observed relationship between the habitat covariates and nest survival rate (Lawonn 2012).

Meal Delivery and Chick Growth

Growth rate, feeding rate, and the length of the prefledge period (hatch to fledge) will be analyzed to determine how these factors interact to influence nest success. For example, variation in prey deliveries may impact growth rates therefore extending or shortening the pre-fledgling period in turn changing the length of exposure to predation.

Of the 16 active nests discovered four produced a chick. Over the course of the field season we observed meal deliveries at all of the nests that reached chick stage. Of the three untrapped nests that reached chick stage, we recorded only 18 fish delivered to chicks for an average of 1.9 fish deliveries per day (Table 5). In 2015 from hatch (day 0) to day three, fish delivered per day (1.92 fish per day), the average sum of deliveries (9), and the average sum of fish lengths (1053.17 mm) were the second lowest compared to all years of the study (Table 6). Average fish length from day 0-3 was lowest in 2015. Delivery frequency and fish size increase after the first few days post-hatch (Appendix I). As in previous years, Pacific sand lance was the most abundant fish species delivered to chicks comprising 76% followed by capelin at 24% (Fig. 9).

Table 5. Annual meal deliveries summary from 2009-2015. Mean meals a day were calculated by taking the average meals a day delivered to a chick and averaging the mean meals a day for all chicks in a given year. Sample size (n) represents number of chicks that received at least one prey delivery and were observed for a full day.

Year	n	Mean meals a day	Total fish delivered	Average fish length (mm)*	Average time between deliveries (hr:min)	Total days monitored post-hatch
2009	2	3.5	117	132.6	5:51	33
2010	5	3.6	173	133.9	5:52	48
2011	13	4.7	984	136.9	4:41	213
2012	12	4.0	730	134.3	5:21	186
2013	10	3.7	701	130.4	5:58	190
2014	8	3.7	310	123.8	5:43	88
2015	3	1.9	18	111.3	8:58	10

*Each fish to adult head ratio obtained from nest images was multiplied by 57.3 mm (assumed adult head length) to obtain an estimated fish length.

We were able to collect only one growth measurement on a single chick in 2015. Data on prey deliveries to chicks in each season will be used to develop models evaluating whether variations in the energy content of prey fish could explain poor reproductive performance in this sensitive species (Appendix H). Unfortunately due to low hatch rate this field season none of the 2015 data will be included in this analysis.

Camera failure was not an issue in 2015 because after the 2014 season, when camera failure was a frequent problem, we sent cameras to Reconyx to be refurbished. The distance of the camera to the nest was dictated by terrain and the need to get clear images of prey deliveries to chicks (Fig. 10). However, based on observations from this field season cameras set on a motion sensor should not be put closer than 0.8 meter, with an optimal distance of 1-1.5 meters.

Conclusion

Nest success of KIMU on Kodiak Island in 2015 was the lowest observed during this eight year study with the exception of the pilot year in 2008 when only one site was searched and four active nests monitored. The main sources of nest failure in 2015 were predation and abandonment. Many nests were

Table 6. Annual meal delivery summary from hatch (day 0) to day 3 during the 2009-2015 breeding season. Sample size (n) represents number of chicks observed continuously from day 0-3.

Year	n	Average deliveries a day from Day 0-3	Average sum of deliveries from day 0-3	Average fish length Day 0-3 (mm)*	Average sum of fish length from day 0-3 (mm)*
2009	2	1.63	6.50	128.70	836.58
2010	2	2.58	12.50	120.62	1495.44
2011	10	3.00	12.40	126.80	1576.15
2012	8	2.53	10.13	120.43	1219.34
2013	6	3.08	12.33	115.35	1422.66
2014	4	2.25	10.25	111.18	1131.65
2015	1	1.92	9.00	110.76	1053.17

*Each fish to adult head ratio obtained from nest images was multiplied by 57.3 mm (assumed adult head length) to obtain an estimated fish length.

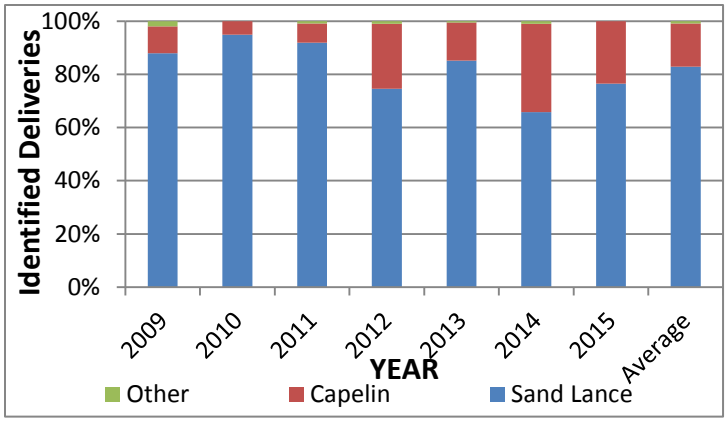

Figure 9. Annual percentages of fish species fed to Kittlitz's murrelet chicks on Kodiak Island, AK from 2009-2015.

Table 7. Frequency of chick meals (single fish) delivered to Kittlitz's murrelet on Kodiak Island, AK in 2015. A total of 20 deliveries were recorded while a live chick was present. Total days monitored post-hatch starts at hatch (day 0). Italicized nest was one of the three trapped during incubation.

Nest ID	Mean meals a day	Range of meals a day	Total fish delivered while active	Total days monitored post-hatch	Nest fate
KODKIMU1502	*1*	*0-2*	*2*	*2*	*Chick death about 2 days post-hatch*
KODKIMU1503	2.5	2-3	5	1	Chick depredated 1 day post-hatch
KODKIMU1510	2.25	0-5	10	4	Chick depredated 4 days post-hatch
KODKIMU1515	1	1	3	2	Chick death & abandonment 3 days post-hatch

Figure 10. ReConyx images of Kittlitz's murrelet adult delivering Pacific sand lance to a chick waiting in a nest on Kodiak Island, AK during the 2015 field season.

abandoned before hatching, hatched chicks received fewer fish than average, and one chick was abandoned (Table 7). In spring of 2015, there were several reports of dead common murres (*Uria aalge*) on Kodiak, in the eastern Aleutian Islands, and on the Kenai Peninsula. Over the course of the breeding season large numbers of emaciated common murres died and washed up along the coast of the Gulf of Alaska (GOA). This seabird die-off event has been described as unprecedented in scale due to the number of birds found dead, the large area over which dead birds were found, and the duration, with fresh carcasses located from April 2015 until February 2016. Overall mortality was estimated in the 100,000s order of magnitude. Based on birds that were necropsied by pathologists at the National Wildlife Health Center starvation was ruled as the cause of death. One proposed explanation for the die-off was changes in the distribution and abundance of preferred cold-water associated forage fish due to record high sea surface temperatures in the North Pacific beginning in 2014. In the GOA seabird productivity in 2015 was below average for almost all common species, black-legged kittiwakes (*Rissa tridactyla*) exhibited widespread breeding failures (Dragoo et al. 2016), and colony abandonment was recorded for common murres, the first time such abandonment has occurred in over 35 years of monitoring. In 2015 we documented the highest rate of nest abandonment (38%). This high rate of abandonment may have resulted from food limitation. Consistent with overall low productivity for seabirds in the GOA in 2015, adult KIMU on Kodiak may have been unable to find the forage fish necessary to complete the nesting effort.

After major declines from 1980 until 2000 it is believed the overall KIMU population stabilized, however, in some regions survey data indicate the species continues to decline. In Icy Bay, AK for example, continued counts indicated an annual decline of 10% from 2002 to 2012 (Kissling et al. 2015). Based on telemetry data, breeding season survival (0.89, SE 0.04) and annual survival (0.80, SE 0.33) in Icy Bay were also lower than predicted based on life history (Kissling et al. 2015). Low nest success and adult survival during the breeding season could be an additional indication of reduced availability or quality of food (Rindorf et al. 2000, Kitaysky et al. 2010).

Data from this research project will continue to be analyzed in cooperation with Southern Illinois University Carbondale, U.S. Geological Survey, and co-operators investigating KIMU chick death attributed to saxitoxin. Our goal is to use the data to investigate the influence diet

composition has on nest success. Research will assess the hypothesis that the KIMU population has declined in part due to lower chick growth rates resulting from reduced availability of high-energy forage fish. This research will offer insights into broader issues such as the 'Junk Food Hypothesis' and effects of oceanic regime shifts on population trends. These factors, mediated by climate change, might have been primary contributors to declines seen across a wide geographic range not only for KIMU but for other marine predators including black-legged kittiwake and Steller sea lion (*Eumetopias jubatus*).

Funding provided by the National Fish and Wildlife Foundation Pacific Seabird Program will allow this research to continue for another nesting season. During the 2016 field season we will follow the same protocols for nest searching and monitoring as in previous field seasons.

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APPENDIX A. Weather conditions, Kodiak Island, AK, 2008-2015 (NOAA, 2016).

Year	Site	Dates	Average Daily Mean Temp (˚C)	Average Daily Max Temp (˚C)	Average Daily Min Temp (˚C)
2008	Booth Lake	14 Jun – 31 Aug	10.8	14.0	7.7
2009	Booth Lake	1 Jun – 31 Aug	10.4	13.4	7.2
2010	Booth Lake	1 Jun – 31 Aug	10.5	12.9	8.0
2011	Booth Lake	1 Jun – 31 Aug	10.1	13.0	7.4
2012	Booth Lake	1 Jun – 31 Aug	10.1	13.3	6.8
2014	Booth Lake	1 Jun – 31 Aug	11.7	15.2	7.7
2015	Booth Lake	1 Jun – 31 Aug	11.9	15.0	8.5

*2013 Data from Booth Lake is unavailable due to equipment malfunction.

Year	Site	Dates	Average Daily Mean Temp (˚C)	Average Daily Max Temp (˚C)	Average Daily Min Temp (˚C)	Total Rainfall (cm)	Average Daily Rainfall (cm)
2008	Kodiak Airport	1 Jun - 31 Aug	10.7	13.7	7.8	65.3	0.71
2009	Kodiak Airport	1 Jun - 31 Aug	11.6	15.0	8.3	42.7	0.46
2010	Kodiak Airport	1 Jun - 31 Aug	11.4	14.1	8.7	33.8	0.37
2011	Kodiak Airport	1 Jun - 31 Aug	11.7	14.5	8.9	32.0	0.35
2012	Kodiak Airport	1 Jun - 31 Aug	11.2	14.2	8.1	20.4	0.22
2013	Kodiak Airport	1 Jun - 31 Aug	13.2	16.7	10.0	36.8	0.40
2014	Kodiak Airport	1 Jun – 31 Aug	12.7	15.9	9.4	39.9	0.43
2015	Kodiak Airport	1 Jun – 31 Aug	13.8	17.2	10.4	21.4	0.23
Mean			12.03	15.16	8.95	36.53	0.40
Standard Deviation			1.006	1.210	0.862	13.197	0.144

*An error was made in the preceding 2013 and 2014 Progress Reports in Appendix A. when reporting total rainfall (cm) and average daily rainfall (cm) at the Kodiak Airport site. The reported total rainfall was actually the average monthly rainfall and average daily rainfall was an incorrect calculation.

APPENDIX B. Adult return time after initial flush, age at discovery, flush distance, and egg measurements for Kittlitz's murrelet nests, Kodiak Island, AK, 2015. Bolded numbers under estimated age at discovery represent known hatch dates obtained from nest cameras.

Nest ID	Return Time (min)	Approximate Age at Discovery (Days)	Flush Distance (m)	Egg mass (g)	Width (mm)	Length (mm)
KODKIMU1501	45	1	2	44.5	37.8	60.9
KODKIMU1502	346	**0**	4	50	39.2	62.2
KODKIMU1503	73	**17**	6	44	38.3	56.6
KODKIMU1504	380	4	1	39.5	37.6	53.3
KODKIMU1505	715	16	3	38	37.2	54.7
KODKIMU1506	753	5	2	42.5	38.1	58.2
KODKIMU1507	639	4	1	43	38.4	55.9
KODKIMU1508	628	5	1	44	38	56.8
KODKIMU1509	335	10	2	41	37.4	55
KODKIMU1510	108	**29**	0.5	~	~	~
KODKIMU1511	131	5	7	46.5	38.5	57.1
KODKIMU1512	26	5	6.5	49	39.85	60.37
KODKIMU1513	20	2	2	40	35.5	58.8
KODKIMU1514	702	25	3.5	40	38.32	56.96
KODKIMU1515	112	**16**	1	41	37.25	60.04
KODKIMU1516	*3404	3	2	43	36.9	58.8
Mean	334.2	9.2	2.8	43.1	37.9	57.7
Standard Deviation	283.4	8.5	2.0	3.3	1.0	2.4

*The return time for KODKIMU1516 was removed from the analysis.

APPENDIX C. Chronology and fate of Kittlitz's murrelet nests in 2015, Kodiak Island, AK.

Nest ID	Date Discovered	Approximate Date Initiated*	Hatch Date	Last Date Known Active	Fate
KODKIMU1501	*29-May*	*28-May*	~	*22-Jun*	*Trapped adult 22 Jun (never returned),egg broke during capture*
KODKIMU1502	*30-May*	*30-May*	***30-Jun***	*1-Jul*	*Trapped adult 23 Jun (never returned), chick death 2 Jul 2 days post-hatch*
KODKIMU1503	6-Jun	20-May	**19-Jun**	20-Jun	Chick depredated by red fox 1 day post-hatch on 20 Jun at 23:43
KODKIMU1504	7-Jun	3-Jun	~	13-Jun	Egg depredated by unknown predator on 13 Jun around 22:35
KODKIMU1505	7-Jun	22-May	~	26-Jun	Egg depredated by red fox on 26 Jun at 4:25
KODKIMU1506	11-Jun	6-Jun	~	26-Jun	Egg depredated by red fox on 26 Jun at 4:00
KODKIMU1507	16-Jun	12-Jun	~	11-Jul	Egg depredated by unknown predator on 11 Jul
KODKIMU1508	17-Jun	12-Jun	~	27-Jun	Egg depredated by red fox on 27 Jun at 1:09
KODKIMU1509	*19-Jun*	*9-Jun*	~	*7-Jul*	*Trapped adult 24 Jun (never returned), incubated sporadically until 7 Jul*
KODKIMU1510	25-Jun	27-May	**26-Jun**	29-Jun	Chick depredated by red fox on 29 Jun at 8:05
KODKIMU1511	30-Jun	25-Jun	~	3-Jul	Egg depredated by red fox on 3 Jul at 2:50
KODKIMU1512	7-Jul	2-Jul	~	3-Aug	Egg abandoned on 3 Jul after sporadic incubation by adults
KODKIMU1513	8-Jul	6-Jul	~	17-Jul	Egg abandoned 17 Jul nine days post discovery
KODKIMU1514	8-Jul	13-Jun	~	15-Jul	Egg abandoned 15 Jul after sporadic incubation by adults
KODKIMU1515	11-Jul	25-Jun	**25-Jul**	28-Jul	Chick death and abandonment on 28 Jul, three meal deliveries in three days
KODKIMU1516	17-Jul	14-Jul	~	17-Jul	Egg abandoned, adult returned once 20 Jul, red fox scavenged egg on 30 Jul

*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 back calculated from hatch documented by camera images, when possible. Bold dates under hatch indicated that hatch was observed from camera images. Italicized nest was one of the three trapped during incubation.

APPENDIX D. Details of Kittlitz's murrelet chick deaths, Kodiak Island, AK, 2012-2015. Italicized nest indicates the nest was trapped during incubation.

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	Notes
KODKIMU1201	4-Jul-12	4-Jul-12	4	50	3.67	4	Chick died 4 days post-hatch, no apparent cause
KODKIMU1206	~ 29-June-12	11-Jul-12	~ 5	45	~	~	*Chick died on nest ~5 days post-hatch
KODKIMU1208	28-Jun-12	30-Jun-12	4	~ 45	2.33	4	Chick died 4 days post-hatch, no apparent cause
KODKIMU1317	22-Aug-13	NA	14	NA	2.07	2	Chick died 14 days post-hatch, no apparent cause
KODKIMU1404	27-Jun-14	NA	~ 5	NA	6	6	**Chick died ~5 days post-hatch, no apparent cause
KODKIMU1406	22-Jun-14	NA	2	NA	2	4	Chick died 2 days post-hatch, no apparent cause
KODKIMU1408	22-Jun-14	25-Jun-14	1	31	2	3	Chick died 1 day post-hatch, no apparent cause
KODKIMU1410	22-Jun-14	25-Jun-14	5	65.5	3	4	Chick died 5 days post-hatch, no apparent cause
KODKIMU1414	23-Jun-14	NA	< 1	NA	0	0	Chick died hours post-hatch, no apparent cause
KODKIMU1502	*2-Jul-15*	*3-Jul-15*	*2*	*22*	*1*	*2*	*Chick died ~2 days post-hatch*
KODKIMU1515	28-Jul-15	4-Aug-15	3	NA	1	0	Chick died ~2 days post-hatch, no apparent cause

*Camera failure after initial setup.

**Camera failure missed hatch and first few days of feeding.

APPENDIX E. Potential Kittlitz's murrelet predator species observed within 1 km of study area, Kodiak Island, AK. Field stay: 1 Jun-3 Aug 2012 (64 days), 4 Jun-4 Aug 2013 (62 days), 24 May to 8 Aug 2014 (77 days), 23 May to 10 Aug 2015 (80 days). Observation days (24 hour period when one group of people at a study site recorded predators seen): 61 in 2012, 65 in 2013, 81 in 2014, and 96 in 2015.

Species		Date first observed	Date last observed	Total Observation Days Seen	Percent of Observation Days Seen	Observation rate (number of locations seen)
Common name	Scientific name	**2012**				
Bald eagle	*Haliaeetus leucocephalus*	2-Jun	31-Jul	38	62.3%	61
Black-billed magpie	*Pica hudsonia*	2-Jun	31-Jul	34	55.7%	51
Common raven	*Corvus corax*	5-Jun	28-Jul	12	19.7%	14
Red Fox	*Vulpes vulpes*	7-Jun	24-Jul	8	13.1%	8
		2013				
Eagle spp. (Bald & Golden)	*H. leucocephalus, A. chrysaetos*	6-Jun	2-Aug	38	58.5%	68
Peregrine Falcon	*Falco peregrinus*	27-Jun	1-Aug	2	3.1%	2
Brown Bear	*Ursus arctos*	8-Jul	8-Jul	1	1.5%	1
Black-billed magpie	*Pica hudsonia*	6-Jun	28-Jul	43	66.2%	73
Common raven	*Corvus corax*	7-Jun	26-Jul	7	10.8%	8
Red Fox	*Vulpes vulpes*	19-Jun	4-Jul	4	6.2%	4
		2014				
Eagle spp. (Bald & Golden)	*H. leucocephalus, A. chrysaetos*	26-May	6-Aug	47	58.0%	97
Peregrine Falcon	*Falco peregrinus*	28-May	1-Jul	3	3.7%	2
Brown Bear	*Ursus arctos*	16-Jun	3-Aug	4	4.9%	4
Black-billed magpie	*Pica hudsonia*	26-May	3-Aug	43	53.1%	102
Common raven	*Corvus corax*	30-May	3-Aug	7	8.6%	8
Red Fox	*Vulpes vulpes*	28-May	7-Aug	19	23.5%	22
		2015				
Eagle spp. (Bald & Golden)	*H. leucocephalus, A. chrysaetos*	25-May	10-Aug	72	75.0%	123
Peregrine Falcon	*Falco peregrinus*	30-Jun	4-Aug	4	4.2%	4
Brown Bear	*Ursus arctos*	12-Jun	1-Jul	5	5.2%	5
Black-billed magpie	*Pica hudsonia*	24-May	8-Aug	60	62.5%	93
Common raven	*Corvus corax*	5-Jun	1-Aug	13	13.5%	15
Red Fox	*Vulpes vulpes*	25-May	13-Jul	20	20.8%	22

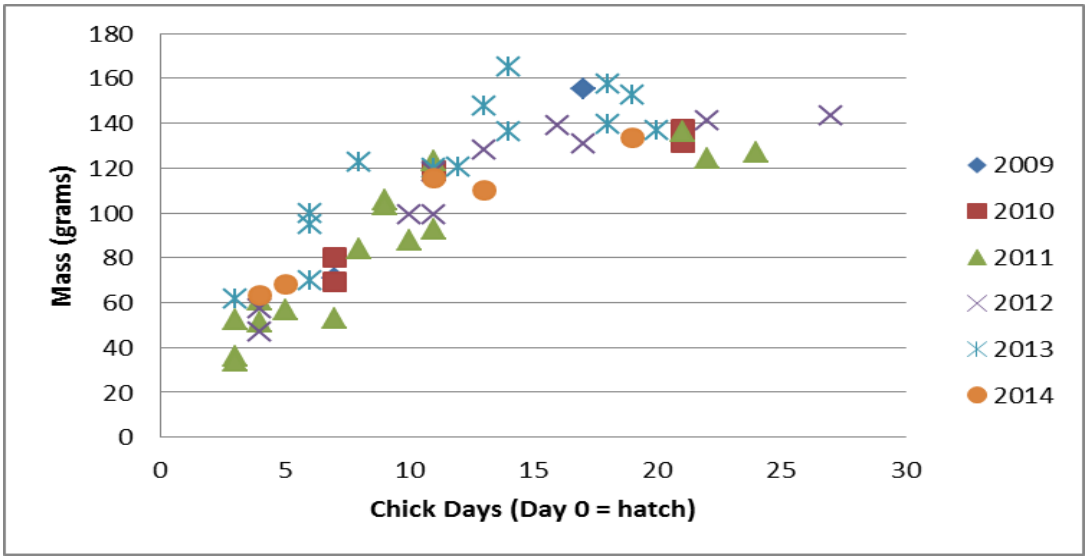
APPENDIX F. Characteristics of Kittlitz's murrelet nests on Kodiak Island, AK from 2008 to 2015.

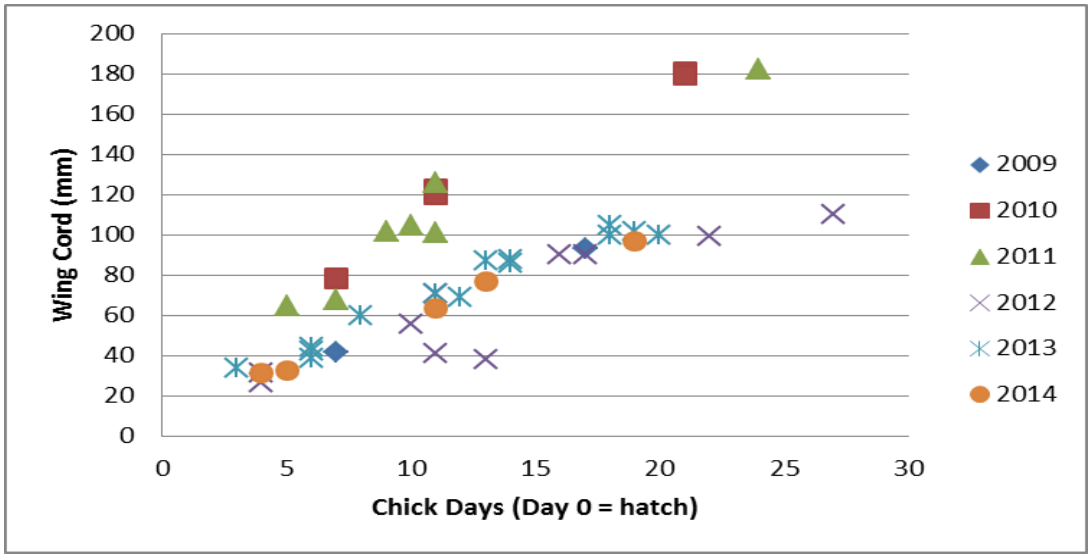
Mean	Elevation (m)	Distance to Ocean(km)	Slope (deg)	5m %Veg	25m %Veg	50m %Veg
2008	394	8.81	30	9	8	9
2009	344	5.78	30	7	8	9
2010	297	6.36	28	7	6	7
2011	304	5.56	29	6	12	16
2012	298	6.20	29	4	4	5
2013	314	6.01	35	10	11	12
2014	325	6.44	37	5	8	9
2015	330	5.91	35	4	5	5
Minimum						
2008	361	5.44	22	2	1	4
2009	247	3.51	20	1	0	0
2010	198	3.96	21	1	1	1
2011	181	3.80	20	1	1	1
2012	219	3.87	20	0	1	1
2013	185	3.50	25	2	2	2
2014	162	4.24	23	0	0	1
2015	242	3.61	20	1	1	1
Maximum						
2008	426	10.18	34	20	15	18
2009	441	9.83	37	32	22	23
2010	443	10.14	36	33	30	30
2011	428	9.66	34	15	45	70
2012	428	10.20	35	30	30	25
2013	447	10.18	44	32	35	38
2014	448	10.18	49	20	30	38
2015	455	10.11	47	12	11	14
2008-2015						
Mean	318	6.17	32	6	8	9
Min	162	3.50	20	0	0	0
Max	455	10.20	49	33	45	70

APPENDIX G. Categorized nest fates of active Kittlitz's murrelet nests found on Kodiak Island between 2008 and 2015.

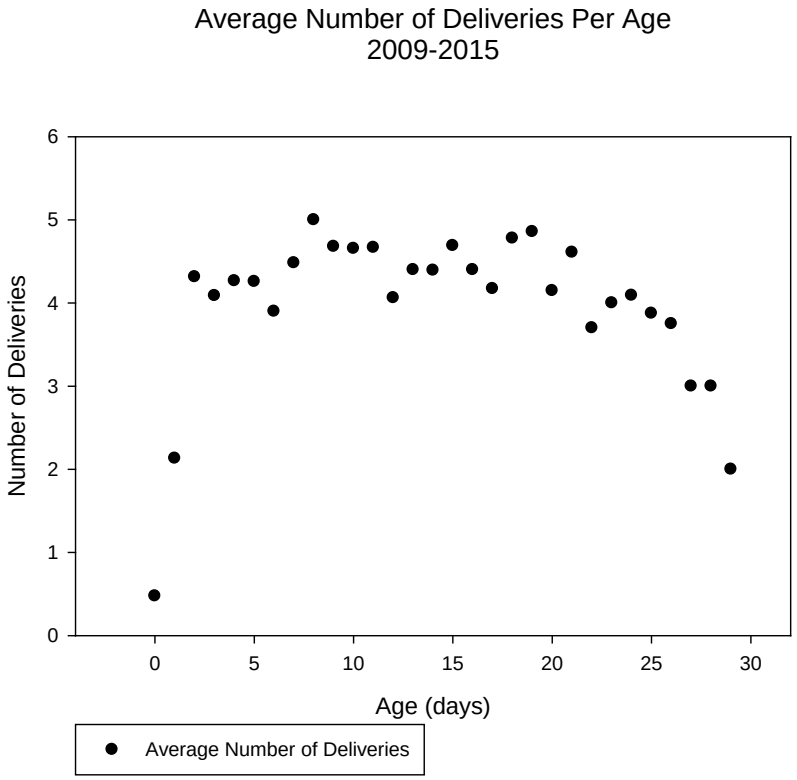
Nest Fate	2008	2009	2010	2011	2012	2013	2014	2015	Total	% Total
Egg abandoned	2	2	2	1	4	1	2	4	18	14
Failed during incubation, red fox depredation	0	2	0	5	2	1	5	4	19	15
Failed during incubation black-billed magpie depredation	0	0	0	0	0	0	2	0	2	2
Failed during incubation, depredation by unknown predator	2	3	3	2	1	3	4	2	20	16
Failed during nestling stage, red fox depredation	0	1	1	1	1	2	1	2	9	7
Failed during nestling stage, unknown predator	0	2	3	1	0	0	0	0	6	5
Failed during nestling stage, dead chick found on nest scrape	0	1	2	8	3	1	5	1	21	16
Trapped during incubation (nest failure)	~	~	~	~	~	~	~	3	3	2
Unknown	0	0	0	0	1	0	0	0	1	1
Fledged young	0	1	4	4	9	8	4	0	30	23
Total	4	12	15	22	21	16	23	16	129	

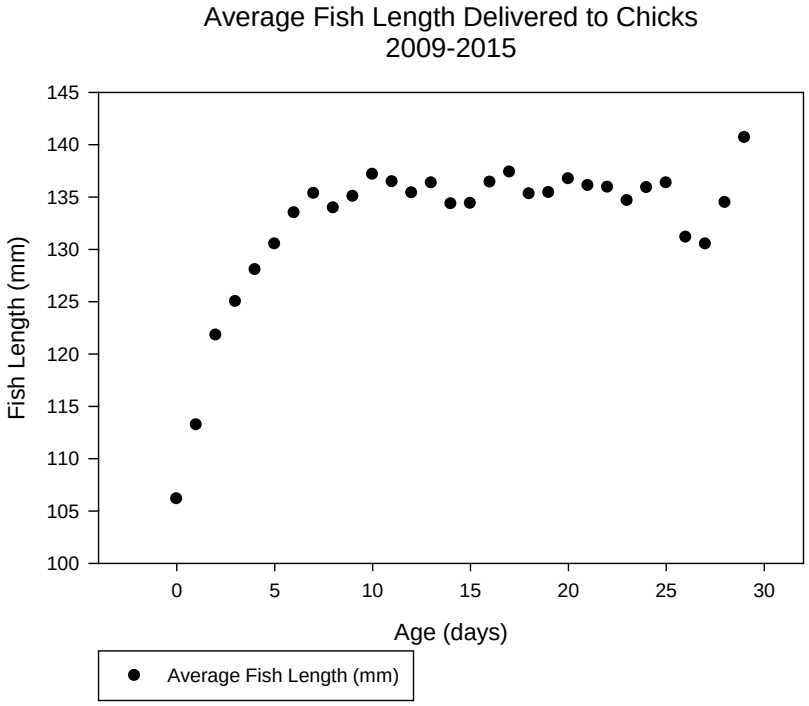
APPENDIX H. Chick days plotted against mass (grams) in the top figure. Chick days plotted with wing chord (mm) in the bottom figure.





APPENDIX I. Average number of deliveries and average fish length delivered a day at each age of chick development from 2009-2015. Fish lengths were estimated using photos from nest cameras. Each fish delivered was recorded as a ratio to adult head length. A head length of 57.3 mm was multiplied by each ratio to obtain an estimated length.





APPENDIX J. Kittlitz's murrelet adults trapped at the nest during incubation on Kodiak Island, AK.

Nest ID	Date Captured	Time of Capture	Estimated Incubation Stage (days)	Capture Method	Return to Incubation	Satellite Transmitter Attached	Sex	Weight (g)	Wing Chord (mm)	Egg Hatched	Nest Failure
KODKIMU1501	22-Jun-15	14:36	25	Mist-net	No	Yes	Male	224	134	No	Yes
KODKIMU1502	23-Jun-15	12:15	25	Mist-net	No	Yes	Female	220	134	Yes	Yes
KODKIMU1509	24-Jun-15	13:45	15	Mist-net	No	Yes	Female	207	129	No	Yes