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Breeding Ecology and Behavior of Kittlitz's Murrelet in Kodiak National Wildlife Refuge, Alaska: 2013 Progress Report

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

USFWS, Kodiak Refuge

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TABLE OF CONTENTS Page

Abstract 1

Introduction 2

Study Area 3

Methods 3

Systematic Nest Searching 3

Procedures at the Nest 4

Nest Cameras and Estimation of Fish Length 5

Nest Site Characteristics 5

Predators Observations 6

Summary of Changes in Methods between 2008-11 and 2012-13 7

Results and Discussion 7

Nest Searching and Monitoring 7

Nest Success 8

Nest Site Characteristics 10

Meal Delivery and Chick Growth 11

Conclusion 13

Acknowledgements 13

Literature Cited 13

LIST OF TABLES Page

Table 1. Summary of Kittlitz's murrelet return times Kodiak Island, Alaska during the 2009 to 2013 nesting seasons. **8**
Table 2. Summary of Kittlitz's murrelet nest fates on Kodiak Island, Alaska during the 2013 nesting season. **9**
Table 3. Fate of Kittlitz's murrelet nests found on Kodiak Island, Alaska during 2008-2013. ..... **10**
Table 4. Frequency of chick meals (single fish) delivered to Kittlitz's murrelet chicks on Kodiak Island, Alaska in 2013. ..... **11**

LIST OF FIGURES Page

Figure 1. Map of study area on the west side of Kodiak Island. **3**
Figure 2. Reconyx image of Kittlitz's murrelet adult delivering Pacific sand lance to a chick in a nest on Kodiak Island, Alaska, during the 2013 field season. **12**
Figure 3. Growth in body mass of Kittlitz's murrelet chicks for known-age chicks on Kodiak Island, Alaska, during the 2013 field season. **12**

LIST OF APPENDICES Page

APPENDIX A. Weather conditions, Kodiak Island, Alaska, 2008-2013. ..... **16**
APPENDIX B. Adult return time after initial flush, age at discovery, flush distance, and egg measurements for Kittlitz's murrelet nests, Kodiak Island, Alaska, 2013. ..... **17**
APPENDIX C. Chronology and fate of Kittlitz's murrelet nests in 2013, Kodiak Island, Alaska. **18**
APPENDIX D. Details of Kittlitz's murrelet chick deaths, Kodiak Island, Alaska, 2012 & 2013. ..... **19**
APPENDIX E. Potential Kittlitz's murrelet predator species observed within one km of study sites, Kodiak Island, Alaska, 4 June-3 Aug, 2013 ..... **20**
APPENDIX F. Characteristics of Kittlitz's murrelet nests on Kodiak Island, Alaska from 2008 to 2013. ..... **21**
APPENDIX G. Fate of Kittlitz's murrelet nests found on Kodiak Island, Alaska during 2008-2013. ..... **22**
APPENDIX H. Measurements obtained from known age Kittlitz's murrelet chicks during the 2012 and 2013 nesting seasons. **23**

Breeding Ecology and Behavior of Kittlitz's Murrelet in Kodiak National Wildlife Refuge, Alaska: 2013 Progress Report

Timothy W. Knudson[1], Robin M. Corcoran[2], James R. Lovvorn[1], John F. Piatt[3], and William H. Pyle[2]

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. Unlike most other seabirds that nest colonially, this cryptically colored Alcid lays a single egg in rocky mountainous terrain at a wide range of elevations. The 2013 field season marked the sixth consecutive year researching the breeding ecology and behavior of Kittlitz's murrelets in a remote region of southwest Kodiak Island, Alaska. The abundance of accessible nesting habitat in the form of ultramaphic rock was systematically searched to locate nests camouflaged on the scree and talus slopes. We placed digital game cameras at each nest to monitor fate, incubation shifts, chick feeding rates, predation, and any other events at the nest. To obtain growth measurements we visited nests at intervals throughout development. When nests were no longer active we measured habitat characteristics at and near nest sites. During our search effort in 2013 we discovered 17 Kittlitz's murrelet nests. Eleven of the 17 nests produced chicks and eight of those fledged. We recorded four depredations, one by an unknown predator and the other three by the only confirmed nest predator of the Kittlitz's murrelet on Kodiak, the red fox (*Vulpes vulpes*). Two pipped eggs were found abandoned at nest sites. At two nests camera images were not sufficient to determine nest fates. These nests were depredated or abandoned then depredated. One chick died at 14 days old due to unknown reasons and was too decomposed to collect. However, camera images indicated this death was consistent with mortality due to saxitoxin, a neurotoxin associated with paralytic shellfish poisoning that resulted in seven chick deaths in 2011-2012. Apparent nest success was 47% in 2013, the highest success observed during this study. In 2012, nest success was also high (43%) compared to the earlier years of the study 2008-2011, when only 17% of nests were successful. We obtained growth measurements from 10 individuals and feeding rates from 11, capturing more than 700 prey deliveries to chicks. A high percentage of the prey deliveries were Pacific sand lance (*Ammodytes hexapterus*) the main forage fish species recorded during the study.

[1]Department of Zoology and Center for Ecology, Southern Illinois University, 1125 Lincoln Drive, MC 6501, Carbondale, IL 62901

[2]Kodiak National Wildlife Refuge, 1390 Buskin River Road, Kodiak, Alaska 99615

[3]Alaska Science Center, US Geological Survey, 4210 University Drive, Anchorage, Alaska 99508

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 and its breeding ecology poorly understood (Day et al. 1999; 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). About 70% of the population nests in coastal Alaska and the rest in eastern Russia (Lawonn 2012).

KIMU became a species of conservation concern when at-sea surveys suggested drastic declines in the population. Concern for this species increased due to its small population, patchy distribution, and observed low reproductive success in the most important breeding areas (Day et al. 1999, Day and Barna 2007). The Department of the Interior recently concluded the population declined about 30% annually beginning in 1989, but stabilized about the year 2000 (Federal Register 2013). Factors such as vessel traffic, gill-net bycatch, and oil pollution may have contributed to the KIMU decline. However, since similar population declines are occurring among many species geographically separated by continents and oceans, local influences do not seem adequate to explain the 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).

The Kodiak National Wildlife Refuge (NWR) 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 what is known as the Kodiak Glacial Refugium (Day and Barna 2007). Research began in coordination with Alaska Maritime National Wildlife Refuge, USGS Alaska Science Center, and Region 7 USFWS Office of Ecological Services. The cooperative project had a five year plan to study KIMU breeding ecology on Kodiak and Agattu Islands. The research plan highlighted eight objectives: 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 in 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 put added emphasis on collecting un-hatched eggs and dead chicks for disease and contaminant analysis (Corcoran et al. 2014). Research on Kodiak was able to continue because the National Fish and Wildlife Foundation provided funding for the 2012-2014 field seasons.

This report summarizes the sixth year of nesting ecology research of KIMU on Kodiak NWR, Alaska. We summarize the results from our systematic nest searches, monitoring of KIMU nests, and measure of nesting habitat collected during the 2013 summer 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, separated from the mainland by the Shelikof Strait. Predator diversity on Kodiak is similar to that on mainland Alaska where it is suspected that most KIMU nest. Outcrop and scree slopes where KIMU nest make up 5% of the total area (46,800 ha) of Kodiak Island, and reach elevations up to 1,200 m (Corcoran et al. 2014). 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. These rocky areas are at elevations from 80 to 471 m, making them accessible to researchers, unlike many areas suspected to hold KIMU nests in more mountainous regions. 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).

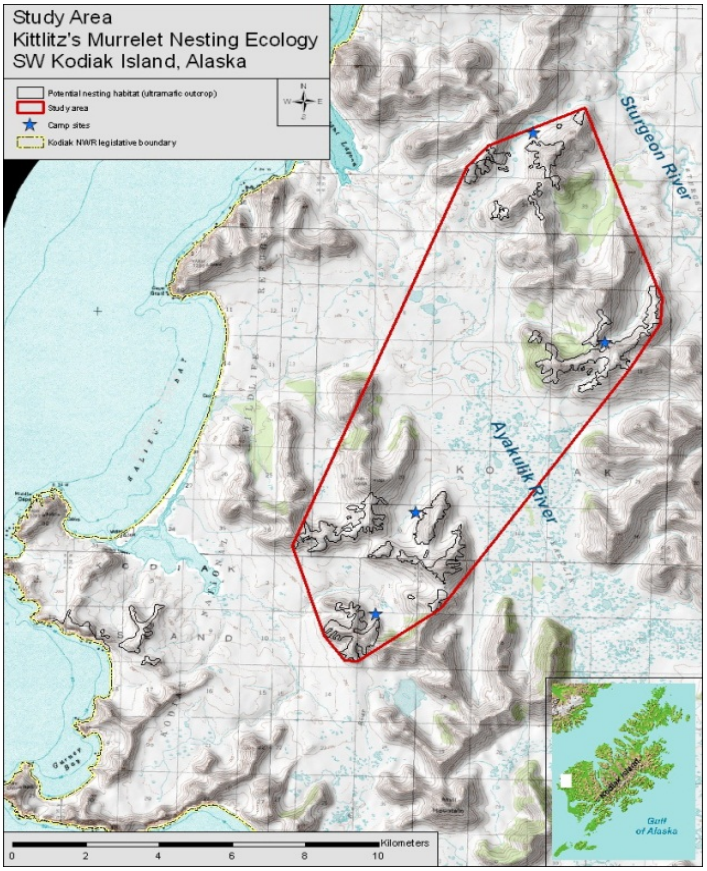

Figure 1. Map of study area on the west side of Kodiak Island, Alaska.

Within the study area (Figure 1), four base camps provided staging points for nest searching and monitoring. Each field camp was located close to a large area of ultramafic rock that was easily accessed with little travel time to the slopes. All camps were accessible by helicopter and one by float plane; otherwise the area was limited to foot travel. Throughout the field season the research team traveled between camp sites to conduct systematic nest searching and monitoring. All areas searched for KIMU nests were between five and 11 km from the ocean.

Methods

Systematic Nest Searching

The nesting habitat consisting of sparsely-vegetated or un-vegetated terrain closest to each camp 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 lesser densities), and finally on low priority sites (where habitat exists to support nesting, but has never been searched or no nests have been found). On the first round of nest searching six to eight work days were spent at each of the four camps covering as much

area as possible. The first search effort concluded on 12 July. Nest searching continued until 22 July when efforts where shifted to collecting nest site characteristics data.

At the start of each day the research team would hike 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 person walked at a constant elevation following the contour of the slope, 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 kept a vertical distance of 5–10 m between each searcher. 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 top of the mountain. A log of all transects was kept with two GPS units. Upon discovery of a nest, data on the nest were collected and the team moved to another face of the mountain or a different slope to encourage the incubating adult to return quickly. In most cases, flushing of an adult from the nest was the method of discovery. An adult would flush downslope, hugging the contour of the mountain. The research team identified the bird as a KIMU based on the outer white rectrices characteristic of this species. Once the bird was out of sight, the team would immediately focus all attention on finding the single egg camouflaged among the rocks.

Procedures at the Nest

Once a nest was discovered, each person put on latex 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 weather-resistant motion-triggered digital game camera (RECONYX™ PC90 RapidFire™ Professional Covert Color IR and RECONYX™ PC900 HyperFire™ Professional High Output Covert Infrared) painted to blend in with the surrounding rocks, and the third person handled the single egg. Each camera was mounted on a stake embedded in the rocks 1 to 1.2 m away from the nest, and aimed at the nest to record incubation shifts and feedings. 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. Stage of development was determined based on an assumed 30-day incubation period (Day et al. 1999) and egg floating benchmarks described by Rizzolo and Schmutz (2007). If the egg was pipped it was not touched.

Aside from recording measurements from the egg handler, the data keeper recorded a nest identification number (KOD for Kodiak, species code KIMU, last two digits of the year, and number of nest found, e.g. KODKIMU1301 for first nest discovered in 2013). Also recorded was the time a nest was discovered, time the nest was left, date, observers, any predators observed, UTM coordinates, confirmation of species, elevation, and the direction the adult flushed. To encourage the adult to return quickly we attempted to keep time at the nest to less than 10 min and moved to a different face of the ridge/peak or to a different ridge post discovery.

Using estimates of hatch date gathered during nest discovery 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 the camera status, looked for prey remains, recorded the weather, and collected morphological measurements of the chick. If a chick was

present it was taken >30m from the nest site to be processed. Morphological measurements taken included: head length, culmen, 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. Other observations recorded include percent coverage of down on the chick, 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 a good representation through development. The second observation period was switched in 2012 from 9–13 days to 14–16 days to obtain growth information for the later period (Corcoran et al. 2014).

Nest Cameras and Estimation of Fish Length

In 2009 and 2010, Lawonn et al. (2012) investigated the effects of cameras on nest predation by 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 has been placed at every nest, and in recent years there has been a substantial increase in nest success (17% to 46%). Before field work begins, each camera is painted to blend in with the surrounding environment, fitted with a visor to reduce glare and rain on the lens, and tested for operation. A variety of memory cards are used including 4, 8, and 16 GB. Nest cameras are set to trigger on motion and at an interval of 3-min to provide images from discovery to fledging. When the motion sensor is triggered the camera snaps three photographs at 1-s intervals. A 3-min interval was adequate to film >99% of visits from parents to the nest. During the 2011 nesting season, three cameras at different nests were set to 1-min intervals. Out of 199 meal deliveries recorded, only one visit was shorter than the 3-min interval (Lawonn et al. 2012).

Camera images from nest discovery until 24 hours after fledging or depredation were reviewed at the end of the field season by trained technicians. Incubation shifts, hatching, adult brooding, meal delivery, depredation, fledging, nest fate, or 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 recorded as a ratio to the number of adult head lengths. For future analysis, estimates of fish length will be made by comparison with the length of the KIMU chick's culmen (Elliott and Gaston 2008) and head measured during nest visits, and the average wing chord (125–140 mm; Day et al. 1999) and exposed culmen (10-13 mm; Day et al. 1999) of adults. 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 after fledging or nest failure, 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.

Nest Site Characteristics

As nest searching came to an end, attention was focused on measuring physical characteristics of each nest site found throughout the season, along with randomly selected sites nearby for comparison. 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 areal 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) (Lawonn et al. 2012).

KIMU lay their single egg in a shallow depression scraped in the rocky substrate, often having a 'nest rock' above the scrape that offers some shelter from the elements and helps 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. The depth and diameter of the nest bowl were measured with a steel ruler to the nearest millimeter. In the 25 and 50 m plots, the percentage of the area that was vegetated, unvegetated, covered with water, and covered with snow was estimated.

Two plots near the nest site were randomly selected in the field. First, a bearing was randomly selected between 1º and 360º by spinning the dial of a compass for about 5 seconds without looking and then stopping. A distance of 50-150 m was used as the center of the random point. This distance was selected using the hundredths of a second indicator on a stop watch. The stop watch was ran for at least the count of three and then stopped. The number seen on the screen was between 1 and 100, and 50 was added to the number displayed to get the distance in meters. With the bearing and distance the team traveled to the destination using the field GPS units. Once the GPS reading was 0-1 m from the location, a pin flag was placed to represent the center of the plot. 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.

Fecal samples were collected during each nest visit from the fecal ring located at the back of the nest. Once back at camp samples were buried to keep cool. Upon returning to town these samples were transferred to a freezer at the USFWS refuge office.

Egg shell fragments and feathers were collected opportunistically, stored in envelopes, and archived for future research. Prey fish left around the nest site were collected when present. These specimens were buried at camp, frozen at the first opportunity in a propane freezer kept at the main field camp (Duncan Lake), and placed in a freezer at the KNWR field office upon return to town.

Predators Observations

Predation has had a large impact on nest success of the Kittlitz's murrelet throughout the study. 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 used for nesting by Kittlitz's murrelet (Lawonn et al. 2012). Using protocol described by Sargaent et al. (1993) the number of predators observed during the field season was recorded. The number of places a species of predator was seen each day was recorded. All observations were within 1 km of ultramaphic rock nesting habitat at the four sites.

Summary of Changes in Methods between 2008-11 and 2012-13

1) Audio-visual surveys were not conducted after 2011
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 2012-13, 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 2012-13 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 three-person research team was flown into Duncan Lake on 4 Jun and spent the summer hiking between base camps to conduct nest searching and monitoring. The first round of searching began on 6 Jun and concluded on 11 Jul, focusing on systematically searching potential ultramaphic rock nesting habitat with slopes greater than 20°. The second round of searching started on 12 Jul and concluded on the 22 Jul. During this second round, the team focused the search effort on steeper slopes and larger patches of ultramaphic rock.

Search efforts yielded 17 KIMU nests, 13 of which were found after flushing an incubating adult from the nest. The average distance at which adult KIMU flushed from the nest in response to searchers was 3 m in 2013. A live chick in a nest was discovered without an adult flushing on three occasions. During these instances the chick was taken >30 m away from the nest for processing. While a chick was being processed a camera was placed at the nest site. There was also one abandoned/inviable egg found during nest searching. This dehydrated, sun-bleached pipped egg was measured, weighed, collected, buried at camp to keep cool, and frozen in the single basecamp propane freezer (Duncan) at the first opportunity.

Instances of birds reusing the same nest bowls from a previous nesting attempt were not observed. However, nests where found in close proximity to old nest sites. The two closest active nests were approximately 100 meters apart.

Similar to previous years there was a wide range of return times for adults after the initial discovery (12-540 min, Table 1). The mean return time for 2013 was, 200.7 min, between the means for 2009-2010 and 2011-2012. On two occasions researchers spotted a returning murrelet

fly by the nesting area while leaving the nest indicating KIMU will return to the nest within 10 minutes of initial flush. KODKIMU1317 was discovered opportunistically during a nest check when no camera was on hand. We returned to the nest 10 days later to put a camera in place before the nest hatched. We flushed the incubating adult who returned three hours later, less than the average return time for the collective five years (2009-2013) of data.

Table 1. Summary of Kittlitz's murrelet return times after initial flush of incubating adult on Kodiak Island, Alaska during the 2009 to 2013 nesting seasons.

Year	Mean Return Time	Min Return Time	Max Return Time
2009	174	15	455
2010	156	17	583
2011	369.6	14	1329
2012	487*	17	776*
2013	200.7	12	540
Mean	277.5	15	736.6

*The outlier of 2135 min was removed from the 2012 analysis.

Based solely on hatch dates documented by camera images the average initiation date was 30 May (range 26 May to 9 Jul). If estimated initiation dates based on egg floating benchmarks are included, the average initiation date was 5 Jun. Mean initiation dates where among the earliest on record. There was one outlier, KODKIMU1317, which initiated on 9 Jul that is likely a re-nesting attempt. In 2011, re-nesting was observed. Tendency to re-nest following initial nest failure has been frequently reported for the congeneric marbled murrelet (Nelson et al. 2010). See Appendix B for nest specific details on return times, flush distances, age at discovery, and egg measurements.

Nest Success

Apparent nest success was the highest ever recorded during this study on Kodiak Island (8 of 17, 47%). Fledging was documented for all eight successful nests from nest camera images. The red fox (*Vulpes vulpes*) had a lower impact on nest success this year than previously recorded on Kodiak. There were three confirmed red fox depredations; one in egg stage and two at chick stage. Two eggs that started pipping never hatched, and one chick died on the nest at 14 days post hatch.

The remaining three nest fates had to be inferred from a combination of physical evidence at the nest and information gathered from the available nest images. Upon the first nest visit to KODKIMU1303, when the chick was scheduled to be about four days old we found an empty nest and a camera that had failed shortly after initial setup. Within the nest bowl there was evidence that the egg may have hatched including egg shell fragments and a trace amount of fecal material. The nest was most likely depredated shortly after hatch. The second nest lacking definitive camera data was KODKIMU1307, where adults seemed to abandon the egg several days after initial discovery. During the first nest check there was a hollowed-out depredated egg hollowed in the nest bowl, but camera images did not reveal any predation, so the predator did not set off the motion sensor and the egg was consumed in under three minutes. The final inferred nest fate at KODKIMU1309, was very similar to KODKIMU1307. The adults seemed to abandon the egg after returning to the nest on two separate occasions. At the first nest visit the bowl was empty with no signs of hatch. Camera images did not reveal what took the egg. In

summary, we concluded that nest KODKIMU1303 was depredated at an unknown stage, but fates at KODKIMU1307 and 1309 were harder to determine because we cannot know if these nest were abandoned and then depredated or abandoned because of depredation.

There was one dead chick found at the nest site (KODKIMU1317) during camera collection at the end of the season. The nest was the latest of the season and hatched the day researchers left the field (4 Aug); therefore, no growth measurements were obtained. Due to logistical reasons we could not get back to collect the camera until 5 Sept when the chick was found decomposed in the nest. Camera footage revealed the chick ingesting a Pacific sand lance (*Ammodytes hexapterus*) at 7:52am on 22 Aug. The chicks last movements were captured at 9:33am after which it was presumed dead. This series of events is similar to those in previous years of monitoring where chick deaths were attributed to saxitoxin, a neurotoxin produced by marine dinoflagellates.

Two unhatched pipped eggs (KODKIMU1310 & KODKIMU1316) were collected. On the first scheduled nest visit for KODKIMU1310 the pipped egg was found 4 m below the nest bowl, at the same stage as the day it was discovered. Researchers do not recall any sounds coming from the egg upon discovery indicating the pipping egg may have failed before discovery. At KODKIMU1316 a pipped egg in a nest bowl was spotted during searching but no adult was ever seeen. The egg was desiccated and bleached white from the sun on one side while retaining the green color with dark spots typical of KIMU eggs on the underside, indicating it had been in this location for some time. Both eggs were collected in Ziploc bags, buried at base camp, and hiked to the propane freezer at Duncan Lake campsite. See Table 2 for a summary of nest fates in 2013; Appendices C and D include nest specific details on chronology and fate.

Table 2. Summary of Kittlitz's murrelet nest fates on Kodiak Island, Alaska during the 2013 nesting season.

Nest Fate	Number of nests
Egg abandoned	2
Failed during incubation, red fox depredation	1
Failed during incubation, depredation by unknown predator	1
Failed during nestling stage, red fox depredation	2
Failed during nestling stage, dead chick found on nest scrape	1
Unknown	2
Fledged young	8
Total	17

Apparent nest success in 2012-2013, 45% and 47% respectively, was significantly higher than the 17% success from 2008-2011. In 2012-2013, nest predation was lower than all previous years of the study, and in 2013 far fewer chicks died on the nest for unknown reasons. In 2011-2012, 11 chicks died on the nest, and in most cases cameras revealed the chicks were being fed regularly and weather conditions were relatively mild ruling out exposure. Eight of those chicks were necropsied and later tested for saxitoxin, one of the toxins responsible for paralytic shellfish poisoning. All three of 2012 chicks had high concentrations of saxitoxin in their system while four of the five chicks examined from 2011 tested positive for saxitoxin but at lower levels than the chicks from 2012 (Shearn-Bochsler et al. 2014). We could not determine if saxitoxin was the cause of death at KODKIMU1317 because the chick was fully decomposed by the final nest visit. However, circumstances were very similar to the deaths in 2011-2012, with an apparently

healthy chick on the nest dying less than two hours after being fed a sand lance. Nest failure due to predation declined in the past two years of the study from 45% from 2008-2011 to 21% in 2012-2013, and this corresponds with an increase in nest success from17% to 45% over the same time periods. There are a number of hypothesis for the decrease in predation, one being that there are fewer fox in the nesting habitat because of the abundance of other prey items such as ptarmigan and tundra voles at lower elevations. The percentage of field days a red fox was seen in 2013 (7%) was less than half of that of 2012 (15%) (Appendix E).

The compiled nest fate data for the six year study are presented in Table 3 (also see Appendix G). There have been 19 camera documented depredation events, and 16 of those have been attributed to the red fox. No other predators have been documented depredating KIMU nests on Kodiak Island, yet there are several potential predators that are frequently observed including: Common Raven (*Corvus corax*), Bald Eagle (*Haliaeetus leucocephalus*), and Black-billed Magpie (*Pica hudsonia*).

Table 3. Fate of Kittlitz's murrelet nests found on Kodiak Island, Alaska during 2008-2013.

Nest Fate	2008	2009	2010	2011	2012	2013	2008-2013
Depredated/nest empty	2	8	6	9	4	4	33
Dead chick found in nest	0	1	2	8	3	1	15
Abandoned/Unviable egg	1	2	3	1	4	2	13
Unknown	1	0	0	0	1	2	4
Fledge	0	1	4	4	9	8	26
Total	4	12	15	22	21	17	91

Nest Site Characteristics

Characteristics of the KIMU nests located during the 2013 season were consistent with those collected during the previous five years of research. All nests where located in ultramaphic rock habitat with less than 35% vegetation coverage within a 5 m radius. Most nests consisted of a shallow nest bowl made in loose rock 1-5 cm in diameter below a large nest rock. This season, the range of elevations over which nests were found was the greatest recorded at this study site. The lowest nest was found at 185 m while the highest was discovered at 447 m. The range and average distance of nest sites from the ocean was similar among all years (see Appendix F). Nest aspects in 2013 showed a slightly more south facing trend than previous years. By examining the coverage plot estimations it can be seen that the range of vegetation coverage is consistent between years (see Appendix F). Search effort is not random so averages could be biased based on effort.

Random vegetation plots were not sampled in 2013 due to logistics. Effort was focused on obtaining growth measurements, nest and near nest characteristics, and nest searches. To date there are over 449 analyzed random plots visited within the searched area from the 2009 to 2012 field seasons. Previous analysis of nest sites on Kodiak 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 habitat covariates and nest survival rate (Lawonn 2012). The data from random plots collected from 2009–2012 should represent the study area in a slowly changing environment.

Meal Delivery and Chick Growth

We monitored 11 chicks documenting 695 meal deliveries. There was a wide range of meal deliveries per day (0-9), with an average of 3.7 meals/day. As in previous years, Pacific sand lance was the most abundant fish species delivered to chicks, making up over 80% of chick meals. Capelin (*Mallotus villosus*) and Pacific herring (*Clupea pallasii*) were also observed being fed to chicks (Figure 2). Images need to be further proofed to assure accuracy of fish species identification.

KIMU chick growth measurements were collected on up to three separate occasions throughout development adding to existing growth data for known age murrelet chicks on Kodiak. Of the 17 nests found 11 nests reached chick stage. Nest visits, between hatch and fledge or failure, from 10 different individuals yielded 25 occurrences where a chick was present to obtain growth measurements. Three full sets of growth measurements were collected from four chicks with known ages that successfully fledged. For one other known age chick, KODKIMU1308, two nest visits occurred to collect growth measurements before the chick was depredated 17 days post-hatch. Another 11 nest visits yielded growth measurements for five different nests with only estimated ages available. Hatch dates are unavailable for these five nests due to three of the nests having a chick present at first discovery and camera failure after initial setup at two nests. There was a wide range of lengths of the pre-fledge period (Table 4). For two known age chicks fledging occurred 20 days post hatch while another took over 30 days. Growth rate, feeding rate, and the length of the pre-fledge period (hatch to fledge) can be analyzed to determine interactions between the three sets of data and nest success (Figure 3; Appendix H). For example, variation in prey deliveries may impact growth rates therefore extending or shortening the pre-fledgling period in turn changing exposure to predation.

Table 4. Frequency of chick meals (single fish) delivered to Kittlitz's murrelet chicks on Kodiak Island, Alaska in 2013 (n=695 fish delivered to active nests, n=17 fish delivered after the nest had fledged or failed).

Nest ID	Mean meals/day	Range of meals/day	Total fish delivered	Total days monitored post-hatching	Nest fate
KODKIMU1301	4.8	1 - 9	120	24	Fledged 24 days post-hatch
KODKIMU1302	4.3	2 - 7	47	10	Fledged at unknown age ~18 days*
KODKIMU1304	4.5	2 - 8	94	20	Fledged 20 days post-hatch
KODKIMU1305	4.4	1 - 6	93	20	Fledged 20 days post-hatch
KODKIMU1306	2.2	1 - 6	42	20	Fledged >30days post-hatch**
KODKIMU1308	4.8	2 - 9	86	17	Chick depredated 17 days post-hatch
KODKIMU1311	~	~	0	2	Chick Depredated at unknown age
KODKIMU1313	3.9	0 - 9	81	21	Fledged 21 days post-hatch
KODKIMU1314	3.75	1 - 9	46	12	Fledged >12 days post-hatch
KODKIMU1315	2.7	0 - 9	57	21	Fledged >21 days post-hatch
KODKIMU1317	2	0 - 4	29	14	Chick died 14 days post-hatch

* Camera malfunction missing images
** Camera failure missing 11 days

Figure 2. Reconyx image of Kittlitz's murrelet adult delivering Pacific sand lance to a chick in a nest on Kodiak Island, Alaska, during the 2013 field season.

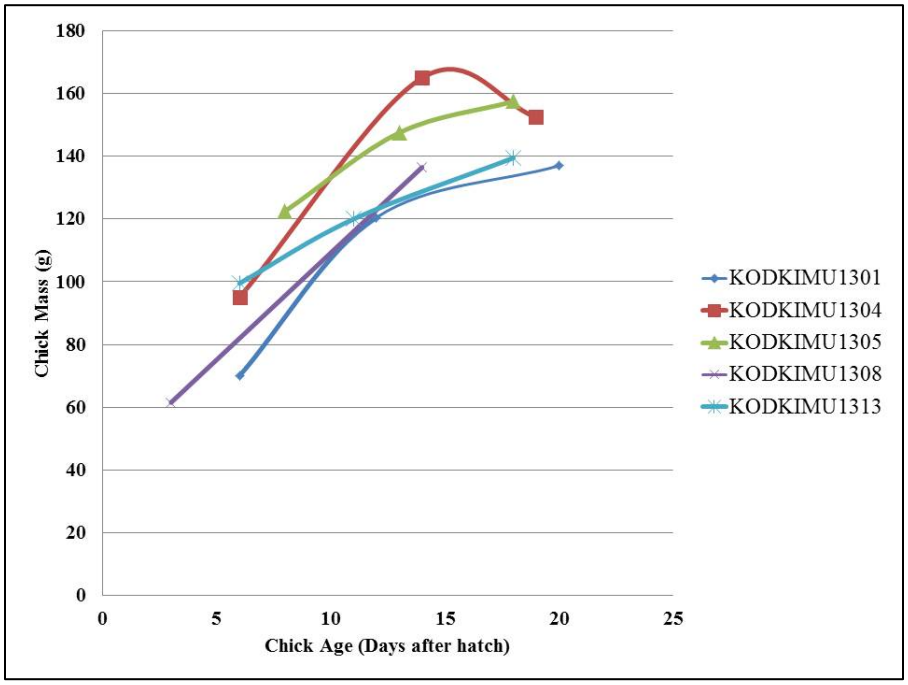

Figure 3. Growth in body mass of Kittlitz's murrelet chicks for known-age chicks on Kodiak Island, Alaska, during the 2013 field season.

Conclusion

The 2013 field season on Kodiak Island researching the nesting ecology of KIMU brought the highest nest success observed during the six year study. The high nest success in 2013 can be attributed in part to lower nest predation and fewer dead chicks found at nest sites then in previous seasons. Data from this research project will continue to be analyzed in cooperation with Southern Illinois University (SIU), U.S. Geological Survey, and co-operators investigating KIMU chick death attributed to saxitoxin. SIU's 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 owing to 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 in some marine bird and mammal populations (DeMaster and Atkinson 2002, Fritz and Hinckley 2005, Österblom et al. 2008). Factors investigated in this research might be primary contributors to declines seen across a wide geographic range not only for KIMU but also for other marine predators such as the black-legged kittiwake and Steller sea lion. The research and monitoring on Kodiak Island is important not only because of the insights it provides into the KIMU population, but as Gill (2007) and Zador et al. (2013) expressed, seabird populations can be indicators of shifts in marine environments, and can provide insights into effects of climate warming and overfishing.

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Literature Cited

Alexander, E. B., R. G. Coleman, T. Keeler-Wolfe, and S. P. Harrison. 2006. Serpentine geoecology of western North America: Geology, soils, and vegetation. Oxford University Press, USA.

Corcoran, R.M., H.L. Mackey, J.F. Piatt, and W.H. Pyle. 2014. Breeding ecology and behavior of Kittlitz's murrelet in Kodiak National Wildlife Refuge, Alaska: 2012 Progress Report. Refuge report no 2014.1, Kodiak National Wildlife Refuge, U.S. Fish and Wildlife Service, Kodiak, AK.

Day, R. H., and J. B. Barna. 2007. Movements and behavior of Kittlitz's murrelets on Kodiak Island, Alaska: A Pilot Study. Unpublished report for US Fish and Wildlife Service, Kodiak National Wildlife Refuge, ABR Inc., Fairbanks, Alaska.

Day, R. H., D. J. Kuletz, and D. A. Nigro. 1999. Kittlitz's murrelet (*Brachyramphus brevirostris*). *in* A. Poole and F. Gill, editors. The Birds of North America. The Birds of North America, Inc., Philadelphia, Pennsylvania.

DeMaster, D. and S. Atkinson. 2002. Steller sea lion decline: is it food II. University of Alaska Sea Grant, AK-SG-02-02, Fairbanks.

Elliott, K.H. and A.J. Gaston. 2008. Mass–length relationships and energy content of fishes and invertebrates delivered to nestling thick-billed murres *Uria lomvia* in the Canadian Arctic, 1981–2007. Marine Ornithology 36:25-34.

Federal Register. 2013. 12-Month finding on a petition to list Kittlitz's murrelet as an endangered or threatened species. United States Department of Interior Fish and Wildlife Service Federal Register 78(192):1-39.

Fritz, L.W. and A. Hinckley. (2005). A critical review of the regime shift – "Junk Food" – nutritional stress hypothesis for the decline of the western stock of Steller sea lion. Marine Mammal Science 21:476-518.

Gill, F.B. 2007. Ornithology. W.H. Freeman and Company, 3rd edition.

Kaler, R. S. A., L. A. Kenney, and B. K. Sandercock. 2009. Breeding ecology of Kittlitz's murrelets at Agattu Island, Aleutian Islands, Alaska. Waterbirds 32:363–373.

Kaler, R. S. A., and L. A. Kenney. 2008. Breeding ecology of Kittlitz's murrelet at Agattu Island, Alaska, in 2008: progress report. United States Fish and Wildlife Service, Alaska Maritime National Wildlife Refuge. U.S. Fish and Wildl. Serv. Rep. AMNWR 08/17.

Kuletz, K. J., S. W. Stephensen, D. B. Irons, E. A. Labunski, and K. M. Brenneman. 2003. Changes in distribution and abundance of Kittlitz's Murrelets (Brachyramphus brevirostris) relative to glacial recession in Prince William Sound, Alaska. Marine Ornithology 31:133–140.

Lawonn, M.J. (2012). Breeding ecology and nest site selection of Kittlitz's murrelets on Kodiak Island, Alaska. M.S. Thesis, Oregon State University, Corvallis.

Lawonn, M. J., J. F. Piatt, R. M. Corcoran, W. H. Pyle, and D. D. Roby. 2012. Breeding ecology and behavior of Kittlitz's murrelet in Kodiak National Wildlife Refuge, Alaska: 2011 progress report. United States Fish and Wildlife Service, Kodiak National Wildlife Refuge.

Nelson, S. K., B. A. Barbaree, B. D. Dugger, and S. H. Newman. 2010. Marbled murrelet breeding ecology at Port Snettisham, southeast Alaska, in 2005-2008. Unpublished report, Oregon State University, Corvallis, OR and Wildlife Trust, New York, NY (prepared for Alaska Department of Fish and Game).

NOAA. 2014. National Climatic Data Center. Weather conditions for Kodiak Airport on Kodiak Island, Alaska.

Österblom, H., O. Olsson. T. Blenckner, and R. W. Furness. 2008. Junk-food in marine ecosystems. Oikos 117:967-977.

Piatt, J. F., and P. Anderson. 1996. Response of common murres to the Exxon Valdez oil spill and long-term changes in the Gulf of Alaska marine ecosystem. American Fisheries Society Symposium 18:720–737.

Rizzolo, D., and J. Schmutz. 2007. Egg flotation estimates nest age for Pacific and red-throated loons. Waterbirds 30:207–213.

Sargeant, A. B., R. J. Greenwood, M. A. Sovada, and T. L. Shaffer. 1993. Distribution and abundance of predators that affect duck production - Prairie Pothole Region. U.S. Fish and Wildlife Service, Resource Publication 194. Jamestown, ND: Northern Prairie Wildlife Research Center Online. http://www.npwrc.usgs.gov/resource/birds/predator/index.htmVersion 16JUL97.

Shearn-Bochsler, V., E.W. Lance, R. Corcoran, J. Piatt, B. Bodenstein, E. Frame, and J. Lawonn. 2014. Fatal paralytic shellfish poisoning in Kittlitz's murrelet (*Brachyramphus brevirostris*) nestlings, Alaska, USA. Journal of Wildlife Diseases 50:933-937.

van Vliet, G. B., and M. McAllister. 1994. Kittlitz's Murrelet: the species most impacted by direct mortality from the Exxon Valdez oil spill? Pacific Seabirds 21:5–6.

Western Regional Climate Center. 2012. Data from remote automated weather station, Booth Lake, AK. http://www.wrcc.dri.edu, accessed 23 July, 2012.

Zador, S., G.L. Hunt, T. TenBrink, and K. Aydin. 2013. Combined seabird indices show lagged relationships between environmental conditions and breeding activity. Marine Ecology Progress Series 485:245-258.

APPENDIX A. Weather conditions, Kodiak Island, Alaska, 2008-2013.

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

*2013 Data from Booth Lake is unavailable due to equipment malfunction; 2008-2011 data provided through Western Regional Climate Center (2012).

Year	Site	Dates	Mean Temp (˚C)	Max Temp (˚C)	Min Temp (˚C)	Total Rainfall (cm)	Average Daily Rainfall (cm)
2008	Kodiak Airport	1 Jun - 31 Aug	10.7	13.7	7.8	21.8	0.24
2009	Kodiak Airport	1 Jun - 31 Aug	11.6	15.0	8.2	14.2	0.16
2010	Kodiak Airport	1 Jun - 31 Aug	11.4	14.1	8.7	11.3	0.12
2011	Kodiak Airport	1 Jun - 31 Aug	11.7	14.5	8.9	10.7	0.12
2012	Kodiak Airport	1 Jun - 31 Aug	11.2	14.2	8.2	6.8	0.07
2013	Kodiak Airport	1 Jun - 31 Aug	13.3	16.7	10.0	12.3	0.13
Mean			11.7	14.7	8.6	12.8	0.14
Standard Deviation			0.899	1.072	0.782	5.008	0.055

*Date source: NOAA 2014

APPENDIX B. Adult return time after initial flush, age at discovery, flush distance, and egg measurements for Kittlitz's murrelet nests, Kodiak Island, Alaska, 2013.

Nest ID	Return Time (min)	Approximate Age at Discovery (days)	Flush Distance (m)	Egg mass (g)	Length (mm)	Width (mm)
KODKIMU1301	525	10	3.5	40.5	56.6	37.3
KODKIMU1302	~	8	3	48.5	59.5	41.1
KODKIMU1303	~	18	3	42.5	57.5	38.7
KODKIMU1304	168	19	3	44	58.9	37.9
KODKIMU1305	540	21	3.5	45.5	60.4	38.9
KODKIMU1306	~	24	2	42	57.8	38.4
KODKIMU1307	31	4	3	40.5	57.7	36.6
KODKIMU1308	29	29	2	~	~	~
KODKIMU1309	103	8	5	45.5	59.3	38.4
KODKIMU1310	22	29	1.5	~	~	~
KODKIMU1311	~	~	~	~	~	~
KODKIMU1312	404	19	3	41.5	63	38.5
KODKIMU1313	12	25	0.5	35	59.2	35.8
KODKIMU1314	~	~	~	~	~	~
KODKIMU1315	~	~	~	~	~	~
KODKIMU1316	~	29	~	22.5	58.6	34.4
KODKIMU1317	~	8	7	~	58.1	39.1
KODKIMU1317	173	18	~	44	57.9	39
mean	200.70	17.93	3.08	41.00	58.81	38.01
standard deviation	210.51	8.53	1.61	6.72	1.61	1.68

APPENDIX C. Chronology and fate of Kittlitz's murrelet nests in 2013, Kodiak Island, Alaska.

Nest ID	Date Discovered	Approximate Date Initiated	Hatch Date	Last Date Known Active	Fate
KODKIMU1301	6-Jun-13	27-May-13	26-Jun-13	20-Jul-13	Fledged on 20-Jul at 23:42, 24 days after hatch
KODKIMU1302	8-Jun-13	31-May-13*	30-Jun-13*	18-Jul-13	Fledged on 18-Jul at 22:51, Camera fail at initial setup missed hatch
KODKIMU1303	12-Jun-13	25-May-13*	24-Jun-13*	12-Jun-13	Depredated by unknown predator, camera failed after initial setup, minimal physical evidence of hatch
KODKIMU1304	14-Jun-13	26-May-13	25-Jun-13	15-Jul-13	Fledged on 15-Jul at 23:24, 20 days post hatch
KODKIMU1305	17-Jun-13	27-May-13	26-Jun-13	16-Jul-13	Fledged on 16-Jul at 22:51 20 days post hatch
KODKIMU1306	18-Jun-13	25-May-13*	24-Jun-13*	1-Aug-13	Fledged on 1-Aug at 4:03 >30 days post hatch (estimated 38 days), camera failure after initial setup replaced at first visit
KODKIMU1307	19-Jun-13	15-Jun-13*	15-Jul-13**	29-Jun-13	Unknown: Adult left & never returned on 29-Jun, 14 days post initiation, egg found depredated in bowl on 20-Jul, missed scavenge or depredation
KODKIMU1308	24-Jun-13	27-May-13	26-Jun-13	13-Jul-13	Chick depredated by a red fox on 13-Jul at 4:29, 17 days post hatch
KODKIMU1309	26-Jun-13	18-Jun-13*	18-Jul-13**	27-Jun-13	Unknown: Adult left & never returned on 27-Jun, egg not present nest check (missed predation or abandonment w/missed scavenge)
KODKIMU1310	28-Jun-13	30-May-13*	29-Jun-13**	30-Jun-13	Abandoned on 30-Jun at 19:39. PIP egg on discovery, egg unhatched found 4 m below nest bowl
KODKIMU1311	29-Jun-13	~	~	30-Jun-13	Chick depredated by a red fox on 30-Jun at 2:56, unknown age
KODKIMU1312	29-Jun-13	10-Jun-13*	10-Jul-13**	2-Jul-13	Egg depredated by red fox on 2-Jul at 2:14, estimated 22 days post initiation
KODKIMU1313	7-Jul-13	12-Jun-13	12-Jul-13	2-Aug-13	Fledged on 2-Aug at 5:39, 21 days post hatch
KODKIMU1314	11-Jul-13	~	~	23-Jul-13	Fledged on 23-Jul at 23:35, 12 days after initial chick discovery
KODKIMU1315	11-Jul-13	~	~	1-Aug-13	Fledged on 1-Aug at 5:03, 21 days after initial chick discovery
KODKIMU1316	12-Jul-13	~	~	~	Abandoned: Unviable pipped egg found abandoned in nest bowl
KODKIMU1317	17-Jul-13	9-Jul-13	8-Aug-13	22-Aug-13	Chick died on 22-Aug at 9:33, 14 days post hatch, last meal Pacific sandlance

*Estimates based a presumed 30-day incubation period (Kaler and Kenney 2008). Egg age estimated by egg floatation in water (Rizzolo and Schmutz 2007, Kaler et al. 2008).

** Hatch did not occur, estimate of date nest was expected to hatch.

APPENDIX D. Details of Kittlitz's murrelet chick deaths, Kodiak Island, Alaska, 2012 & 2013.

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
KODKIMU1317	22-Aug-13	NA	14	NA	2.07	2	2	Chick died 14 days post hatch, no apparent cause, last meal pacific sand lance

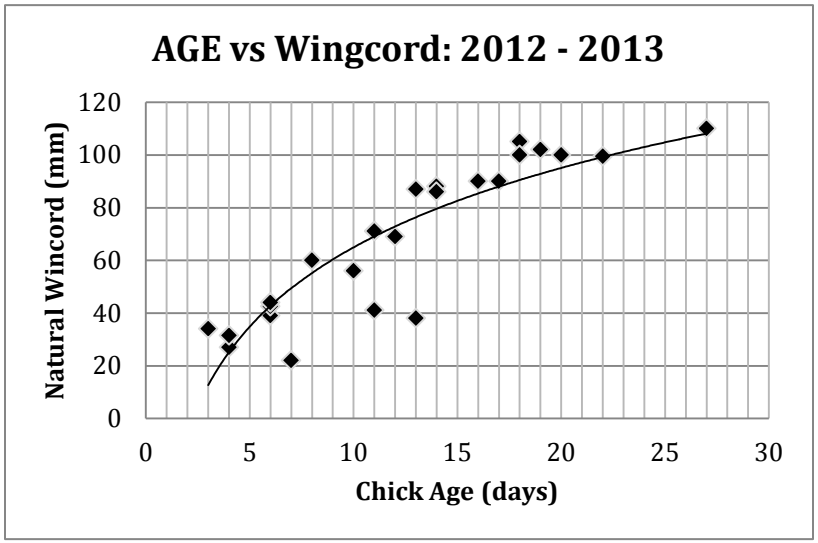
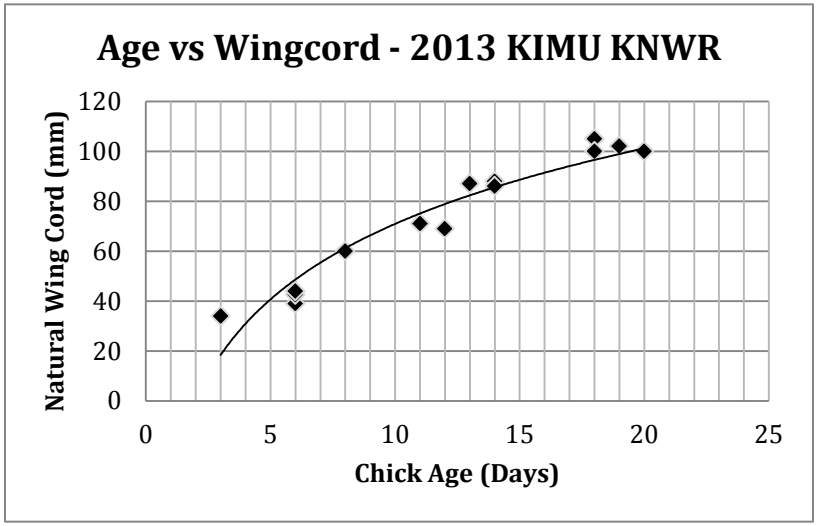
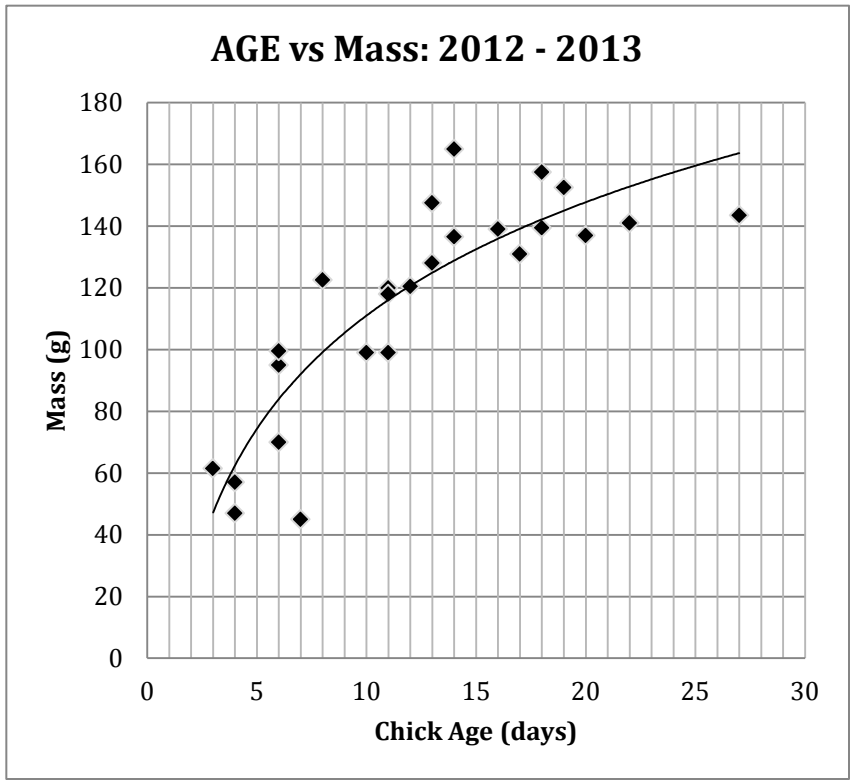
APPENDIX E. Potential Kittlitz's murrelet predator species observed within one km of study sites, Kodiak Island, Alaska, 4 June-3 Aug, 2013.

Species		Date first observed	Date last observed	Total days observed	% field days observed	Observation rate (number of locations seen)
Common name	Scientific name					
Eagle spp. (Bald & Golden)	*Haliaeetus leucocephalus*	6-Jun	2-Aug	37	60.66	68
Peregrine Falcon	*Falco peregrinus*	27-Jun	1-Aug	2	3.28	2
Parasitic Jaeger	*Stercorarius parasiticus*	5-Jul	5-Jul	1	1.64	1
Brown Bear	*Ursus arctos*	8-Jul	8-Jul	1	1.64	1
Black-billed magpie	*Pica hudsonia*	6-Jun	28-Jul	40	65.57	73
Common raven	*Corvus corax*	7-Jun	26-Jul	6	9.84	8
Red Fox	*Vulpes vulpes*	19-Jun	4-Jul	4	6.56	4

APPENDIX F. Characteristics of Kittlitz's murrelet nests on Kodiak Island, Alaska from 2008 to 2013.

Mean	Elevation (m)	Distance to Ocean(km)	Slope (degrees)	Aspect (degrees)	5m Plot %Vegetation	25m Plot %Vegetation	50m Plot %Vegetation
2008	394	~	30	316	9	8	9
2009	344	5.78	30	242	7	8	9
2010	297	6.36	28	238	7	6	7
2011	304	5.56	29	236	6	12	16
2012	298	6.20	29	232	4	4	5
2013	314	6.01	35	200	10	11	12
Minimum							
2008	361	~	22	294	2	1	4
2009	247	3.51	20	17	1	0	0
2010	198	3.96	21	8	1	1	1
2011	181	3.80	20	4	1	1	1
2012	219	3.87	20	6	0	1	1
2013	185	3.50	25	8	2	2	2
Maximum							
2008	426	~	34	330	20	15	18
2009	441	9.83	37	347	32	22	23
2010	443	10.14	36	341	33	30	30
2011	428	9.66	34	358	15	45	70
2012	428	10.20	35	353	30	30	25
2013	447	10.18	44	339	32	35	38
2008-2013							
Mean	314	5.97	30	234	7	8	10
Min	181	3.50	20	4	0	1	1
Max	447	10.20	44	358	33	45	70

APPENDIX G. Fate of Kittlitz's murrelet nests found on Kodiak Island, Alaska during 2008-2013.

Nest Fate	2008	2009	2010	2011	2012	2013	2008-2013	Total %
Depredated/nest empty	2	8	6	9	4	4	33	36.26
Dead chick found in nest	0	1	2	8	3	1	15	16.48
Abandoned/Unviable egg	1	2	3	1	4	2	13	14.29
Unknown	1	0	0	0	1	2	4	4.40
Fledge	0	1	4	4	9	8	26	28.57
Total	4	12	15	22	21	17	91	100
Annual Fledge %	0.00	8.33	26.67	18.18	42.86	47.06	28.57	
Annual Depredation %	25.00	66.67	46.67	40.91	19.05	23.53	36.26	

APPENDIX H. Measurements obtained from known age Kittlitz's murrelet chicks during the 2012 and 2013 nesting seasons.