AMNWR 2011/01

BREEDING ECOLOGY OF KITTLITZ'S MURRELET AT AGATTU ISLAND, ALASKA, IN 2010: PROGRESS REPORT

Photo: R. Kaler/USFWS

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Key Words: Alaska, Aleutian Islands, *Brachyramphus brevirostris*, breeding ecology, growth rates, Kittlitz's murrelet, Near Islands, nest site selection, parental provisioning, reproductive success.

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Cite as: Kaler, R.S.A., L.A. Kenney, J.C. Williams, G.V. Byrd, and J.F. Piatt. 2011. Breeding biology of Kittlitz's murrelet at Agattu Island, Alaska, in 2010: progress report. U.S. Fish and Wildl. Serv. Rep. AMNWR 2011/01.

TABLE OF CONTENTS

INTRODUCTION

The Kittlitz's murrelet (*Brachyramphus brevirostris*) is one of the rarest breeding seabirds in the North Pacific and one of the least studied in North America. Long-term population monitoring in core Kittlitz's murrelet areas in the Gulf of Alaska region has revealed declining trends with up to 80% of local populations disappearing over the past 10 to 20 years (Kuletz et al. 2003, Van Pelt and Piatt 2003, Kissling et al. 2007, Drew and Piatt 2008). Causes for the rapid decline of this species are uncertain, but likely include anthropogenic sources of mortality including oil spills, gillnet bycatch, vessel disturbance in core foraging areas, as well as natural sources such as habitat loss due to climate change and glacial retreat, and changes in food abundance. Limited knowledge of the ecology of this species hampers conservation efforts (Day and Nigro 2004). Data gaps include basic knowledge about their nesting habitat, mortality factors, demographic vital rates, and diets. While considered a monophyletic species (Gaston and Jones 1998, Day et al. 1999), two preliminary studies using cytochrome *b* sequences, allozymes, and mtDNA, revealed that the western Aleutian population from Attu Island was genetically differentiated from the south coastal Alaska populations of Kachemak Bay and Glacier Bay (Friesen et al. 1996, MacKinnon 2005), suggesting a subdivided population structure meriting additional study. Focusing research efforts on these knowledge gaps is crucial for developing an effective recovery plan for this candidate species proposed for listing under the Endangered Species Act.

While a significant proportion (35%) of birds may breed in the Russian Far East, 65% of the estimated world population of 31,000 Kittlitz's murrelets occurs in Alaska, with the core of their range being linked with glacial fjords, tidewater glaciers, and glacial stream outflows of southeastern Alaska and Prince William Sound (Day et al. 1999, USFWS 2010). Patterns of nest site selection also suggest an association with past and present glacial activity, with nesting habitat having sparse or no vegetation and typically found at relatively high elevations (Thompson 1966, Day et al. 1983, Murphy et al. 1984). While the Aleutian Archipelago has no tidewater glaciers and few glacial river outflows, probable nesting habitat does exist at many alpine areas throughout these islands and breeding has been confirmed at two (Atka Island, Day et al. 1983; Agattu Island, Kaler et al. 2009). Because global warming and glacial recession have been identified as possible causes for the current rapid decline in Kittlitz's murrelets in southeast Alaska, studying the adaptation of murrelets to the non-tidewater glacier habitat of the Aleutian Islands may provide some insight into mechanisms of this decline.

In 2008, we initiated the first year of a comprehensive 4-year monitoring project to study the breeding ecology of Kittlitz's murrelets at Agattu Island with the following objectives: 1) describe habitat characteristics of nest sites; 2) quantify breeding chronology; 3) determine chick growth rates, nestling diet and adult nest attendance patterns; 4) measure nest survival rates and overall reproductive success; 5) collect genetic samples for comparative study of murrelet populations; and, 6) to compare all these findings with a similar multi-year study of Kittlitz's murrelets at Kodiak Island (Lawonn et al. 2011).

This progress report for the 2010 season, the third year of the comprehensive 4-year study, contains summary data for some but not all of the parameters we measured. Analysis is pending on nest survival models and nest site selection (R. Kaler, USFWS), sex determination and population genetics (V. Friesen, Queen's University), and diet analyses of chicks (R. Kaler, USFWS; J. Piatt and M. Arimitsu, USGS). All data will be incorporated and compared in the final comprehensive report after the final year of the study (2011).

STUDY AREA

Agattu Island (52.43° N, 173.60° E) is part of the Near Islands; a group of five islands found at the western end of the Aleutian Archipelago (Fig. 1) and is also part of the Aleutian Islands Unit of the Alaska Maritime National Wildlife Refuge. Agattu covers an area of 22,474 ha with three-fourths of the island composed of a rolling plateau occurring below 230 m in elevation. The Agattu mountain range, composed of seven sub-massifs and covering one-fourth of the island, extends from the north central side eastward to the island's northeast point (Fig. 1).

The Near Islands experienced intense glaciation during Wisconsinian time (30,000 to 10,000 years before present; Gates et al. 1971). The cirques and glacial passes of the Agattu range indicate the upward limits of ice at about 300 to 365 m (Schafeb 1971). The passes of the main divide were glaciated, whereas all secondary divides are sharp, knife-like ridges, formed by parallel glacial erosion. No glaciers are currently present in the Near Islands group. The westernmost sub-massif is composed of five peaks that rise to 518 - 693 m, and includes the highest point on the island (693 m). Frost action has fractured the bedrock and basalt surface layer and has created expansive talus mountain slopes.

Daily mean minimum and maximum temperatures during 1 June to 26 August 2010 (weather data were collected at the Binnacle Bay camp on the north side of Agattu; Fig. 1) were 6.2 °C (range = 3.6 to 8.7 °C) and 14.1 °C (range = 9.2 to 17.7 °C), respectively. Average monthly precipitation during the three month period was 9.4 cm (range = 3.8 to 12.3 cm). Average monthly wind velocities for the three month period was 41.5 kilometers per hour (range = 18.5 to 74.0 kilometer per hour).

METHODS

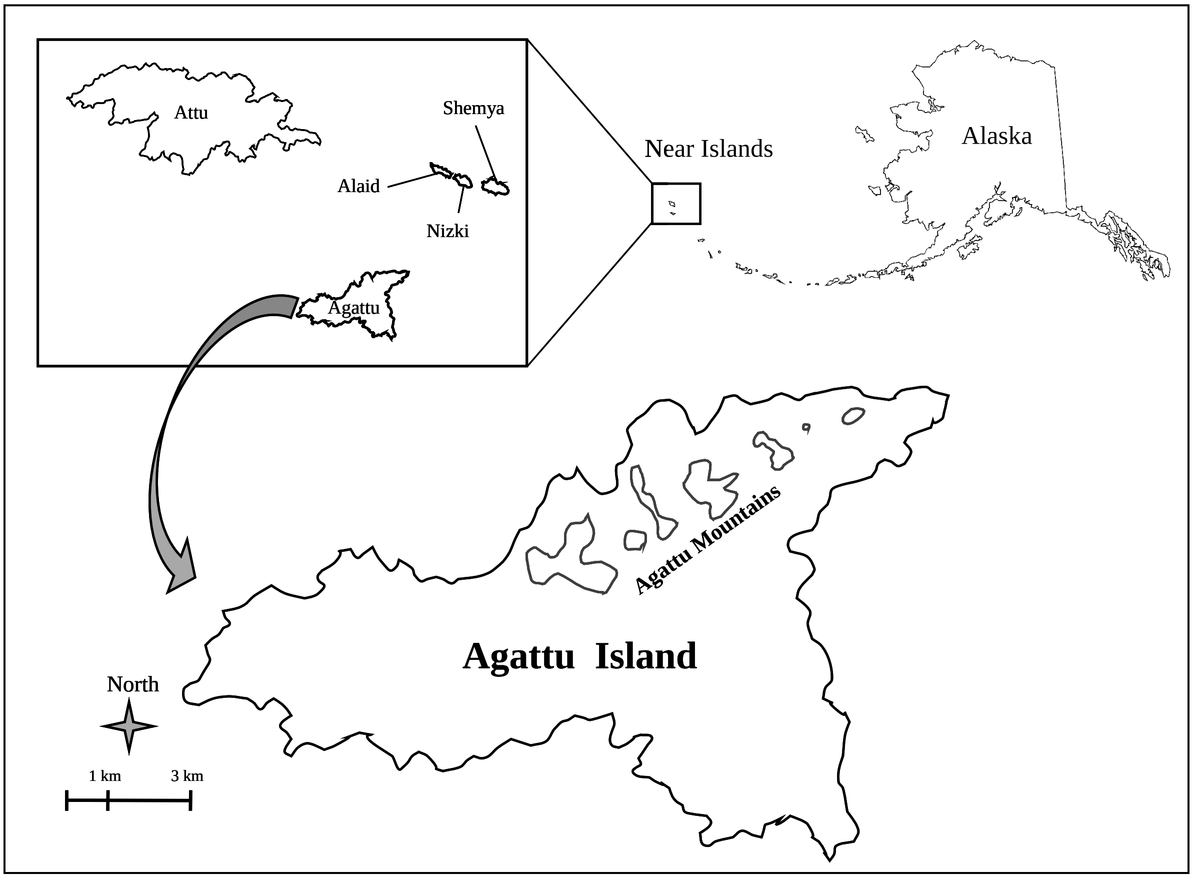
NEST SEARCHING AND MONITORING

Nests were located by searching suitable terrain (e.g., Day and Stickney 1996, Kaler et al. 2009). Search efforts were concentrated on rocky-talus covered areas ≥200 m above sea level. Despite efforts to locate incubating adults without disturbance, the majority of nests (83%, 15 of 18) were located by flushing the incubating adult at the time of discovery.

Egg length and width were measured using dial calipers (±0.1 mm). Egg mass was measured using a spring scale (±0.5 g), and eggs were floated in water to estimate the stage of embryonic development (Westerskov 1950, Kaler et al. 2009). Nests were visited infrequently (once every 7-14 days) during the incubation period in order to minimize disturbance to incubating adults. Presence of an adult at a nest was confirmed from a distance of ≥30 m.

To examine possible adverse effects of researcher visits on nest survival during the nestling period, nests were paired with their nearest neighbor and then randomly assigned to a *disturbed* (n = 4) or *control* (n = 6) treatment group. Chicks at *control* nests were visited and measured four times (1^{st} = 5-8 d age; 2^{nd} = 14-20 d age; 3^{rd} = 24-26 d age, and 4^{th} = >30 d age to determine success). Chicks at *disturbed* nests were visited and measured every 4-5 days during the nestling period.

Figure 1. Location of Kittlitz's murrelet breeding ecology study at Agattu Island, Aleutian Archipelago, Alaska. Agattu Island is part of the Near Islands group (inset) found farthest west in the archipelago. Nest searching efforts were focused in the Agattu Mountains located in the northeast portion of the island. Outline of Agattu Mountains indicated by 300 m contour line.



During each visit to nest sites during the nestling period, chick mass was measured to the nearest 1 g (for masses <100 g) or 2 g (for masses >100 g) using Pesola spring scales. We measured the unflattened (natural) wing length from the wrist to the wing tip (±1 mm) using a wing chord ruler. Dial calipers were used to take linear measurements (±0.1 mm) of the total head, exposed culmen, tarsus, and tail length. A blood sample was collected from the right brachial vein from each nestling for genetic analyses and sex determination. All nest visits were conducted between 15:00 and 19:00 Hawaii-Aleutian Daylight Time (HADT) to maintain consistency of measurements. No chicks were handled during adverse weather (i.e., wind >30 kilometers per hour, heavy mist or rain).

Nests receiving the disturbed treatment were monitored by time-lapse game cameras (Reconxy PC90 RapidFire Professional Covert, Holmen, WI) placed 2 m from the nest. Cameras were camouflaged and a visor attached in order to reduce drawing attention by avian predators to nest locations (Fig. 2). Due to the small size of adult murrelets and their wellinsulated plumage, neither motion-activated nor infra-red triggers reliably activate cameras, thus we programmed cameras to record one image every 2-minutes, for 24-hours per day while the nest was active. The 2-minute time delay period between photos was based on the minimum time duration of a nest visit by an adult for a Kittlitz's murrelet nest monitored using real-time video cameras near Kachemak Bay, Alaska (N. Naslund, pers. comm.). Because cameras recorded images once every two minutes, reported values should be considered as the minimum time duration of a parental visit (i.e., if adults arrived one second before the first image was recorded and departed one second after the final image was recorded). Data from cameras were downloaded every 4-5 days and batteries were replenished every 5-7 days.

Figure 2. Photo of game camera deployed ~2 m distance from Kittlitz's murrelet nest during the nestling period at Agattu Island, Alaska. Cameras were modified using camouflaged paint and the attachment of a visor in order to cover reflective lens surfaces from detection by avian predators.

NEST SITE SELECTION

Nest site characteristics were measured after completion of nesting. Vegetation data were collected in 25 m radius plots centered at each nest site and at four points placed at random bearings and distances 50-100 m from each nest. In each plot, percentage classes of each general vegetation type present were estimated using the classification system of Viereck et al. (1992). Topographic data also were recorded for each of these 25-m plots. Using a 5-m radius plot nested within the center of each 25 m plot, a single observer scored ground cover on a 10-point scale (0 = <<1%, 1 = <1%, 2 = 1-4%, 3 = 5-10%, 4 = 11-25%, 5 = 26-50%, 6 = 51-75%, 7 = 76-90%, 8 = 91-95%, 9 = 96-100%). In cases where more than one nest was located on a single submassif, we used ArcView GIS 3.2a software (Environmental Systems Research Institute, Inc.) to calculate straight-line distances between nest locations, as well as distance to the ocean.

NON-ACTIVE NESTS FROM PREVIOUS BREEDING ATTEMPTS

While revisiting known murrelet nests from previous years (2006; 2008-2009), we observed vegetation growing at old nest sites. In particular, nests which had survived into the later stages of the nestling period frequently contained a dense accumulation of mosses, grasses, and/or forbs. Based upon these observations, we searched for non-active nests (pre-2010 nests) using the visual cues of a dense vegetative patch in an otherwise sparsely vegetated hillside. Once a possible nest site was identified using these vegetative cues, we confirmed murrelet use by carefully excavating the scrape to locate murrelet egg shell fragments, murrelet feathers, or chick remains. Only sites containing definitive sign of nesting (murrelet egg shell fragments, feathers, or chick remains) are reported.

BREEDING CHRONOLOGY

Dates of clutch initiation were calculated by backdating from known hatching dates using a 30 d mean incubation period (assuming an incubation time similar to marbled murrelets [*Brachyramphus marmoratus*]; Nelson 1997, Day et al. 1999). A hatching date was assigned to nests using the midway point between the last time the nest contained an egg and the first day the nest contained a chick. In cases where nests were discovered after hatching, we assigned age based on chick development, accumulation of feces at the nest scrape, and flight feather growth. Day of hatch was designated as day 1 for all backdating of nests.

NESTLING DIET AND ADULT PROVISIONING PATTERNS

Rates of chick meal deliveries were estimated using time-stamped photos (time-lapse: 1 picture recorded every 2 minutes). For nests where individual adults could be distinguished by their unique plumage characteristics, the frequency of visits for each parent was calculated. Images will also be used to quantify chick diet at a later time (R. Kaler, USFWS; J. Piatt and M. Arimitsu, USGS).

DATA ANALYSIS

Daily survival of eggs and chicks was estimated using the modified Mayfield method (Mayfield 1961, 1975; Bart and Robson 1982, Hines 1996). To calculate Mayfield estimates, the date of failure was assumed to be the midpoint between the last two nest checks. Estimates of time of hatching were accurate to two days, thus exposure days were assigned to the incubation or the nestling periods. Orientation of murrelet nests was analyzed with circular statistics of Program Oriana (ver. 3.2, Kovach Computing Services, Anglesey, Wales, UK).

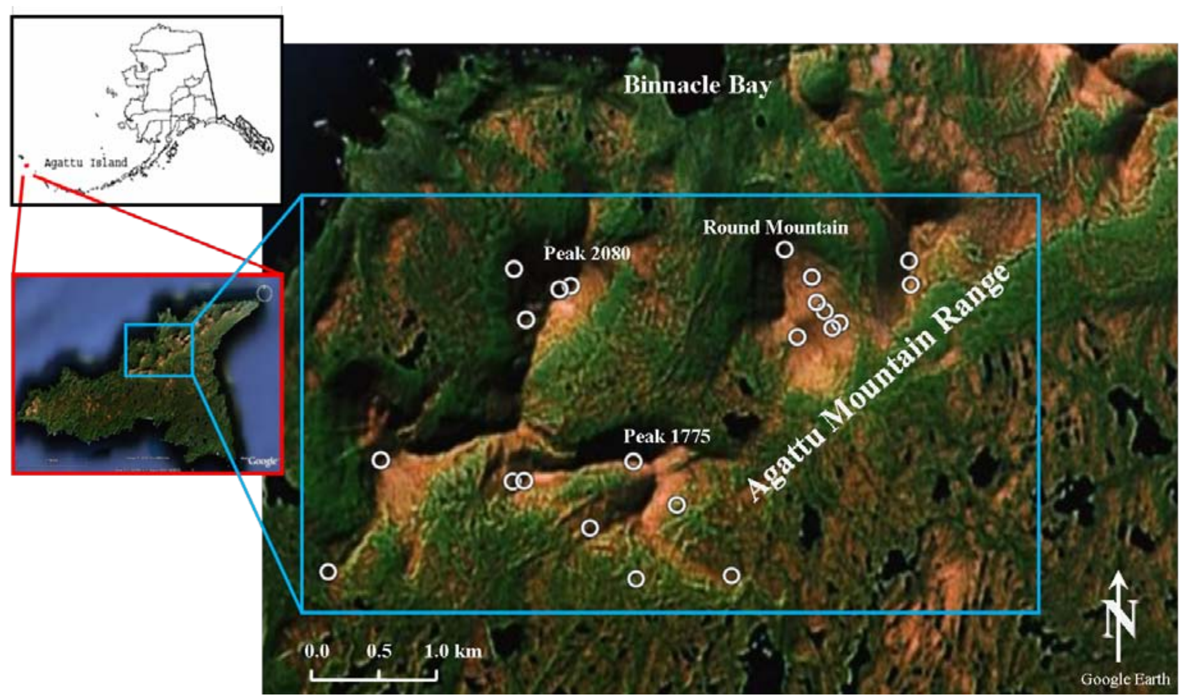
Rates of chick development were calculated for mass (g/day) and wing chord length (mm/day) for each chick during the linear phase of growth by fitting a straight line to the data using the least squares method. We defined linear growth as the time period during which mass or wing length measurements increased. Growth rates were averaged across all chicks to calculate a mean growth value. Means are presented ±SE, unless otherwise stated.

RESULTS

Characteristics and Selection of Nest Sites

During June to August 2010, 19 Kittlitz's murrelet nests (where an egg or chick was observed) were located and monitored at Agattu Island (Fig. 3). An additional four nests containing either an abandoned egg (n = 1) or a dead chick (n = 3) were discovered and were used to quantify nesting habitat. Nest sites (defined as 25-m radius area around nest) were found on moderate mountain slopes (mean slope = 32° ± 1° SE, range = 10° to 50°, n = 22) with a mean elevation of 434 m ± 107 meters above sea level (range = 223 to 629 m, n = 22). The average straight line distance from nest sites to the ocean was 2.3 ± 0.2 km (range = 1.3 to 3.9 km, n = 22). The mean vegetative cover was 37% ± 20% (range = 10% to 70%, n = 22). Nest scrapes were typically located on the downhill side of a medium to large rock (≥20 cm diameter) or rock ledge associated with bedrock or basaltic formations. Nest sites had a random orientation with respect to slope (r = 0.11 ± 0.89; n = 22; Rayleigh test, z = 0.264, P = 0.722).

Figure 3. Nest sites of Kittlitz's murrelets discovered at Agattu Island, Alaska, 2010. Circles represent 22 nest locations; one nest was reused during the same season. Nest searching efforts were based out of Binnacle Bay, located on the north side of Agattu Island, and focused on searching higher elevation areas (≥200 m above sea level) in the Agattu Mountains. Peak 1775, Round Mountain, and Peak 2080 are labeled for reference purposes for Figures 4-6.



Breeding murrelets at Agattu may be somewhat aggregated by behavior and/or scarcity of habitat. On three submassifs where ≥3 nests were located, distances between neighboring nest sites averaged 894 ± 84 m (Peak 1775: Fig. 4, range = 518 to 1376 m, *n* = 10), 534 ± 274 m (Round Mountain: Fig. 5, range = 110 to 1017 m, *n* = 20) and 561 ± 89 m (Peak 2080: Fig. 6, range = 128 to 701 m, *n* = 4), apart, respectively.

Figure 4. Kittlitz's murrelet nests located at Peak 1775, Agattu Island, Alaska, 2010. White circles represent nest locations. Yellow line indicates approximate 300 m contour line demarcating alpine habitat.

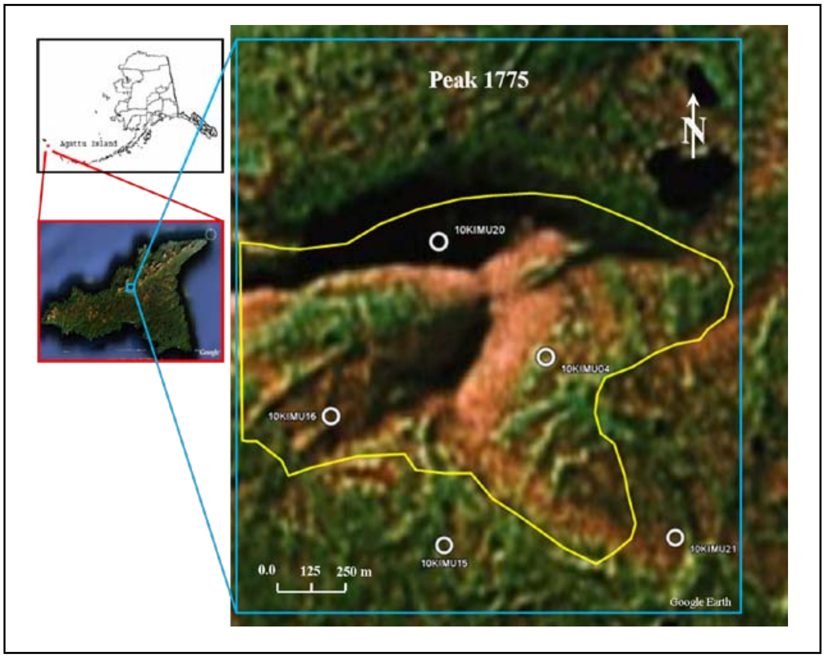


Figure 5. Kittlitz's murrelet nests located at Round Mountain, Agattu Island, Alaska, 2010. White circles represent nest locations. Yellow line indicates approximate 300 m contour line demarcating alpine habitat.

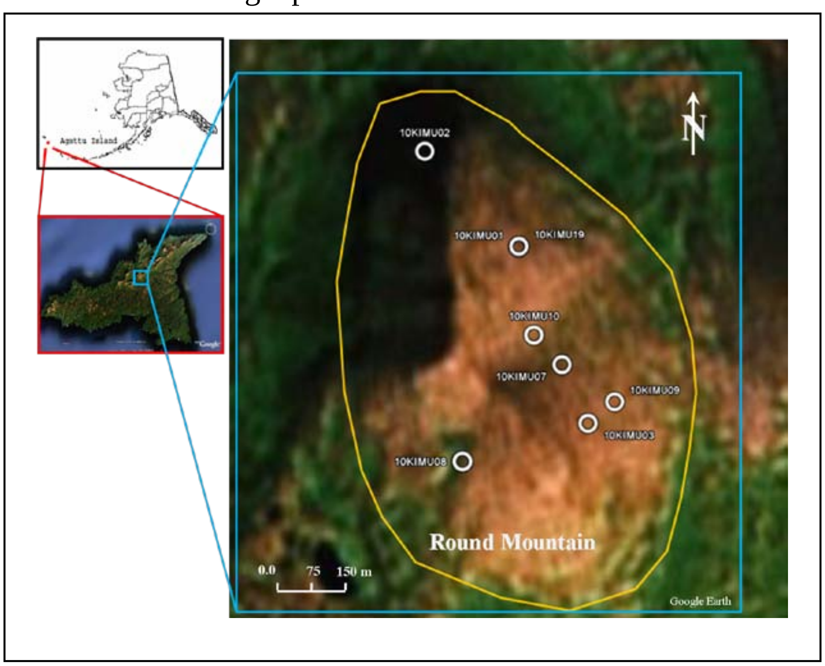
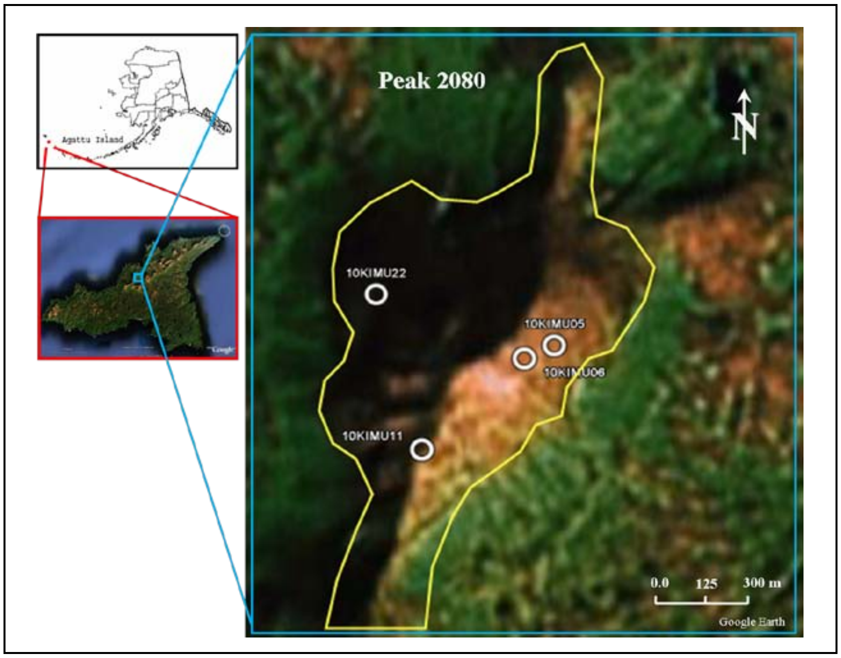


Figure 6. Kittlitz's murrelet nests located at Peak 2080, Agattu Island, Alaska, 2010. White circles represent nest locations. Yellow line indicates approximate 300 m contour line demarcating alpine habitat.



Nest vegetation data were collected for 22 nest site plots and 82 non-use plots; one nest was reused and thus additional vegetation data were not collected. A discriminant function analysis will be conducted to quantify nest site selection by breeding murrelets at a later time (R. Kaler, USFWS).

NON-ACTIVE NESTS FROM PREVIOUS BREEDING ATTEMPTS

In addition to the 19 active nests found in 2010, and four nests located after nesting failure (one abandoned egg, three dead chicks), we located 35 *non-active* murrelet nests from previous years that were not active in 2010 (Fig. 7). At a minimum, these *non-active* nests contained murrelet eggshell fragments (n = 24); 11 nests also contained feathers and/or bones of deceased chicks which had failed to fledge (Fig. 8). Based upon the overall appearance of the nest scrape and the depth of egg shell fragments in the nest substrate, we believe only two of the 35 *non-active* nests found may have been active in 2009. Based upon appearance (i.e., compressed and weathered), all other *non-active* nests were apparently used in 2008 or before.

Figure 7. Non-active nest sites of Kittlitz's murrelets discovered at Agattu Island, Alaska, 2010. Circles indicate locations of 35 non-active nests containing eggshell fragments and/or chick remains.

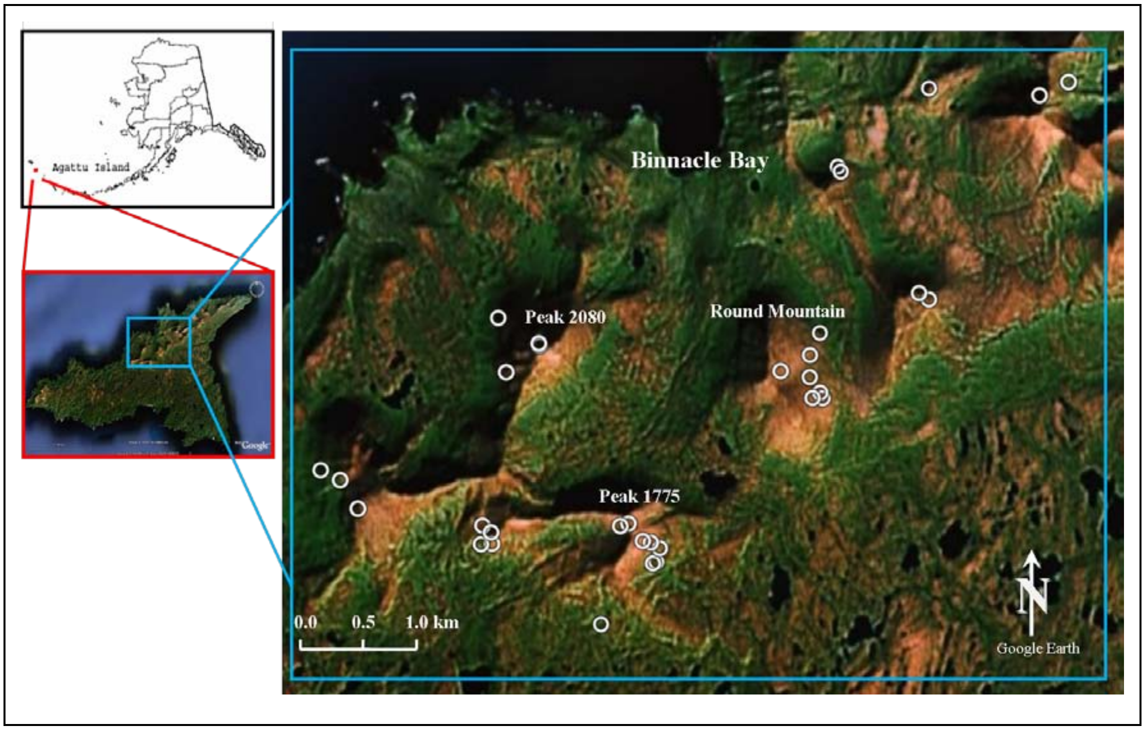


Figure 8. Example of non-active Kittlitz's murrelet nest site at Agattu Island, Alaska, 2010. (a) Large patch of mosses located at base of ≥20 cm rock (15 cm ruler inserted for scale); (b) bone found among mosses; (c) mosses collected from nest scrape; and (d) Kittlitz's murrelet eggshell fragments found at base of moss scrape.

Breeding Chronology, Egg, Chick, and Chick Growth

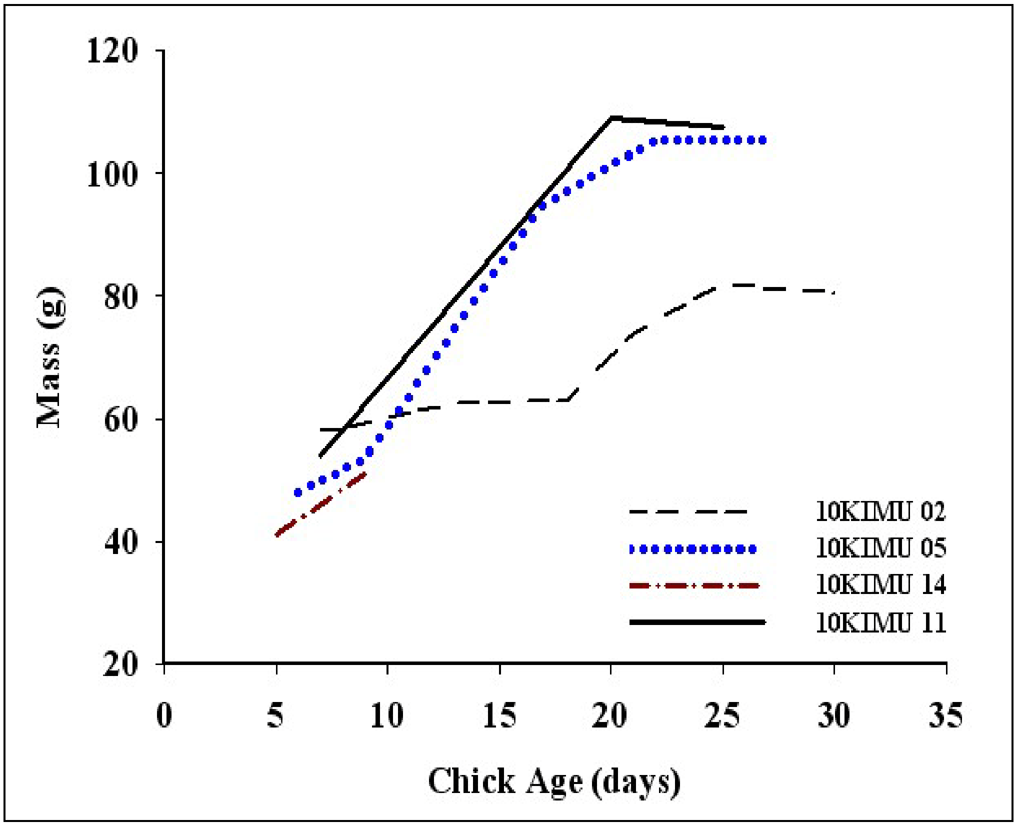
The breeding period (from first egg to last chick fledged) of Kittlitz's murrelets at Agattu in 2010 extended from 5 June to 16 August. Median dates of egg laying and hatching were 21 June (SE = 2.6; range = 5 June to 8 July, n = 18) and 19 July (SE = 2.8, range = 9 July to 7 August, n = 11), respectively.

All clutches contained one egg. Eggs were sub-elliptical in shape and measured an average of 57.7 x 38.3 mm (length: SE = 0.5, range = 54.7 to 62.9 mm, n = 17; width: SE = 0.3, range = 36.7 to 40.8 mm, n = 17). The average mass of fresh eggs (≤5 d old) was 44.4 ± 1.0 g (range = 39.5 to 49.5 g, n = 11), ~20% of adult body mass (adult mass = 224 g). Eggs were pale-green with irregular brownish-black, tar-colored spots that ranged from speckling (<1 mm) to patches and streaks (<10 mm). These marks covered the eggs entirely and were especially dense at the blunt end.

Figure 9. Photo of Kittlitz's murrelet egg, Agattu Island, Alaska, 2010.

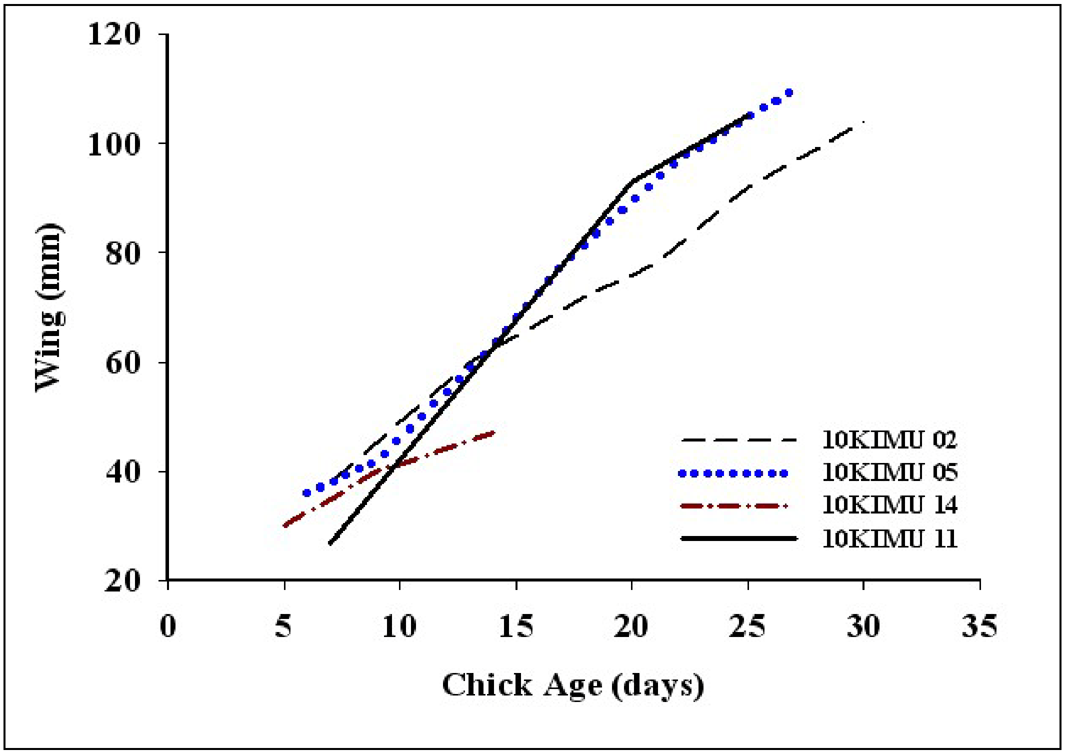
Chick mass increased for the first 20 days (Fig. 10). Patterns of chick development became less predictable thereafter, probably associated with either unpredictable provisioning rates or low quality food. Typical S-shaped sigmoid growth curves are not evident for all chicks, probably due in part to minimal sampling (to avoid disturbance) and in part to low growth rates in mid- to late stages of development; however, chick mass did appear to asymptote after ~20 days of chick age and ranged from 80 to 107 g at the time of nest departure, approximately 36 to 48% of adult mass (adult mass = 224 g).

Figure 10. Changes in body mass of Kittlitz's murrelet chicks at Agattu Island, Alaska, 2010. Lines represent individual chicks; dashed or dotted lines represent three *disturbed* nests which received visits by researcher every four to five days until fledging and solid line represents a single *control* nest which received three visits by researchers during the 30 d nestling period.



Wing chord (including outer primaries) increased linearly throughout development after primaries began emerging from feather sheaths at approximately day 5 of the nestling period (Fig. 11). As the primaries developed, wing chord increased to a maximum length of 110 mm, or 74% of adult wing length at 30 d post-hatching (adult wing length = 143 mm).

Figure 11. Changes in wing length of Kittlitz's murrelet chicks at Agattu Island, Alaska, 2010. Lines represent individual chicks; dashed or dotted lines represent three *disturbed* nests which received visits by researcher every four to five days until fledging and the solid line represents a single *control* nest which received three visits by researchers during the 30 d nestling period.



Growth rates in chick mass between control and disturbed groups could not be compared because insufficient data were available (most chicks died during the first week post-hatching). Furthermore, because the sample size for *control* nests was one, a measure of variance could not be calculated. Mean mass increase for *disturbed* nests was 2.3 ± 0.5 g/day, (range = 1.2 to 3.1 g/day, $n = 3$). Mass increase for the single *control* nest was 4.2 g/day. The pooled mean for mass for the two groups was 2.8 ± 0.6 g/day (range = 1.2 to 4.2 g/day, $n = 4$). Mean wing length for *disturbed* nests was 2.8 ± 0.5 mm/day (range = 1.9 to 3.7 mm, $n = 3$). Wing length for the single *control* nest was 4.5 mm/day. The pooled mean for wing length for the two groups was 3.2 ± 0.6 mm/day (range = 1.9 to 4.5 mm/day, $n = 4$).

TISSUE SAMPLES AND GENETIC MATERIALS COLLECTED FOR POPULATION STUDY

Using the brachial vein bleeding technique, blood samples were collected into centrifuge tubes containing 95% ethyl alcohol (ETOH) from chicks at age 15 to 20 days ($n = 2$), as well as onto filter paper ($n = 2$). Chicks that died at the nest and were in salvageable condition ($n = 6$) were collected and preserved in 95% ETOH. Pin feathers of dead chicks found at later stages of decay were collected and preserved in 95% ETOH ($n = 2$). Eggs that failed to hatch and were abandoned were collected and preserved in 95% ETOH ($n = 3$).

NESTLING DIET AND ADULT PROVISIONING PATTERNS

Adult attendance was most common during dawn (07:00-09:00 HADT) and dusk (22:00-24:00 HADT), but visits occurred throughout the day. No adults were observed feeding chicks between 01:00 - 06:00 HADT in the morning. All food loads consisted of single fish carried crosswise in the adults' bill. Two sand lances (*Ammodytes hexagrammos*; total lengths 36 mm and 123 mm, respectively) were collected from separate nest sites and preserved in 95% ETOH. Photos will be examined to identify specific prey items brought to nestlings by adults (R. Kaler, USFWS, J. Piatt and M. Arimitsu, USGS).

Time-lapse cameras were deployed at four nests, of which three nests survived ≥3 days. Average number of nest visits by adults per nest ranged from 5.9 to 8.5 visits per day. The total number of days which a nest was monitored by camera ranged from 5 to 25 days (Table 1). Nest attendance patterns at nests with >9 visits were evenly distributed between adults (Table 2). Average duration of a nest visit ranged from 9 to 14 minutes (range = 2 to 56 minutes, n = 382 visits) for the three nests with cameras (Table 3). Two minutes is the minimal time-lapse setting for image capture and could be shorter.

Table 1. Parental provisioning rate by adult Kittlitz's murrelets from time-lapse images collected at murrelet nests during the nestling period at Agattu Island, Alaska, 2010. Days with partial data excluded (i.e., day of camera deployment or day of chick mortality).

Nest	Average # visits/day	SD	Range of visits/day	Total visits during nestling period	Total days monitored
10KIMU 05	8.5	2.6	4 – 13	179	21
10KIMU 02	6.4	2.9	1 – 12	160	25
10KIMU 14	5.9	3.6	3 – 12	31	5

Table 2. Individual feeding visits of adult Kittlitz's murrelets from time-lapse images collected at murrelet nests during the nestling period at Agattu Island, Alaska, 2010. Days with partial data excluded (i.e., day of camera deployment or day of chick mortality).

Nest	Adult	Total nest visits	% of nest attendance
10KIMU 05			
	Dark adult	97	54
	Light adult	75	42
	Unknown adult	8	4
	Total visits	180	100
10KIMU 02			
	Dark adult	81	51
	Light adult	73	46
	Unknown adult	6	4
	Total visits	160	100
10KIMU 14			
	Dark adult	14	47
	Light adult	11	37
	Unknown adult	5	17
	Total visits	30	100

Table 3. Duration of provisioning visits of adult Kittlitz's murrelets at Agattu Island, Alaska, 2010. Time lapse images were recorded every 2-minutes for 24 hours per day during the nestling period at murrelet nests. Values are presented as minutes.

Nest	*n*	Average	SD	Range
10KIMU 05	183	0:10	0:05	0:02 - 0:56
10KIMU 02	162	0:14	0:05	0:02 - 0:40
10KIMU 14	37	0:09	0:06	0:02 - 0:28

BREEDING SUCCESS

Of the 23 nests found, we monitored 19 during either the incubation period or the nestling period; four nests located after nesting failure were excluded from Mayfield nest survival estimates. Eighteen murrelet nests were located during the incubation period and one was found at day five of the nestling period. Daily nest survival during the incubation stage was 0.979 ± 0.034 (seven losses per 328 exposure days, n = 18), and the probability an egg would survive the 30 d incubation period was 0.524 ± 0.118. Daily nest survival for the nestling stage was 0.930 ± 0.085 (nine losses per 129 exposure days, n = 9), and the probability of a chick surviving the 30 d nestling period was 0.113 ± 0.106. Overall, nest survival from clutch initiation to fledging, calculated as the product of the stage-specific rates over the incubation and nestling periods, was 0.059 ± 0.079 (Table 4).

Causes of nest failure during the incubation period included egg predation (26%, five of 19 eggs) and non-hatching eggs which were eventually abandoned by adults (11%, two of 18 eggs). The remaining ten eggs hatched successfully. The only cause of nest failure during the nestling period was either exposure to inclement weather and/or starvation (75%, nine of 12 chicks; no chicks were depredated. Of the chicks that fledged, one from a *control* nest fledged around day 29 and two chicks from *disturbed* nests fledged at day 30 and day 33, respectively.

2010 SUMMARY AND RECOMMENDATIONS

In 2010, we located and monitored 19 Kittlitz's murrelet nests at Agattu Island, and found an additional four which had failed prior to discovery. Stage-specific Mayfield estimates of daily nest survival were similar to previous values reported from our research in 2008 and 2009 (Table 4). During all three years (2008-2010), 70-75 % of nests failed owing to chick death due to exposure and/or starvation (Fig. 12). We emphasize that finding three nests which had failed due to exposure/starvation prior to our discovery (each nest contained a dead chick) infers that this cause of breeding failure is not a result of researcher activities. We cannot definitively assign the causes of chick mortality to exposure or starvation; the high rate of chick mortality is likely due to multiple factors including diet, weather, and provisioning rates by adults.

Table 4. Mayfield nest survival estimates (±SE) for Kittlitz's murrelets at Agattu Island, Alaska 2008-2010. Number of nests is in parentheses.

Estimate Type	2008[c]	2009[d]	2010
Single-stage estimates[a]			
Incubation	0.318 ± 0.129 (13)	0.708 ± 0.126 (13)	0.524 ± 0.118 (18)
Nestling	0.190 ± 0.139 (8)	0.119 ± 0.103 (10)	0.113 ± 0.106 (9)
Stage-specific estimates[b]			
Stage specific	0.060 ± 0.060 (16)	0.085 ± 0.077 (13)	0.059 ± 0.079 (18)

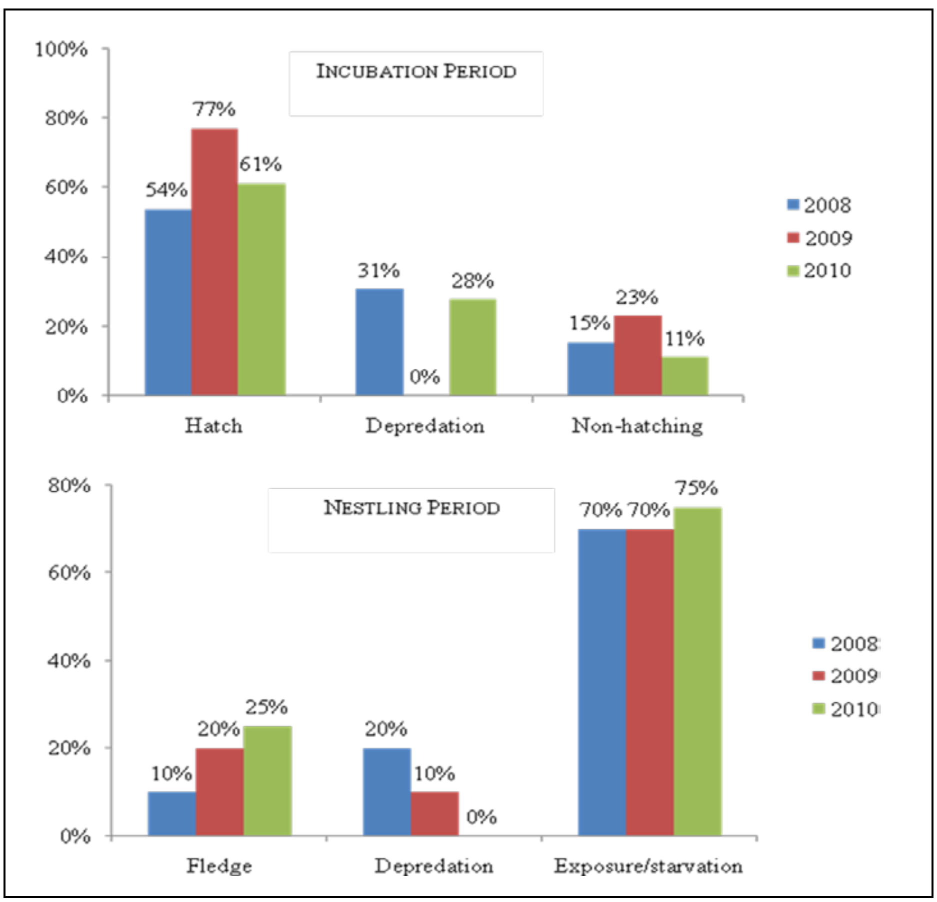
[a] Survival for a single stage (incubation or nestling) = (Daily Survival Rate)^d, where *d* is 30 d.

[b] Calculated at the product of stage-specific survival of the incubation and nestling periods.

[c] Kaler et al. 2008.

[d] Kaler et al. 2010.

Figure 12. Nest fates of 19 Kittlitz's murrelet nests during the incubation and nestling period at Agattu Island, Alaska, 2008-2010. Totals exclude four nests found after nest failure.



RECOMMENDATIONS

We recommend expanding the Kittlitz's murrelet research initiated at Agattu to other islands in the Aleutians Archipelago. In particular, conducting nest searches of suitable habitat at islands where murrelets have been observed foraging in nearshore waters (Adak, Atka, Unalaska) would be a prudent use of funds and would help elucidate the breeding range of this little-studied seabird. A rapid assessment of potential habitat could be conducted by experienced nest searchers during the months of June to September.

Searching murrelet habitat for both active and non-active nests provides a new tool to delineate breeding sites of *Brachyramphus* murrelets on other Aleutian Islands. In 2009, we found that nest sites used by *Brachyramphus* murrelets (presumably Kittlitz's murrelets) in previous years could be located during area searches conducted in suitable murrelet nesting habitat at Agattu Island. In 2010, we found an additional 35 non-active nests based on the presence of vegetative cues at Agattu and this technique could be used to delineate the breeding range of *Brachyramphus* murrelets throughout the Aleutian Islands. If the high rate of nest area fidelity observed at Agattu is a common aspect of murrelet breeding behavior, then locating nests that are inactive will expedite the process of finding active nests. Indeed, five nests were located at Agattu by thoroughly searching areas where non-active nests had been discovered. The use of vegetation cues has great utility in the Aleutian Islands and merits testing elsewhere in their breeding range.

From 2003 to 2005, the U.S. Fish and Wildlife Service and the U.S. Geological Survey conducted systematic surveys in the Aleutians in order to determine the at-sea density, distribution, and population size of *Brachyramphus* murrelets and included Atka Island (Romano et al. 2004), Unalaska Island (Romano et al. 2005), and the Near Islands (Piatt et al. 2005). We recommend replication of surveys at these islands in order to assess the stability of the Aleutian murrelet population. Pairing these types of surveys with land-based nest searching efforts is a prudent use of resources (i.e., maximizing research vessel's time with regard to personnel transport). Additionally, Unimak Island represents the largest unsurveyed Aleutian Island containing protected bays (Bechivin and Ikatan Bays), alpine nesting habitat, and remnant glaciers on the slopes of Shishaldin Volcano.

CONCLUSION

Information regarding the breeding ecology of Kittlitz's murrelet was very limited until the discovery of a breeding population at Agattu Island in 2005. Since then, we have monitored 62 nests (Kaler 2006, Kaler et al. 2008, Kaler et al. 2009, Kaler et al. 2010) and contributed important information to our understanding of breeding success, chick diet, parental behavior, and nest site selection in the western Aleutian Islands. The Aleutian population of Kittlitz's murrelets, estimated to comprise ~18% of the Alaskan population, helps provide basic information on natural history which will aid in recovery planning for this candidate species for listing under the Endangered Species Act. We recommend continued monitoring of nests using remote, time lapse field cameras to elucidate parental provisioning rates and nestling diets, as well as expanding nest searching efforts to other islands in the Aleutian Archipelago. The consistent high rate of nest failure due to chick mortalities at Agattu over the past 3-years owing to exposure and/or starvation warrants an increased focus on this aspect of murrelet breeding ecology. Studying breeding success at other Aleutian islands would provide an excellent point of contrast to examine whether high rates of chick mortality is a regular pattern in the Aleutian

Islands or is specific to the western Aleutian murrelet population. It will also be valuable to compare results with a similar study of Kittlitz's Murrelet on Kodiak Island, in the western Gulf of Alaska (Lawonn et al. 2011). Is the Near Islands Kittlitz's murrelet population an example of an extremely K-selected species which may be maintaining population equilibrium over the long-term by the production of a few young per decade by breeding pairs? Have the Kittlitz's murrelets in the Aleutian Islands evolved a suite of adaptations that buffer them from the environmental changes which appear to be affecting their population numbers in the eastern portion of their range? Only by expanding our research efforts in the Aleutian Islands can we begin to elucidate the challenges faced by Kittlitz's murrelets throughout their range.

ACKNOWLEDGMENTS

This research would not have been possible without the hard work and dedication of the staff at the Alaska Maritime National Wildlife Refuge. We thank Nicholas Metheny for his hard work at Agattu Island. We thank the crew of the M/V Tiglax for providing safe passage to the outer Aleutians and for help establishing the Agattu field camp. We are grateful for the help of Erica Madison in logistics and obtaining field equipment. We thank Google Earth for their detailed images of Agattu Island. The National Fish and Wildlife Fund provided financial support for field work. A Challenge Cost-Share Grant awarded by the U.S. Fish and Wildlife Service provided additional funding for this research. We are grateful to Brie Drummond and Don Dragoo for providing comments on an earlier draft of this report.

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APPENDIX A - Annotated list of species observed at Agattu Island, Alaska, 26 May to 26 August 2010.

Abundance categories were defined at Agattu Island as follows:
Abundant: 50 individuals per day or 6 per hour
Common: 10-49 individuals per day or 2-5 per hour
Fairly common: 5-9 individuals per day or 1 per hour
Uncommon: 2-4 individuals per day or <1 per hour
Rare: 1 individual per day
For breeding status, refer to Appendix B.

Birds

Red-throated loon (*Gavia stellata*).--Uncommon breeder. A pair was observed nesting at a small lake south of the Binnacle Bay camp. Adults were heard or seen flying between this site and Binnacle Bay on 60 days from 31 May-25 August. On 22 June, 2 eggs and a single adult were observed at the lake nest site. On 10 August, two flightless hatching-year birds were observed at the lake nest site.

Common loon (*Gavia immer*).--Uncommon. Birds were observed on 45 days from 2 June-23 August. Single pairs were observed on multiple lakes on the south and west sides of the mountains at Agattu.

Horned grebe (*Podiceps auritus*).--Rare. One bird was observed on 24 June on the south side of Agattu near Karab Cove during a circumnavigation aboard the M/V Tiglax.

Laysan albatross (*Phoebastria immutabilis*).--Uncommon. One bird was observed on 24 June near McDonald Cove during a circumnavigation of the island. One bird was observed on 5 August during another circumnavigation of the island. This species is uncommon offshore of Agattu Island.

Northern Fulmar (*Fulmarus glacialis*).--Uncommon. One bird was observed offshore near McDonald Cove on 5 August during a circumnavigation of Agattu Island.

Shearwater spp. (*Puffinus* spp.).--Rare. Several unidentified shearwaters were observed foraging ~2 km offshore from Binnacle Bay on 7 June. Several birds were observed during the travel between Attu and Agattu Islands on 5 August.

Fork-tailed storm-petrel (*Oceanodroma furcata*).--Common breeder. Birds were regularly heard at night at Binnacle Bay from 30 May-20 August for a total of 57 days detected. Multiple colonies were encountered and elevation of colonies ranged from 150 to 500 m above sea level. Colonies were located in either boulder fields covered with a dense *Sphagnum* moss and/or ericaceous dwarf shrub mat or in exposed boulders with no vegetative cover. Adults were commonly heard calling from boulder crevices during the day. Common ravens were frequently observed at colonies, presumably excavating for adults, young, and eggs.

Leach's storm-petrel (*Oceanodroma leucorhoa*).--Common breeder. Birds were regularly heard at night at Binnacle Bay from 27 May-21 August for a total of 59 days detected. Multiple colonies were encountered and elevations ranged from 150 to 500 m above sea level. See colony description above for fork-tailed storm-petrel.

Red-faced cormorant (*Phalacorcorax urile*).--Uncommon breeder. Observed at Binnacle Bay on 12 days from 26 May-25 August. Individuals were seen foraging near the mouth of Binnacle stream or in the middle of the bay. A small colony of red-faced and pelagic cormorants breeds at Aga Cove on the east side of the island.

Pelagic cormorant (*Phalacorcorax pelagicus*).--Uncommon breeder. Observed at Binnacle Bay on 6 days from 9 July-5 August. Individuals were seen foraging near the mouth of Binnacle stream or in the middle of the bay. A small colony of red-faced and pelagic cormorants breeds at Aga Cove on the east side of the island.

Aleutian cackling goose (*Branta hutchinsii leucopareia*).--Abundant breeder. Geese were one of the most frequently encountered breeding birds at Agattu and were observed on 87 days from 26 May-24 August. The first goslings were observed on 25 June. Geese were commonly encountered at both low and high elevations.

Mallard (*Anas platyrhynchos*).--Rare. Pairs were observed on 10 days from 2 June-12 July at inland lakes.

Eurasian green-winged teal (*Anas crecca crecca*).--Uncommon breeder. This species was seen on 76 days from 26 May-21 August. One female and a brood of six young were seen in the ephemeral wetland area near the Binnacle Bay camp site on 27 June. A female and young were frequently heard vocalizing at night from 1 July to 13 August in the same wetland area.

Greater scaup (*Aythya marila*).--Rare breeder. This species was seen on 2 days; 31 July and 15 August.

Harlequin duck (*Histrionicus histrionicus*).--Uncommon. Birds were observed on 10 occasions from 30 May-19 August. Birds were generally observed foraging at the mouth of Binnacle stream and occasionally seen loafing on rocks. Additionally, a single female was observed ~300 upstream from the mouth of Binnacle stream on three occasions, suggesting a possible breeding attempt; however, no nest was confirmed.

Common eider (*Somateria mollissima*).--Abundant breeder. Eiders were one of the most frequently observed species at Binnacle Bay and were seen on 91 days from 26 May-25 August. The first hatching-year young were seen on 27 June at Binnacle Bay. Females with ducklings would congregate in groups of 2-8 individuals and fiercely protect the young from Glaucous-winged gulls. Male eiders generally foraged and loafed singly or in small groups with other males or females after chicks hatched.

Red-breasted merganser (*Mergus serrator*).--Uncommon. This species was observed on 17 days from 3 June-23 July. Pairs were seen on inland lakes, but more commonly were observed at Binnacle Bay.

Rough-legged Hawk (*Buteo lagopus*).--Rare. One immature bird was observed on three occasions from 27 May to 3 August.

Peregrine falcon (*Falco peregrinus*).--Uncommon breeder. This species was seen on 38 days from 6 June-24 August. On 9 June, nest defense was observed by both the male and female along the east side of Binnacle Bay. On 19 July, we observed a fledged hatching year bird.

Rock ptarmigan (*Lagopus muta evermannii*).--Uncommon breeder. Rock ptarmigan were observed on 64 days ranging from 29 May-23 August. Two nests were found during the laying period on 6 and 7 June, respectively. Using broadcast surveys to determine population size at Agattu, we counted 30 territorial males.

Sandhill Crane (*Grus canadensis*).--Rare. A single adult was observed on 15 occasions beginning 23 June and ending 2 August.

Rock sandpiper (*Calidris ptilocnemis*).--Common breeder. Sandpipers were observed on 79 days from 26 May-21 August. The first nest was discovered during the egg laying period on 2 June and contained 3 eggs.

Gray-tailed tattler (*Heteroscelus brevipes*)--.Rare. One adult was observed on two occasions; 19 August along Binnacle stream and on 25 August at the mouth of Binnacle stream. On each occasion, vocalization of the bird confirmed species' identification.

Parasitic jaeger (*Stercorarius parasiticus*).--Uncommon breeder. Primarily dark morph parasitic jaegers were observed on 32 days from 29 May to 21 August. Adults were generally observed in upland habitat singly or in pairs. Jaegers were observed quartering low above hillsides at high elevation areas.

Glaucous-winged gull (*Larus glauc*escens).--Abundant breeder. Gulls were observed on a total of 85 days from 26 May-26 August. Four nests, each containing 3 eggs, were discovered on the east side of Binnacle Bay stream along the beach. In general, it appeared to be an average breeding year for gulls based upon the number of hatching-year young observed at Binnacle Bay (~ 8 precocial young regularly tended by adults).

Black-legged Kittitwake (*Rissa tridactyla*).--Common breeder. Birds seen rarely at Binnacle Bay; however, a breeding colony occurs at Aga Cove on the eastern side of Agattu Island on was visited on 5 August. Kittiwakes were seen three times from 24 June-5 August.

Common murre (*Uria aalge*).--Uncommon breeder. One to four adults were seen foraging at Binnacle Bay on 25 days from 23 June-16 August. A breeding colony occurs at Aga Cove on the east side of the island and was visited on 5 August.

Thick-billed murre (*Uria lomvia*).--Uncommon breeder. One to two adults were seen foraging at Binnacle Bay on 8 days from 24 June-5 August. A breeding colony occurs at Aga Cove on the east side of the island and was visited on 5 August.

Pigeon guillemot (*Cepphus columba*).--Common breeder. Four to 8 individuals were observed on 66 days from 26 May-25 August. Guillemots were concentrated mostly along the east side of Binnacle Bay. One hatching-year young was observed on 25 August. Guillemots were commonly observed foraging among tufted and horned puffins.

Kittlitz's murrelet (*Brachyramphus brevirostris*).--Uncommon breeder. Twenty-three nests were discovered in montane habitat at Agattu Island. Either incubating adults or unattended chicks were seen on 38 days from 8 June-16 August. No adults or fledged young were observed at Binnacle Bay.

Ancient murrelet (*Synthliboramphus antiquus*).--Rare. On 24 June, 1 individual was seen offshore near McDonald Cove during a circumnavigation of Agattu Island. Additionally, remains of ancient murrelets were found in snowy owl pellets.

Parkeet auklet (*Aethia psittacula*).--Rare. One individual seen offshore on 23 June during a circumnavigation of the island.

Least auklet (*Aethia pusilla*).--Rare. One individual seen offshore near McDonald Cove on 5 August during a circumnavigation of the island.

Horned puffin (*Fratercula corniculata*).--Common breeder. Horned puffins were observed on 22 days from 26 May-22 August. Individuals were commonly observed foraging on the east side of Binnacle Bay among tufted puffins.

Tufted puffin (*Fratercula cirrhata*).--Common breeder. This species was observed on 66 days from 26 May-25 August. Tufted puffins were usually observed foraging or resting on the water on the eastern side of Binnacle Bay and typically outnumbered horned puffins 10:1.

Snowy owl (*Bubo scandiacus*).--Uncommon. Nine sightings of snowy owls occurred between 29 May-12 August. Based on plumage differences, we estimate at least 3 individuals were present at Agattu. Fresh pellets and feathers were collected at Agattu for an analysis of their diets.

Common raven (*Corus corax*).--Uncommon. Up to six individuals were seen on 70 days from 28 May-25 August. It was common to see ravens in small groups (2-6 individuals) doing synchronized flights and exchanging loud vocalizations. Ravens were frequently observed in upland habitat and in Rampart and Binnacle valleys. Additionally, ravens were observed at storm-petrel colonies where they excavate the burrows and consume adults, young, and presumably eggs.

Pacific wren (*Troglodytes pacificus*).--Common breeder. Birds were observed on 39 days from 9 June-25 August, most commonly in dense forbs along the beach. Wrens were rarely encountered at inland sites.

Gray-crowned rosy finch (*Leucosticte tephrocotis*).--Uncommon breeder. Observed on 60 days from 29 May-24 August. Birds were seen from low to high elevations. Nest tending was first observed 18 July, and young of the year were first seen 19 July.

Common redpoll (*Acanthis flammea*).--Rare. Three individuals were seen on 2 July.

Song sparrow (*Melospiza melodia*).--Common breeder. Birds were observed on 84 days from 26 May-25 August, mostly along the beaches and in dense forbs near the beach. A nesting pair was observed at camp from 26 May-25 August had three clutches based on nests discovered, behavioral observations of adults carrying food, removing fecal sacs, and attending to recently fledged young. Fledglings were first observed on 9 June.

Lapland longspur (*Calcarius lapponicus*).--Abundant breeder. Birds were observed along grassy slopes throughout the island. Observations were made on 78 days from 26 May-25 August. Nest tending was first seen 10 July and young of the year were observed 12 July.

Snow bunting (*Plectrophenax nivalis*).--Fairly common breeder. Individuals were observed on 73 days from 26 May-25 August. Young were first seen 8 July.

Brambling (*Fringilla montifringilla*).--Rare. One individual was seen at Binnacle Bay on 4 June

Mammals

Sea otter (*Enhydra lutris*).--Rare. Otters were observed at Binnacle Bay on 4 days from 2 June-9 August.

Harbor seal (*Phoca vitulina*).--Uncommon. Seals were seen at Binnacle Bay on 56 days from 28 May-25 August. On 1 July, one recently born pup was observed with a female. Harbor seals were frequently seen hauled-out on rocks on the west side of Binnacle Bay.

APPENDIX B - Breeding status and abundance of birds observed at Agattu Island, Alaska, 2010.

Species	Date First Observed	Date last Observed	No. Days Observed	Breeding Status	Comments
Red-throated loon	31-May	25-Aug	60	CE	Abundant on multiple days
Common loon	2-Jun	23-Aug	45	PO	Commonly observed on lakes
Horned grebe	24-Jun	.	1	O	Observed off shore near Karab Cove
Laysan albatross	24-Jun	5-Aug	2	O	Observed off shore near McDonald Cove
Northern Fulmar	5-Aug	.	1	O	Observed off shore near McDonald Cove
Shearwater spp.	7-Jun	5-Aug	2	O	Observed off shore near Binnacle Bay
Fork-tailed storm-petrel	30-May	20-Aug	57	CE	Abundant on multiple days
Leach's storm-petrel	27-May	21-Aug	59	CE	Abundant on multiple days
Red-faced cormorant	26-May	25-Aug	12	PN	Observed in Binnacle Bay
Pelagic cormorant	9-Jul	5-Aug	6	O	Observed in Binnacle Bay
Aleutian cackling goose	26-May	24-Aug	87	CE	Abundant on multiple days
Mallard	2-Jun	12-Jul	10	PO	Observed on ephemeral lake on west side of Island
Green-winged teal	26-May	21-Aug	76	CG	Observed at camp
Greater scaup	31-Jul	15-Aug	2	O	Rare
Common Eider	26-May	25-Aug	91	CE	Common in Binnacle Bay
Harlequin duck	30-May	19-Aug	10	PO	Common at mouth of Binnacle Stream
Red-breasted merganser	3-Jun	23-Jul	17	PO	Pair observed at lakes on south side of island
Rough-legged Hawk	27-May	3-Aug	3	O	Rare
Peregrine falcon	6-Jun	24-Aug	38	PA	Observed in Binnacle Bay
Rock ptarmigan	29-May	23-Aug	64	CR	Abundant on multiple days
Sandhill crane	23-Jun	2-Aug	15	O	Single individual observed on multiple days
Gray-tailed Tattler	19-Aug	25-Aug	2	O	One adult observed at Binnacle Bay
Rock sandpiper	26-May	21-Aug	79	CE	Abundant on multiple days

Species	Date First Observed	Date last Observed	No. Days Observed	Breeding Status	Comments
Parasitic jaeger	29-May	21-Aug	32	CR	Abundant on multiple days
Glaucous-winged gull	26-May	26-Aug	85	CE	Abundant on multiple days
Black-legged kittiwake	24-Jun	5-Aug	3	CN	Breeding colony in Aga Cove
Common murre	23-Jun	16-Aug	25	CN	Observed in Binnacle Bay; breeding colony in Aga Cove
Thick-billed murre	24-Jun	5-Aug	8	O	Observed in Binnacle Bay; breeding colony in Aga Cove
Pigeon guillemot	26-May	25-Aug	66	CR	Abundant on multiple days in Binnacle Bay
Kittlitz's murrelet	8-Jun	16-Aug	38	CE	Only observed in the Mountains
Ancient murrelet	24-Jun	.	1	O	Observed off shore near McDonald Cove
Parakeet aucklet	23-Jun	.	1	X	Rare
Least auklet	5-Aug	.	1	O	Observed off shore near McDonald Cove
Horned puffin	26-May	22-Aug	22	CF	Abundant on multiple days in Binnacle Bay
Tufted puffin	26-May	25-Aug	66	CF	Abundant on multiple days in Binnacle Bay
Snowy owl	29-May	12-Aug	9	X	Uncommon
Common raven	28-May	25-Aug	70	X	Abundant on multiple days
Winter wren	9-Jun	25-Aug	39	CR	Common on multiple days
Song sparrow	26-May	25-Aug	84	CR	Abundant on multiple days
Lapland longspur	26-May	25-Aug	78	CR	Abundant on multiple days
Snow bunting	26-May	25-Aug	73	CR	Abundant on multiple days
Gray-crowned rosy-finch	29-May	24-Aug	60	CR	Common on multiple days
Common redpoll	2-Jul	.	1	O	One group of 3 birds seen
Brambling	4-Jun	.	1	O	Rare

O= Observed/non-breeding
X= Observed in breeding habitat
PO= Pair observed
PA= Agitated behavior
PN= Nest-site Visitation

CG= Precocial Young
CN= Carrying Nest Material
CE= Nest with Eggs
CF= Carrying Food
CY= Nest with Young

CI= Feeding Recently Fledged Young
CO= Occupied Nest
CR= Recently Fledged Young
C= Confirmed

APPENDIX C - Plant chronology at Agattu Island, Alaska, 2010.

Family	Scientific Name	First bloom	
		2009	2010
Apiaceae	*Angelica lucidia*	20-Jul	10-Aug
	Heracleum lanatum	25-Jul	17-Jul
	Conioselinum chinense	25-Jul	-
	Ligusticum scoticum hultenii	16-Jul	15-Aug
Asteraceae	*Achillea borealis*	24-Jul	28-Jul
	Anaphalis margaritaceae	19-Jul	8-Aug
	Antennaria dioica	30-Jun	-
	Antennaria sp.	30-Jun	1-Jul
	Arnica unalaschensis	1-Aug	10-Aug
	Artemesia arctica	18-Jul	27-Jul
	Cacalia auriculata kamtschatica	16-Jul	27-Jul
	Chyrsanthemum arcticum	13-Jul	25-Jul
	Cirsium kamtschaticum	31-Jul	6-Aug
	Erigeron humilis	4-Jul	18-Jul
	E. peregrinus	13-Jul	16-Jul
	Hieracium triste	1-Aug	28-Jul
	Senecio cannabifolius	14-Aug	21-Aug
	S. pseudoarnica	31-Jul	10-Aug
	Taraxacum trigonolobum	3-Jul	18-Jul
	T. ceratophorum	< 3 July	-
	T. alaskanum	< 3 July	-
Aspidiaceae	*Polystichum lonchitis*	4-Jun	-
Athyriaceae	*Athyrium filix-femina cyclosorum*	10-Jun	-
	Cystopteris fragilis	22-Jun	-
Brassicaceae	*Cardamine umbellata*	2-Jul	-
	Draba borealis	14-Jun	8-Jun
	D. alpina	< 6 July	20-Jun
	Arabis lyrata kamchatica	18-Jun	9-Jul
Boraginaceae	*Mertensia maritima*	21-Jul	31-Jul
Campanulaceae	*Campanula chamissonis*	4-Aug	26-Jul
	C. lasiocarpa lasiocarpa	23-Jul	-
Caprifoliaceae	*Linnaea borealis borealis*	22-Jul	2-Aug

Family	Scientific Name	First bloom	
		2009	2010
Caryophyllaceae	*Cerastrium aleuticum*	12-Jun	-
	C. Fischerianum	16-Jun	26-Jul
	C. beeringianum beeringianum	4-Jul	29-Jul
	Honckenya peploides	2-Jul	14-Jul
	Moehringia lateriflora	25-Jul	-
	Sagina intermedia	28-Jun	30-Jun
	Stellaria ruscifolia	1-Aug	-
	S. calycatha	1-Aug	-
Cornaceae	*Cornus suecica*	16-Jun	20-Jun
Cyperaceae	*Carex microchaeta*	15-Jun	-
	Carex pluriflora	26-Jun	-
	Eriophorum russeolum	26-Jun	-
	Juncus arcticus	28-Jun	-
	J. falcatus	28-Jun	-
Droseraceae	*Drosera rotundifolia*	1-Aug	27-Jul
Empetraceae	*Empetrum nigrum*	< 31 May	<26-May
Equisetaceae	*Equisetum arvense*	23-Jun	21-Jun
Ericaceae	*Cassiope lycopodioides*	22-Jun	20-Jun
	Loiseleuria procumbens	3-Jun	4-Jun
	Phyllodoce aleutica aleutica	18-Jun	4-Jul
	P. aleutica X *P. coerulea*	2-Jul	-
	Rhododendron camtschaticum	13-Jul	17-Jul
	Vaccinium uliginosum	30-Jun	20-Jun
	V. vitis-idaea	10-Jul	4-Jul
Fabaceae	*Lathyrus maritimus*	28-Jul	-
	Lupinus nootkatensis	28-Jun	1-Jul
Geraniaceae	*Geranium erianthum*	26-Jun	25-Jun
Gentianaceae	*Gentiana propinqua aleutica*	16-Aug	11-Aug
	Gentianella auriculata	16-Aug	11-Aug
Haloragaceae	*Hippuris vulgaris*	6-Jul	2-Jul
Iridaceae	*Iris setosa setosa*	18-Jul	18-Jul
Isoetaceae	*Isoetes muricata*	23-Jul	17-Jul
Lamiaceae	*Prunella vulgaris*	14-Aug	15-Aug
Lentibulariaceae	*Pinguicula vulgaris vulgaris*	3-Jul	11-Jul
Liliaceae	*Frittillaria camschatcensis*	5-Jul	29-Jun
	Maianthemum dilatatum	2-Jul	7-Jul

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Liliaceae	*Streptopus amplexifolius*	30-Jun	10-Aug
	Tofieldia coccinea	28-Jun	25-Jul
	T. pusilla	28-Jun	25-Jul
	Veratrum viride	6-Jul	27-Jul
Lycopodiaceae	*Lycopodium alpinum*	-	-
	L. annotinum	-	-
	L. clavatum	-	-
Onagraceae	*Epilobium glandulosum*	13-Jul	-
	E. latifolium	> 1 Aug	-
	Epilobium spp.	12-Jul	21-Jul
Ophioglossaceae	*Botrychium lanceolatum*	12-Jun	1-Jun
	B.minganense	12-Jun	1-Jun
	B. pinnatum	12-Jun	1-Jun
Orchidaceae	*Cyprideium guttatum*	26-Jul	21-Jul
	Dactylorhiza aristata	20-Jun	29-Jun
	Listera cordata	19-Jul	17-Jul
	Platanthera dilatata	18-Jul	17-Jul
	P. tipuloides var. *behringiana*	9-Jul	21-Jul
Plantaginaceae	*Plantago macrocarpa*	30-Jun	10-Jun
Poaceae	*Agrostis exarata*	1-Jul	-
	Bromus sitchensis	1-Jul	
	Festuca rubra	1-Jul	-
	Hierochloe odorata	1-Jul	-
	Hordeum brachyantherum	1-Jul	-
	Luzula parviflora	1-Jul	-
	L. multiflora	1-Jul	-
	Poa arctica	1-Jul	-
	P. macrocalyx	1-Jul	-
Polypodiaceae	*Polypodium vulgare*	5-Jul	1-Jul
Portulacaceae	*Claytonia sibirica*	4-Jul	29-Jun
	C. arctica	26-Jul	2-Jul
Primulaceae	*Primula cuneifolia saxifragifolia*	1-Jun	2-Jun
	P. cuneifolia cuneifolia	1-Jun	2-Jun
	Trientalis europaea arctica	23-Jun	2-Jul
Polygonaceae	*Koenigia islandica*	1-Jul	-
	Oxyria digyna	26-Jun	29-Jun
	Polygonium viviparium	23-Jun	20-Jul
	Rumex fenestratus	20-Aug	13-Aug

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		2009	2010
Scrophulariaceae	*Euphrasia mollis*	14-Aug	-
	Lagotis glauca	9-Jun	31-May
	Pedicularis langsdorffii	22-Jul	26-Jul
	Rhianthus minor borealis	1-Aug	9-Aug
	Veronica americana	24-Jul	10-Aug
	V. grandiflora	21-Jun	25-Jun
	V. stelleri	19-Jul	13-Jul
	V. serpyllifolia	13-Jul	17-Aug
Violaceae	*Viola langsdorffii*	15-Jun	17-Jun