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Breeding Ecology and Behavior of Kittlitz's Murrelet in Kodiak National Wildlife Refuge, Alaska: 2014 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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The mission of the National Wildlife Refuge System is to administer a national network of lands and waters for the conservation, management and where appropriate, restoration of the fish, wildlife, and plant resources and their habitats within the United States for the benefit of present and future generations of Americans.

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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 of Alaska and eastern Russia. Little is known about the species' nesting ecology, winter range, and juvenile recruitment. The 2014 field season marked the seventh consecutive year that we studied the breeding ecology and behavior of murrelets in a remote area on southwest Kodiak Island, Alaska. Accessible nesting habitat formed by ultramafic rock outcroppings was searched systematically to locate nests on the scree and talus slopes. We placed digital game cameras at nest sites to monitor nest fate, incubation shifts, chick feeding rates, and predation events. We visited nests at regular intervals throughout chick development and measured chick size and mass. When nests were no longer active we characterized habitat features at and near nest sites. During our search effort we discovered 23 active Kittlitz's murrelet nests. Ten of the 23 nests produced chicks and four of those fledged. We obtained growth measurements from four individuals and feeding rates at eight nests, documenting >300 prey deliveries over 79 chick-days monitored. Pacific sand lance (*Ammodytes hexapterus*) were the main forage fish species recorded during the study. We recorded 12 depredations, six by the only confirmed nest predator of the Kittlitz's murrelet on Kodiak prior to 2014, the red fox (*Vulpes vulpes*). For the first time in this study, we observed two nests depredated at the egg stage by black-billed magpies (*Pica hudsonia*). Five chicks under six days of age died for unknown reasons. Three of these were scavenged and two collected and sent to the National Wildlife Health Center for analysis. Four of the five chicks died under conditions similar to those of seven chicks that died on the nest in 2011-2012, and subsequently tested positive for saxitoxin (one of the toxins responsible for paralytic shellfish poisoning). Apparent nest success was 17% in 2014, the lowest rate observed since 2009. In 2012 and 2013, apparent nest success was high (45%) compared to the earlier years of the study 2008-2011. Over the seven years of study, 114 active nests have been located and overall, 30 (26%) successfully fledged chicks.

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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 this birds nesting ecology was limited to the 25 nests recorded prior to the 2000s (Day et al. 1999). KIMU are a relatively long-lived (ca. 10-15 years) Alcid with an estimated global population of at least 33,600 individuals (Federal Register 2013). About 70% of the population nests in coastal Alaska and the remainder 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 about 30% annually beginning in 1989 until it stabilized about the year 2000 (Federal Register 2013). Anthropogenic factors such as vessel traffic, gill-net bycatch, and oil pollution may have contributed to KIMU declines. However, similar declines have been observed among other marine bird and mammal species in the Gulf of Alaska and Bering Sea, so local influences do not seem adequate in themselves to explain recent population 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 be indicators of regime shifts in marine environments, and can provide insights into effects of climate change and overfishing (Gill 2007, Zador et al. 2013). As in the North Pacific, both climate change and overfishing are increasing in the North Sea, where seabirds in 2004 experienced the lowest breeding success on record (Gill 2007).

Concern for this species arose due to its small population, patchy distribution, evidence of decline throughout all or part of its 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 conducting studies of KIMU breeding biology continuously since 2008. Following the opportunistic discovery of the first nest on Kodiak in 2006 (Stenhouse et al. 2008), 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. The cooperative project had a five-year plan to study Kittlitz's murrelets 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 feathers and egg-shell fragments for 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 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 growing chicks. Research on Kodiak continued with funds for the 2012-2014 field seasons provided by the National Fish and Wildlife Foundation and the U.S. Fish and Wildlife Service.

This report summarizes the seventh year of study on the nesting ecology of KIMU on the Kodiak National Wildlife Refuge, Alaska. We summarize the results from our systematic nest searches, nest monitoring, and measurement of nesting habitat characteristics collected during the summer of 2014 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 (46,700 ha) of Kodiak Island and reach elevations up to 1,200 m (mostly >600 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. All 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 mainland areas where the birds 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 leads to very limited plant growth (Alexander et al. 2006).

Within the study area (Fig. 1), four base camps provide staging points for nest searching and monitoring. Field camps are located close to a large area of ultramafic rock that can be easily accessed with little travel time to the slopes. All camps are accessible by helicopter and one by float plane; otherwise the area is limited to foot travel. Throughout the field season the research team traveled between camp sites to conduct systematic searching and nest monitoring.

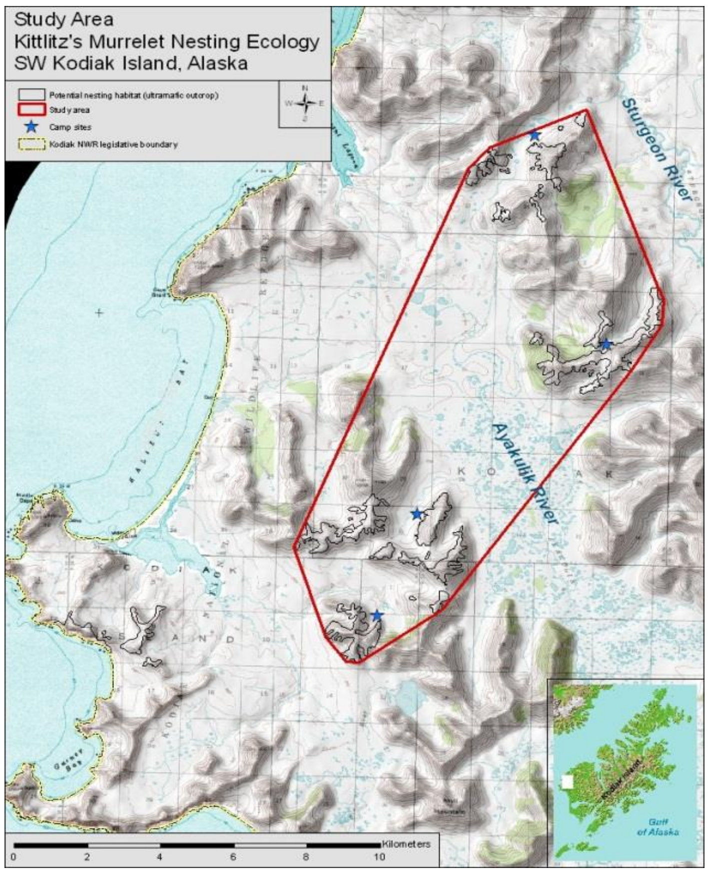

Figure 1. Map of the Kittlitz's murrelet nesting ecology study area on the west side of Kodiak Island, AK.

Methods

Systematic Nest Searching

Nesting habitat in ultramafic rock outcropping close to each campsite was searched to the fullest extent possible from 28 May to 21 July, 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 searching, we spent four to eight days based at each camp and searched as much area in the vicinity as possible in that time. After nest searching ended in late July efforts where shifted to collecting data on nest site characteristics. We searched an area of suitable nesting habitat adjacent to one of the campsites twice in June as part of an agreement between KNWR and the U.S. Coast Guard. This was a measure to avoid impacts to KIMU agreed to in a biological consultation with the USFWS by the U.S. Coast Guard before construction of a tower facility to augment and upgrade the Rescue 21 nautical communication system and provide very high frequency (VHF) radio coverage for emergency communication at Middle Cape.

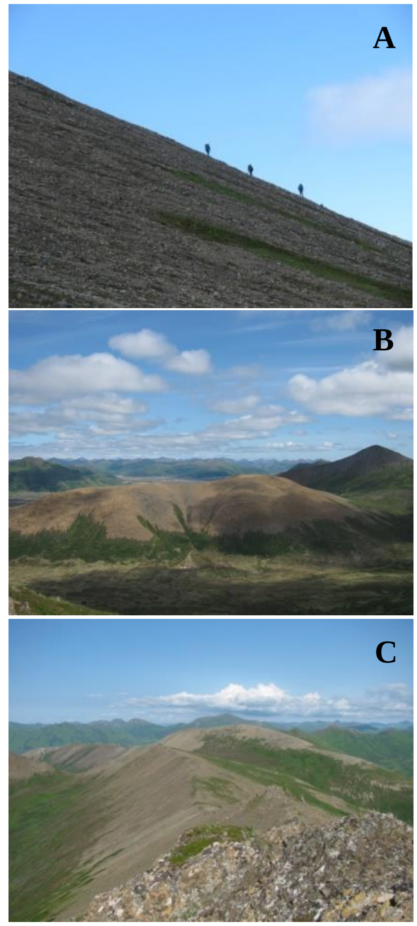

Figure 2. Image A shows researchers conducting systematic nest searching, and B & C show nesting habitat of Kittlitz's murrelet on Kodiak Island, AK.

At the start of each day we hiked to the lowest elevation of nesting habitat to be searched that day. We positioned ourselves perpendicular to the slope with a gap of 5–10 m between each person (Fig. 2A). 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. 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, we moved up and reversed course, systematically searching the entire area to the ridge top. A log of all transects was recorded with two GPS units.

Upon discovery of a nest, data on the nest were collected and we moved to another face of the mountain or a different slope to encourage the incubating adult to return quickly. In previous seasons, flushing an adult from the nest was by far the most common method of discovery. Lone chicks have also been found while searching and adults have been spotted on the ground prior to flush. Adults tended to flush and fly directly downslope, hugging the slope of the mountain.

Adult KIMUs can be identified inflight by outer white rectrices characteristic of this species. Once the bird was out of sight, attention was immediately focused 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 Reconyx camera 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 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 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).

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

In addition to 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. KODKIMU1401 for first nest discovered in 2014). The date, UTM coordinates, time a nest was discovered, time the nest was left, observers, any predators observed, confirmation of species, elevation, and the direction the adult flushed were also recorded. Prior to leaving the nest a makeshift nest bowl similar to the active nest (i.e. similar nest bowl composition, aspect, and nest rock) was constructed within a 3 m radius of the nest where a temperature data logger (Thermochron iButtons, Embedded Data Systems DS1922L-F5#) was placed. 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 get a better understanding of thermoregulatory costs for each chick. To encourage the adult to return quickly we attempted to spend less than 10 min at the nest and then moved to a different face of the ridge/peak or to a different ridge post discovery.

Using estimates of hatch date determined during nest discovery, nest sites were subsequently visited at three intervals during the fledgling period 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 processed >30m from the nest in order to avoid disturbance at the nest site. 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. We also recorded percent coverage of down on the chick and the 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 intervals of 4 to 6 days, 14 to 16 days, and 18 to 21 days to get a good sample of growth measurements 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).

Nest Cameras and Estimation of Fish Length

A camera, either a Reconyx PC90 or PC900, was placed at each nest after discovery. 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%). 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. Upon discovery of a nest we fastened a Reconyx camera to a metal stake pounded into the ground and then attempted to conceal the camera setup with flat rocks from the vicinity. 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 the 2011 nesting season, 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 depredation were reviewed at the end of the field season by trained Southern Illinois University zoology student volunteers. 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 recorded as a ratio to the number of adult head lengths.

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, were interpreted as evidence of a successful nest. If there was no chick present on the first nest check, hatch was inferred from fecal and egg fragments and a depredation event was assumed.

Nest Site Characteristics

As nest searching efforts ended, the remainder of the field season was spent visiting nests to gather growth rate data, and measuring physical characteristics at each nest site and at randomly selected sites near the original nest site locations. We measured slope, aspect, and elevation, and noted whether the ocean could be viewed from the site. 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. Nests often have a large '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 each rock (length × width × height). These rocks were usually directly above (up-slope to) 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, we estimated the percentage of the area that was vegetated and unvegetated. 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, we took photographs of the habitat from all directions.

We collected fecal samples during each nest visit from the fecal ring located at the back of the nest, and later buried these at campsites to keep them cool. Upon returning to Kodiak, these samples were stored in a freezer at the KNWR headquarters. Any prey fish present around the nest site were collected. These specimens were also buried at camp, frozen at the first chance, and later stored in a freezer at the KNWR headquarters. Egg shell fragments and adult contour feathers were collected opportunistically, stored in envelopes, and archived at the KNWR headquarters.

Predators Observations

Predation has had a large impact on KIMU nest success throughout the study. Using protocols described by Sargeant et al. (1993) the number and location of all predators observed during the field season were recorded on a daily basis. All observations were within 1 km of ultramaphic rock nesting habitat at the four sites.

Results and Discussion

Nest Searching and Monitoring

On 24 May, our research team consisting of one biological science technician and three refuge volunteers flew to Duncan Lake on the west side of Kodiak Island. During the summer we circulated between four basecamps that served as staging points to systematically search for KIMU nests on mountainous ultramafic rock outcroppings (Fig. 4). Once we completed our monitoring effort, we surveyed nest-site characteristics until the end of the field season. Dedicated nest searching began on the 28 May and concluded on the 21 July (77 days). The crew returned to Kodiak on 8 August, even though two nests were still active. In previous years searching has been completed at each of the four main study areas before searching an area for a second time. We required additional search effort to complete the U.S. Coast Guard communications tower assessment at Middle Cape, and this pushed the first round of searching further into July. Hence one site (Anvil) was searched later and less intensely than in previous years. The first round of searching concluded on 3 July yielding 19 active Kittlitz's murrelet nests and one nest that was discovered with a depredated egg in the nest bowl. During this time the research team systematically searched potential ultramafic rock nesting habitat with slopes greater than 20°, focusing the search effort on steeper slopes and larger outcrops of ultramafic rock. The second round of nest searching concluded on the 21 July, yielding discovery of four active nests. Only three of the four areas were searched on the second round and with more limited effort (2-3 search days per camp). Beginning 25 June, time was dedicated to nest monitoring and travel between sites was often dictated by the schedule of nest checks. Further, the research team was reduced to only 3 biologists after 22 June.

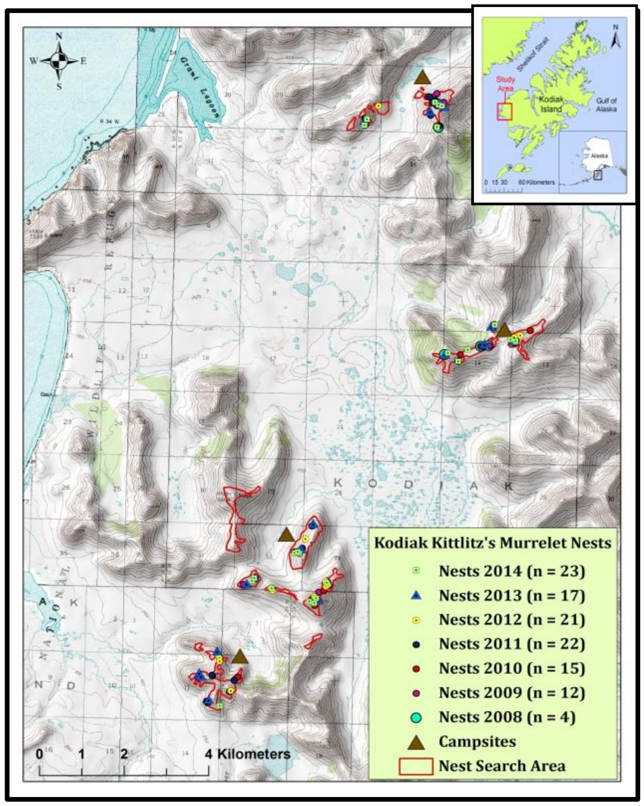

Figure 4. Kittlitz's murrelet nest locations from 2008-2014 on Kodiak Island, AK.

A total of 23 active KIMU nests were discovered in the egg stage, 20 of which were found after we flushed an incubating adult from the nest. We discovered the other three nests during systematic searches when an observer spotted an adult incubating among the rocks. The average distance at which an adult KIMU flushed from the nest in response to searchers was 3.2 meters in 2014, similar to (within 1.1 m) annual flush distances recorded previously during this 7-year study. The range of flush distances was also similar to previous years of the study, and ranged from 0.5 m to 7.5 m in 2014. A live chick in a nest was discovered without an adult flushing on three occasions in 2013, but no nests were found in this manner in 2014. One nest discovered in the egg stage had evidence of prior use (an unhatched egg with old egg fragments in the nest bowl). Several nests were found in close proximity (< 20 m) to old nest sites, and two nests were active within 100 m of each other.

As in previous years, there was a wide range of return times for adults after initial flush (15-1025 min). The mean return time for 2014, 359 min, was in the upper range for the seven year study (Table 1). Average time from initial flush to when researchers left the nest was 12 minutes in 2014, slightly higher than the 10 minute goal. Issues with cameras malfunctioning and iButton placement increased the amount of time spent at a nest after first discovery. On two occasions we spotted a returning murrelet fly by the nesting area

Table 1. Summary of Kittlitz's murrelet adult return times after initial flush of incubating adult during the 2009 to 2014 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
Mean	293	17	785

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

as we were leaving the nest, indicating that KIMU will return to the nest within 10-12 minutes of initial flush. After each new nest was discovered we moved to another slope or peak to continue searching and did not return to the slope until at least the next day. Aside from scheduled nest visits, we maintained a distance of at least 50 m from all active KIMU nests during subsequent search efforts and activities in the area.

Based on hatch dates documented by camera images, the average initiation date was 6 June (n=8, range 18 May to 7 July). If we include estimates based on egg-floating benchmarks, the average initiation date was 4 June (n=15, range 18 May to 11 July). Mean initiation dates were among the earliest recorded on Kodiak Island (Table 2). Probable renesting has been observed in several seasons (2011, 2013, and 2014), as indicated by birds that initiated nests far later than mean initiation dates recorded for this species on Kodiak Island. Tendency to re-nest following initial nest failure has been reported frequently for the congeneric marbled murrelet (Nelson et al. 2010).

Table 2. Kittlitz's murrelet nest initiation dates from 2008-2014. 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

Nest Success

Apparent nest success was 17% (4 of 23), the lowest recorded on this study since 2009 (Figure 5). Nest success was lower than the previous two years due to increases in nest predation (n=12) and unexplained chick deaths (n=5) which collectively accounted for 74% of nest failures. As in previous years, when predation rates were high, red fox (*Vulpes vulpes*) predation was the major cause of nest failures. 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. In one instance camera images reveal that the magpie drove off an incubating adult before consuming the egg (Figure 8). Apparent nest success in 2012 (45%) and 2013 (47%) was substantially higher than the 17% average nest success observed during other years of the study (Figure 5). 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. Predation rates dropped from 49% in 2008-2011 to 26% in 2012-2013, and coincided with an increase in nest success during the same time period. In 2014 predation rates rose to 52%, the second highest recorded on Kodiak. Red fox were observed on 25% of field days in 2014 compared to only 15% of field days in 2012 and 7% in 2013 (Appendix E). The decline in predation rates during the 2012-2013 nesting season might have been related to a higher abundance of alternate prey (such as willow ptarmigan (*Lagopus*

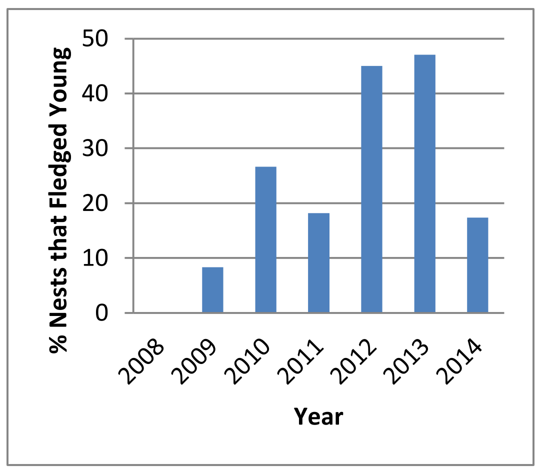

Figure 5. Annual percentage of Kittlitz's murrelet nests that fledged chicks on Kodiak Island, AK from 2008-2014.

lagopus), rock ptarmigan (*Lagopus muta*), and tundra voles (*Microtus oeconomus*) in more vegetated habitats at lower elevations. It is beyond the scope of our current research to determine how much KIMU predation might be influenced by these other factors.

Of the 23 active nests being monitored, three fledging events were documented with nest cameras and another fledge was inferred from physical evidence at the nest. The egg in the latter nest hatched two days before we left the field. Prior to leaving, we replaced the camera on the recently hatched chick, but the camera failed shortly after startup. However, a large fecal ring and chick down around the nest provided physical evidence to infer that the chick had fledged successfully. Six nests were depredated by red fox (five at the egg stage and one at the chick stage), two were depredated by black-billed magpies in the egg stage, five chicks died from unknown causes, and two eggs were abandoned (Table 3). The predator at four nests could not be identified due to camera failure or malfunction and fate had to be determined by a combination of physical evidence at the nest and existing camera images (KODKIMU1402, KODKIMU1409, KODKIMU1411, KODKIMU1416). Detailed nest fates for 2014 can be found in Appendix C and nest fates from 2008-2014 can be found in Appendix G and Table 4.

Table 3. Summary of Kittlitz's murrelet nest fates on Kodiak Island, AK during the 2014 nesting season.

Nest Fate	Number of nests
Egg abandoned	2
Failed during incubation, red fox depredation	5
Failed during incubation black-billed magpie depredation	2
Failed during incubation, depredation by unknown predator	4
Failed during nestling stage, red fox depredation	1
Failed during nestling stage, dead chick found on nest scrape	5
Fledged young	4
Total	23

Figure 6. The chick from KODKIMU1410 found dead at the nest with a partially ingested sand lance protruding from its bill.

Camera images show five chicks dying on the nest for unknown reasons. Of the five chicks that died, three carcasses were scavenged. Two were present and in good condition, and so we collected them for later necropsy. One of these had a partially ingested fish protruding from its bill (Figure 6). The two chicks that we salvaged were weighed, measured, bagged, buried at base camp to keep cool, and frozen the next day in a propane freezer. Twelve days later the specimens (KODKIMU1408 & KODKIMU1410) were flown back to KNWR Headquarters and were later sent to the National Wildlife Health Center for necropsy. The series of events leading up to four of the five chick deaths were similar to those from 2011-2012, when seven chick deaths were attributed to saxitoxin, a neurotoxin produced by some species of marine dinoflagellates (Shearn-Bochsler et al. 2014). In the cases of chick death due to saxitoxin recorded by cameras in 2011-2012, healthy chicks that were being fed regularly died on the nest less than two hours after being fed a sand lance. Of the five chicks that died in 2014, one was never fed and so saxitoxin poisoning seemed implausible. The remaining four chicks died within six hours of ingesting their last prey; in most cases sand lance. Four of the five chicks died within a 34-hour period between 22-23 June, and the fifth chick died five days after the first on 27 June. All chicks were about five days old or younger. Refer to Appendix D for more information on chick deaths. There was no significant weather event during the 21-27 June that would suggest exposure was the cause of death at these nests (Appendix A).

Over seven years (2008-2014) of study on Kodiak, 114 KIMU nests were discovered and monitored to determine the fate of eggs or chicks (Fig. 7, Table 4). The predator responsible for nest depredation was recorded by camera images at 24 of the 48 nests that failed due to predation. Of those 24 identified predators, 22 were red fox. The majority (34) of depredation events occurred during incubation and only a few (13) during chick rearing.

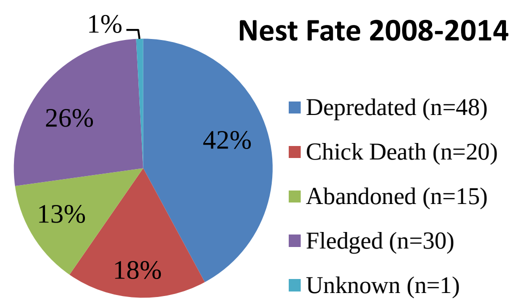

Figure 7. Overall nest fate of Kittlitz's murrelet from 2008-2014 on Kodiak Island, AK.

Predator Observations

Beginning in 2012, the documentation of predator activities was standardized by using protocols described by Sargeant 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 75 days in 2014, and 59 days in both 2012 and 2013. The red fox was seen on a greater percentage of days in 2014, 25%, than 2012 and 2013 with 15% and 7% respectively. The total number of red fox detections from 2012-2014 was 34 with 22 (65%) of those observations during 2014 (Appendix E).

Black-billed magpie detections in 2014 where double that of 2012 and 25% greater than 2013. However, the percentage of days magpies were observed in 2014 was about 10% less than in 2012 and 2013. The black-billed magpie has been the most frequently observed predator within our study sites in recent years. While we have not yet seen other predators

Figure 8. Black-billed magpie and a red fox photographed depredating Kittlitz's murrelet nests during the 2014 field season.

depredating KIMU nests on Kodiak Island, there are several potential predator species that are frequently observed including: common raven (*Corvus corax*), and golden eagle (*Aquila chrysaetos)* and bald eagle (*Haliaeetus leucocephalus*). For more information on predator observations refer to Appendix E.

Table 4. Fate of Kittlitz's murrelet nests on Kodiak Island, AK during 2008-2014.

Nest Fate	2008	2009	2010	2011	2012	2013	2014	2008-2014
Depredated/scavenged	2	8	7	9	4	6	12	48
Dead chick	0	1	2	8	3	1	5	20
Abandoned/Unviable egg	2	2	2	1	4	2	2	15
Fledge	0	1	4	4	9	8	4	30
Unknown	0	0	0	0	1	0	0	1
Total	4	12	15	22	21	17	23	114

*Two nests from 2013 were reclassified from unknown fate to depredated/scavenged.

Nest Site Characteristics

Characteristics of the KIMU nests located during the 2014 season were consistent with the observations collected during the previous six years of research. All nests where located in ultramafic 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, and situated directly below (down-slope) a large rock (we call it a "nest rock"). However, two of the 23 nest bowls observed in 2014 were located in small patches of vegetation among the rocks. See Figure 9 for photographs of these two nests and the associated terrain (KODKIMU1405 and KODKIMU1421).

The percent of vegetation coverage within a 5 m, 25 m, and 50 m radius of nests discovered in 2014 was within 1% of the seven year averages of 5%, 8%, and 9% respectively. In 2014, the range of elevations at which nests were found was the greatest recorded at this study site, with the lowest nest found at 162 m and the highest at 448 m. The 2014 mean nesting elevation (325 m) was higher than the average across all seven years (316 m). Nests in 2014 were found on steeper slopes (mean 37°, range 23-49°) than the average for the previous six field seasons 2008-2013 (mean 31°; range 20-44°). Additional information on nest site characteristics can be found in Appendix F. Search effort is not randomized so averages could be biased based on search effort.

In 2014, due to an extended field stay and limited nest monitoring, there was time to complete all random and near nest vegetation plots with the exception of the two nests that were still active on departure from the field. Data have been collected on about 700 random plots within the search area from 2008-2014. Analysis of nest site habitat characteristics from 2008-2011 indicated that KIMU selected sites with lower vegetation cover, more rocks in the 5–30 cm size range, 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).

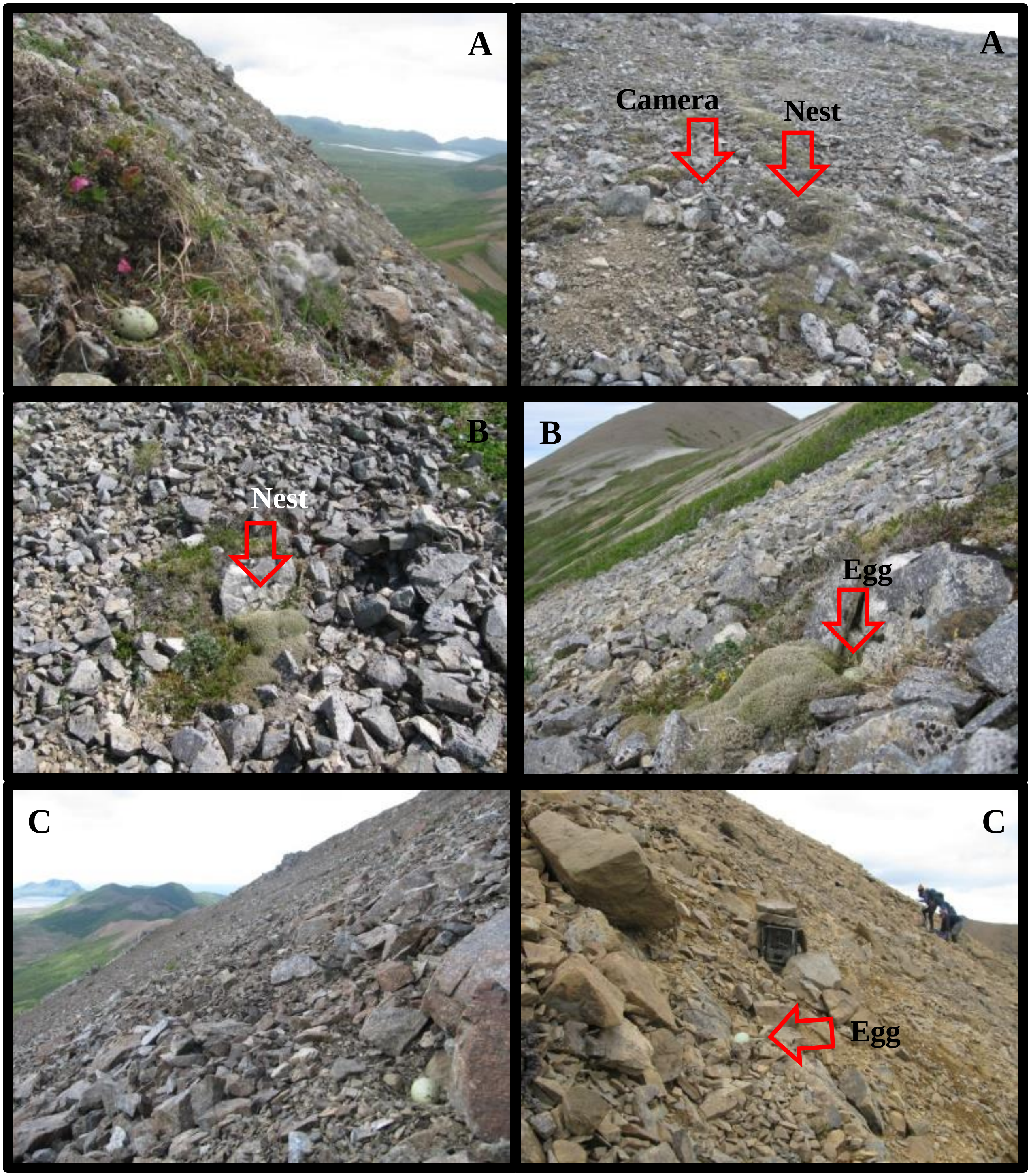

Figure 9. Images from two nests found in clumps of vegetation, KODKIMU1405 (A) and KODKIMU1421 (B), compared to nests found in more typical rocky locations (C).

Meal Delivery and Chick Growth

Of the 23 active nests, ten produced a chick. The three successful nests where chick-rearing was documented by nest cameras (KODKIMU1413, KODKIMU1417, KODKIMU1422) contributed 61 of the 79 chick-days monitored and accounted for 80% of all prey deliveries. Over the course of chick-rearing, average prey delivery rates at these three successful nests were 3.5, 3.4, and 4.8 fish per day. The chick at KODKIMU1418 was monitored for 14 days post-hatch, received an average of 3.3 meal deliveries a day, and 33 meal deliveries overall before being depredated by a red fox. Over the course of the field season we observed meal deliveries at 8 of the 10 nests where chicks hatched. In total, 303 fish were recorded by cameras being delivered to active nests with an average of 3.5 fish delivered per day (Table 6). The number of deliveries per day ranged from 0 to 9. Fish deliveries per day in 2012 and 2013 field seasons were slightly higher than 2014 (Table 5). As in previous years, Pacific sand lance was the most abundant fish species delivered to chicks making up about 71% in 2014 (ca. 80% overall years). Capelin was the second most frequent fish species fed to chicks and made up a higher percentage (23%) of prey deliveries in 2014 than in previous seasons. Pacific herring were also observed being fed to chicks. The decrease in unknown fish over the years is likely a factor of cameras being placed closer to nests in recent years.

Table 5. Summary of prey deliveries to Kittlitz's murrelet chicks from 2009-2014. Mean number of prey/day was calculated by combining the mean prey/day delivered to each chick and averaging them for all chicks in a given year. Sample size (n) represents number of chicks that received at least one prey delivery.

Year	n	Mean prey/day	Total fish delivered	Total days monitored post-hatch
2009	2	4.0	116	31
2010	5	3.4	177	48
2011	13	4.2	945	209
2012	12	4.0	732	168
2013	10	3.7	695	181
2014	8	3.5	303	79

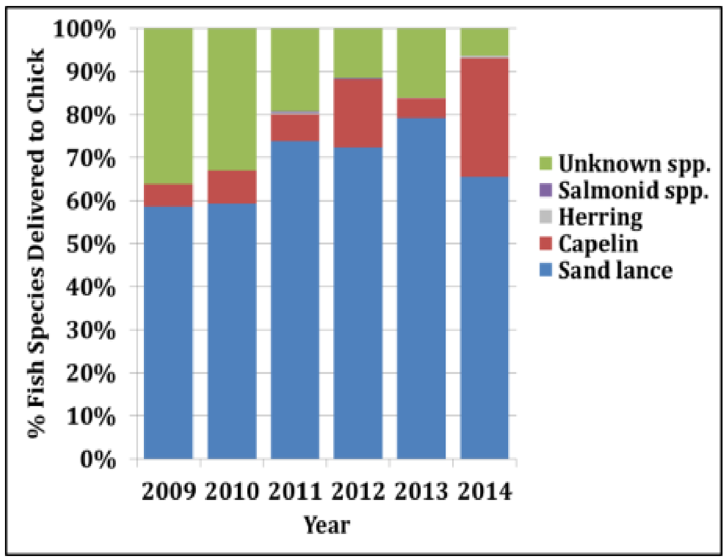

Figure 10. Annual percentages of fish species fed to Kittlitz's murrelet chicks on Kodiak Island, AK from 2009-2014.

We determined the number of days from hatch to fledge (pre-fledge period) for three of the four successful nests. For the two nests where hatch and fledge were captured on camera (KODKIMU1417 and KODKIMU1422) the pre-fledge period lasted 23 days. Exact hatch date was not recorded at KODKIMU1413 due to camera failure, but this chick was estimated to fledge at about 27 days post hatch.

Table 6. Frequency of chick meals (single fish) delivered to Kittlitz's murrelet on Kodiak Island, AK in 2014. A total of 303 deliveries were recorded while a live chick was present. Total days monitored post-hatch starts at hatch (day 0).

Nest ID	Mean meals a day	Range of meals a day	Total fish delivered while active	Total days monitored post-hatch	Nest fate
KODKIMU1404	6	~	6	1	*Chick died ~5 days post hatch
KODKIMU1406	2	0 - 4	4	2	Chick died 2 days post hatch
KODKIMU1408	2	1 - 2	3	2	Chick died 1 day post hatch
KODKIMU1410	3	1 - 4	15	5	Chick died 5 days post hatch
KODKIMU1413	3.5	1 - 6	57	17	*Fledged ~27 days post hatch
KODKIMU1414	~	~	~	0	Chick died hours after hatch
KODKIMU1417	3.4	0 - 6	75	21	**Fledged 23 days post hatch
KODKIMU1418	3.3	1 - 5	33	8	**Chick depredated 14 days post hatch
KODKIMU1422	4.8	2 - 9	110	23	Fledged 23 days post hatch
KODKIMU1423	~	~	~	0	***Fledged fecal & down

*Camera failure after initial setup missed hatch

**Camera malfunction KODKIMU1417 missing two days, KODKIMU1418 missing five days

***Camera failure after initial setup and after first nest visit, missed hatch and fledge.

We collected body measurements of four chicks on nine separate nest visits in 2014. We collected a full set of three body measurements on two chicks that successfully fledged.

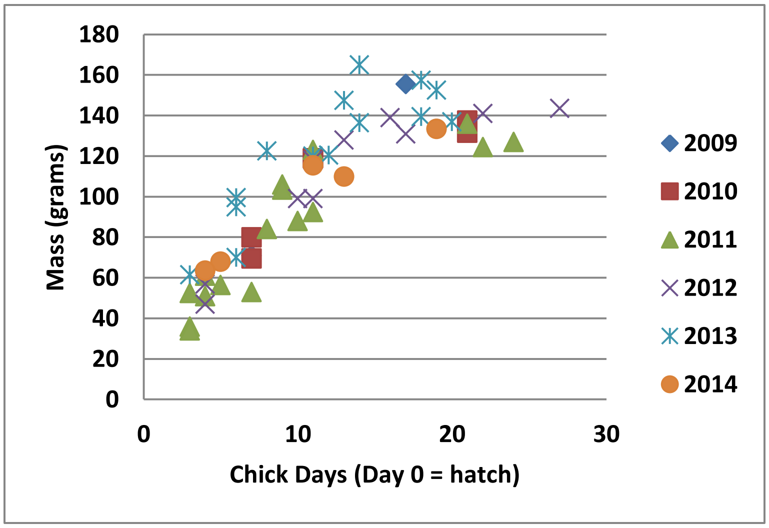

Figure 11. Growth in body mass of Kittlitz's murrelet for known-age chicks on Kodiak Island, AK from 2009 to 2014. Day 0 represents the day of hatch.

Camera failure was a frequent problem in 2014 despite all cameras being tested before the start of the season to confirm they were functioning properly. In most instances we could not determine the cause of camera failure. In two isolated cases cameras were likely set up too close to the nest (0.5 m) causing the motion sensor to trigger excessively, draining the camera battery and filling the memory card. The distance of the camera to the nest was dictated by terrain and the need to get clear images of prey deliveries to chicks. 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.

Figure 12. Reconyx images of Kittlitz's murrelet adult delivering Pacific sand lance to a chick waiting in a nest on Kodiak Island, AK during the 2014 field season.

Conclusion

Nest success of KIMU on Kodiak Island in 2014 was among the lowest observed during seven years of study. High nest failure was due largely to high predation rates, but also to unexplained high mortality of chicks. Data from this study will continue to be analyzed in cooperation with Southern Illinois University Carbondale (SIU), U.S. Geological Survey, and co-operators investigating the possibility of KIMU chick death attributed to saxitoxin. SIU's goal is to use the data to investigate the influence of diet composition 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. Results 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. Research and monitoring on Kodiak Island is important not only for 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.

Funding provided by the National Fish and Wildlife Foundation Alaska Fish and Wildlife Fund will allow this research to continue for another nesting season. During the 2015 field season we will follow the same protocols for nest searching and monitoring as in previous field seasons. We will also attempt to capture up to three adult murrelets at the nest site during the later stages of incubation to attach satellite transmitters that will provide information on important foraging areas. Currently KIMU foraging locations in the Kodiak Archipelago are unknown. Identifying KIMU foraging locations would allow us to monitor prey in these areas for temporal differences in forage fish quality and saxitoxin levels, and to evaluate the possible importance of these factors in population trends. Forage fish species that sustain Kittlitz's murrelets also support many other seabirds, marine mammals, such as the Steller sea lion, and fish species important to the commercial fishing industry.

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APPENDIX A. Weather conditions, Kodiak Island, Alaska, 2008-2014 (NOAA, 2014).

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
2014	Booth Lake	1 Jun – 31 Aug	11.4	~

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

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
2014	Kodiak Airport	1 Jun – 31 Aug	12.6	15.8	9.4	13.3	0.15
Mean			11.8	14.8	8.7	12.9	0.14
Standard Deviation			0.895	1.072	0.767	4.575	0.050

APPENDIX B. Adult return time after initial flush, age at discovery, flush distance, and egg measurements for Kittlitz's murrelet nests, Kodiak Island, Alaska, 2014. Bolded numbers under estimated age at discovery represent known hatch dates obtained from nest cameras.

Nest ID	Return Time (min)	Estimated Age at Discovery (Days)	Flush Distance (m)	Egg mass (g)	Widt h (mm)	Length (mm)
KODKIMU1401	810	5	5	43	38	56.1
KODKIMU1402	47	2	3	43	40.1	56.5
KODKIMU1403	418	10	5	43.5	37	61.9
KODKIMU1404	~	10	7.5	47	38.7	59.7
KODKIMU1405	468	6	2	46.5	39.6	58.1
KODKIMU1406	26	**15**	3	46	39	59.2
KODKIMU1407	554	7	2	38.5	36.5	57.9
KODKIMU1408	471	**17**	2	41	37.9	59.7
KODKIMU1409	309	19	3.5	39.5	37.7	55.8
KODKIMU1410	41	**23**	0.5	39	37.8	55.8
KODKIMU1411	367	3	2.5	40	38.2	56.5
KODKIMU1412	30	19	2	47	39.9	59.4
KODKIMU1413	~	26	6	44.5	38.5	60.5
KODKIMU1414	31	**25**	0.5	35.5	35.9	57.7
KODKIMU1415	42	5	5	42	36.8	59.7
KODKIMU1416	792	21	3.5	37.5	35.55	59.2
KODKIMU1417	234	**16**	5	45.5	39.4	58
KODKIMU1418	890	**8**	2.5	41	37.5	55.1
KODKIMU1419	568	2	5	42.5	36.9	58.6
KODKIMU1420	1025	1	3	50.5	39.8	60.6
KODKIMU1421	75	19	3	39	37.2	57.9
KODKIMU1422	329	**9**	1	46.5	38.9	58.8
KODKIMU1422	15	**24**	1.5	42.5	38.9	58.9
KODKIMU1423	~	**13**	3	40	36.9	57.6
Mean	359	13	3.2	42.5	38.0	58.3
Standard Deviation	322	8	1.8	3.6	1.3	1.7

*KODKIMU1422 was flushed a second time to place a new camera at the nest prior to leaving the field site for the remainder of the season aside from camera collection in early September.

APPENDIX C. Chronology and fate of Kittlitz's murrelet nests in 2014, Kodiak Island, Alaska.

Nest ID	Date Found	Approximate Date Initiated*	Hatch Date	Last Date Known Active	Fate
KODKIMU1401	28-May	23-May	22-Jun	5-Jun	Egg depredated by red fox on 5 Jun at 00:28, ~12 days post initiation
KODKIMU1402	1-Jun	30-May	29-Jun	21-Jun	Depredated, unk. predator, camera failure after 20 days, no sign of hatch
KODKIMU1403	1-Jun	22-May	21-Jun	2-Jun	Egg depredated by BBMA on 2 Jun, ~11 days post initiation
KODKIMU1404	2-Jun	23-May	22-Jun	27-Jun	Chick death 27 Jun, ~5 days post hatch, scavenged by unknown predator
KODKIMU1405	2-Jun	27-May	26-Jun	3-Jun	Abandoned after adults returned briefly (egg collected)
KODKIMU1406	5-Jun	21-May	***20-Jun***	22-Jun	Chick death 22 Jun, 2 days post hatch, scavenged by unk. predator 24 Jun
KODKIMU1407	8-Jun	1-Jun	1-Jul	12-Jun	Egg depredated by red fox on 12 Jun at 5:00, ~12 days post initiation
KODKIMU1408	8-Jun	22-May	***21-Jun***	22-Jun	Chick death on 22 Jun after sand lance feeding 1 day post hatch (collected)
KODKIMU1409	8-Jun	20-May	19-Jun	19-Jun	Depredated by unknown predator on 19 Jun, ~30 days post initiation
KODKIMU1410	10-Jun	18-May	***17-Jun***	22-Jun	Chick death 22 Jun in early AM 5 days post hatch (collected)
KODKIMU1411	10-Jun	7-Jun	7-Jul	19-Jun	Egg depredated unk. pred. 19 Jun ~12 days post initiation cam malfunction
KODKIMU1412	14-Jun	26-May	25-Jun	22-Jun	Egg depredated by red fox on 22 Jun at 6:00, ~27 days post initiation
KODKIMU1413	15-Jun	20-May	19-Jun	16-Jul	Fledged on 16 Jul at 23:08, estimated 27 days post hatch
KODKIMU1414	18-Jun	24-May	***23-Jun***	23-Jun	Chick death hours after hatch on 23 Jun, Scavenged by unk. pred. 28 Jun
KODKIMU1415	18-Jun	13-Jun	13-Jul	22-Jun	Egg depredated by black-billed magpie on 22 Jun, ~9 days post initiation
KODKIMU1416	20-Jun	30-May	29-Jun	23-Jun	Egg depredated by unknown predator on 23 Jun, ~24 days post initiation
KODKIMU1417	20-Jun	4-Jun	***4-Jul***	27-Jul	Fledged on 27 Jul at 23:24, 23 days post hatch
KODKIMU1418	21-Jun	13-Jun	***13-Jul***	27-Jul	Chick depredated by red fox on 27 Jul at 0:58, 14 days post hatch
KODKIMU1419	2-Jul	30-Jun	30-Jul	14-Jul	Egg depredated by red fox on 14 Jul at 23:28, ~14 days post initiation
KODKIMU1420	12-Jul	11-Jul	10-Aug	14-Jul	Abandoned after adults after returned briefly (egg collected)
KODKIMU1421	14-Jul	25-Jun	25-Jul	26-Jul	Egg depredated by red fox on 26 Jul at 2:33, about 31 days post initiation
KODKIMU1422	16-Jul	7-Jul	***6-Aug***	29-Aug	Fledged on 29 Aug at 22:00, 23 days post hatch
KODKIMU1423	20-Jul	7-Jul	**6-Aug**	7-Aug	Fledged at unknown age, nest check fecal & down present (camera failure)

*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.

APPENDIX D. Details of Kittlitz's murrelet chick deaths, Kodiak Island, Alaska, 2012-2014.

Chick Death Nest ID	Date of chick death	Date chick collected	Chick age at death (days post-hatch)	Chick carcass mass (g)	Failed chick feeding rate (fish/day)	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

*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 one km of study area, Kodiak Island, Alaska, 2 Jun-31 Jul 2012 (59 days), 4Jun-3Aug 2013 (59 days), 25 May to 7 Aug 2014 (74 days).

Species		Date first observed	Date last observed	Total days observed	% field days observed	Observation rate (number of locations seen)
Common name	**Scientific name**			**2012**		
Bald eagle	*Haliaeetus leucocephalus*	2-Jun	31-Jul	40	73	61
Sharp-shinned Hawk	*Accipiter striatus*	28-Jul	28-Jul	1	2	1
Parasitic Jaeger	*Stercorarius parasiticus*	10-Jun	31-Jul	7	13	7
Black-billed magpie	*Pica hudsonia*	2-Jun	31-Jul	35	64	51
Common raven	*Corvus corax*	5-Jun	28-Jul	12	22	14
Northwestern crow	*Corvus caurinus*	6-Jun	6-Jun	1	2	1
Red Fox	*Vulpes vulpes*	7-Jun	24-Jul	8	15	8
				2013		
Eagle spp. (Bald & Golden)	Family: Accipitridae	6-Jun	2-Aug	37	61	68
Peregrine Falcon	*Falco peregrinus*	27-Jun	1-Aug	2	3	2
Parasitic Jaeger	*Stercorarius parasiticus*	5-Jul	5-Jul	1	2	1
Brown Bear	*Ursus arctos*	8-Jul	8-Jul	1	2	1
Black-billed magpie	*Pica hudsonia*	6-Jun	28-Jul	40	66	73
Common raven	*Corvus corax*	7-Jun	26-Jul	6	10	8
Red Fox	*Vulpes vulpes*	19-Jun	4-Jul	4	7	4
				2014		
Eagle spp. (Bald & Golden)	Family: Accipitridae	26-May	6-Aug	46	61	97
Peregrine Falcon	*Falco peregrinus*	28-May	1-Jul	2	3	2
Parasitic Jaeger	*Stercorarius parasiticus*	29-Jul	29-Jul	1	1	1
Brown Bear	*Ursus arctos*	16-Jun	3-Aug	4	5	4
Black-billed magpie	*Pica hudsonia*	26-May	3-Aug	42	56	102
Common raven	*Corvus corax*	30-May	3-Aug	7	9	8
Merlin	*Falco columbarius*	26-Jul	28-Jul	3	4	3
Red Fox	*Vulpes vulpes*	28-May	7-Aug	19	25	22

APPENDIX F. Characteristics of Kittlitz's murrelet nests on Kodiak Island, Alaska from 2008 to 2014.

Mean	Elevation (m)	Distance to Ocean(km)	Slope (degrees)	5m Plot %Vegetation	25m Plot %Vegetation	50m Plot %Vegetation
2008	394	~	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	~	37	5	8	9
Minimum						
2008	361	~	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	~	23	0	0	1
Maximum						
2008	426	~	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	~	49	20	30	38
2008-2014						
Mean	316	5.97	31	6	8	10
Min	162	3.50	20	0	0	1
Max	448	10.20	49	33	45	70

APPENDIX G. Categorized nest fates of active Kittlitz's murrelet nests found on Kodiak Island between 2008 and 2014.

Nest Fate	2008	2009	2010	2011	2012	2013	2014	Total	% Total
Egg abandoned	2	2	2	1	4	2	2	15	13
Failed during incubation, red fox depredation	0	2	0	5	2	1	5	15	13
Failed during incubation black-billed magpie depredation	0	0	0	0	0	0	2	2	2
Failed during incubation, depredation by unknown predator	2	3	3	2	1	3	4	18	16
Failed during nestling stage, red fox depredation	0	1	1	1	1	2	1	7	6
Failed during nestling stage, unknown predator	0	2	3	1	0	0	0	6	5
Failed during nestling stage, dead chick found on nest scrape	0	1	2	8	3	1	5	20	18
Unknown	0	0	0	0	1	0	0	1	1
Fledged young	0	1	4	4	9	8	4	30	26
Total	4	12	15	22	21	17	23	114	

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