Effect of variation in ocean temperature on nest attentiveness of a rare seabird, the Kittlitz’s Murrelet (Brachyramphus brevirostris)

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Effect of variation in ocean temperature on nest attentiveness of a rare seabird, the Kittlitz’s Murrelet (*Brachyramphus brevirostris*)

A Thesis Proposal Presented by

Katie Stoner

to

The Rubenstein School of Environment and Natural Resources

The Honors College

The University of Vermont

In Fulfillment of the Requirements of the Honors College Degree May 2016
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ABSTRACT

Seabird reproductive success relies on forage availability not only when adults are feeding nestlings, but also during the pre-breeding period when adults must secure nutrients for egg production and incubation. Ocean conditions, particularly temperature, may have significant effects on the availability of food resources both during and prior to nest initiation. Incubation behavior has been proposed as an indicator of the impacts of ocean climate variability on seabird reproductive success. Little is known, however, about the incubation behavior of seabirds such as the Kittlitz’s Murrelet (*Brachyramphus brevirostris*). The Kittlitz’s Murrelet is a small seabird that breeds on the western coast of Alaska, USA. The species experienced rapid population declines in the 1980s and 1990s and remains a rare species with low reproductive success. To determine the influence of warming sea surface temperatures (SSTs) on the incubation behavior of the Kittlitz’s Murrelet, I analyzed digital camera images collected at nests (n = 68) from 2009 to 2015 on Kodiak National Wildlife Refuge. Kittlitz’s Murrelets must attend nests at rates exceeding 94.7% for the probability of hatch to exceed the probability of nest failure pre-hatch. A logistic regression indicated a significant negative relationship between ocean temperature and parental attentiveness during the incubation period. SSTs taken from the National Oceanic and Atmospheric Administration’s National Buoy Database indicate El Niño conditions in 2015, and total nest attentiveness was most variable in this year. Parental attentiveness of the Kittlitz’s Murrelet during incubation may be an important indicator of environmental stress caused by warming SSTs. Climate models predict increasing intensity and frequency of El Niño events, leading to concerns regarding population-level impacts. Further studies should explore the interactions between ocean temperature, initiation date, nest attentiveness, and nest success.

Keywords: Alaska, climate variability, El Niño, incubation, Kittlitz’s Murrelet, nest attentiveness
INTRODUCTION

Fluctuating sea surface temperatures (SSTs) present new challenges for many species in the northeastern Pacific Ocean. In winter 2013 greater than normal SSTs were recorded in the eastern Pacific Ocean. This concentration of warm water was termed “the blob” (Bond et al. 2015). Anomalous SSTs continued through 2015 and are suspected as the cause of poor salmon returns, a large algal bloom off the coast of California, and unusual reports of warm-water fish and copepod species in the northeastern Pacific (Peterson et al. 2015). The Oceanic Niño Index indicated greater than normal SSTs beginning in August 2014 and surpassing El Niño thresholds in February to March 2015. El Niño conditions continued through the end of 2015 (National Oceanic and Atmospheric Administration 2015). Conservation agencies across the Pacific coast reported abnormally low seabird breeding success and large-scale die-offs at seabird colonies (USFWS Alaska Migratory Bird Management 2015). High rates of nest failure and adult mortality have been documented during previous El Niño events, such as in Oregon in 1982 to 1983 and Alaska in 1997 to 1998 (Hodder and Graybill 1985; Piatt et al. 1999a). Fluctuations in SSTs are especially concerning for rare species such as the Kittlitz’s Murrelet (*Brachyramphus brevirostris*) that may be unable to rebound from dramatic breeding failure or large-scale adult mortality events (U. S. Fish & Wildlife Service 2013).

The Kittlitz’s Murrelet is a rare seabird that ranges from the western coast of Alaska and the Aleutian Islands to the eastern coast of Russia, including much of the Chukchi Sea (U. S. Fish & Wildlife Service 2013). At-sea population surveys conducted in Glacier Bay, Alaska in the 1990s and early 2000s were used to estimate total population size and indicated sharp declines over the 17-year study (Piatt et al. 2011). These findings led to concerns about the future state of the species. More recent investigations, however, have indicated that populations are
declining less rapidly and have stabilized in some areas (U. S. Fish & Wildlife Service 2013). In 2012 the International Union for Conservation of Nature down listed the Kittlitz’s Murrelet from “critically endangered” to “near threatened” on the IUCN Redlist of Threatened Species due to population stabilization (BirdLife International 2014). The global population is estimated at approximately 34,000 individuals (U. S. Fish & Wildlife Service 2013).

High inter-annual variation and spatial variability in populations create challenges to monitoring the Kittlitz’s Murrelet (Kissling et al. 2007). Concerns for the fate of the species led to a petition for listing under the U.S. Endangered Species Act in 2001. In 2013 the U.S. Fish and Wildlife Service determined that listing was not warranted at the time because available information did not indicate significant immediate threats to populations and no single stressor, or combination of stressors, could be identified as having a population or species-level impact on this widely distributed species (U. S. Fish & Wildlife Service 2013). However, if environmental variability, such as the anomalous ocean conditions observed in 2013 to 2015, negatively impacted the species’ persistence, the species may be reassessed for listing.

One method to determine the impact of SSTs on seabirds involves investigating breeding behavior and nest success during El Niño events. Observed abnormal behaviors during incubation, such as changes in attentiveness, may be early-warning predictors of breeding impacts related to decreased adult fitness (Ronconi and Hipfner 2009). Studies investigating the incubation habitats of seabirds have found that breeding adults may be able to adjust shift length when environmental conditions (i.e., food availability) fall below a certain threshold (Chaurand and Weimerskirch 1994; Shoji et al. 2012). However, increased rates of egg neglect and reproductive failure suggest that behavioral responses may be inadequate below critical levels of resource availability (Shoji et al. 2012).
Nest attentiveness can be used to evaluate the impacts of environmental conditions prior to hatching. Pre-breeding conditions are crucial to reproductive success as birds that end the incubation period in low body condition may be at a disadvantage to provide adequate food resources to nestlings (Shultz et al. 2009). An examination of incubation behavior may be a useful method to assess environmental trends, such as warming SSTs. Altered incubation behavior or nest attentiveness may dramatically affect reproductive success and consequently the size of future seabird populations, especially for rare species such as the Kittlitz’s Murrelet.

To better understand the impact of environmental trends such as warming SSTs on the Kittlitz’s Murrelet, my objectives were to: (1) describe the incubation behavior of the Kittlitz’s Murrelet, (2) determine the impact of warming SSTs on nest attentiveness, and (3) investigate the relationship between nest attendance and hatch success.

METHODS

*Study Species*

Prior to the mid 1990s, less than 20 Kittlitz’s Murrelet nests had been documented and described (Piatt et al. 1999b). The first nest documented in Kodiak National Wildlife Refuge was discovered in 2006 (Stenhouse et al. 2008). Because the Kittlitz’s Murrelet is a solitary nester, nest detection is difficult and presents challenges to closing data gaps (Day et al. 1999). Breeding characteristics, such as clutch size and nest site selection make the Kittlitz’s Murrelet highly susceptible to nest failure, particularly through predation and environmental conditions. It lays one single, cryptically-colored egg per breeding season (Day et al. 1999). Kittlitz’s Murrelet chicks are semi-precocial, require moderate parental care upon hatching, and fledge around 24 days post-hatch (Day et al. 1999). The species can live up to 15 years (Day et al. 1999).
Inaccessible nesting habitat provides challenges for researchers attempting to monitor reproductive success. In most of its range, the Kittlitz’s Murrelet nests at high elevations in mountainous areas on steep, rocky slopes with little to no vegetation (Day et al. 1999). Nest sites often include bare ground, cliff edges, and gravel (U. S. Fish & Wildlife Service 2013). Kittlitz’s Murrelets lay their eggs on bare rocks, or build a simple nest of small rocks to surround the egg (Piatt et al. 1999b). Avoidance of predators, such as red fox (Vulpes vulpes), is thought to be the driving factor behind nest behavior and nest site selection (U. S. Fish & Wildlife Service 2013). The Kittlitz’s Murrelet mainly forages on zooplankton and larval fishes pre-breeding, but feeds on schooling fishes, sand lance (Ammodytes spp.), herring (Clupea spp.), and walleye (Sander vitreus) during the breeding season (U. S. Fish & Wildlife Service 2013). On Kodiak Island, 80% of identified fish fed to chicks were Pacific sand lance (Ammodytes hexapterus) (Knudson et al. 2014).

Incubation habits, including nest attentiveness, have not been evaluated, but the length of the incubation period is assumed the same as the Marbled Murrelet (Brachyramphus marmoratus) at approximately 30 days (Day et al., 1999). In the case of the Kittlitz’s Murrelet, both adults share incubation duties, as indicated by the presence of brood patches on both sexes (Day et al. 1999).

Study Area

Kodiak National Wildlife Refuge is in the Kodiak Archipelago, Alaska, located in the western Gulf of Alaska, and separated from the Alaskan Peninsula by the Shelikof Strait (Stenhouse et al. 2008). Kodiak National Wildlife Refuge is over 7600 sq km, and includes
variable habitats, such as tundra, wetlands, Sitka spruce forests, and mountainous terrain. Peaks within the refuge rise over 1,200 m.

Research was conducted on a 700-ha study area located within Kodiak National Wildlife Refuge (Fig. 1). The study area was on the southwest side of Kodiak Island, 5 to 11 kilometers from the ocean, and the elevation of the area ranged from 80 to 470 m. The study area included steep slopes covered in ultramafic rock and provided habitat characteristics required by the Kittlitz’s Murrelet for nesting. Nest searching occurred at four main study sites located within 1 km of four basecamps in the study area.

Data Collection

Field research teams (three to four individuals per nesting season) conducted nest searching from 2008 to 2015. Teams searched for nests from late May to late July using horizontal transects in scree habitat. Researchers were spaced 5 to 10 m apart along the transect and used reference flags to mark the upper elevation of the line. Transects began at the lowest elevation of the slope face containing scree (or 150 m elevation if scree continued below 150 m) and continued upslope until the entire scree patch was searched or a nest was located.

Nests were typically located by flushing incubating adults, which were identified as Kittlitz’s Murrelets by white outer tail feathers. Nest processing procedures were designed to minimize disturbance to the nest sites. At each nest site, researchers recorded time of nest discovery and departure, predators observed during processing, and nest location. During nest processing researchers wore gloves to decrease scent transfer. The egg was weighed with a spring scale to the nearest 0.5 g, and egg length and width were measured with digital calipers to the nearest 0.1 mm. We floated the egg to estimate the stage of development using benchmarks.
described for Common Loons (*Gavia immer*) (Rizzolo and Schmutz 2007). Initiation date was estimated by back-calculation based on the development stage determined from egg float and was categorized as “early” (May 15 to June 4), “middle” (June 5 to June 24), or “late” (June 25 to July 14). We placed a camouflaged digital, motion-triggered camera 1 m from the nest. The camera photographed the nest at three-minute intervals continuously. If the camera detected movement at the nest, it captured three photographs, each one second apart.

*Data Analyses*

Camera photos from 2009 to 2015 were reviewed to record the dates and times of relevant nest events, such as parents switching incubation duties, leaving the nest, returning to the nest, and hatch. If adults were trapped at a nest, as occurred during a pilot study in 2015 to attach radio transmitters, it was excluded from the analysis (n=3). I also excluded nests that produced less than 4320 min (three days) of data. Camera failure, discovery of a chick, or abandonment immediately following flush were examples of factors that produced less than 4320 min of nest data and subsequent exclusion from analysis.

Breaks in continuous incubation longer than three min were classified as time off the nest, while absences less than three min were assumed to be associated with a switch in incubation duties between adults. Nest absences of exactly three min were alternately ascribed to time on or off the nest. Total possible incubation time (the total amount of time the camera observed the nest) was calculated as the time when the adult returned to the nest post-flush until the egg hatched or the nest failed. Parental attentiveness during incubation was calculated as the total number of minutes the adults were observed at the nest divided by the total possible incubation time.
I assigned binary nominal values to indicate hatch (1) and nest failure before hatch (0). I used logistic regression to determine the relationship between the proportions of parental attentiveness during incubation period and the outcomes of egg stage.

I conducted a preliminary analysis to assess the influence of environmental variables on nest attentiveness of the Kittlitz’s Murrelet. A Kruskal-Wallis test indicated that nest attentiveness was not significantly different across the four study sites ($\chi^2_{3,68} = 4.39, P = 0.22$). I used the method of least squares to assess the relationship between nest attentiveness and slope, aspect, elevation, SSTs, and number of observed predator locations. The relationships between SSTs ($P < 0.001$) and slope ($P < 0.007$) and nest attentiveness were both significant. However, multivariate correlation indicated that only SSTs were significantly correlated with nest attentiveness ($r_{68}=-0.40, P < 0.001$).

I obtained SSTs from the National Buoy Data Center operated by the National Oceanic and Atmospheric Administration (NOAA). Station ALIA2 recorded SSTs off the coast of Kodiak Island in Alitak Bay every 6 minutes from 2009 to 2014. Data from 2015 were not available from Station ALIA2. I obtained SSTs from Station KDAA2 near Kodiak, Alaska for 2015. To confirm the observed trend in SSTs, I examined the relationship between ALIA2 and KDAA2 for all days when temperatures were available from both stations during the study period. SSTs from ALIA2 and KDAA2 were significantly correlated ($r_{341}=0.93, P < 0.001$). To identify an average SST during the incubation period for each nest, I calculated the average SST per day for each nesting season. I then averaged the daily temperatures for the specific days during which the cameras recorded incubation behavior. This resulted in one SST value per nest that represented the average temperature for the duration of incubation. I used Oceanic Niño Index values for May, June, and July to verify the relationship between 2015 temperatures taken
from KDAA2 and 2009 to 2014 temperatures taken from ALIA2 (National Oceanic and Atmospheric Administration 2015). I used a linear regression to determine the relationship between SST and proportion of nest minutes attended using nest as the sampling unit. All analyses were conducted with JMP statistical software (Pro 12.1.0, SAA, Cary, North Carolina, USA).

RESULTS

Of over 130 nests documented on Kodiak Island, 68 met my criteria to be included in the analysis of incubation behavior (Table 1). The sample size of nests per year varied based on inclusion criteria. On average Kittlitz’s Murrelets attended the nest 95.6% (±11.23%) of total incubation time. Average annual nest attentiveness ranged from 99.5% in 2012 to 82.0% in 2015.

I found a significant negative linear relationship between SSTs and adult nest attentiveness from 2009 to 2015 ($F_{1,66}= 12.69, P < 0.001$; Fig. 2). Notably, Oceanic Niño Index values for May, June, and July, 2009 to 2015, indicated that 2015 was the only year that met thresholds for El Niño conditions (National Oceanic and Atmospheric Administration 2015). SSTs indicated warmer temperatures during the 2014 and 2015 breeding seasons than in previous years (National Oceanic and Atmospheric Administration 2015; Fig. 3). In 2015, nest attentiveness was less than in 2009 to 2014 (Fig. 4).

A positive relationship existed between adult nest attentiveness and probability of hatch (Logistic regression, $\chi^2_{1,68} = 5.16, P = 0.02$; Fig. 5). Using inverse prediction, the model indicated that parental attentiveness must exceed 94.7% to achieve a 50% probability of hatching. A contingency analysis of hatch revealed that the logistical model correctly predicted hatch in 94.4% of nests. However, the model only correctly predicted failure to hatch in 25% of
nests. This is likely a result of the greater standard deviation in nest attentiveness for failed nests (Table 2). The overall misclassification rate was 0.40.

The relationship between nest attentiveness, probability of hatch, and SSTs was complicated by nest initiation date. In particular, nests in 2015 demonstrated late initiation dates and reduced attentiveness (Fig. 6). In general, nests initiated later in the breeding season showed reduced nest attentiveness (Fig. 7). Across all years, nests initiated later in the season hatched less frequently than nests initiated early in the breeding season, and the range of attentiveness values for late-initiated nests was greater than for nests initiated early or mid season (Fig. 8).

DISCUSSION

Kittlitz’s Murrelets are more likely to hatch eggs when adult attendance rates exceed 94.7%. Greater rates of attendance trend toward increased probability of hatch, indicating that more consistent incubators will hatch eggs more frequently than neglectful parents. This interpretation is consistent with nesting characteristics and foraging behavior of the Kittlitz’s Murrelet that indicate the benefits of consistent nest attendance during incubation (Skutch 1962). Optimal parental attentiveness is largely linked to trade-offs between predator avoidance strategies and thermal requirements of incubating eggs (Skutch 1962). Long incubation periods and high attentiveness have been associated with species that build simple nests and for which predation is a key cause of nest failure (Skutch 1962). Longer incubation periods are necessary to prevent heat loss to eggs laid in simple nests with limited insulations and to avoid attracting predators by minimizing adult movements to the nest site (Skutch 1962). Red fox predation is a primary cause of nest failure for Kittlitz’s Murrelet nests on Kodiak National Wildlife Refuge (Knudson et al. 2014). Additionally, greater adult attendance rates suggest greater distances
between nest sites and feeding areas (Skutch 1962). Increased traveling time to foraging grounds is documented as a consequence of nest site selection for the Kittlitz’s Murrelet and is compatible with greater consistency in nest attendance (Kaler et al. 2009). Kittlitz’s Murrelets nesting on Kodiak National Wildlife Refuge have suspected foraging grounds near the Trinity Islands, Alaska, which are located up to 80 km from nesting areas on Kodiak Island (Kissling and Knudson, personal communication).

The negative relationship between SSTs and nest attentiveness highlights the importance of environmental factors as drivers of reproductive success in seabirds such as the Kittlitz’s Murrelet. Current models predict that climate warming attributed to greenhouse gas emissions will produce El Niño events of greater frequency and intensity in the Central Pacific over the course of the twenty-first century (Di Lorenzo et al. 2010). Interactions between Central Pacific warming, El Niño Southern Oscillation, and North Pacific Gyre Oscillation indicate the North Pacific Ocean may also experience intensifying El Niño events in the coming years (Di Lorenzo et al. 2010). If the relationship between high SSTs and reduced parental attentiveness is robust, reduced attentiveness should document an increase in breeding failures pre-hatch. Kittlitz’s Murrelet nesting results from 2015 showed the first signs of this impact. Of analyzed nests, 2015 exhibited the lowest rate of hatch of any year of the study at just 20% of nests. The four nests abandoned in 2015 all initiated after July 1, 2015 and had parental attentiveness rates of less than 80%.

SSTs have been proposed as a driver of abundance, availability, and quality of forage fish, thereby impacting seabird foraging success (Thayer et al. 2008). Cooler SSTs have been associated with greater availability of high-quality forage fish, probably due to increased copepod prey availability that promotes juvenile fish growth and survival (Thayer et al. 2008).
Warm SSTs may cause abnormal movements, such as increased use of deep-water environments, which prevent seabirds from locating forage fish and thereby reduce food availability (Oatley et al. 1992). Consequently decreased forage fish availability may contribute to reproductive failure by constraining adult energy reserves pre-breeding. Studies examining the pre-breeding body condition of other seabird species have associated reduced female body weight with reduced egg mass, and egg mass at laying is positively correlated with reproductive success (Wendeln 1997). Reduced quality of available forage fish results in a similar effect. This “junk-food hypothesis” proposes that pre-breeding nutritional stress results from the consumption of fish with low nutritional or energy content. As a result, adult Kittlitz’s Murrelets must leave the nest to replenish energy reserves after long incubation shifts, reducing incubation consistency.

Abnormal densities, movements, or qualities of forage fishes caused by fluctuating SSTs may increase Kittlitz’s Murrelet foraging time during incubation and result in low nest attentiveness (Blight et al. 2010).

As indicated by logistic regression, lower nest attentiveness reduced the probability of hatch for the Kittlitz’s Murrelet. Prolonged adult absence from the nest may cause thermal stress leading to unviable eggs or may leave the nest exposed to predation, both causes of reproductive failure. Therefore, environmental factors, such as high-quality forage availability which allow adults to incubate consistently, increase the likelihood of nest success by increasing the likelihood of hatch success (Martin 1987). El Niño ocean conditions that reduce forage fish availability and energy content may limit the reproductive potential of seabirds, such as the Kittlitz’s Murrelet.

Observed initiation dates similarly suggest that warm SSTs nutritionally constrain adult seabirds through lack of available high-quality forage. Adults unable to build energy reserves
sufficient for egg production prior to the breeding season may initiate nests late. Initiation dates observed in 2015 support this hypothesis. Previous studies of seabirds have found that prey availability pre-breeding can impact the timing of initiation and ultimately the ability of the adult to hatch the egg (Shultz et al. 2009). While low energy content of forage pre-breeding has not been associated with low female body mass, it has been associated with delayed initiation (Wendeln 1997). Late initiation can increase the likelihood of nest failure as forage quality and quantity decline later in the breeding season (Martin 1987). Consequently, late initiation compounds the effects of energy constraints pre-breeding and post-laying, and may necessitate abandonment.

Nutritionally limited adults are prone to greater levels of the stress hormone cortisol (Kitaysky et al. 2010). High cortisol predisposes birds to breeding failure (Kitaysky et al. 2010). Stress hormones elevated above threshold values due to nutritional deficiencies may negatively influence adult survival (Kitaysky et al. 2010). Thus, reduced nest attentiveness during incubation may suggest trade-offs between adult body condition and lifetime fecundity (Ronconi and Hipfner 2009).

Recent studies have focused on assessing and monitoring the breeding ecology of the Kittlitz’s Murrelet to better understand factors influencing low rates of recruitment and juvenile survival (Knudson et al. 2014). Reduced nest attentiveness during high SSTs indicates that El Niño conditions may limit breeding success by predisposing nests to thermal strain, predation, or abandonment. However, the long lifespan and low average reproductive output of the Kittlitz’s Murrelet indicate that population size and stability may be more tied to adult survival than juvenile survival (U. S. Fish & Wildlife Service 2013). Because reduced nest attentiveness
suggests insufficient energy reserves for breeding, environmental factors that cause reductions also place adults at high risk of mortality through poor body condition.

Kittlitz’s Murrelet incubation behavior may be an indicator of food web dynamics and the effects of changing environmental conditions on those associations. Examining the breeding behavior of the Kittlitz’s Murrelet can provide clues to the impacts of environmental variation, particularly changing ocean regimes in response to climate warming. Studying the breeding ecology and factors influencing reproductive success is crucial to predicting and managing for viable populations of the Kittlitz’s Murrelet. Attentiveness may be an important indicator of stress on adult birds, and may forecast future population declines. Future research should explore the relationship between available forage pre-breeding and the impacts of forage quantity and quality on breeding efficiency and success. Because El Niño events are likely to increase in frequency and intensity in the North Pacific, studying the impacts of changing ocean regimes on rare species, such as the Kittlitz’s Murrelet, is crucial to ensuring species persistence in the face of climate warming.
ACKNOWLEDGMENTS

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Table 1. Mean (±SD) adult attentiveness of the Kittlitz’s Murrelet (*Brachyramphus brevirostris*) from 2009 to 2015 on Kodiak Island, Alaska, USA. Attentiveness estimated as adult time on the nest divided by total observed nest time.

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of nests</th>
<th>Mean attentiveness</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009</td>
<td>6</td>
<td>0.968</td>
<td>0.058</td>
</tr>
<tr>
<td>2010</td>
<td>6</td>
<td>0.987</td>
<td>0.014</td>
</tr>
<tr>
<td>2011</td>
<td>14</td>
<td>0.988</td>
<td>0.021</td>
</tr>
<tr>
<td>2012</td>
<td>12</td>
<td>0.995</td>
<td>0.012</td>
</tr>
<tr>
<td>2013</td>
<td>6</td>
<td>0.954</td>
<td>0.092</td>
</tr>
<tr>
<td>2014</td>
<td>14</td>
<td>0.969</td>
<td>0.074</td>
</tr>
<tr>
<td>2015</td>
<td>10</td>
<td>0.820</td>
<td>0.231</td>
</tr>
<tr>
<td>Total</td>
<td>68</td>
<td>0.956</td>
<td>0.112</td>
</tr>
</tbody>
</table>
Table 2. Mean (±SD) adult attentiveness by hatch outcome of the Kittlitz’s Murrelet (*Brachyramphus brevirostris*) from 2009 to 2015 on Kodiak Island, Alaska.

<table>
<thead>
<tr>
<th>Hatch</th>
<th>Number of nests</th>
<th>Mean attentiveness</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hatch</td>
<td>36</td>
<td>0.9821</td>
<td>0.0464</td>
</tr>
<tr>
<td>No hatch</td>
<td>32</td>
<td>0.9259</td>
<td>0.1520</td>
</tr>
</tbody>
</table>
Figure 1. Kittlitz’s Murrelet (*Brachyramphus brevirostris*) nesting ecology study area on Kodiak Island, Alaska. Red areas indicate suitable scree habitat searched in 2009 to 2015.
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Figure 3. Average sea surface temperature (SST) from Alitak Bay, Alaska from 2009 to 2015. Temperatures for 2015 taken from Kodiak, Alaska.
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Figure 5. Probability of hatch based on adult nest attentiveness of the Kittlitz’s Murrelet (*Brachyramphus brevirostris*) on Kodiak Island, Alaska from 2009 to 2015. Line indicates logistic relationship.
Figure 6. Adult attentiveness of the Kittlitz’s Murrelet (Brachyramphus brevirostris) per nest (n = 68) by initiation date on Kodiak Island, Alaska from 2009 to 2015.
Figure 7. Adult attentiveness of the Kittlitz’s Murrelet (*Brachyramphus brevirostris*) per nest (n = 68) by initiation date on Kodiak Island, Alaska from 2009 to 2015. Line indicates linear relationship.
Figure 8. Outcome of incubation stage of the Kittlitz’s Murrelet (*Brachyramphus brevirostris*) on Kodiak Island, Alaska from 2009 to 2015 expressed with maximum and minimum parental attentiveness.